Monetary Policy with Racial Inequality*

Makoto Nakajima
FRB Philadelphia

March 1, 2023

Abstract

I develop a heterogeneous-agent New-Keynesian model featuring racial inequality in income and wealth, and studies interactions between racial inequality and monetary policy. Black and Hispanic workers gain more from accommodative monetary policy than White workers mainly due to higher labor market risks. Their gains are larger also because of a larger proportion of them are hand-to-mouth, while wealthy White workers gain more from asset price appreciation. Monetary and fiscal policies are substitutes in providing insurance against labor market risks. Racial minorities gain even more from an accommodative monetary policy in the absence of income-dependent fiscal transfers.

JEL classification: E21, E52, J15, J64
Keywords: monetary policy, racial inequality, labor market, unemployment, wealth distribution, hand-to-mouth, marginal propensity to consume, business cycle, heterogeneous agents.

*Address: Research Department, Federal Reserve Bank of Philadelphia. Ten Independence Mall, Philadelphia, PA 19106-1574. E-mail: `makoto.nakajima@gmail.com`. I thank participants to presentations at CIGS, UAB, Jinan IESR Workshop in Quantitative Macroeconomics, Boston College, University of Houston, MMM at Utah State University, NASMES at University of Miami, SED Annual Meeting at University of Wisconsin, Madison, FRB System Meeting on Macroeconomics at FRB Dallas, Bank of Canada, FRB Richmond Race and Economic Outcomes Conference, and Winter Meeting of the ES, for their comments and suggestions. The views expressed here are mine and do not necessarily reflect the views of the Federal Reserve Bank of Philadelphia or the Federal Reserve System.

1 Introduction

As inequality in income and wealth has grown over time, and racial inequality is gaining attention, the question as to what the monetary authority can and should do about racial inequality has become more important. According to the conventional view, the monetary authority can only smooth business cycles mainly using policy rate adjustments, and long-term structural issues such as racial disparities cannot be dealt with by monetary policy. However, the opinion that the monetary authority has to do something about the racial disparities is getting stronger. Then-Democratic presidential nominee Joe Biden proposed in a speech in July 2020 that Congress amend the Federal Reserve Act to *"add to that responsibility and aggressively target persistent racial gaps in job, wages, and wealth."* The Federal Reserve is considered by many to have taken a step toward more emphasis on inequality already. For example, Chair Jerome Powell of the Federal Reserve unveiled a new strategy that *"emphasizes that maximum employment is a broad-based and inclusive goal"* in August 2020. However, it is a fair assessment that there is no consensus yet as to what the monetary authority can and should do to. The fact that the Federal Reserve recently hosted a series of Racism and the Economy conferences indicates that the role of the monetary authority is still an open question.

Against such a background, this paper builds a heterogeneous-agent New-Keynesian (HANK) model with racial inequality in labor market risks and wealth, and studies how monetary policy affects different racial groups. The goal of the paper is modest. I want to be clear about what this paper does not try to answer. The paper is not intended to answer why racial inequalities in income and wealth exist.[1] Instead, I take the observed racial disparities as given, embed into a canonical HANK model in that manner which is both tractable and I thin is reasonable, so that the model can be used to study how monetary policy affects different racial groups differently. Particularly, the model is used to answer which racial groups gain the most from an accommodative monetary policy. An important assumption is that workers of different racial groups have common preferences. Instead, racial heterogeneity in unemployment and hand-to-mouth shocks and rate-of-return heterogeneity are used to replicate the observed racial heterogeneity in income and wealth. I use the HANK model, since it is an extension of the New-Keynesian Dynamic Stochastic General Equilibrium (NK-DSGE) model, which is a workhorse model used by monetary authorities, and introducing heterogeneous agents is crucial to capture various dimensions of racial inequality. With these considerations in mind, I try to stay close to the standard NK-DSGE model as much as possible, but at the same time try to incorporate various dimensions of observed racial disparities. My hope is that the model presented in this paper can be a benchmark model to think about the interactions between monetary policy and racial inequality. As an example, at the end of the paper, I study the implications of a hypothetical monetary policy in which the Black unemployment rate instead of the overall unemployment rate is used as a monetary policy target.

The HANK model developed in this paper incorporates two important dimensions of racial differences that I present in the next section. First, Hispanic and Black workers not only earn less on average but also face a higher risk of unemployment, and the risk rises dispropor-

[1] In Appendix D, I compute what fraction of uncontrolled "racial differences" in the unemployment rate and the fraction of hand-to-mouth can be attributed to differences in the composition of educational attainment across racial groups.

tionately during a recession. When the shock driving the business cycle is common for all racial groups, this means that accommodative monetary policy brings down the unemployment rates of Hispanic and Black workers more strongly and benefits them disproportionately. Indeed, Bartscher et al. (2021) compute that a 25bp reduction in the policy rate lowers the unemployment rate of Black workers 0.34pp more than that of White workers. The model is successfully calibrated to replicate this empirical finding. Second, more Hispanic and Black workers are either poor or wealthy hand-to-mouth, i.e., liquidity constrained. The combination of the two is crucial in thinking about the role of monetary policy for different racial groups. The heterogeneous labor income risks imply that an accommodative monetary policy could alleviate unemployment risks of Hispanic and Black workers to a larger extent, while the racial heterogeneity in hand-to-mouth implies that, since many of them are liquidity constrained, their consumption responds more to a lower unemployment rate and a higher wage caused by accommodative monetary policy. Since monetary policy benefit racial minorities partly because they insure against rising risks of unemployment in recessions, interactions with public insurance provided through fiscal transfers are found to be important in understanding the gains from an accommodative monetary policy.

There are five main findings. First, the model indicates that, although all racial groups gain from an accommodative monetary shock, Black and Hispanic workers gain more due to the combination of higher unemployment risks they face and a higher probability of being hand-to-mouth and thus liquidity constrained. White workers gain more than racial minorities from the asset valuation channel, as emphasized by Bartscher et al. (2021), but the channel is not strong enough to make them benefit more than racial minorities. Second, interactions between fiscal and monetary policies are important, when monetary policy provides partial insurance against cyclical labor market risks. The welfare gains from an accommodative monetary shock is found to be larger in the absence of income-dependent fiscal transfers. Third, the model can replicate the facts that the unemployment rate for Black workers is more volatile over the business cycle, and the unemployment rate for Black workers declines 0.34pp more than that for White workers in response to a -25bp monetary policy shock because of the higher job separation rate among Black workers. A shorter expected duration of jobs among Black workers makes the number of vacancy postings for Black workers more sensitive to the business cycle and monetary policy. Fourth, the model is consistent with the empirical finding by Ganong et al. (2020) that the consumption of Black workers is 50% more sensitive to income shocks than that of White workers. This is because of the higher fraction of both poor and wealthy hand-to-mouth among Black workers, documented in Section 2. Finally, replacing the overall unemployment rate with the Black unemployment rate as a monetary policy target is equivalent to making monetary policy more accommodative with the overall unemployment rate. This is because the unemployment rates for all racial groups move in parallel over the business cycle, as shown in Section 2.

This paper contributes to four strands of literature. First, to the literature studying monetary policy in the presence of racial inequality, the current paper contributes by developing the first HANK model featuring racial inequality. This emerging literature includes a recent paper by Bartscher et al. (2021), who empirically study racial inequality in wealth. Another recent paper by Lee et al. (2021) emphasizes racial heterogeneity in the consumption basket, which implies that inflation affects different racial groups differently over the business cycle. They build a stylized macro model with two (Black and White) agents to study policy implications. Aliprantis et al. (2019) and Boerma and Karabarbounis (Forthcoming) ask what is behind the racial wealth gap. Cajner et al. (2017) document racial difference in labor market outcomes.

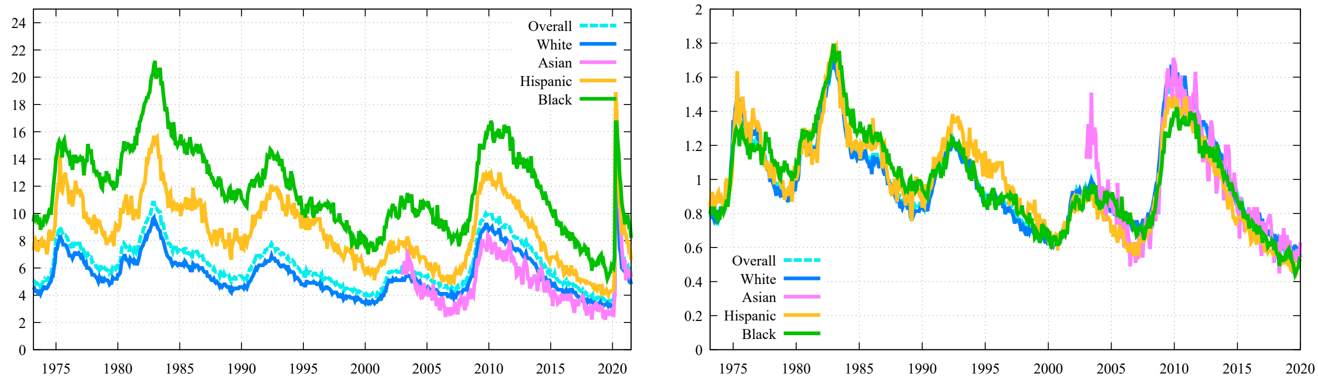
Second, the current paper extends the literature of HANK models by introducing racial inequality. Papers such as Kaplan et al. (2018), Gornemann et al. (2021), and Bayer et al. (2020) combine the incomplete-market heterogeneous-agent model with aggregate uncertainty (Krusell and Smith (1998), which is the Bewley-Aiyagari-Huggett model with aggregate shocks) with New-Keynesian nominal frictions, to investigate interactions between heterogeneity and monetary policy. The current paper is the first to introduce race as one dimension of heterogeneity into the otherwise standard HANK model. An important property of the HANK model is that if more consumers are either poor or wealthy hand-to-mouth, the model generates a stronger response of consumption when income increases. What the current paper emphasizes is that racial minorities are more likely to be hand-to-mouth, and thus their consumption is more strongly affected by monetary policy. As a result, the HANK model exhibits strong amplification of shocks.

Third, the current paper extends the literature of developing the macro model with search frictions in the labor market by introducing racial heterogeneity in labor market risks. Andolfatto (1996) and Merz (1995) first introduce search frictions in the labor market into a canonical real business cycle (RBC) model. Nakajima (2012a) and Krusell et al. (2010) introduce labor market search into the incomplete-market heterogeneous-agent model with aggregate uncertainty. Gornemann et al. (2021) add New-Keynesian friction into such model so that monetary policy can affect unemployment risks. The current paper is a natural extension of Gornemann et al. (2021) in the sense that monetary policy can affect different racial groups differently, partly because they face different labor market risks.

Finally, the paper makes a small contribution to the literature which makes the computation of the HANK models easier and more accessible. Solving a HANK model is not easy because of the large state space (distribution of heterogeneous agents) and the difficulty in solving the optimal decision problem for heterogeneous agents. The first paper that solves a heterogeneous-agent macro model (Krusell and Smith (1998)) employs global approximation, which is slow, especially with rich heterogeneity. Therefore, various methods relying on local approximation (perturbation) have been developed. Reiter (2009) proposes the first popular local-approximation method to solve the HANK model. This method can be understood as an extension of the local-approximation method developed for solving a representative-agent macro model by Schmitt-Grohé and Uribe (2009). More recently, an efficient continuous-time version of the local-approximation method was developed to solve the model in Kaplan et al. (2018), and a more efficient local-approximation method was developed to solve the model in Bayer et al. (2019).[2] The modest contribution of the current paper to this literature is to develop a toolkit called the `jhank toolkit`, which is available in Fortran90, Julia, and Matlab, to implement the simple local-approximation method by Reiter (2009) a little more easily. The current paper is an example of how to use the `jhank toolkit`.[3]

[2] Codes to implement these solution methods can be found at Moll's website (`https://benjaminmoll.com`) and Luetticke's website (`https://www.ralphluetticke.com/`).

[3] The `jhank toolkit` will be available at `https://makotonakajima.github.io/jhank/`.



(a) Unemployment Rate

(b) Normalized Unemployment Rate

Figure 1: Unemployment Rate and Normalized Unemployment Rate

The remainder of the paper is organized as follows. Section 2 presents racial differences in terms of labor market characteristics and wealth holding. These are the facts that motivate the model constructed in Section 3. Section 4 explains calibration. Section 5 investigates wealth inequality in the model. Section 6 studies marginal propensity to consume (MPC) in the model. Section 7 shows how workers of different racial groups are affected by a monetary policy shock. Section 8 studies how different monetary policy rules can affect different racial groups differently over the business cycle. Section 9 investigates interactions between fiscal and monetary policies. Section 10 concludes.

2 Racial Inequality in Income and Wealth

This section documents racial differences in the U.S. in terms of labor market (Section 2.1) and wealth (Section 2.2) characteristics. The key takeaway from this section is that racial groups that face high labor market risks are also the groups that exhibit low liquid wealth, which makes it difficult to smooth consumption expenditures. These findings motivate how I embed permanent differences in the model that I build in Section 3. I focus on four major racial groups in the U.S., namely, White, Asian, Hispanic, and Black.[4] In Appendix D, I look at workers with different education attainment within each racial group.

2.1 Racial Heterogeneity in Labor Market Risks

This section presents what I think are key differences in labor market risks across the four racial groups. Figure 1(a) shows the unemployment rate for the overall population as well as for the four racial groups, based on monthly data of the Current Population Survey (CPS) from 1973 to 2021. As is well known, the overall unemployment rate is countercyclical, sharply rising during

[4] I follow the definitions of races used by the Census Bureau in terms of the three racial groups used in the empirical analysis — White, Black (same as African), and Asian. I exclude American Indians, Alaskan Natives, Native Hawaiians and Other Pacific Islanders, and Two or More Races from the analysis. These groups made up 2.1% of the labor force on average between 2003 and 2018. Hispanic is an identity, and a Hispanic person can be of any race. When I compute numbers for the Hispanic, I include all individuals who identify as Hispanic, regardless of the race of the individuals. When I compute numbers for White, Black, and Asian workers, I exclude those who identify as Hispanic.

recessions and gradually going down during expansions. Regarding the unemployment rate for each racial group, three characteristics can be pointed out. First, there are permanent differences in levels. The unemployment rate for Black workers is consistently the highest among the four racial groups. The Hispanic unemployment rate is the second. The unemployment rates for White and Asian workers are similar and lower than those of Black and Hispanic workers. As shown in Table 1, the average unemployment rate is 11.8% for Black workers, 8.8% for Hispanic workers, 4.9% for Asian workers, and 5.5% for White workers. Second, although the levels are different, the unemployment rates for all racial groups move in parallel, as can be seen in Figure 1(a). Table 1 shows that the correlation coefficients between the overall unemployment rate and the unemployment rates for the four racial groups are all above 0.9. Third, the unemployment rates for Hispanic and Black workers are more volatile, but the volatility is approximately proportional to the level. As shown in Table 1, the standard deviation of the overall unemployment rate is 1.70, but it is 1.56 for White workers, 2.50 for Hispanic workers and 3.12 for Black workers. But the coefficient of variation (ratio of standard deviation to mean) is similar across all racial groups; it is 0.27 for the overall unemployment rate, 0.28 for White workers, 0.29 for Hispanic workers, and 0.26 for Black workers. Asian workers' coefficient of variation (0.42) is higher because their data start from 2003, and the short period contains two large recessions.

Another way to see what the paragraph above describes is to compare the "normalized" unemployment rate of the overall population and the four racial groups.[5] This is shown in Figure 1(b). The normalized unemployment rate is constructed by dividing the unemployment rate by the average unemployment rate for each group. For example, a value of 1 for Black workers in Figure 1(b) means that the unemployment rate is equal to the Black unemployment rate (11.8%). What is remarkable in Figure 1(b) is that the five lines are generally on top of each other, meaning that all the unemployment rates move in sync, and the volatility is close to proportional to the average unemployment rate. The exception is the Asian unemployment rate in the early 2000s; it is either due to some data issue at the beginning of covering Asian workers or due to the declining trend of the Asian unemployment rate.

Table 1 contains other variables of interest.[6] The second block of the table contains the "unemployment rate gap." For example, the Black-White unemployment rate gap is the difference between the Black unemployment rate and the White unemployment rate. As shown in Table 1, the average unemployment rate gap is 3.2 percentage points for Hispanic workers and White workers, 6.3 percentage points for Black workers and White workers, while it is –0.6 percentage point between Asian workers and White workers. Since the unemployment rates for Black workers and Hispanic workers are consistently more volatile but move in parallel with that of White workers, the unemployment rate gaps are naturally countercyclical. Besides, not surprisingly, the gaps for Hispanic and Black workers are positively correlated with the overall unemployment rate. Table 1 shows that the correlation coefficient with the overall unemployment rate is 0.70 for the Black-White unemployment rate gap and 0.65 for the Hispanic-White unemployment rate gap. For the Asian-White gap, correlation is close to zero (–0.02), but it is

[5] The figure shows the normalized unemployment rate up to 2020, since the historically high level of the normalized unemployment rate during the pandemic makes the figure before the pandemic hard to see.

[6] Appendix A contains additional information about the unemployment rate gap, the labor force participation rate, and the median earnings.

Table 1: Labor Market Statistics of Four Racial Groups

	Overall	White	Asian	Hispanic	Black
Unemployment Rate (UR)					
Average	6.29	5.53	4.90	8.75	11.80
Standard Deviation	1.70	1.56	2.05	2.50	3.12
Coefficient of Variation	0.27	0.28	0.42	0.29	0.26
Correlation with Overall UR	1.000	0.997	0.909	0.937	0.919
Unemployment Rate Gap					
Average	–	–	–0.57	3.22	6.27
Correlation with Overall UR	–	–	–0.019	0.655	0.702
Labor Force Participation Rate (LFPR)					
Average	64.7	64.9	64.7	66.0	62.6
Correlation with Overall LFPR	1.000	0.998	0.906	0.764	0.913
Real Median Usual Weekly Earnings					
Dollar Values	748	770	887	551	605
Relative to Overall	100.0	103.3	118.7	73.7	80.9

Note: Source for the unemployment rate and the labor force participation rate is the CPS, from March 1973 to July 2021, except for Asian, whose data are available from January 2003. The source for real median usual weekly wage is also the CPS, from 2003 to 2018.

not important, as the unemployment rates for White and Asian workers are almost on top of each other. The third block of Table 1 shows the labor force participation rate (LFPR). There are also persistent differences in the level of the LFPRs, and the LFPRs for the four racial groups move in parallel. However, since the dispersion of the LFPRs across racial groups is smaller than that of the unemployment rate, and the cyclicality is weaker, I do not model the labor force participation decision in this paper. The last block of Table 1 shows median usual weekly earnings. The first line shows the average dollar value (in 2010 dollars), and the second line shows the values normalized such that the overall median is 100 each year. Median weekly earnings of White workers are consistently higher than the overall median by 3%. Median weekly earnings of Black workers are consistently lower by about 20% than the overall median. Median weekly earnings of Hispanic workers are 73.7% of the overall median, although the ratio changed significantly over time (see Appendix A). Median weekly earnings of Asian workers are about 20% higher than the overall median earnings, because the proportion with a college degree among Asian workers is above 50%, unlike other racial groups, which implies that median earnings of Asian workers are significantly affected by a rising college premium.

Unemployment rates are consistently higher among Hispanic and Black workers, but it is because their job-finding rates are lower, or is it because their separation rates are higher? Table 2 answers this question. The numbers in the table are taken from Cajner et al. (2017), who use CPS microdata from 1994 to 2016 to compute monthly transition rates among three labor market statuses (employed, unemployed, and out-of-labor-force), separately for three racial groups (White, Hispanic, and Black workers) and two genders. In terms of the transition rates between employment and unemployment, which is the focus of the current paper, there are

Table 2: Monthly Transition Rates

	Male			Female		
	White	Hispanic	Black	White	Hispanic	Black
EU Rate	1.2	2.2	2.3	1.0	1.7	1.7
UE Rate	25.6	28.4	18.2	25.0	20.4	17.2
EN Rate	2.1	2.5	3.4	3.1	4.8	3.7
NE Rate	4.6	7.5	4.9	3.8	5.1	4.5
UN Rate	18.5	19.5	24.8	24.5	31.7	28.7
NU Rate	2.4	5.1	5.1	1.7	3.3	4.0

Note: U = unemployment, E = employment, and N = out-of-labor-force. Monthly transition rates in percent. Source is Cajner et al. (2017). Based on the CPS microdata, longitudinally matched, from 1994 to 2016.

three takeaways from the first block of Table 2. First, both Hispanic and Black workers exhibit a higher separation (EU) rate than White workers. This makes the average job tenure of Black and Hispanic workers shorter and pushes up their unemployment rate. Among males, the EU transition probability is 2.2% per month for Hispanic workers and 2.3% for Black workers, compared with 1.2% for White workers. There is a similar tendency among female workers. Second, Black workers have a lower job-finding rate (UE transition rate) than White workers, making their unemployment rate even lower. Among Black males, the UE transition rate is 18.2% per month, which is about 70% of the White males' UE transition rate (25.6%). The job-finding rate for Black and White females is similar to their male counterparts. However, third, Hispanic males have a higher UE transition rate (28.4%) than White males. This is probably due to the type of jobs and industries in which many Hispanic workers work. This is why the unemployment rate among Hispanic workers is lower than Black workers' unemployment rate even though both racial groups exhibit similarly high separation rates. Among Hispanic females, the job-finding rate is slightly lower than that of White females but still higher than that of Black females.

In terms of the flow rates in and out of the labor force, what stands out is that all transition rates are higher among Black and Hispanic workers than White workers. In other words, labor market status is less stable among Black and Hispanic workers. Specifically, Black and Hispanic workers exhibit a higher EN rate, NE rate, UN rate, and NU rate, compared with White workers. Black and Hispanic workers exhibit a higher probability of getting out of the labor force (E+U into N) and a higher probability of coming back to the labor force (N to E+U) than White workers.

2.2 Hand-to-Mouth and Racial Wealth Inequality

In this section, I use the Survey of Consumer Finances (SCF), which is a cross-sectional household survey of wealth conducted by the Board of Governors of the Federal Reserve System every three years, from 1989 to 2016, and document wealth inequality across racial groups. Regarding sample selection, I follow Kaplan et al. (2014) and include households whose head

Table 3: U.S. Wealth Distribution for Four Racial Groups

	Overall	White	Asian	Hispanic	Black
Measures of Hand-to-Mouth Households					
Total Hand-to-Mouth	30.3	25.2	27.9	48.7	47.0
Poor Hand-to-Mouth	11.3	7.2	12.1	27.9	22.3
Wealthy Hand-to-Mouth	19.0	18.0	15.8	20.8	24.7
Measures of Wealth					
Mean Total Wealth	365,994	451,376	368,207	104,132	93,566
Relative to White	81.1	100.0	81.6	23.1	20.7
Median Total Wealth	89,564	127,725	82,123	9,553	16,706
Relative to White	70.1	100.0	64.3	7.5	13.1
Mean Illiquid Wealth	264,006	318,743	291,230	93,147	83,733
Median Illiquid Wealth	78,998	111,262	69,449	7,219	14,781
Mean Liquid Wealth	101,987	132,633	76,977	10,984	9,833
Median Liquid Wealth	2,777	5,268	4,750	207	293

Note: The source is the the Survey of Consumer Finances (SCF) Extract Public Dataset. Averages of the 1989 to 2016 waves (10 waves, as the SCF is available every three years) are shown. The definitions of hand-to-mouth and wealth, as well as sample selection (households whose head is between 22 and 79 years old, and whose non-financial income is strictly positive, are included) follow Kaplan et al. (2014). The sample household weights provided by the SCF are used. With the Extract Public dataset, Asian households are bunched together with all the other racial groups. Dollar amounts are shown in 2010 dollars.

is between 22 and 79 years old, and that report strictly positive non-financial income.[7] Since the SCF over-samples wealthier households, I use the sample weights provided by the SCF in computing all statistics. Table 3 summarizes the results, and Appendix B provides additional results.[8] Table 3 has five columns. The first column includes all racial groups. The second column includes only households whose head is White. The third column is labeled Asian but indeed includes households whose head is "other" racial groups, i.e, neither White, Hispanic, or Black. I label this column Asian, because the majority of the households of "other" races are Asian. This is a limitation of using the Extract Public Dataset of the SCF. The fourth and the fifth columns are associated with households whose head is Hispanic and Black, respectively.

The upper block of Table 3 summarizes the fraction of households that are classified as hand-to-mouth according to the definition of Kaplan et al. (2014).[9] Simply put, households whose

[7] Non-financial income is the sum of wage income from work and various transfers from the government, such as unemployment insurance, and social security.

[8] Figure A.2 in Appendix B shows that the fraction of hand-to-mouth households remained stable. Table A.1 in Appendix B contains the fraction of hand-to-mouth and statistics of wealth, according to alternative measures of wealth.

[9] Following Kaplan et al. (2014), liquid wealth is the sum of checking, savings, money market, and call accounts, directly held pooled investment funds, directly held individual stocks and bonds, net of credit card balance. Illiquid wealth is the sum of certificates of deposit, saving bonds, cash value of life insurance, all kinds of retirement accounts, value of primary and other residences, net equity in non-residential real estate, net of mortgages and other types of home equity loans. See Appendix C for more details about how Kaplan et al. (2014) define

liquid wealth holding is less than half of the non-financial income per pay period (two weeks) are classified as hand-to-mouth. Moreover, if a household that is classified as hand-to-mouth has zero or negative illiquid wealth, the household is classified as poor hand-to-mouth, while a hand-to-mouth household with strictly positive illiquid wealth is called wealthy hand-to-mouth. Total wealth is the sum of liquid and illiquid wealth. Averaged between 1989 and 2016, 30.3% of all households are hand-to-mouth. Among them, about 1/3 (11.3%) are poor hand-to-mouth, while the remaining 2/3 (19.0%) are wealthy-hand-to-mouth. These numbers are very close to the numbers that Kaplan et al. (2014) report using pooled data from 1989 to 2010.[10]

As can be seen from the second to fifth columns of the top block, there is significant racial heterogeneity in terms of the proportions of hand-to-mouth. Among White households, there are fewer hand-to-mouth. The total fraction of hand-to-mouth among White households is 25.2%; 7.2% are poor hand-to-mouth and 18.0% are wealthy hand-to-mouth. All numbers are below the overall ratios. The fractions of hand-to-mouth among Asian households are close to the overall fractions; 12.1% are poor hand-to-mouth, 15.8% are wealthy hand-to-mouth, and thus 27.9% are hand-to-mouth households in total. On the other hand, there are significantly more hand-to-mouth households among Hispanic and Black households. Among Hispanic and Black households, almost half (48.7% of Hispanic households, 47.0% of Black households) are hand-to-mouth. Among Hispanic hand-to-mouth households, the fraction of poor hand-to-mouth is particularly high, at 27.9%. This number is close to three times the overall proportion and more than four times the proportion of poor hand-to-mouth among White households. The fraction of wealthy hand-to-mouth is only slightly higher than the overall fraction, at 20.8%. Among Black households, 22.3% are poor hand-to-mouth, which is about twice as high as the overall fraction and three times as high as that of White households. Among Black hand-to-mouth households, 24.7% are wealthy hand-to-mouth, compared with 19.0% among overall households.

The lower block of Table 3 shows mean and median total wealth, liquid wealth and illiquid wealth, for all households as well as the four racial groups. Including all households, mean total wealth is $366,000 in 2010 dollars, while median total wealth is $90,000. For both mean and median total wealth, all minority groups hold less wealth than White households. The difference is especially large among Hispanic and Black households. Mean wealth of Asian, Hispanic, and Black households is 81.6%, 23.1%, and 20.7% of mean wealth of White households, respectively. Median total wealth for Asian, Hispanic, and Black households is 64.3%, 7.5%, and 13.1%, respectively, of median total wealth of White households. For all households, liquid wealth makes up a smaller portion of total wealth, but the fraction is significantly smaller for Hispanic and Black households. Median liquid asset holding for Hispanic households is only $207. For Black households, it is $293. This small liquid asset holding is consistent with the large fraction of hand-to-mouth households for these two racial groups.

hand-to-mouth.

[10] According to them, the fraction of hand-to-mouth is 31.2%, 39% of which (12.1% of total households) are poor hand-to-mouth, while the remaining 62% (19.2% of the total) are wealthy hand-to-mouth.

3 Model

Time is discrete and infinite, starting from $t = 0$. The economy is populated by workers, investment firms, capital firms, labor firms, intermediate good firms, final good firms, mutual funds, the government, and the monetary authority. The model is intended to stay close to the canonical one-asset heterogeneous-agent model with the standard New Keynesian nominal frictions, with the main innovation being having multiple types capturing different races.

3.1 Worker

There are mass of infinitely lived workers. A worker is characterized by permanent type s, discount factor β_t, persistent idiosyncratic productivity shock p_t, unemployment shock $e_t \in \{1, 2\}$, wealthy hand-to-mouth shock $h_t \in \{1, 2\}$, and asset holding a_t. The permanent type s captures racial differences in labor market risks, average earnings, liquidity risks, and the rate of return for assets. The basic idea is to assume the same preferences across racial groups but use s to capture heterogeneity in the economic environment that different racial groups face in the U.S. economy. The discount factor shock and the persistent productivity shock help the model replicate the observed inequality in wealth (Krusell and Smith (1998), De Nardi and Fella (2017)). The unemployment shock is endogenous and heterogeneous across racial groups, and is thus an important channel through which monetary policy has diverse effects on different racial groups. Asset holding is an endogenous variable and is crucial in generating poor hand-to-mouth workers. The wealthy hand-to-mouth shock captures the liquidity constraint due to allocating a large fraction of wealth into illiquid assets, without introducing complication associated with multiple (liquid and illiquid) assets. The problem of a worker is the following:

$$\max_{\{c_t, a_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \left(\prod_{\tilde{t}=0}^{t} \beta_{\tilde{t}} \right) u(c_t) \tag{1}$$

subject to:

$$earn_t = \begin{cases} w_t p_t \eta_s & \text{if } e_t = 1 \\ \min(\phi_0 w_t p_t \eta_s, \phi_1 \overline{wp\eta}_s) & \text{if } e_t = 2 \end{cases} \tag{2}$$

$$c_t + p_t^a a_{t+1} = (1 + r_t + \iota_s)\, p_t^a a_t + tr(earn_t) + (1 - \mathbb{1}_{e_t=1}\tau_{ui,t} - \tau_{tr,t}) earn_t \tag{3}$$

$$a_{t+1} \geq \begin{cases} 0 & \text{if } h_t = 1 \\ (1 - \delta_h) a_t & \text{if } h_t = 2 \end{cases} \tag{4}$$

Both β_t and p_t follow a first-order Markov process, with transition probabilities $\pi_{\beta_{t+1}|\beta_t}$ and $\pi_{p_{t+1}|p_t, e_t, e_{t+1}}$, respectively. The transition probabilities for p_t depend also on e_t and e_{t+1}, which helps capturing earnings loss upon job loss. Details will be discussed in the calibration section. As for the unemployment shock, $e_t = 1$ and 2 denote being employed and unemployed, respectively. $\pi_{e_{t+1}|s, e_t}$ denotes the transition probabilities of e for a type-s worker. When a worker is employed, the worker loses its job and becomes unemployed in the next period at a type-s specific but exogenous separation rate λ_s. If the worker is unemployed, the worker finds a job and becomes employed at an endogenous job-finding rate $f_{s,t}$. The wealthy hand-to-mouth shock h_t is i.i.d. and $h_t = 1$ with probability $1 - \pi_s^h$ and $h_t = 2$ with probability π_s^h.[11] Notice that

[11] Although it is reasonable to think that the wealthy hand-to-mouth shock might be persistent and state-dependent, I assume it is i.i.d. for two reasons. First, it helps computationally to have a smaller state space

π_s^h is type-specific.

In the maximand (1), $u(c)$ is the period utility function with the functional form of $u(c) = \frac{c^{1-\sigma}}{1-\sigma}$, where σ is the coefficient of relative risk aversion. c_t is consumption. $\mathbb{E}$ is an expectation operator. (2) defines the non-financial pre-tax income. An employed worker ($e_t = 1$) receives earnings, which is characterized as a product of the wage rate per efficiency unit w_t, productivity shock p_t, and the type-specific productivity η_s. An unemployed worker ($e_t = 2$) receives UI benefits. The amount of UI benefits is the replacement rate ϕ_0 times the would-be (pre-tax) labor income, with the upperbound of $\phi_1 \overline{wp\eta}_s$, where $\overline{w}$ is the steady-state wage, $\overline{p}$ is the average labor productivity shock, $\overline{\eta}_s$ is the average η_s across all types, and ϕ_1 controls the upperbound of UI benefits, as a fraction of the average wage. In the budget constraint (3), p_t^a is the price of assets, r_t represents the average rate of return of assets. ι_s is a type-specific premium for the rate of return of assets. Basically, ι_s makes the return from holding assets permanently different for different racial groups. $tr(.)$ is a function that determines the amount of income-dependent government transfers. The last term of equation (3) is the after-tax non-financial income. $\tau_{tr,t}$ is the tax to finance the government transfers, while $\tau_{ui,t}$ is the UI tax rate, which is only applied to employed workers.

The liquidity constraint (4) has two cases depending on h_t. If $h_t = 1$, the worker is not subject to hand-to-mouth shock, and the liquidity constraint basically states that the worker cannot borrow, but can use all the assets for current consumption. If $h_t = 2$, the worker is liquidity constrained in a way that captures wealthy hand-to-mouth. Specifically, a_{t+1} is constrained to be above $(1 - \delta_h)a_t$. In other words, the worker that is subject to the wealthy hand-to-mouth shock can use only a fraction δ_h of the current asset holding a_t for consumption smoothing, while the fraction $(1-\delta_h)a_t$ remains illiquid and cannot be liquidated for current consumption. This is a simplified way to introduce wealthy hand-to-mouth in a model that abstracts from a two-asset setup like the one developed by Kaplan et al. (2018).[12]

3.2 Investment Firm

Competitive investment firms purchase final goods, convert into investment goods and sell to capital firms at price p_t^i, subject to a quadratic investment adjustment cost and a marginal efficiency of investment (MEI) shock z_t^{MEI} (Justiniano et al. (2010)). The problem of investment firms is as follows:

$$\max_{\{i_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \left(\prod_{\tilde{t}=0}^{t} Q_{\tilde{t}} \right) \left[i_t z_t^{MEI} \left(p_t^i - \frac{\psi_i}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 \right) - i_t \right] \tag{5}$$

The term $\frac{\psi_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2$ represents the quadratic investment adjustment cost. Log of the MEI shock follows an AR(1) process with persistence ρ_{MEI} and the variance of the normal innovation σ_{MEI}^2. Future profits are discounted by a discount factor Q_t, which will be discussed later.

for storing the type distribution of workers. By assuming that the wealthy hand-to-mouth shock is i.i.d., the size of the state space halves. Second, the data related to hand-to-mouth is obtained using the Survey of Consumer Finances (SCF). Since the SCF is a cross-sectional data set and available every three years, I cannot compute the persistence or state-dependence of the wealthy hand-to-mouth shock using the SCF.

[12] In a related setup, Bayer et al. (2020) assume that workers can adjust illiquid asset holding with an i.i.d. probability. The wealthy hand-to-mouth shock here can be considered as a one-asset version of their setup.

Current profits of investment firms can be defined as:

$$d_t^{INV} = i_t z_t^{MEI} \left(p_t^i - \frac{\psi_i}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 \right) - i_t \tag{6}$$

3.3 Capital Firm

The problem of competitive capital firms can be characterized as follows:

$$\max_{\{k_t, n_t\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty} \left(\prod_{\tilde{t}=0}^{t} Q_{\tilde{t}} \right) \left[r_t^k n_t k_t - p_t^i i_t z_t^{MEI} \right] \tag{7}$$

subject to:

$$k_{t+1} = (1 - \delta_0 n_t^{\delta_1}) k_t + i_t z_t^{MEI} \tag{8}$$

where r_t^k is the real rate of return of capital. Following Greenwood et al. (1988), $\delta_0 n_t^{\delta_1}$ is the depreciation rate, which depends on the level of utilization n_t. Profits of the capital firms are:

$$d_t^{CAP} = r_t^k n_t k_t - p_t^i i_t z_t^{MEI} \tag{9}$$

3.4 Labor Firm

Labor markets are segmented for different types. An unmatched labor firm can post a vacancy in a type-s market by paying a cost κ_s. Whether an unmatched firm posting a vacancy is matched with a worker or not is determined by a matching function. If matched, the firm and the worker produces and sells labor services to intermediate good firms, and the revenue is shared between the worker (wages) and the firm (profits). The bargaining is simplified by assuming the following simple surplus sharing rule.[13]

$$w_t = \omega_0 \overline{x} + \omega_1 (\log x_t - \log \overline{x}) + \omega_2 (\log \pi_t - \log \overline{\pi}) \tag{10}$$

ω_0 captures the worker's share out of total surplus in the steady state, with $\overline{x}$ being the steady-state rental rate of labor services or labor productivity. ω_1 captures the elasticity of the wage with respect to labor productivity. ω_2 is intended to capture nominal wage rigidity. With $\omega_2 \in (-1, 0)$, a higher inflation rate implies a lower real wage, but not one-to-one with the inflation rate.

The value function of a labor firm matched with a type-(s, p) worker is:

$$J_{s,p,t} = (x_t - w_t) p \eta_s + \mathbb{E}_t Q_{t+1} (1 - \lambda_s) \sum_{p'} \pi_{p'|p,1,1} J_{s,p',t+1} \tag{11}$$

[13] A common choice for the surplus sharing rule is the generalized Nash bargaining. Nakajima (2012a) uses the generalized Nash bargaining in a heterogeneous-agent model with the same labor market frictions. However, the generalized Nash bargaining would make it significantly hard to solve the model, as the bargaining outcome would depend on all the characteristics of the worker in the bargaining, including savings. Since savings are endogenous, the workers internalize the effect to the bargaining outcome when making the saving decision. In the end, Nakajima (2012a) quantitatively shows that the bargaining outcome is not sensitive to savings. Gornemann et al. (2021) also use a simple surplus sharing rule like the one used here.

where $x_t - w_t$ is the profits per efficiency unit. $p\eta_s$ represents the individual productivity of the worker. Each period, the match is destroyed at the separation rate λ_s. The worker type s does not change, but the individual labor productivity p changes according to $\pi_{p'|p,e=1,e'=1}$, where $e = e' = 1$ means the worker remains employed.

Unmatched firms keep entering the markets until the expected profits of entering the type-s market are equal to the vacancy posting cost, as follows:

$$\kappa_s = \frac{\mu v_{s,t}^{\alpha} u_{s,t}^{1-\alpha}}{v_{s,t}} \sum_{p} \pi_{p|s,e=2} \sum_{p'} \pi_{p'|p,2,1} J_{s,p',t} \tag{12}$$

$v_{s,t}$ and $u_{s,t}$ are the number of vacancies and the number of unemployed (and thus job-searching) workers in the type-s market, respectively. $m(v_{s,t}, u_{s,t}) = \mu v_{s,t}^{\alpha} u_{s,t}^{1-\alpha}$ is the matching function, where μ is the matching efficiency and α is the elasticity of matches with respect to $v_{s,t}$. Labor market search and matching occurs before production in period t. $\pi_{p|s,e=2}$ denotes the distribution of individual productivity p among the currently unemployed ($e = 2$) workers of type-s. $\pi_{p'|p,2,1}$ is the transition probability of p for a worker who finds a job. The transition of p here allows the model to capture earnings loss upon job loss. I will come back with more details in the calibration section. The expected zero profit condition virtually determines the equilibrium $v_{s,t}$ for each type-s. Once $v_{s,t}$ is determined the fob-finding rate $f_{s,t}$, can be characterized as:

$$f_{s,t} = \frac{\mu v_{s,t}^{\alpha} u_{s,t}^{1-\alpha}}{u_{s,t}} \tag{13}$$

Current total profits of labor firms in period t, d_t^{LAB}, can be characterized as follows:

$$d_t^{LAB} = \int \mathbb{1}_{e=1}(x_t - w_t) p\eta_s \, d\, m_{t+1} - \sum_{s} \kappa_s v_{s,t} = (x_t - w_t)\ell_t - \sum_{s} \kappa_s v_{s,t} \tag{14}$$

3.5 Final Good Firm

Following the standard New Keynesian setup, there is a continuum of intermediate good firms indexed by $j \in [0, 1]$ producing differentiated output $y_t(j)$ at nominal prices $P_t(j)$. These intermediate goods are bundled into final output y_t with the following production function, with elasticity of substitution among intermediate goods $\epsilon_p > 1$.

$$y_t = \left(\int_0^1 y_t(j)^{\frac{\epsilon_p - 1}{\epsilon_p}} dj \right)^{\frac{\epsilon_p}{\epsilon_p - 1}} \tag{15}$$

The profit-maximization problem of a representative final good firm is:

$$\max_{\{y_t(j)\}_{j \in [0,1]}} P_t \left(\int_0^1 y_t(j)^{\frac{\epsilon_p - 1}{\epsilon_p}} dj \right)^{\frac{\epsilon_p}{\epsilon_p - 1}} - \int_0^1 P_t(j) y_t(j) dj \tag{16}$$

The first order condition with respect to an intermediate goods output $y_t(j)$ is:

$$y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon_p} y_t \tag{17}$$

This is virtually a demand function by the final good firm, taken as given by intermediate good firms. The aggregate price index P_t in the equation above is characterized by:

$$P_t^{1-\epsilon_p} = \int_0^1 P_t(j)^{1-\epsilon_p} dj \tag{18}$$

Final good firms make zero profits in equilibrium.

3.6 Intermediate Good Firm

Intermediate good firms produce differentiated goods j, using the following technology:

$$y_t(j) = z_t^{TFP}(k_t(j)n_t(j))^{\theta}\ell_t(j)^{1-\theta} \tag{19}$$

where $k_t(j)$ is capital, $n_t(j)$ is the level of utilization, and $\ell_t(j)$ is labor used by the intermediate firm j. z_t^{TFP} is total factor productivity shock that follows an AR(1) process with the persistence ρ_{TFP} and the variance of the normal innovation σ^2_{TFP}. The nominal profit of the intermediate good firm j is:

$$D_t(j) = P_t(j)y_t(j) - R_t^k(k_t(j)n_t(j)) - X_t\ell_t(j) - \frac{\psi_1}{2}\left(\frac{P_t(j)}{P_{t-1}(j)} - \bar{\pi}\right)^2 y_t P_t - \psi_0 P_t \tag{20}$$

$P_{t-1}(j)$ is the nominal price of intermediate good j in the previous period. P_t is the aggregate price of intermediate goods, taken as given by an intermediate good firm j. R_t^k and X_t are the nominal rental rate of capital and labor, respectively. Following the standard New-Keynesian setup (Rotemberg (1982)), I assume a quadratic nominal price adjustment cost, with ψ_1 determining the degree of nominal price rigidity. $\bar{\pi}$ is the steady-state inflation rate. ψ_0 is a fixed cost, which ensures that profits (and dividends) are zero in the steady state.

Dividing by the nominal price of intermediate goods P_t, the real profit of a firm j is:

$$\frac{D_t(j)}{P_t} = \frac{P_t(j)}{P_t}y_t(j) - \frac{R_t^k}{P_t}(k_t(j)n_t(j)) - \frac{X_t}{P_t}\ell_t(j) - \frac{\psi_1}{2}\left(\frac{P_t(j)}{P_{t-1}(j)} - \bar{\pi}\right)^2 y_t - \psi_0 \tag{21}$$

And the optimization problem of an intermediate good firm j is as follows:

$$\max_{\{P_t(j),(k_t(j)n_t(j)),\ell_t(j)\}_{t=0}^{\infty}} \mathbb{E}_0 \sum_{t=0}^{\infty}\left(\prod_{\tilde{t}=0}^{t} Q_{\tilde{t}}\right)\frac{D_t(j)}{P_t} \tag{22}$$

subject to:

$$y_t(j) = \left(\frac{P_t(j)}{P_t}\right)^{-\epsilon_p} y_t \tag{23}$$

$$y_t(j) = z_t^{TFP}(k_t(j)n_t(j))^{\theta}\ell_t(j)^{1-\theta} \tag{24}$$

The total real profits of intermediate good firms, d_t^{INT}, can be defined as follows:

$$d_t^{INT} = \int_0^1 \frac{D_t(j)}{P_t} dj \tag{25}$$

3.7 Government

The government runs two separate social insurance programs. The first is the UI program. The budget of the UI program is balanced each period by adjusting the UI tax rate $\tau_{ui,t}$. The government budget constraint associated with the UI program is as follows:

$$\tau_{ui,t} \int \mathbb{1}_{e=1} w_t p \eta_s \, d\, m_{t+1} = \int \mathbb{1}_{e=2} \min(\phi_0 w_t p \eta_s, \phi_1 \overline{wp\eta}_s) \, d\, m_{t+1} \tag{26}$$

where m_{t+1} is the type distribution of workers in period t after labor market transitions. The second is the income-dependent transfer program. Following Guner et al. (2021), income-dependent transfers include the Earned Income Tax Credit (EITC), various transfers to households with children (the Child Tax Credit (CTC), the Child and Dependent Care Tax Credit, and childcare subsidies), and income-dependent welfare programs (the Temporary Assistance to Needy Families (TANF) and the Supplemental Nutrition Assistance Program (SNAP). The government budget constraint associated with the income-dependent transfers is as follows:

$$\tau_{tr,t} \int earn_t \, d\, m_{t+1} = \int tr(earn_t) \, d\, m_{t+1} \tag{27}$$

$\tau_{tr,t}$ adjusts each period such that the budget constraint is satisfied.

3.8 Monetary Authority

Monetary policy is characterized by the following Taylor rule with interest rate smoothing:

$$\frac{R_t}{\overline{R}} = \left(\frac{R_{t-1}}{\overline{R}}\right)^{\rho_R} \left(\frac{\pi_t}{\overline{\pi}}\right)^{(1-\rho_R)\phi_\pi} \left(\frac{y_t}{\overline{y}}\right)^{(1-\rho_R)\phi_y} z_t^{MP} \tag{28}$$

where the first term represents the interest rate smoothing and ρ_R is the smoothing parameter. z_t^{MP} is a monetary policy shock, which follows an AR(1) process with the persistence ρ_{MP} and the variance of the normal innovation σ^2_{MP}. The assumed timing is that R_t is applied to nominal assets saved in period t (and the return is paid in period $t+1$). ϕ_π and ϕ_y represent the response of monetary policy against inflation and output, respectively. Taking the log of both sides yields:

$$\begin{aligned} \log R_t = (1-\rho_R)\log \overline{R} + \rho_R \log R_{t-1} \\ + (1-\rho_R)[\phi_\pi(\log \pi_t - \log \overline{\pi}) + \phi_y(\log y_t - \log \overline{y})] + \log z_t^{MP} \end{aligned} \tag{29}$$

3.9 Mutual Funds

Workers own all firms and assets through mutual funds. This is a way to avoid a portfolio choice problem at the individual level and force all workers to have the same representative portfolio. The price of a share of mutual funds is p_t^a. The dividend of mutual funds, d_t, is:

$$d_t = d_t^{INV} + d_t^{CAP} + d_t^{LAB} + d_t^{INT} \tag{30}$$

where d_t^{INV} ,d_t^{CAP}, d_t^{LAB} and d_t^{INT} denote real profits from investment firms, capital firms, labor firms, and intermediate good firms, respectively. The total number of mutual fund shares is fixed at $\overline{a}$. The discount factor that is used for intertemporal decision of firms can be defined as:

$$Q_{t+1} = \frac{p_t^a}{p_{t+1}^a + d_{t+1}} \tag{31}$$

Remember workers of different type-s face different rate of returns of assets ι_s. In aggregate, the following budget constraint holds for mutual funds:

$$r_t + \int \iota_s a_t \, m_{t+1} = \frac{d_t}{p_t^a} \tag{32}$$

Given the type distribution m_{t+1}, dividends d_t, and the price of assets p_t^a, this equation gives the average rate of return for workers, r_t.

3.10 Solving the Model

The equilibrium of the model is solved using the first-order (linear) perturbation method proposed by Schmitt-Grohé and Uribe (2009). Appendix E provides the details.

4 Calibration

One period is a quarter. Section 4.1 discusses common parameters and Section 4.2 covers type-specific parameters. Tables 4 and Table 5 summarize the calibration of the common parameters and the type-specific parameters, respectively. By imposing the steady-state conditions ($\mathbf{x}_t = \mathbf{x}_{t+1} = \overline{\mathbf{x}}$ and $\mathbf{y}_t = \mathbf{y}_{t+1} = \overline{\mathbf{y}}$), I can obtain equations characterizing the steady-state values of aggregate variables. The steady-state values of the aggregate variables, together with how they are obtained, are summarized in Table A.3 in Appendix F.

4.1 Common Parameters

The coefficient of relative risk aversion is set at σ=2.0, a commonly used value. I assume two values of β. The calibration of β_1 and β_2 is discussed in the next section, since the βs are calibrated together with type-dependent parameters. As for the transition probabilities of β, I assume symmetry. The transition matrix is characterized by one parameter, ρ_β, which is the probability that β stays the same from one period to the next. ρ_β is set at 0.9957, which is consistent with the average duration of β being 58 years (232 quarters). I choose 58 years since the statistics associated with hand-to-mouth are computed using household whose head is between the ages of 22 and 79 (Section 2.2).

The transition probabilities of an individual labor productivity shock p depend on the employment status before and after the employment transition. If a worker remains employed (e_t=e_{t+1}=1), the transition probabilities are obtained from the discretized AR(1) process with persistence ρ_p and standard deviation σ_p. ρ_p = 0.9160 and σ_p = 0.3085 are taken from Storesletten et al. (2001).[14] Since they estimate these parameters using annual data, I assume that, with a probability of 0.75 (three quarters out of four), individual productivity remains the same, while, with a probability of 0.25 (one quarter out of four), individual productivity changes according to the discretized Markov process using the annual productivity shock. On top of this

[14] σ_p is the average between its values in expansions and recessions, estimated by Storesletten et al. (2001).

Table 4: Summary of Calibration: Common Parameters

	Value	Description	Target
σ	2.0000	Relative risk aversion	Standard in literature
β_1	0.9865	Discount factor (high)	See text
β_2	0.9276	Discount factor (low)	See text
ρ_β	0.9957	Persistence of discount factor shock.	Avg. duration of β = 58 years
ρ_p	0.9160	Persistence of individual prod. shock	Storesletten et al. (2001)
σ_p	0.3085	S.D. of individual prod. shock	Storesletten et al. (2001)
δ_p	0.3352	Earnings loss upon job loss	Greenstone and Looney (2021)
δ_h	0.0182	Liquidity for wealthy hand-to-mouth	Ratio of credit limit to wealth
$\overline{a}$	1.0000	Total supply of mutual fund shares	Normalization
μ	0.8005	Matching efficiency	Avg. job-finding rate is 62.6%
α	0.7944	Matching elasticity	Bartscher et al. (2021)
ω_0	0.9700	Steady-state wage share	Nakajima (2012b)
ω_1	0.4490	Sensitivity of wage to productivity	Nakajima (2012b)
ω_2	–0.1326	Nominal wage stickiness	Gertler et al. (2008)
ψ_i	0	Investment adjustment cost	Volatility of PCE
δ_0	0.0150	Avg. depreciation rate	From NIPA
δ_1	1.5833	Curvature of depreciation cost	Steady-state utilization rate $= 1$
ϵ_p	20.000	Elasticity of substitution	Price mark-up of 5%
θ	0.3000	Capital share of production	Labor share = 2/3
ψ_0	0.1145	Fixed cost of production	Steady-state profit = 0
ψ_1	38.080	Price adjustment cost	Avg. price duration = 5 quarters
ϕ_0	0.4610	UI replacement rate	Avg. across U.S. states
ϕ_1	0.5120	Upperbound of UI benefits	Avg. across U.S. states
ϕ_2	0.1519	Size of transfers for income = 0	Guner et al. (2021)
ϕ_3	0.1028	Slope of transfer function	Guner et al. (2021)
ρ_R	0.8460	Interest rate smoother	Castelnuovo (2003)
ϕ_π	1.3790	Taylor response to inflation	Castelnuovo (2003)
ϕ_y	0.2010	Taylor response to output	Castelnuovo (2003)
$\overline{\pi}$	1.0050	Avg. inflation rate	Annual inflation rate of 2%
$\overline{R}$	1.0138	Avg. nominal interest rate	Endogenously obtained
ρ_{MP}	0.4380	Persistence of monetary policy shock	Castelnuovo (2003)
σ_{MP}	0.0025	S.D. of monetary policy shock	Standard in literature
ρ_{TFP}	0.9500	Persistence of TFP shock	Standard in literature
σ_{TFP}	0.0035	S.D. of TFP shock	Justiniano et al. (2010)
ρ_{MEI}	0.8100	Persistence of MEI shock	Justiniano et al. (2010)
σ_{MEI}	0.1284	S.D. of MEI shock	Justiniano et al. (2010)

Note: Quarterly frequency.

usual stochastic transitions of labor productivity, I introduce long-term loss of earnings upon job loss. Davis and Von Wachter (2011), among others, find that when a worker loses a job, the worker suffers a long-term loss of earnings. I introduce this fact in a stylized manner. Specifically, when a worker was employed but lost a job during the employment status transition ($e_t = 1, e_{t+1} = 2$), the productivity of the worker stays the same. While the worker remains unemployed ($e_t = e_{t+1} = 2$), the productivity stays the same as well. But when the worker finds a new job, the productivity of the worker declines by a fixed fraction δ_p. δ_p is calibrated to 0.3352, which makes the degree of the long-term loss of earnings by a worker who lost a job consistent with empirical evidence by Greenstone and Looney (2021).[15] The parameter controlling the amount of liquidity available when a worker is hit by a wealthy hand-to-mouth shock, δ_h, is set at 0.0182, based on the ratio of the median credit card limit across all households (which is equivalent to one month's earnings, following Kaplan et al. (2014)) and median total wealth. The supply of mutual fund shares is normalized to $\overline{a} = 1$.

In order to pin down the matching efficiency parameter μ, first I assume that the average vacancy posting cost ($\overline{\kappa}$) is 1.5 months' equivalent of the average wage (= $0.5\overline{wp\eta}$). Using the zero-profit condition for labor firms posting a vacancy to hire an average worker and the average job-finding rate of 63.4% per quarter, the matching efficiency parameter μ =0.8005 is obtained. Once μ is fixed, I can compute a type-specific κ_s that is consistent with the job-finding rate f_s. The elasticity of the matching function α is typically estimated to be around 0.5 (Petrongolo and Pissarides (2001)). However, I calibrate α to be 0.7944, such that the Black-White unemployment rate gap shrinks by 0.34pp in response to a 25bp policy rate cut (the estimate by Bartscher et al. (2021)). I will discuss the effects of a monetary policy shock in Section 7.2. Following Nakajima (2012b), ω_0 = 0.97 reflects that profits for firms out of production are 3% of the total surplus. The sensitivity parameter of the wage to changes in labor productivity is ω_1 = 0.449 (Hagedorn and Manovskii (2008)). The sensitivity parameter of the wage to inflation (price changes) is set at ω_2 = -0.1326, based on Gertler et al. (2008). In their estimated model with staggered nominal wage bargaining, the fraction 0.283 of firms re-optimize the nominal wage, which means that the inflation rate does not affect the bargained wage in real terms. The nominal wage of the remaining (the fraction of 0.717) firms is not optimally adjusted. In particular, the elasticity of the nominal wage in terms of the inflation rate is estimated to be 0.815. In other words, the elasticity of real wage in terms of the inflation rate is -0.185. I do not model explicitly staggered nominal wage bargaining, but using these two pieces of information implies that the average elasticity of the real wage to inflation is ω_2 = -0.185×0.717 = -0.1326.

As for the production block, the parameter controlling the investment adjustment cost is set at ψ_i=0. The intention is to use this parameter to match the volatility of aggregate consumption, but it turns out that the consumption volatility generated by the model is already higher than the data with ψ_i=0. The average depreciation rate is set at δ_0 = 1.5%, following NIPA. The curvature parameter of the depreciation cost function is set at δ_1 = 1.583, which guarantees that the

[15] Specifically, for each p, I first compute $\log(p) - \delta_p$, and find grids $\log(p_i)$ and $\log(p_{i+1})$ between which $\log(p) - \delta_p$ falls into. Then I assign probabilities to the two grids in a proportional manner so that the average earnings loss is equal to δ_p. The alternative timing assumption is that the productivity of a worker declines at the time of job loss, and the productivity stays the same after that, including the time when the worker finds a new job. However, this timing assumption makes the productivity of the worker who lost a job already lower while receiving the UI benefits. This is inconsistent with the fact that the amount of the UI benefits depends on the level of earnings before job loss.

steady-state utilization rate is one. ϵ_p is set at 20, implying a price mark-up of 5% (Bayer et al. (2019)). The capital share parameter of the production function θ is set at 0.30, which implies that the resulting labor share (after taking into account the price mark-up and the profits of labor firms) is about 2/3. The fixed cost of production is set at ψ_0=0.1145, making sure that the steady-state profit (and dividends) is zero. The price adjustment cost parameter ψ_1 is set at 38.08, such that, when converted into the Calvo framework, the parameter value implies the nominal price is adjusted every five quarters on average (Gornemann et al. (2021)). This is common in the New-Keynesian literature.

In the policy block, the UI replacement rate and the upperbound of the UI benefits are obtained using the average across U.S. states. Specifically, the UI replacement rate is ϕ_0 = 0.461 and the upperbound of the UI benefits is ϕ_1 = 0.512 of average earnings. As for the income-dependent transfers, Guner et al. (2021) summarize the relationship between the income and the total amount of various transfers.[16] I capture the relationship using a simple functional form: $tr(earn) = \max(\phi_2 - \phi_3 earn, 0)$. ϕ_2 is the amount of transfers for those with zero earnings, which is set at the model equivalent of $\$8,800$, following Guner et al. (2021). ϕ_3 is the slope of the income-dependent transfer function $tr(.)$. ϕ_3 is set using the condition that the amount of income-dependent transfers goes down such that it becomes zero at the mean income.[17] Monetary policy parameters are mostly taken from Castelnuovo (2003), which estimates a flexible form of the Taylor rule for the U.S. The interest rate smoothing parameter is set at ρ_R=0.846, which is within the standard range in the literature. The Taylor response parameters to the inflation gap and to the output gap are set at ϕ_π=1.379 and ϕ_y=0.201 (quarterly), which are close to the commonly used values of ϕ_π=1.50 and ϕ_y=0.125. The average inflation rate is set at $\overline{\pi}$=1.005, implying a 2% annual inflation target. The average nominal interest rate is $\overline{R}$=1.0138, which is obtained from the average inflation rate and the steady-state real rate of return. The standard deviation of the monetary policy shock is set at σ_{MP}=0.0025. The persistence of the monetary policy shock is set at ρ_{MP}=0.438.

There are three aggregate shocks: the total factor productivity (TFP) shock z_t^{TFP}, the marginal efficiency to investment (MEI) shock z_t^{MEI}, and the monetary policy shock z_t^{MP}. The persistence and the standard deviation of the monetary policy shock are already discussed. The persistence of the TFP shock is set at ρ_{TFP} = 0.95, which is standard. The persistence of the MEI shock is set at ρ_{MEI} = 0.81, following Justiniano et al. (2010). The standard deviation of the TFP shock and that of the MEI shock are calibrated such that (1) the output volatility in the model is 1.23%, and (2) the ratio of the fractions of the output variance accounted for by the two shocks is 0.25/0.60. 1.23% is the standard deviation of detrended U.S. GDP from 1980 to 2019. 0.25/0.60 is based on the estimated model of Justiniano et al. (2010). Their variance decomposition suggests that 0.25 and 0.60 of the output variations in business cycle frequencies (between 6 and 32 quarters) are accounted by the TFP shock and the MEI shock, respectively.[18]

[16] Figure 4 of their paper.

[17] This simple functional form cannot capture the fact that households whose income is above the mean income also receive small amount of transfers on average, but this is a limitation of a simple functional form that I use to characterize $tr(.)$. In addition, modifying the $tr(.)$ to capture the small amount of transfers that high-income households receive does not significantly change the main results of the paper.

[18] The contributions from other shocks are as follows: monetary policy shock = 0.04, government expenditure shock = 0.02, investment specific productivity shock = 0.00, price mark-up shock = 0.02, wage mark-up shock =

Table 5: Calibration: Different Types

s (Type)	π_s	η_s	f_s	λ_s	u_s/π_s	v_s	κ_s	π^h_s	ι_s
1 (White)	68.25	1.030	66.0	3.80	5.44	0.0291	0.949	19.4	0.002
2 (Asian)	5.08	1.184	69.7	3.59	4.90	0.0021	1.144	18.0	–0.007
3 (Hispanic)	15.28	0.735	69.1	6.20	8.23	0.0105	0.369	28.9	–0.032
4 (Black)	11.39	0.810	49.5	6.44	11.52	0.0072	0.422	31.8	–0.030

Note: π_s is the fraction of each type, in percent. η_s is the productivity of each type, normalized such that the overall average is one. Both are obtained from the CPS. f_s is the quarterly job-finding rate, and λ_s is the quarterly separation rate, both in percent. They are obtained from Cajner et al. (2017) and converted from monthly to quarterly numbers. u_s is the number of unemployed workers of type-s. u_s/π_s is the unemployment rate, which is implied by the job-finding rate and the separation rate, in the steady state. v_s is the number of vacancy postings. κ_s is the vacancy posting cost. They are obtained from the steady-state conditions of the model. π^h_s is the probability of the wealthy hand-to-mouth shock, obtained from the proportions of wealthy hand-to-mouth in Table 3. ι_s is the type-specific savings interest rate premium, calibrated to match the fraction of poor hand-to-mouth for each type, except for White workers, whose ι_s is pinned down to satisfy a zero average premium.

σ_{TFP} = 0.0035 and σ_{MEI} = 0.1284 satisfy the two targets simultaneously.

4.2 Permanent Types

This section describes calibration of type-specific parameters. Table 5 summarizes the parameter values. The basic principle is to assume common preferences across all racial types, but assume heterogeneity in labor market and financial conditions, to replicate racial differences documented in Section 2. I assume 4 types, with $s = 1, 2, 3, 4$ representing White, Asian, Hispanic, and Black workers, respectively. The type-dependent parameters are associated with the job-finding rate (κ_s), the separation rate (λ_s), average earning levels (η_s), the probability of the wealthy hand-to-mouth shock (π^h_s), and premium to the rate of return of savings (ι_s).

In Table 5, π_s shows the proportion of each type, computed as the share within labor force, using the Current Population Survey (CPS), Annual Social and Economic Supplement (ASEC). I take the average between 2003 and 2018. η_s is the average labor productivity for each type, obtained from the median usual weekly earnings for each racial group, reported by the Bureau of Labor Statistics (BLS). Values of η_s are normalized by the overall median usual weekly earnings. f_s and λ_s are the quarterly job-finding rate and the quarterly separation rate, respectively. These numbers are based on the monthly transition rates reported by Cajner et al. (2017). Specifically, I convert the monthly transition rates into quarterly rates and adjust both rates by the same proportion, so that the implied steady-state unemployment rate for each racial group matches the unemployment rate in the CPS, shown in the next column as u_s/π_s. Once the parameters of the matching function are set (discussed in the previous subsection), the number of vacancy postings for each type-s, v_s can be backed up using the formula for the job-finding rate. Then, the vacancy-posting cost for each type, κ_s, can be backed up using the free-entry condition. Basically, κ_s for each racial group guarantees that the job-finding rate

0.01, intertemporal preference shock = 0.05.

for each racial group in the data is replicated in the steady state of the model. The next two columns show the obtained values of v_s and κ_s. π_s^h is the i.i.d. probability of the wealthy hand-to-mouth shock. These are obtained using the fraction of the wealthy-hand-to-mouth for each type-s, reported in Table 3.[19] ι_s the type-specific premium to the rate of return to savings ι_s.

Let me discuss how ι_s is pinned down, together with other parameters. First, I fix the steady-state capital-output ratio to be 12 (the annualized ratio of 3), which implies that the real interest rate is 0.875%.[20] Conditional on ι_s, this pins down the return of shares of mutual funds for workers. β_1 (the higher β) is used to guarantee that total demand for the mutual fund shares is equal to their supply ($\overline{a} = 1$). Now, I have five parameters (β_2, and ι_s for $\forall s$) to match the fraction of poor hand-to-mouth workers for the four racial groups. In order to match the number of targets and that of parameters, I impose one condition: $\int \iota_s a \, dm = 0$, where m is the steady-state type distribution. This condition states that the average race-specific premium is zero. This leaves ι_s for three racial groups for the fraction of poor hand-to-mouth for three racial groups. I use ι_s for Asian, Hispanic, and Black workers to match the fraction of poor hand-to-mouth for these three racial minorities. Finally, β_2 (the lower β) is pinned down such that the fraction of poor hand-to-mouth among White workers in the model matches the data.

Notice that the resulting race-specific premium ι_s varies greatly across racial groups. For White workers, the premium is positive and small at 0.2%, meaning that their type-specific saving rate is 0.875% + 0.2% = 1.075% per quarter. For Asian workers, ι_s is also relatively small but negative at -0.7%. It has to be lower than ι_s for White workers, since the fraction of poor hand-to-mouth among Asian workers (12.1%) is higher than that of White workers (7.2%), while preferences are assumed to be the same.[21] Compared with White and Asian workers, ι_s for Hispanic (-3.2%) and Black workers (-3.0%) are larger. These numbers imply that the quarterly rate of return of savings for Hispanic and Black workers is -2.3% and -2.2%, respectively. The rate of return of savings for Hispanic and Black workers turns out to be negative since ι_s is the only difference that workers of different racial groups face in the financial market. In other words, the differences in ι_s, by construction, capture a variety of racial differences in financial market conditions, such as the difficulty in purchasing a house or obtaining a mortgage and thus the ability to enjoy high returns from homeownership, or portfolio allocation into equity, which are associated with a higher average return. Boerma and Karabarbounis (Forthcoming) argue that the *perceived* rate of return of risky assets for racial minorities could be low due to lack of experiences in investment and entrepreneurship, which creates persistent racial wealth gaps. Under the assumption that preferences are common across racial groups, the dispersion of ι_s could be interpreted as Hispanic and Black workers facing disadvantages in the financial market. In the literature trying to account for the Black-White wealth gap, Aliprantis et al. (2019) downplay that the Black-White differences in the rate of return in explaining the wealth gap, while Bartscher et al. (2021) and Derenoncourt et al. (2022) emphasize the differences in portfolio composition and differences in returns of assets in the widening of the wealth gap in the

[19] Since workers with zero savings are poor hand-to-mouth and cannot be wealthy hand-to-mouth even if they are hit by the shock, π_s^h can be obtained by $\pi_s^{h2m\text{-}w}/(1 - \pi_s^{h2m\text{-}p})$, where $\pi_s^{h2m\text{-}p}$ and $\pi_s^{h2m\text{-}w}$ are the fraction of poor and wealthy hand-to-mouth for type-s, respectively.

[20] In the steady state, the real interest rate is equal to the rate of return of capital, characterized by Equation (A.20).

[21] Lower labor market risks among the Asian workers weaken the precautionary motive for them, but this turns out to be insufficient.

Table 6: Wealth Distribution for Four Racial Groups

	Overall	White	Asian	Hispanic	Black
Data					
Total Hand-to-Mouth	31.4	25.2	27.9	48.7	47.0
Poor Hand-to-Mouth	12.3	7.2	12.1	27.9	22.3
Wealthy Hand-to-Mouth	19.1	18.0	15.8	20.8	24.7
Mean Total Wealth	100.0	123.3	100.6	28.5	25.6
Median Total Wealth	24.5	34.9	22.4	2.6	4.6
Model					
Total Hand-to-Mouth	31.4	25.2	27.9	48.7	47.0
Poor Hand-to-Mouth	12.3	7.2	12.1	27.9	22.3
Wealthy Hand-to-Mouth	19.1	18.0	15.8	20.8	24.7
Mean Total Wealth	100.0	133.9	84.7	14.8	17.9
Median Total Wealth	26.7	52.2	37.5	3.7	3.7

Note: Data are computed using the Survey of Consumer Finances. See the note for Table 3 for details. Model statistics are computed using the steady state of the baseline model. Mean and median wealth are normalized such that the overall mean (shown in the first column) is 100.

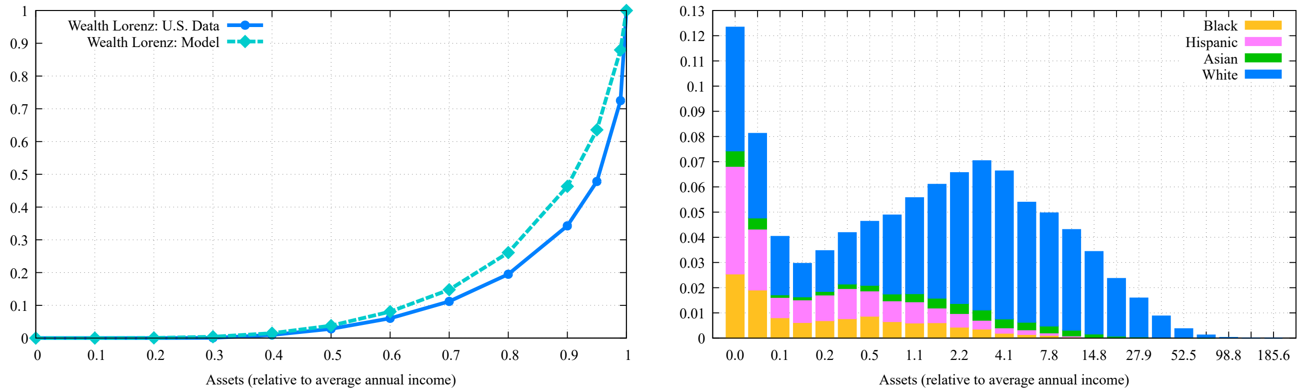
recent decades. Finally, one of the possible reasons why racial minorities hold smaller amount of wealth is the existence of means-tested social insurance, as emphasized by Hubbard et al. (1995). The model features income-dependent transfers, which weakens precautionary saving motive for Hispanic and Black workers, who tend to have lower income and thus benefit more from the income-dependent transfers, but heterogeneity in ι_s is needed on top of means-tested social insurance. The means-tested social insurance is important. Without it, ι_s has to be significantly more dispersed to match the observed heterogeneity in wealth holding. Section 9 explores the role of income-dependent transfers.

5 Racial Wealth Inequality in the Model

The model features racial inequality in terms of both income and wealth. Income inequality is mostly exogenous, as the model is calibrated to replicate observed differences in average income and unemployment risks across racial groups. Meanwhile, wealth inequality is endogenous. In this section, I compare the racial inequality in wealth between the data and the model. Table 6 compares the proportion of hand-to-mouth as well as mean and median wealth, in the U.S. data (top panel) and in the steady-state of the baseline model (bottom panel). The data are mostly the same as those in Table 3, but mean and median wealth data are normalized such that overall mean wealth is 100.0, for easier comparison.[22]

Regarding the proportion of hand-to-mouth (top three rows of each panel), the model matches the data perfectly by construction, as described in Section 4.2. In terms of mean and median wealth (the bottom two rows of each panel), although they not targeted and the fit is not perfect, the model captures the salient features of the empirical racial inequality in wealth holding.

[22] The proportion of hand-to-mouth including all racial groups is slightly different because I use the proportion of each racial group in the labor force in this table, while the racial composition is taken from the SCF in Table 3.



(a) Wealth Lorenz: Data and Model

(b) Histogram of Wealth Distribution: Model

Figure 2: Wealth Distribution

Specifically, Black and Hispanic workers hold significantly less wealth than other workers. Both in the data and in the model, their median wealth is less than 5.0, meaning they hold less than 1/5 of the overall median wealth. The mean wealth of Black and Hispanic workers is about 25% of the overall mean wealth in the data, while it is less than 20% of the overall mean wealth in the model. Asian workers hold less wealth than White workers in terms of both mean and median wealth. The model does not match the data better partly because I use the race-specific rate of return in capturing the racial wealth inequality. This is a parsimonious assumption, and thus is not rich enough to capture within-racial group heterogeneity. For example, homeowners and the wealthier among Black and Hispanic workers might enjoy a higher rate of return for their wealth than others in the same racial group, but this is not captured in the model.

In terms of the overall wealth distribution, the Gini index for wealth for all racial groups in the model (0.716) is close but slightly lower than that in the data (0.785). Figure 2(a) compares the wealth Lorenz curves of the data and the model, including all racial groups. Since the model is calibrated to match the fraction of poor hand-to-mouth, the Lorenz curve of the model is close to the empirical counterpart for the bottom 60% of wealth distribution. Among the wealthiest 40 percent, wealth is more concentrated in the data compared with the model, which is a common issue of the model without additional features such as entrepreneurship, an extremely high labor productivity, or richer rate of return heterogeneity.[23] Figure 2(b) shows a histogram of wealth for the four racial groups in the model. There is a large mass of White, Asian, Hispanic, and Black workers at the lower part of histogram, which represent a large proportion of poor hand-to-mouth, while the top end of wealth distribution is mostly represented by White workers.

6 Racial Differences in Marginal Propensity to Consume (MPC)

This section explores the heterogeneity in the marginal propensity to consume (MPC), which is measured as the consumption response to an unexpected one-time income transfer. I focus on the heterogeneity in MPCs across racial groups, which indicates how differently different

[23] See Quadrini and Ríos-Rull (1997) and De Nardi and Fella (2017) for review of the literature.

Table 7: Racial Differences in Marginal Propensity to Consume

MPC (%)	All	Poor H2M	Wealthy H2M	No H2M	All	All
Transfer	\$500	\$500	\$500	\$500	\$250	\$1,000
Overall	10.9	29.7	25.5	3.4	12.4	9.0
White	9.5	29.7	27.7	3.2	10.5	8.1
Asian	11.2	33.4	28.5	3.7	12.8	9.7
Hispanic	14.7	28.8	21.5	4.2	17.9	11.8
Black	13.8	30.1	19.9	4.0	16.1	10.8

Note: For the first four columns, MPC is defined as the quarterly percentage change in consumption in response to an unexpected one-time transfer of \$500, divided by \$500. For the 5th and the 6th columns, the amount of transfer is \$250 and \$1,000, respectively. No general equilibrium effects are considered.

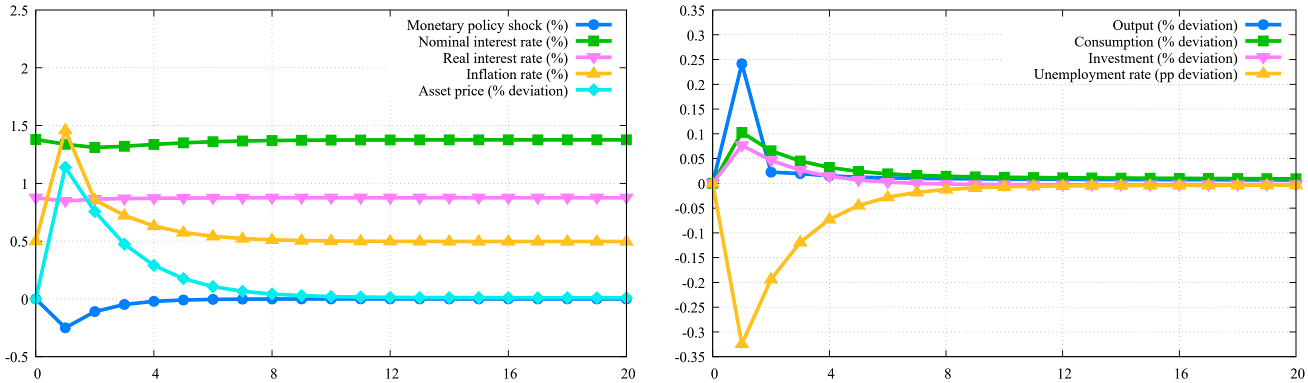
racial groups could be affected by monetary policy. Table 7 shows how the MPC is different across different racial groups (rows) as well as how the MPC is different across workers who are either poor or wealthy hand-to-mouth or not hand-to-mouth (columns). For the first four columns, following the standard, the MPC in the baseline is defined as the immediate (within one quarter) response of consumption expenditures to an unexpected one-time transfer of \$500, divided by \$500.[24] The 5th and the 6th columns show the overall MPC when the amount6 of the transfer is \$250 and \$1,000, respectively, to show the non-linearity of the MPC.

The overall MPC in the model is 10.9%. This is below the lower bound of the range of empirical estimates summarized by Kaplan and Violante (2021), which is between 15% and 25%. Ganong et al. (2020) estimate the MPC to be 23%. Interestingly, as shown in the first column, there is a noticeable racial heterogeneity. The MPC of White workers is 9.5%, and that of Asian workers is 11.2%. On the other hand, the MPCs of Hispanic and Black workers are 14.7% and 13.8%, respectively. The result that the MPC of Black workers is 45% higher than the MPC of White workers is broadly consistent with a finding of Ganong et al. (2020) that Black households cut their consumption 50% more than White ones when faced with an income shock of the similar size. They find that the MPC of Hispanic households is only 20% higher than that of White households, while the MPC of Hispanic workers is 55% higher in the model.

The second to the fourth columns of Table 7 show poor (second column) and wealthy (third column) hand-to-mouth workers exhibit a significantly higher MPC than workers which are not hand-to-mouth (fourth column), whose low MPC is typical in the representative-agent model. Including all racial groups, the MPC among workers who are not hand-to-mouth is 3.4%. The MPC among poor hand-to-mouth workers is 29.7%, while the MPC among wealthy hand-to-mouth workers is 25.5%. The main reason why Hispanic and Black workers exhibit a higher MPC is a composition effect. A larger proportion of them are either poor hand-to-mouth or wealthy hand-to-mouth.

The last two columns of Table 7 show that the MPC exhibits non-linearity with respect to

[24] Kaplan and Violante (2021) study the MPC in heterogeneous-agent macro models. Carroll et al. (2017) argue that the MPC in heterogeneous-agent models critically depends on the wealth distribution in the model. Jappelli and Pistaferri (2010) review different approaches of measuring the MPC.



(a) Financial Variables

(b) Output and Unemployment Rate

Figure 3: Effects of Monetary Policy Shock: Macro Variables

the amount of transfers. When the amount of transfers is smaller (larger), the MPC becomes larger (smaller). This is mostly because the higher MPC among both wealthy and poor hand-to-mouth. With a smaller amount of transfers, it is more likely that hand-to-mouth workers want to spend all the transfers and are still constrained. On the other hand, when the amount of transfers is larger, even hand-to-mouth workers might not want to spend all the transfers. Meanwhile, workers who are not hand-to-mouth do not spend a large fraction out of transfers, which is typical of the representative-agent model. In short, the non-linearity is generated by having hand-to-mouth workers in the model.

7 Racial Heterogeneity in the Effects of Monetary Policy

This section studies how an accommodative monetary shock affects different racial groups differently. Section 7.1 looks at the response of macroeconomic aggregates. Section 7.2 investigates a monetary policy shock affects different racial groups differently. Section 7.3 investigates welfare implications. Section 7.4 is about monetary transmission with racial inequality.

7.1 Macroeconomic Effects

Figure 3 summarizes macroeconomic effects in response to a quarterly -25bp accommodative monetary policy shock, up to 20 quarters. The effects are standard in the New-Keynesian DSGE model. Panel (a) shows financial variables. After the initial shock, the monetary policy shock gradually goes back to its steady-state level (dark blue line). The nominal interest rate declines (green line). Because of the nominal rigidity the real interest rate also declines (pink line). The asset price rises (cyan line), reflecting the stimulated economic activities. The response of the asset price in the model is qualitatively and quantitatively consistent with the empirical finding by Bernanke and Kuttner (2005). In the baseline model, the asset price gains by 1.14% on impact, while Bernanke and Kuttner (2005) find that an unanticipated -25bp rate cut is associated with a 1% increase in broad stock indexes. On the other hand, Bartscher et al. (2021) find that stock prices rise by 5% and house prices increase by 2% in response to the same monetary policy shock. Additionally, they find that the asset prices exhibit a hump-shaped response, while the response of the asset price in the baseline model is not persistent.

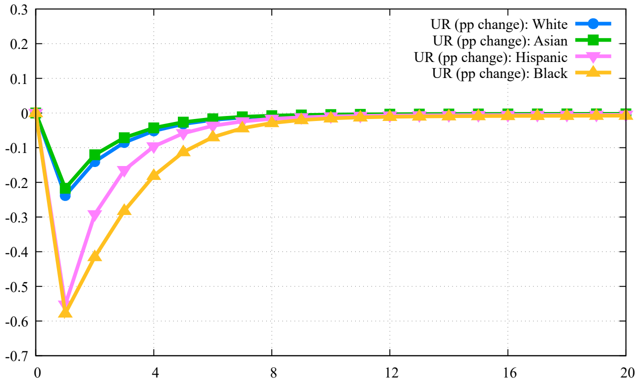
Panel (b) shows output and its components, and the unemployment rate. Due to the monetary stimulus, the number of vacancies and thus the job finding rates go up, and the unemployment rate declines, sizably, by 0.32pp (orange line). Output increases (blue line) as aggregate demand is stimulated, and both labor input and capital stock increase. Consumption increases (green line) for two reasons. First, there is the standard intertemporal substitution effect; a lower real interest rate discourages savings and brings forward consumption. Second, when a worker is hand-to-mouth, either because the worker has zero assets and thus is poor hand-to-mouth or because the worker is hit by the wealthy hand-to-mouth shock and cannot use the whole savings for consumption even if the worker wants, a lower unemployment rate, a higher wage, and a higher asset price boost consumption of constrained workers. Investment also increases (pink line), increasing capital stock.

7.2 Heterogeneous Effects of Monetary Policy to Different Racial Groups

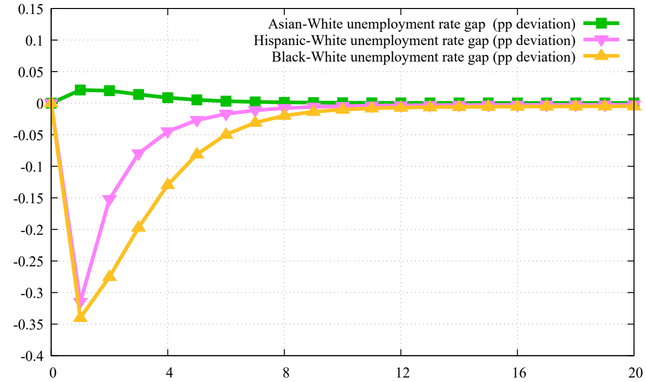
Figure 4 shows how the accommodative monetary shock affects workers of different racial groups. Panel (a) shows that the unemployment rate declines for all four racial groups, but the unemployment rates for Black and Hispanic workers decline more than those for White and Asian workers. Panel (b) shows the same differently, using the unemployment rate gaps. For example, the Black-White unemployment rate gap (yellow line) is the difference between the unemployment rate of Black workers and that of White workers, normalized such that the steady-state gap is zero. Since the Black unemployment rate declines more than the White one, the Black-White unemployment rate gap declines, by 0.34pp on impact. As I discussed in the calibration section, Bartscher et al. (2021) estimate that the Black-White unemployment rate gap shrinks by 0.34pp in response to a -25bp monetary policy shock. I calibrate the elasticity of the matching function, α, to replicate this empirical response. Panel (b) also shows that the Hispanic-White unemployment rate gap responds at a similar magnitude as the Black-White one, while the Asian-White gap remains close to zero in response to the monetary policy shock. The latter is consistent with the fact that the impulse responses of the unemployment rate are similar between White and Asian workers, as shown in Panel (a).

Why does the unemployment rate respond differently to the common monetary policy shock for different racial groups? And why does the Black-White unemployment rate gap shrink in response to the accommodative monetary policy shock? Since the separation rate is exogenously fixed, the different responses of the unemployment rate are due to different responses of the job-finding rate (Figure 4(c)). In response to a -25bp monetary policy shock, the job-finding rates for Black (yellow line) and Hispanic (pink line) workers increase more than 10%, while the job-finding rates for White (blue line) and Asian (green line) workers increase by less than 7%. Mechanically, these differences in the response of the job-finding rate yield the different responses of the unemployment rate. Why do the job-finding rates for Black and Hispanic workers rise more than those of White and Asian workers? In order to answer this question, three alternative models are studied. Figure 5 shows the results of the three alternative models as well as the baseline model (blue lines).[25] The impulse responses of the overall unemployment rate to the -25bp accommodative monetary policy shock are shown in Figure 5(a), and the impulse responses of the Black-White unemployment gap are shown in Figure 5(b). In the first alternative model (green lines), the steady-state job-finding rates for all racial groups are

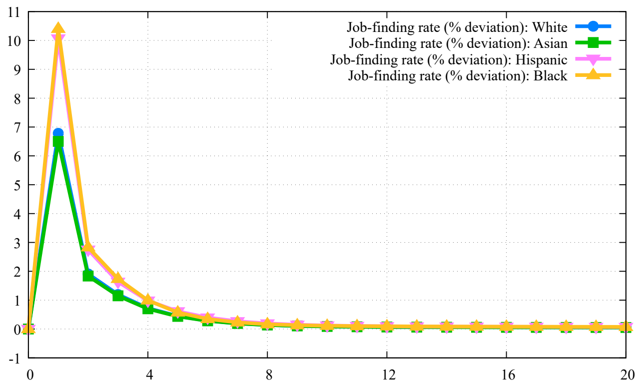
[25] Figure A.3 in Appendix G presents additional results of the three alternative models.



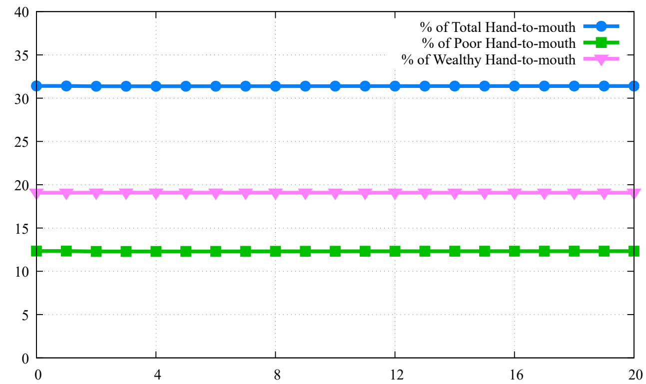
(a) Unemployment Rate



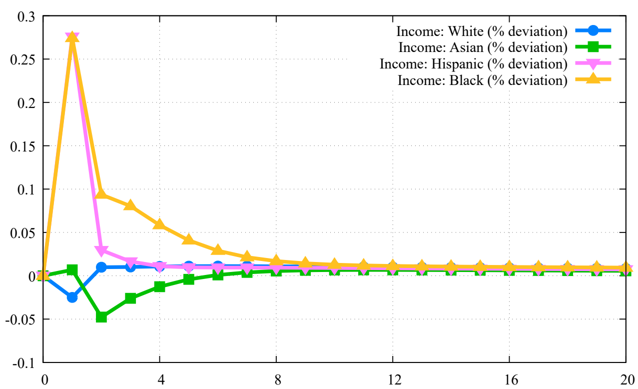
(b) Unemployment Rate Gap



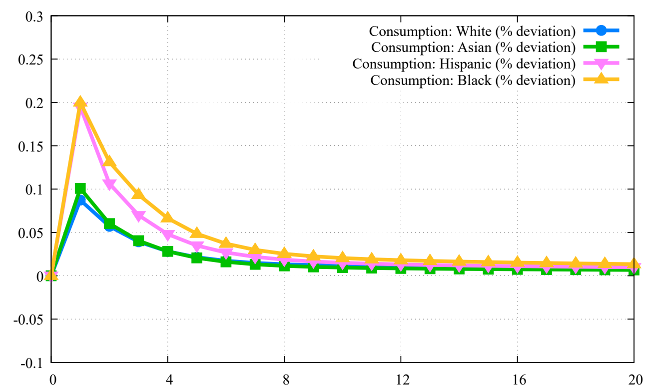
(c) Job-Finding Rate



(d) Proportion of Hand-to-Mouth



(e) Income

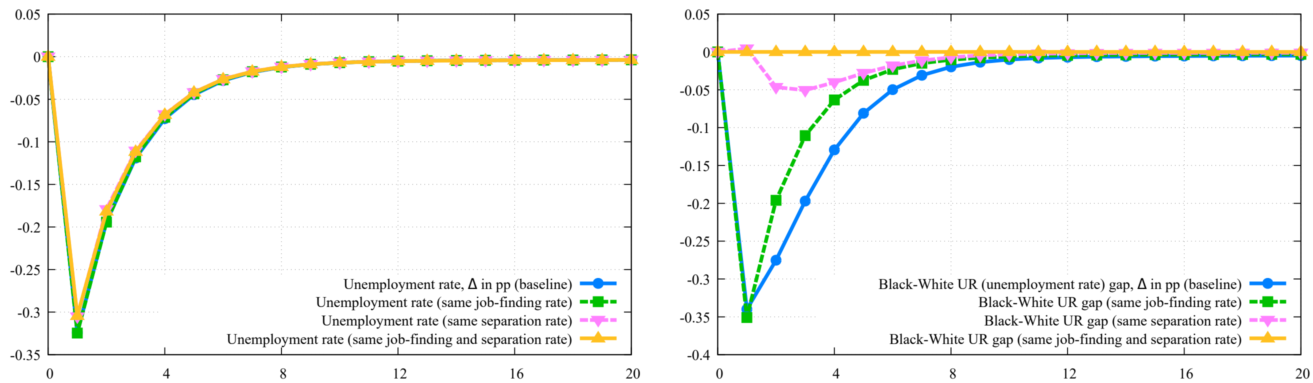


(f) Consumption

Figure 4: Effects of Monetary Policy Shock: Racial Inequality

set the same at the overall job-finding rate, while the separation rates are left unchanged.[26] In the second alternative model (pink lines), I do the opposite. The separation rates for all races are set at the same overall separation rate, while the job-finding rates are left at the levels as

[26] To be precise, I adjust κ_s for each s so that the same job-finding rate is achieved in the steady state.



(a) Unemployment Rate (b) Unemployment Rate Gap

Figure 5: Role of Labor Market Risk Heterogeneity

in the baseline model. In the third alternative model (yellow lines), Both the job-finding rates and the separation rates for the four racial groups are fixed as equal to their respective overall average.

When the steady-state job-finding rates for all racial groups are set the same, both the overall unemployment rate and the Black-White unemployment rate gap respond to the monetary policy shock similarly to the baseline model. In other words, the strong response of the Black-White unemployment rate gap in the baseline model is not due to the racial differences in the steady-state job-finding rate. On the other hand, when the separation rates are set the same, the response of the Black-White unemployment rate gap weakens significantly. Instead of declining 0.34pp in the baseline model, the Black-White unemployment rate gap declines up to 0.05pp in the model with the common separation rate. The overall unemployment rate declines slightly less than in the baseline model because the Black unemployment rate declines less. If both the job-finding and the separation rates are set the same in the steady state, the unemployment rates for all racial groups move in parallel, and the Black-White unemployment rate gap doesn't respond to an accommodative monetary shock.

The intuition is the following. In the baseline model (blue lines), as the separation rate is higher for Black workers, a temporary increase in the labor productivity induced by the monetary stimulus affects the value of the labor firm matched with a Black worker more strongly, since labor productivity will be higher for a larger fraction of the expected duration of the match. Therefore, the number of vacancies posted in the labor market for Black workers increases more than that for White workers, and the Black-White unemployment rate gap narrows. On the other hand, when the steady-state separation rate is assumed the same for all racial groups (pink lines), the unemployment rate gap does not shrink on impact because the value of a match with a Black worker and that with a White worker are affected by a temporarily high labor productivity by the same proportion, and thus their job-finding rates are affected by the same proportion. Since the job-finding rate is higher for White workers than for Black workers, the job-finding rate increases more for White workers, but the unemployment rate is lower among White workers. In the end, the change in the unemployment rate among White workers turns out to be similar to that of Black workers. The unemployment rate gap shrinks from the second quarter on after the monetary policy shock because the job-finding rate for White workers is higher, and thus their unemployment rate reverts back faster than that for Black workers. In the model in which the steady-state job-finding rate is set the same for all racial groups (green lines), the unemployment rate gap declines as much as in the baseline model, due to the same intuition as the baseline model. The unemployment rate gap shrinks faster than in the baseline model, because the job-finding rate for Black workers is higher and thus their unemployment rate reverts back to the steady-state level faster when the job-finding rate goes back to the initial level after the effects of monetary stimulus wanes.

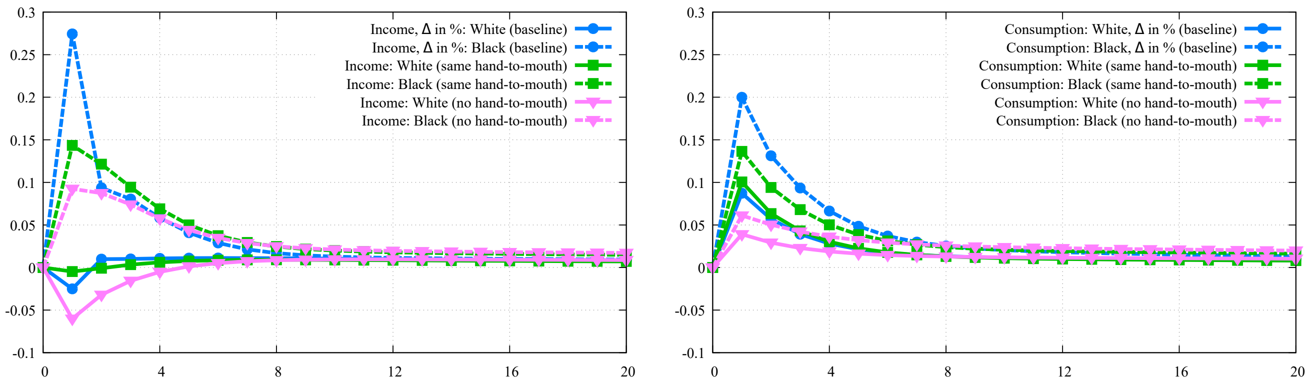
Figure 4(d) shows that the fraction of total, poor, and wealthy hand-to-mouth workers do not respond to the monetary stimulus in a sizable manner. Panel (e) shows an interesting heterogeneity in terms of how average income for the four racial groups change in response to the monetary stimulus.[27] While the Black and the Hispanic workers' average incomes increase, the White workers' average income declines. The Asian workers' average income slightly increases on impact but declines subsequently. Income composition matters in understanding this heterogeneity. For Black and Hispanic workers, whose income is mainly labor income, a lower unemployment rate and a higher wage pushes up their average income. On the other hand, since the interest rate goes down with the monetary stimulus, financial income declines, which lowers the White workers' average income, a large part of which is financial income. The response of the Asian workers' average income is combination of the two. Specifically, Black and Hispanic workers' average incomes increase by 0.28% and 0.27% on impact, respectively, while the White workers' average income declines by 0.02%. The Asian workers' average income increases less than 0.01% before declining by 0.05% in the next quarter.

Panel (f) shows the consumption response for the four racial groups. The average consumption responds more strongly for racial minorities. Black (0.20%) and Hispanic (0.19%) workers increase their consumption more than White (0.09%) and Asian (0.10%) workers. However, differences in the average consumption response across racial groups are smaller than those of income (Panel (e)). This is due to three effects. First is intertemporal consumption smoothing. Black, Hispanic, and Asian workers spread the additional income gains over time. Second is an intertemporal substitution effect; unconstrained White workers bring forward more consumption than the increase in income because of the lower real interest rate induced by the monetary accommodation. Third is the role of capital gains. The capital gains from the asset price increase give wealthy White workers additional resources for increasing consumption expenditures.

In order to see the role of hand-to-mouth in shaping the heterogeneous effects of monetary policy, Figure 6 compares the impulse responses of the average income (Panel (a)) and the average consumption (Panel (b)) of Black and White workers to the -25bp monetary policy shock in the baseline model (blue lines) and two alternative models in terms of hand-to-mouth heterogeneity.[28] In the first alternative model (green lines), the parameters associated with hand-

[27] Income does not include capital gains, i.e., effects from the change in p_t^a.

[28] Figure A.4 in Appendix G contains additional results of the two alternative models studied here. Figure A.5 shows results of the models in which only either poor hand-to-mouth or wealthy hand-to-mouth is turned off or assumed to be the same across all racial groups.



(a) Average Income: White and Black Workers (b) Average Consumption: White and Black Workers

Figure 6: Role of Hand-to-Mouth Heterogeneity

to-mouth are recalibrated such that all racial groups face the same fraction of both poor and wealthy hand-to-mouth.[29] In the second alternative model (pink lines), the model elements that generate poor and wealthy hand-to-mouth workers are turned off.[30]

When hand-to-mouth heterogeneity is turned off, and all racial groups face the same degree of hand-to-mouth (green lines), the differences in the impulse response of the average income between Black and White workers become smaller than in the baseline model, but are still significant. The average Black income goes up and gradually comes back, while the average White income goes down slightly, in response to the monetary stimulus. The average Black income goes up but less dramatically, because the increase in the labor income is mitigated by the lower financial income. Without poor hand-to-mouth heterogeneity, Black workers hold significantly more wealth on average, and thus the effects of lower financial income due to the monetary accommodation mitigate the effects of higher labor income more strongly. The negative response of the average White income is substantially mitigated because the amount of wealth that White workers own (and the amount of financial income they receive) is smaller than in the baseline model. The racial differences in the consumption response remain, but become smaller, reflecting the smaller degree of heterogeneity in the income response.

When hand-to-mouth is shut down completely (pink lines), the heterogeneity in the average income response remains, but the responses of the average income of both Black and White workers shift down compared with the model without hand-to-mouth heterogeneity (green lines). This is because the effects of the monetary stimulus become weaker without hand-to-mouth. The unemployment rate goes down in response to the monetary stimulus but less so, and the wage increases less. On the other hand, the real interest rate declines more. Consequently, the average Black income increases less in the model without hand-to-mouth, and the average White income declines more since the effects of lower financial income (from a lower

[29] Specifically, π_s^h is assumed to be the same for $\forall s$ and set to match the overall fraction of wealthy hand-to-mouth (0.215). As for poor hand-to-mouth, $\iota_s = 0 \; \forall s$, and the low discount factor, which is common for all racial groups, is calibrated such that the overall fraction of poor hand-to-mouth (0.123) is generated by the model.

[30] Specifically, $\iota_s = 0$ for $\forall s$, and discount factor shock is also turned off. The single discount factor is calibrated to match the aggregate amount of savings. $\pi_s^h = 0$ for $\forall s$ as well.

Table 8: Heterogeneous Welfare Effects of Accommodative Monetary Shock

		Overall	White	Asian	Hispanic	Black
	% Change in Consumption					
1	Baseline Model	0.104	0.087	0.101	0.195	0.200
2	Model with Same f_s	0.104	0.088	0.102	0.196	0.199
3	Model with Same λ_s	0.102	0.094	0.116	0.135	0.142
4	Model with Same f_s and λ_s	0.103	0.094	0.118	0.135	0.140
5	Model with Same Poor Hand-to-Mouth	0.106	0.099	0.098	0.132	0.140
6	Model with Same Wealthy Hand-to-Mouth	0.104	0.090	0.106	0.182	0.186
7	Model with Same Hand-to-Mouth	0.106	0.100	0.099	0.129	0.136
8	Model without Poor Hand-to-Mouth	0.071	0.066	0.064	0.092	0.089
9	Model without Wealthy Hand-to-Mouth	0.051	0.039	0.049	0.112	0.113
10	Model without Hand-to-Mouth	0.042	0.039	0.038	0.056	0.061
11	Model without Fiscal Transfers	0.115	0.095	0.114	0.239	0.247
	% Change in Welfare (in CEV)					
1	Baseline Model	0.020	0.019	0.018	0.022	0.024
2	Model with Same f_s	0.020	0.020	0.019	0.022	0.023
3	Model with Same λ_s	0.020	0.020	0.020	0.019	0.020
4	Model with Same f_s and λ_s	0.020	0.021	0.020	0.019	0.019
5	Model with Same Poor Hand-to-Mouth	0.023	0.023	0.023	0.024	0.027
6	Model with Same Wealthy Hand-to-Mouth	0.021	0.020	0.019	0.023	0.025
7	Model with Same Hand-to-Mouth	0.023	0.022	0.022	0.025	0.028
8	Model without Poor Hand-to-Mouth	0.014	0.013	0.013	0.015	0.017
9	Model without Wealthy Hand-to-Mouth	0.016	0.015	0.014	0.017	0.020
10	Model without Hand-to-Mouth	0.015	0.014	0.014	0.016	0.019
11	Model without Fiscal Transfers	0.028	0.025	0.025	0.033	0.037

Note: In response to a -25bp monetary policy shock. % change in consumption denotes the largest response of average consumption, which happens on impact. % change in welfare is measured by consumption equivalence variations (CEV).

interest rate) dominate more. The consumption response becomes smaller for both Black and White workers, because of the weaker monetary stimulus. But the difference in the consumption response between Black workers and White workers in the model without hand-to-mouth (pink lines) remains similar to the model without hand-to-mouth heterogeneity (green lines).

7.3 Heterogeneous Welfare Effects of Monetary Policy

Table 8 summarizes the welfare consequences of a -25bp monetary policy shock for different racial groups, in the baseline model (line 1) as well as various alternative models. In lines 2-4, either the heterogeneity in the job-finding rate or the heterogeneity in the separation rate is turned off. In lines 5-7, heterogeneity of either poor or wealthy hand-to-mouth across racial groups is shut down. In lines 8-10, either poor or wealthy hand-to-mouth is shut down. In the last line, the fiscal transfers (modeled as $tr(.)$) is eliminated from the baseline model. I will come back to this model in the next section. The upper panel of Table 8 shows the maximum consumption response in percent to the monetary policy shock, which happens on impact in all models. The lower panel shows the welfare effects of the accommodative monetary shock, measured in consumption equivalence variations (CEV).

In the baseline model (line 1), overall average consumption rises by 0.10% right after a −25bp monetary policy shock, and workers on average gain equivalent of 0.020% of consumption every period. White and Asian workers enjoy smaller welfare gains. The average consumption of White and Asian workers increases by 0.09% and 0.10%, respectively, and their welfare gains are slightly below 0.02% of flow consumption. On the other hand, Black and Hispanic workers gain more from the monetary stimulus. Average consumption of Black and Hispanic workers increase by about 0.20%. The average welfare gains by Hispanic and Black workers are 0.022% and 0.024% of flow consumption, respectively.

It is interesting to point out that racial minorities gain more from the monetary stimulus, even though they tend to be less wealthy and thus gain less from the asset revaluation effect. Using a back-of-envelope calculation, Bartscher et al. (2021) argue that the average White household gains more from monetary stimulus than the average Black household because White households tend to hold more wealth and allocate more wealth into assets whose prices are more sensitive to monetary policy. Black households tend to gain more from a lower unemployment rate induced by monetary accommodation, but the gains from the lower unemployment rate are smaller compared with the gains from the asset revaluation effect. There are three key differences between their exercise and my exercise. First, their estimated impulse responses indicate that house prices and equity prices respond more strongly to monetary stimulus than the model here. Specifically, according to Bartscher et al. (2021), house prices go up by up to 2% and equity prices go up by as much as 5% in response to a −25bp monetary policy shock, while the asset price increases by 1.1% in the baseline model. The asset revaluation effect is weaker in the model, but the magnitude of the response in the model is consistent with another empirical evidence by Bernanke and Kuttner (2005). Second, Bartscher et al. (2021) take into account that White households allocate more wealth into assets whose value appreciates more strongly in response to monetary stimulus, which makes the welfare gains from the monetary stimulus among White households greater, while I assume all workers have the same portfolio allocation. Finally, the higher incident of hand-to-mouth among racial minorities make the decrease in the unemployment rate due to the monetary stimulus more valuable in terms of welfare effects in the model. The combination of higher labor market risks and a higher incident of hand-to-mouth among racial minorities makes welfare gains from the monetary stimulus large among racial minorities.

How important are differences in labor market risks across racial groups? When all racial groups face the same steady-state job-finding rate (line 2), both the consumption responses and the welfare effects for different racial groups are similar to the baseline model. This is not surprising considering that, as discussed in Section 7.2, the impulse response of the unemployment rate gap doesn't change substantially in the model with the common job-finding rate. On the other hand, when all racial groups face the same steady-state job separation rate (line 3), the average consumption response and the average welfare effect stay the same as in the baseline model, but the heterogeneity in the welfare gains from the monetary stimulus all but disappears, and all racial groups gain 0.02% in CEV. This happens even though Black and Hispanic workers are still more likely to be hand-to-mouth, and there is still racial heterogeneity in consumption responses. If both the racial heterogeneity in the job-finding rate and that of the separation rate are turned off (line 4), the results are similar to the case with the common separation rate.

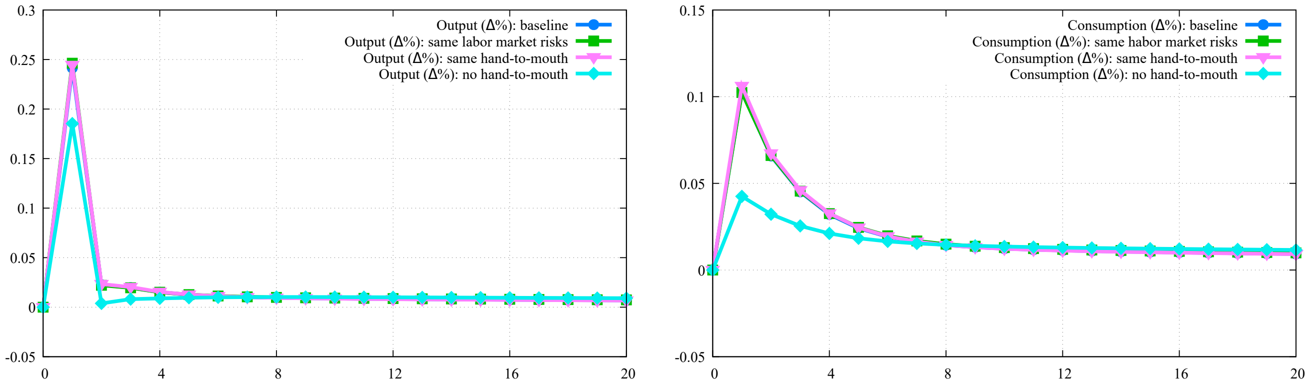
Lines 5-7 show the role of heterogeneity in the incident of hand-to-mouth across racial groups. As for the consumption response, the overall average response stays the same, at around 0.1%, in all models shown in lines 5-7, but the dispersion of the consumption responses narrows. In the model with the common fraction of poor hand-to-mouth (line 5), the ratio between the consumption response of Black workers and that of White workers shrinks from 2.3 (=0.200/0.087) in the baseline model to 1.5 (=0.140/0.094). With the common wealthy hand-to-mouth shock (line 6), the ration shrinks slightly, to 2.1 (=0.186/0.090). However, interestingly, welfare gains from the monetary stimulus remain diverse across racial groups, and increase for all racial groups. As for the first point, the welfare gains for White workers are larger simply because more of them are hand-to-mouth. What is less obvious is why the welfare gains for Hispanic and Black workers do not shrink. This is because less of them are hand-to-mouth in the alternative model, but they gain more from a higher asset price now that they have more wealth. As for the second point, the welfare gains are higher for all racial groups, for a technical reason; the discount factor of all workers are calibrated to be lower, which magnifies welfare gains from short-run increase in consumption.

Lines 8-10 show what happens to the effects of the monetary stimulus if either poor or wealthy hand-to-mouth is eliminated from the model. Without poor hand-to-mouth (line 8), consumption response becomes weaker, with the overall average response of 0.07% instead of 0.10%, and the welfare effects of the monetary stimulus become smaller. The overall average welfare effects are 0.014% in CEV, instead of 0.020% in the baseline model. Racial minorities still gain more, because of the larger labor market risks they face. Without wealthy hand-to-mouth (line 9), the overall average consumption response (0.05%) becomes half of that of the baseline model (0.10%), because the consumption response of (wealthy) White workers becomes weaker. On the other hand, the welfare gains from the monetary stimulus become smaller, but less so compared with the model without poor hand-to-mouth. Even if both types of hand-to-mouth are shut down, Black workers' welfare gains (0.019% in CEV) are larger than White workers' welfare gains (0.014%), which underscores the importance of the heterogeneous labor market risks in evaluating welfare gains from monetary accommodation.

7.4 Racial Inequality and Monetary Transmission

In this section, I investigate how the macroeconomic effects of a monetary policy shock are affected by the presence of racial heterogeneity in labor market risks or hand-to-mouth. Figure 7 shows how output (Panel (a)) and consumption (Panel (b)) are affected by a -25bp monetary policy shock in the baseline model economy (blue lines), as well as in the alternative model in which racial heterogeneity in labor market risks is shut down (green lines), the alternative model in which heterogeneity in hand-to-mouth is shut down (pink lines) and the alternative model in which hand-to-mouth is eliminated (cyan lines).

When racial heterogeneity in labor market risks or hand-to-mouth is shut down, monetary



(a) Output (b) Consumption

Figure 7: Racial Inequality and Monetary Transmission

transmission is not affected significantly. The lines for the two alternative models in Figure 7 are almost on top of the lines for the baseline model. However, when hand-to-mouth is eliminated, monetary transmission changes significantly. The peak response of output to the accommodative monetary policy shock declines by about a quarter, from 0.24% to 0.19% (Panel (a)). This is because the consumption response weakens significantly when workers are not hand-to-mouth, as shown in Panel (b). The peak response of the aggregate consumption to the monetary policy shock declines from 0.10% to 0.04%. When aggregate consumption demand does not respond strongly to monetary accommodation, monetary transmission becomes significantly weakened.

In sum, racial heterogeneity per se does not matter sizably for monetary transmission, but the existence of both poor and wealthy hand-to-mouth matters for the strength of the monetary transmission, since the consumption response of hand-to-mouth workers to a monetary policy shock is strong. This is consistent with Figure 6(b), which shows that the consumption responses of both White and Black workers become muted in the absence of hand-to-mouth. On the other hand, when the racial heterogeneity in labor market risks is turned off, Table 8 (line 4) shows that the aggregate consumption response does not change significantly, as the average consumption by White workers responds more, while the average consumption by Black workers responds less.

8 Racial Inequality over the Business Cycle

This section studies how different monetary policy rules affect different racial groups over the business cycle. Section 8.1 overviews aggregate dynamics. Section 8.2 looks at how business cycles are different across racial groups. Section 8.3 investigates the heterogeneous effects of different monetary policy rules. Finally, Section 8.4 studies the effects of using the Black unemployment rate instead of the overall unemployment rate in the monetary policy rule.

8.1 Aggregate Business Cycle Dynamics

Table 9 compares business cycle statistics between the U.S. economy (1980:1-2019:4) and the baseline model economy. The volatility of output in the model is the same as in the data by

Table 9: Business Cycle Statistics: U.S. Data and Baseline Model

	U.S. Data			Baseline Model		
	S.D.(%)	Rel S.D.	Corr(Y)	S.D.(%)	Rel S.D.	Corr(Y)
Output	1.232	1.000	1.000	1.232	1.000	1.000
Consumption	0.951	0.772	0.863	0.982	0.797	0.948
Investment	6.029	4.892	0.900	1.899	1.542	0.919
Utilization	2.801	2.273	0.824	2.296	1.864	0.753
Real wage	0.596	0.484	–0.333	0.349	0.283	0.745
Inflation	0.319	0.259	0.314	1.168	0.948	–0.231
UR (Overall)	10.756	8.729	–0.870	13.545	10.994	–0.495
UR (White)	11.246	9.126	–0.872	12.734	10.336	–0.501
UR (Hispanic)	11.825	9.596	–0.801	15.999	12.986	–0.492
UR (Black)	9.552	7.752	–0.773	13.832	11.227	–0.471

Note: All U.S. data are quarterly, from 1980:1 to 2019:4. Output is real GDP, consumption is real PCE, and investment is real gross private domestic investment, all of which are from the BEA. Inflation is the headline PCE inflation rate from the BEA. Utilization is the capacity utilization of all industries from the Board of Governors of the Federal Reserve System. The real wage is real median usual weekly earnings from the BLS. UR is the unemployment rate, also from the BLS. All series of the data and the model are in log and detrended using the Hodrick-Prescott filter with a smoothing parameter of 1600.

construction.[31] The volatility of aggregate consumption expenditures and its correlation with output are close to but higher than in the data. I introduced a quadratic investment adjustment cost to adjust investment (and thus consumption) volatility, but it turns out that the consumption volatility in the baseline model is higher than in the data, without the investment adjustment cost. Investment in the baseline model is much less volatile (S.D. of 1.9%) than in the data (6.0%). This is common when aggregate demand consists only of consumption and gross investment, and there are no inventory adjustments, government expenditures or net exports. The utilization rate in the model is slightly less volatile (2.3%) than in the data (2.8%), but both are strongly procyclical. The real wage in the baseline model (S.D. of 0.3%) is also less volatile than in the data (0.6%). However, while the real wage is procyclical in the model (correlation with an output of 0.75), it is countercyclical in the data (–0.33). This might be because I use real median usual weekly earnings as the measure of real wage, or because the nominal wage rigidity in the model is not as strong as in the data.[32] On the other hand, the inflation rate is countercyclical in the model, while it is procyclical in the data. The supply side shocks seem to be too important as a driving force of business cycles in the model than in the data. The volatility of inflation in the model (S.D. of 1.2%) is also higher than in the data (0.3%).

The last four rows of Table 9 contain the overall unemployment rate and the unemployment rate for White, Hispanic, and Black workers.[33] As for the overall unemployment rate, the volatil-

[31] See Section 4.1 for details.

[32] There is downward pressure to the median real wage in an expansionary period because workers with lower wages are more likely to find jobs in an expansion.

[33] I omit the results for Asian workers as they are similar to Whites' in the model. On the data side, as discussed in

ity in the model (13.5%) is higher than in the data (10.8%), but the model captures the fact that the unemployment rate is extremely volatile compared with output. Moreover, although the correlation between output and the unemployment rate in the model (–0.50) is weaker than in the data (–0.87), the model captures the countercyclicality. Notice that the cyclical properties of the unemployment rate are not directly targeted when the model is calibrated. Three key parameters that are important in generating the large volatility of the unemployment rate are the parameter that guarantees small profits for labor firms (ω_0), the parameter that yields real wage rigidity (ω_1), and the parameter that controls the elasticity of vacancy postings (α). ω_0 and ω_1 are calibrated to match the small profits of firms and real wage elasticity (Hagedorn and Manovskii (2008)), while α is calibrated to match the empirical response of the Black-White unemployment rate gap to a monetary policy shock (Bartscher et al. (2021)). This approach guarantees that the unemployment rate is generally volatile, but the success that the volatility of the unemployment rate in the baseline model is close to the data is not directly targeted. Notice that, in the data, the unemployment rate volatility for all racial groups is about 8-9 times larger than output volatility. This is because the unemployment rate is logged, and thus the volatility is relative to the level of the unemployment rate. In the baseline model, the unemployment rate for all racial groups is about 10-13 times larger than output volatility.

8.2 Business Cycle and Racial Inequality

The top half of Table 10 compares the volatility of output, income, consumption, the unemployment rate, the inflation rate, and the average White and Black income, and the average White and Black consumption, in the baseline model, the model in which all racial groups face the same labor income risks, the model in which all racial groups exhibit the same fraction of hand-to-mouth, the model without wealthy or poor hand-to-mouth, and the model without income-dependent fiscal transfers. The first four models are covered in this section, and the model without transfers will be discussed in Section 9.

The first column shows that, in the baseline model, Black workers face a higher volatility in average income and average consumption than White workers do. The volatility of average income is 0.76% for White workers and 1.12% for Black ones. The volatility of average consumption is 0.97% for White workers and 1.09% for Black workers. The volatility in the average Black income is higher because they face more volatile fluctuations in the unemployment rate. The higher volatility in the average Black consumption is a combination of volatile income and a higher fraction of hand-to-mouth who cannot effectively smooth consumption.

In terms of the business cycle properties of the three alternative models, there are three key takeaways. First, in terms of the business cycle volatility, racial heterogeneity in either labor market risks (column 2) or the fractions of hand-to-mouth (column 3) does not have a substantial effect, but the volatility declines sizably if hand-to-mouth is shut down (column 4). The standard deviation of output declines by 9.4%, from 1.23% to 1.12%. As shown in the last section, both poor and wealthy hand-to-mouth generate strong amplification of shocks. Second, if both the job-finding rate and the separation rate are set the same across racial groups, the volatility of average income (from 1.18% to 0.76%) and that of average consumption (from

Section 2.1, the time series for the Asian unemployment rate is short and thus excessively affected by two recent deep recessions.

Table 10: Business Cycle Statistics in Various Models

	Baseline	Same f_s & λ_s	Same H2M	No H2M	No Transfers
S.D.% with Baseline Monetary Policy					
Output	1.232	1.255	1.243	1.117	1.297
(Δ% from Baseline)	–	+1.87	+0.90	–9.36	+5.29
Income	0.755	0.775	0.768	0.578	0.829
Consumption	0.982	1.007	0.997	0.775	1.070
Unemployment rate	13.545	12.989	13.640	12.322	14.160
Inflation rate	1.168	1.166	1.168	1.144	1.169
Income: White	0.755	0.819	0.730	0.550	0.829
Income: Black	1.117	0.761	1.053	0.811	1.250
Cons: White	0.971	1.017	0.991	0.764	1.027
Cons: Black	1.094	0.961	1.062	0.869	1.425
Δ% in S.D. with Accommodative Monetary Policy					
Output	–12.3	–12.6	–12.5	–10.7	–12.8
Income	–6.7	–7.0	–7.1	–3.1	–7.8
Consumption	–11.0	–11.3	–11.3	–9.0	–11.8
Unemployment rate	–20.6	–20.9	–20.7	–20.0	–21.2
Inflation rate	+30.2	+31.1	+30.0	+27.9	+30.4
Income: White	–4.9	–6.5	–5.5	–1.0	–6.1
Income: Black	–15.8	–9.1	–13.4	–12.0	–16.4
Cons: White	–10.1	–10.6	–11.0	–8.6	–10.6
Cons: Black	–15.9	–14.0	–12.8	–11.1	–17.3

Note: Standard deviations are computed after taking log and being detrended using the Hodrick-Prescott filter with a smoothing parameter of 1600. All models share the same aggregate shocks which are calibrated for the baseline model. Accommodative monetary policy is the one with $\phi_y = 0.40$ instead of $\phi_y = 0.20$.

1.09% to 0l.96%) go down significantly for Black workers. Indeed, their income and consumption volatility become lower than those of White workers, whose income and consumption are more strongly affected by fluctuations of the asset price and the financial return. The existence of the income-dependent transfers is important for this result. Without the income-dependent transfers, consumption volatility of the White workers is still lower than that of Black workers (not shown in the table). Third, when racial heterogeneity in the fraction of hand-to-mouth is shut down, the volatility of average income and consumption among White and Black workers do not change substantially, but when hand-to-mouth is completely eliminated, the Black income volatility declines significantly while the White income volatility declines slightly. The Black income volatility declines because of the lower volatility of the unemployment rate. On the other hand, consumption volatility declines significantly both for Black and White workers, due to the absence of hand-to-mouth.

8.3 Monetary Policy Rule and Racial Inequality

The bottom half of Table 10 shows the percentage changes in the standard deviation when the monetary policy changes from the baseline monetary policy rule (with $\phi_y = 0.20$) to the accommodative monetary policy rule ($\phi_y = 0.40$), in the five models. In this section, the first four models (columns 1-4) are examined, while the model without transfers (column 5) will be discussed in Section 9.

Let me make three remarks. First, the size of the decline in the volatility of aggregate variables under the accommodative monetary policy rule is similar across four models but slightly smaller in the model without hand-to-mouth (column 4). This is because of a lack of amplification of aggregate demand through hand-to-mouth workers. Second, the decline in the volatility of average income and consumption is larger with Black workers than with White workers. Racial minorities benefit more from an accommodative monetary policy since they are facing larger labor market risks, and they are more likely to be hand-to-mouth, and thus their average income and consumption become even less volatile. In the baseline model, the average consumption volatility declines by 15.9% for Black workers and by 10.1% for White workers. Third, in the model without either heterogeneity in labor market risks (column 2) or heterogeneity in hand-to-mouth (column 3), the size of the decline in average income and consumption volatility among White workers is larger than in the baseline model, while the size of the decline in average income and consumption volatility among Black workers is smaller. This is because, in these two alternative models, the differences between White and Black workers are smaller than in the baseline model. In other words, the results from these two alternative models underscore the importance of both the heterogeneity in labor market risks, and the heterogeneity in the fraction in hand-to-mouth.

8.4 Monetary Policy Rule with Black Unemployment Rate

I conduct hypothetical experiments in which the monetary policy is based on the *Black* unemployment rate instead of the *overall* unemployment rate or output. What I will show is that, since the unemployment rate moves in parallel across different racial groups (see Section 2.1), the monetary policy rule based on the Black unemployment rate works virtually in the same way as the monetary policy rule with the overall unemployment rate, with a higher value of the Taylor rule coefficient. Table 11 summarizes the results. Column (1) presents some statistics of the baseline model economy. In Column (2), I first change the Taylor rule to the following:

$$\log R_t = (1-\rho_R)\log \overline{R} + \rho_R \log R_{t-1} + (1-\rho_R)[\phi_\pi(\log \pi_t - \log \overline{\pi}) - \phi_u(u_t - \overline{u})] + \log z_t^{MP} \quad (33)$$

where u_t is the overall unemployment rate in period t and $\overline{u}$ is the steady-state (or target) unemployment rate. Basically, I replaced the output in the original Taylor rule with the overall unemployment rate. There is a minus sign attached to the Taylor rule coefficient ϕ_u because the unemployment rate is countercyclical. Then I calibrate ϕ_u such that the model produces the same output volatility as in the baseline model (see the output volatility in Columns (1) and (2)). As is clear by comparing Columns (1) and (2), the model with ϕ_u=0.039 (shown in Column (2)) is found to behave virtually in an identical manner to the baseline model.

Now, what happens if the same Taylor rule coefficient is maintained, but the *Black* unemployment rate is used instead of the *overall* unemployment rate? The results are shown in Column (4), with the Taylor rule coefficient attached to the Black unemployment rate set at ϕ_b=0.039. In the model shown in Column (4), output volatility declines by almost 10%, to 1.12%. On the other hand, the volatility of the inflation rate goes up, from 1.1% to 1.3%, due to the

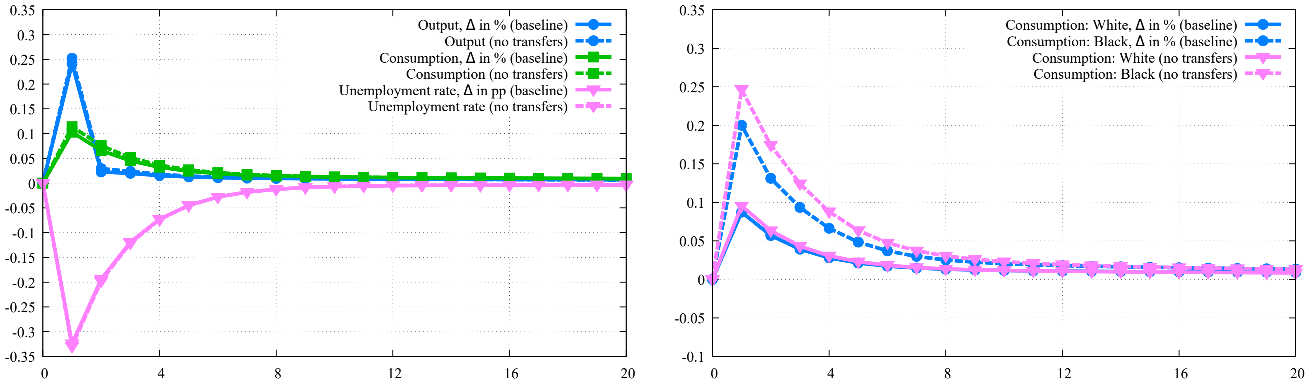
Table 11: Monetary Policy Rule Based on Black Unemployment Rate

	(1) Baseline	(2) Overall UR	(3) Overall UR	(4) Black UR	(5) Black UR
		$\phi_u = 0.039$	$\phi_u = 0.071$	$\phi_b = 0.039$	$\phi_b = 0.021$
Output	1.232	1.232	1.120	1.120	1.232
Consumption	0.982	0.982	0.903	0.903	0.982
Unemployment rate	13.545	13.484	11.306	11.275	13.467
Inflation rate	1.168	1.122	1.322	1.309	1.114
White Incm	0.755	0.754	0.726	0.726	0.754
Asian Incm	0.675	0.673	0.650	0.650	0.673
Hispanic Incm	0.965	0.964	0.852	0.852	0.964
Black Incm	1.117	1.116	0.985	0.985	1.116
White Cons	0.971	0.971	0.900	0.900	0.971
Asian Cons	1.027	1.027	0.940	0.940	1.027
Hispanic Cons	0.993	0.993	0.878	0.878	0.993
Black Cons	1.094	1.094	0.966	0.965	1.093

Note: All numbers are standard deviations in percent and in log, and detrended using the Hodrick-Prescott filter with a smoothing parameter of 1600. The 1st column shows the standard deviations in the baseline model. The 2nd and the 3rd columns show the results of the model in which the Taylor rule includes the overall unemployment rate (with the coefficient ϕ_u) instead of output. The 4th and the 5th columns show the results of the model in which the Taylor rule includes the Black unemployment rate (with the coefficient ϕ_b) instead of output.

standard trade-off between output stability and price stability. Volatility of all the other variables decline similarly to output volatility. In other words, using the Black unemployment rate as the monetary policy target instead of the overall unemployment rate, but keeping the monetary policy response coefficient the same, is equivalent to making the monetary policy rule more accommodative, and smoothing fluctuations of output and the unemployment rate, at the expense of less emphasis on price stability.

In order to make this point clearer, I conduct two additional experiments, shown in Column (3) and Column (5). In Column (3), I go back to the model in which the overall unemployment rate as the monetary policy target and re-calibrate ϕ_u such that output volatility is the same as the model with ϕ_b=0.039 (Column (4)). It is found that, with ϕ_u=0.071, the model with the overall unemployment rate as a policy target behaves in an identical manner to the model with ϕ_b=0.039 and the Black unemployment rate as the policy target. Simply put, using the Black unemployment rate as a monetary policy target is equivalent to the case in which the monetary policy response to the overall unemployment rate is 82% (=0.071/0.039-1) stronger. It is no a coincidence that the ratio of the two ϕ_u (1.82) is close to ratio of the average Black unemployment rate to the average overall unemployment rate, which is 1.87. As discussed in Section 2.1, the overall unemployment rate and the Black unemployment rate move in parallel over the business cycles. Therefore, using the Black unemployment rate (whose volatility is 1.87 times the volatility of the overall unemployment rate) as the policy target while keeping the response to the changes of the Black unemployment rate the same is equivalent to keeping the overall unemployment rate as the policy target but making the response coefficient 1.82



(a) Output, Consumption, and Unemployment (b) Average Consumption: White and Black Workers

Figure 8: Role of Income-Dependent Fiscal Transfers

times stronger. In Column (5), I did the opposite experiment; I re-calibrate ϕ_b so that the model with the Black unemployment rate as a monetary policy target behaves in an identical manner to the baseline model. This process yields ϕ_b=0.021. The ratio of the two values of the Taylor coefficient (0.039/0.021=1.86) is again very close to the ratio of the Black unemployment rate volatility and the overall unemployment rate volatility (1.87). In sum, if the monetary authority wants to focus on the Black unemployment rate as a monetary policy target, the monetary authority can achieve the goal just by raising the Taylor rule coefficient attached to the overall unemployment rate by about 80% and responding to changes to the overall unemployment rate more strongly instead of changing the Taylor rule in a more drastic manner and changing a monetary policy target to the Black unemployment rate.

9 Fiscal and Monetary Policy Interactions

In the U.S., like other developed economies, fiscal transfers in various forms are available for low-income individuals. It is an insurance against income risks. I introduce the income-dependent fiscal transfers following the work of Guner et al. (2021). Since monetary policy in this paper provides in a sense another form of insurance against income risks, there are interactions between monetary and fiscal policies. This section explores the interactions. Figure 8(a) shows the impulse response functions of aggregate variables in the baseline model and the alternative model in which the income-dependent fiscal transfers are shut down.[34] The figure shows that the model without the income-dependent fiscal transfers exhibit a slightly stronger amplification of the monetary policy shock compared with the baseline model. However, the income-dependent fiscal transfers substitute part of the functions of monetary policy of insuring against cyclical income risks. Figure 8(b) shows how average consumption of Black and White workers respond to the -25bp monetary stimulus in the two model economies. In both models, the average Black consumption responds more strongly than the average White consumption. However, more interestingly, without the income-dependent fiscal transfers, consumption responds more strongly, especially among Black workers. In other words, with-

[34] The alternative model is re-calibrated such that all the calibration targets in the baseline model are met in the alternative model without the income-dependent transfers.

out the income-dependent fiscal transfers, or, if the amount of fiscal transfers is cut down, the role of monetary policy in providing support for low-income workers becomes more important.

Lines 11 of Table 8 show the welfare effects of the -25bp accommodative monetary policy shock in the model without the income-dependent fiscal transfers. Consistent with Figure 8, consumption responses are stronger in the absence of the income-dependent fiscal transfers. The overall average consumption increases by 0.115% instead of 0.104%, and the average Black consumption rises by 0.25% instead of 0.20% without the income-dependent transfers. Welfare gains measured as CEV are also larger. Without the income-dependent fiscal transfers, the monetary stimulus provides welfare gains of 0.028% instead of 0.02% for all workers, and 0.037% instead of 0.024% for Black workers. Again, the results shown in the table confirm that the role of monetary policy in alleviating the unemployment risks is more important when income-dependent fiscal transfers are not present, especially among racial minorities.

Finally, the last column of Table 10 summarizes cyclical properties of the model without the income-dependent fiscal transfers. The top panel shows the business cycle statistics of the model. Consistently with what Figure 8(a) shows, the output volatility is 5.3% higher in the model without the income-dependent transfers. All the other aggregate variables are more volatile compared with the baseline model. In terms of average income, average income is more volatile than in the baseline model for both White and Black workers. The volatility of average income for White workers is 9.8% higher, while it is 11.9% higher for Black workers. The difference is due to the exposure of Black workers to higher labor market risks. What is more striking is the difference in the consumption volatility between White and Black workers. The average consumption volatility is only 5.8% higher among White workers. This magnitude is similar to the difference in the output volatility. The average consumption volatility for Black workers, however, is 30.3% higher. This is because the income-dependent fiscal transfers play a significant role in lowering the consumption volatility among Black workers. Without the transfers, the Black consumption volatility increases significantly. The bottom panel of Table 10 shows the percentage changes in the standard deviation when the monetary policy switches to the accommodative monetary policy rule. Due to the lack of income support from fiscal transfers, a stronger countercyclical monetary policy lowers business cycle volatilities more than in the baseline model. In particular, the volatility of the average Black consumption declines by 17.3% in the model without the income-dependent transfers compared with 15.9% in the baseline model.

10 Conclusion

I build a heterogeneous-agent New-Keynesian (HANK) model with racial inequality in terms of labor market characteristics and wealth, and study how monetary policy affects workers of different racial groups differently. I find that the combination of higher labor market risks and a higher proportion of hand-to-mouth among Black and Hispanic workers is the key in shaping their stronger consumption response to monetary policy changes and larger welfare gains from accommodative monetary policy. At the same time, since an important role of monetary policy in the world where markets are incomplete is to provide partial insurance against cyclical income risks, interactions between income-dependent fiscal transfers and monetary policy is found to be important in understanding the effects of monetary policy, especially for racial minorities. The welfare gains from an accommodative monetary policy shock would be larger for racial minorities without income-dependent transfers. I also find that using the Black unemployment rate instead of the overall rate as a policy target in the monetary policy rule is equivalent to making the policy rule more accommodative, because unemployment rates for all racial groups move in parallel over the business cycles.

Going forward, I consider this paper as the first step to understanding how different racial groups are affected differently by monetary policy, and there are many other dimensions of racial differences that can be investigated in future research. Let me list five. First, I do not consider the labor force participation decision here in the model, but as shown in Section 2.1, there are persistent differences in the labor force participation rate across racial groups. Second, introducing multiple assets, in particular housing, into the model is an interesting avenue to proceed. Third, an interesting dimension of racial differences that is not in the current paper is the difference in the consumption basket and thus the difference in the average inflation rates that different racial groups face. This is emphasized by Lee et al. (2021). Fourth, racial inequality in terms of access to credit is also considered an important issue. Finally, racial heterogeneity in family composition is well known. For example, there are more singles and single parents among Black households. This heterogeneity could also play an important role in shaping the racial differences in terms of the efficacy of monetary policy.

References

Aliprantis, Dionissi, Daniel R. Carroll, and Eric R. Young, "The Dynamics of the Racial Wealth Gap," *FRB Cleveland Working Paper*, 2019, *No. 19-18*.

Andolfatto, David, "Business Cycles and Labor-Market Search," *American Economic Review*, 1996, *86* (1), 112–132.

Bartscher, Alina K., Moritz Kuhn, Moritz Schularick, and Paul Wachtel, "Monetary Policy and Racial Inequality," *FRB New York Staff Report No. 959*, 2021.

Bayer, Christian, Benjamin Born, and Ralph Leutticke, "Shocks, Frictions, and Inequality in US Business Cycles," 2020. CEPR Working Paper No. 14364.

_, Ralph Leutticke, Lien Pham-Dao, and Volker Tjaden, "Precautionary Savings, Illiquid Assets, and the Aggregate Consequences of Shocks to Household Income Risk," *Econometrica*, 2019, *87* (1), 255–290.

Bernanke, Ben S. and Kenneth N. Kuttner, "What Explains the Stock Market's Reaction to Federal Reserve Policy?," *Journal of Finance*, 2005, *60* (3), 1221–1257.

Boerma, Job and Loukas Karabarbounis, "Persistent Racial Wealth Gaps," *NBER Macroeconomics Annual*, Forthcoming.

Cajner, Thomas, Tyler Radner, David Ratner, and Ivan Vidangos, "Racial Gaps in Labor Market Outcomes in the Last Four Decades and over the Business Cycle," 2017. Federal Reserve Board of Governors Finance and Economics Discussion Series (FEDS) 2017-071.

Carroll, Christopher, Jiri Slacalek, Kiichi Tokuoka, and Matthew N. White, "The Distribution of Wealth and the Marginal Propensity to Consume," *Quantitative Economics*, 2017, *8*, 977–1020.

Castelnuovo, Efrem, "Describing the Fed's Conduct with Taylor Rules: Is Interest Rate Smoothing Important?," 2003. European Central Bank Working Paper No. 232.

Davis, Steven J. and Till Von Wachter, "Recessions and the Costs of Job Loss," *Brookings Papers on Economic Activity*, Fall 2011, pp. 1–55.

De Nardi, Mariacristina and Giulio Fella, "Saving and Wealth Inequality," *Review of Economic Dynamics*, 2017, *26*, 280–300.

Derenoncourt, Ellora, Chi Hyun Kim, Moritz Kuhn, and Moritz Schularick, "Wealth of Two Nations: The U.S. Racial Wealth Gap, 1860-2020," *NBER Working Paper No. 30101*, 2022.

Ganong, Peter, Damon Jones, Pascal Noel, Diana Farrell, Fiona Greig, and Chris Wheat, "Wealth, Race, and Consumption Smoothing of Typical Income Shocks," *Becker Friedman Institute Working Paper No. 2020-49*, 2020.

Gertler, Mark, Luca Sala, and Antonella Trigari, "An Estimated Monetary DSGE Model with Unemployment and Staggered Nominal Wage Bargaining," *Journal of Money, Credit, and Banking*, 2008, *40* (8), 1713–1764.

Gornemann, Nils, Keith Kuester, and Makoto Nakajima, "Doves for the Rich, Hawks for the Poor? Distributional Consequences of Systematic Monetary Policy," *FRB Minneapolis Opportunity and Inclusive Growth Institute Working Paper No. 50*, 2021.

Greenstone, Michael and Adam Looney, "Unemployment and Earlings Losses: A Look at Long-Term Impacts of the Great Recession on American Workers," November 2021. Brookings on Job Numbers.

Greenwood, Jeremy, Zvi Hercowitz, and Gregory W. Huffman, "Investment, Capacity Utilization, and the Real Business Cycle," *American Economic Review*, 1988, *78* (3), 402–417.

Guner, Nezih, Remzi Kaygusuz, and Gustavo Ventura, "Rethinking the Welfare State," 2021. Unpublished.

Hagedorn, Marcus and Iourii Manovskii, "The Cyclical Behavior of Equilibrium Unemployment and Vacancies Revisited," *American Economic Review*, 2008, *98* (4), 1692–1706.

Hubbard, R. Glenn, Jonathan Skinner, and Stephen P. Zeldes, "Precautionary Saving and Social Insurance," *Journal of Political Economy*, 1995, *103* (3), 360–399.

Jappelli, Tullio and Luigi Pistaferri, "The Consumption Response to Income Changes," *Annual Reviews in Economics*, 2010, *2* (1), 479–506.

Justiniano, Alejandro, Giorgio E. Primiceri, and Andrea Tambalotti, "Investment Shocks and Business Cycles," *Journal of Monetary Economics*, 2010, *57* (2), 132–145.

Kaplan, Greg and Giovanni L. Violante, "The Marginal Propensity to Consume in Heterogeneous-Agent Models," *in preparation for the Annual Review of Economics*, 2021.

_ , Benjamin Moll, and Giovanni L. Violante, "Monetary Policy According to HANK," *American Economic Review*, 2018, *108* (3), 697–743.

_ , Giovanni L. Violante, and Justin Weidner, "The Wealthy Hand-to-Mouth," *Brookings Papers on Economic Activity*, 2014, *45* (1), 77–153.

Krusell, Per and Anthony A. Smith Jr., "Income and Wealth Heterogeneity in the Macroeconomy," *Journal of Political Economy*, 1998, *106*, 867–896.

_ , Toshihiko Mukoyama, and Ayşegűl Şahin, "Labor-Market Matching with Precautionary Savings and Aggregate Fluctuations," *Review of Economic Studies*, 2010, *77* (4), 1477–1507.

Lee, Munseob, Claudia Macaluso, and Felipe Schwartzman, "Minority Unemployment, Inflation, and Monetary Policy," 2021. Unpublished manuscript.

Merz, Monika, "Search in the Labor Market and the Real Business Cycle," *Journal of Monetary Economics*, 1995, *36*, 269–300.

Nakajima, Makoto, "Business Cycles in the Equilibrium Model of Labor Market Search and Self-insurance," *International Economic Review*, 2012, *53* (2), 399–432.

_ , "A Quantitative Analysis of Unemployment Benefit Extensions," *Journal of Monetary Economics*, 2012, *59* (7), 686–702.

Petrongolo, Barbara and Christopher A. Pissarides, "Looking into the Black Box: A Survey of the Matching Function," *Journal of Economic Literature*, 2001, *39* (2), 390–431.

Quadrini, Vincenzo and José-Victor Ríos-Rull, "Understanding the U.S. Distribution of Wealth," *Federal Reserve Bank of Minneapolis Quarterly Review*, 1997, *21* (2), 22–36.

Reiter, Michael, "Solving Heterogeneous-Agent Models by Projection and Perturbation," *Journal of Economic Dynamics and Control*, 2009, *33* (3), 649–665.

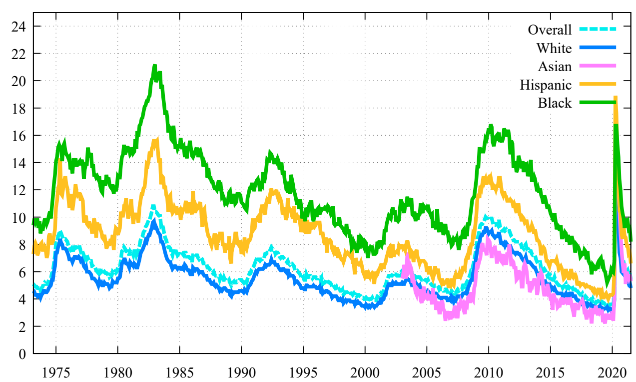
Rotemberg, Julio J., "Sticky Prices in the United States," *Journal of Political Economy*, 1982, *90* (6), 1187–1211.

Schmitt-Grohé, Stephanie and Martin Uribe, "Perturbation Methods for the Numerical Analysis of DSGE Models: Lecture Notes," 2009. Available at `http://www.columbia.edu/~mu2166/1st_order/1st_order.htm`.

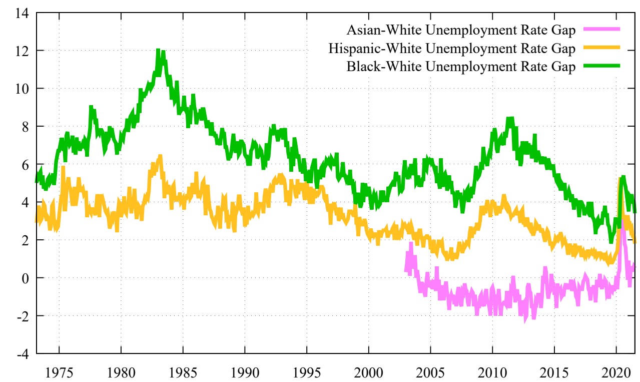
Storesletten, Kjetil, Chris I. Telmer, and Amir Yaron, "The Welfare Cost of Business Cycles Revisited: Finite Lives and Cyclical Variation in Idiosyncratic Risk," *European Economic Review*, 2001, *45* (7), 1311–1339.

Appendix

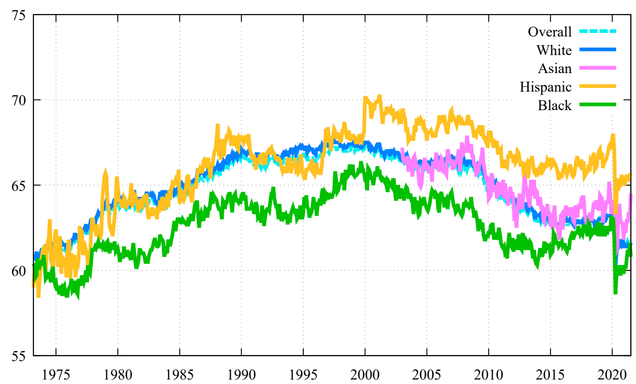
A Additional Facts about Racial Inequality in Labor Markets



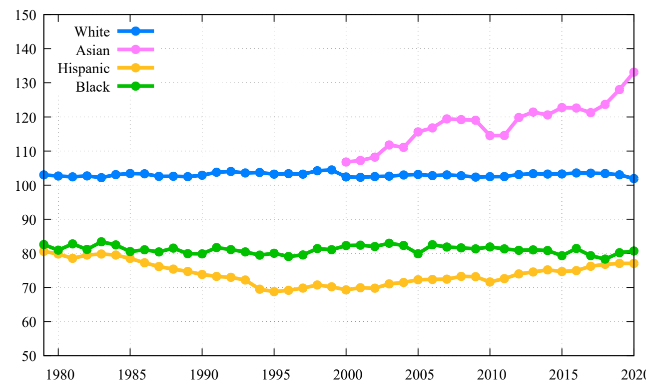
(a) Unemployment Rate



(b) Unemployment Rate Gap



(c) Labor Force participation rate



(d) Median Earnings Relative to Overall Median

Figure A.1: Racial Differences in Labor Market Characteristics: Additional Facts

Figure A.1 shows time series of selected labor market variables for the four racial groups. Figure A.1(a) shows the unemployment rate for the overall labor force, as well as for the four racial groups. This is the same as Figure 1(a), but this is shown again since this is the basis of the unemployment rate gaps, shown in Figure A.1(b). Since the unemployment rates for Black and Hispanic workers are consistently more volatile but move in parallel with that of White workers, the unemployment rate gaps are naturally countercyclical, going up in recessions and going down in expansions. Besides, not surprisingly, the gaps for Hispanic and Black workers are positively correlated with the overall unemployment rate, as shown in Table 1. The correlation coefficient with the overall unemployment rate is 0.70 for the Black-White unemployment rate gap and 0.65 for the Hispanic-White unemployment rate gap. For the Asian-White gap, the correlation is close to zero (–0.02), but it is not important, as the unemployment rates for White and Asian workers are almost on top of each other.

Although there is no labor force participation decision in the model, let's look at the labor force participation rate (LFPR) in the U.S. data, shown in Figure A.1(c). The overall LFPR gradually went up, from 60.8% in 1973 to 67.3% in 2000, and gradually went down since. The LFPR was 63.3% in December 2019, before the COVID-19 pandemic started. As with unemployment rates, LFPRs for all racial groups exhibit a similar trend as the overall LFPR. The correlation coefficient with the overall LFPR is 0.998 for White workers, 0.906 for Asian workers, 0.764 for Hispanic workers, and 0.913 for Black workers (Table 1). The correlation for the Hispanic LFPR is lower because of the sudden upward shift in 2000. The Hispanic LFPR tracks closely the White LFPR until 2000, but is consistently higher than the White LFPR by 2.5 percentage points on average after 2000. This might be due to some changes not related to actual changes of labor force participation decisions among Hispanic workers. Similar to the unemployment rate, there are permanent differences in the level of participation rates across racial groups, although the differences are smaller compared with those of the unemployment rate. The Black LFPR is consistently lower than others, while the Asian LFPR is close to that of White workers. The average Black LFPR is 62.6%, while the rate is 64.9% for White workers and 64.7% for Asian workers. The average Hispanic LFPR is 66.0%, which is higher than the LFPR of White workers because of the jump in 2000.

Figure A.1(d) shows the median usual weekly earnings for the four racial groups, normalized by the overall median usual weekly earnings for each year. The median weekly earnings of White workers are consistently higher than the overall median by 3%, as confirmed in Table 1. The median weekly earnings of Black workers are consistently lower by about 20% than the overall median. Median Hispanic weekly earnings went down from 1978 to the late 1990s but went up since then, and have been consistently below the median Black earnings. The average for Hispanic workers is 73.7% of the overall median. Median earnings for Asian workers show significant growth since 2000. This is because the proportion with a college degree among Asian workers is above 50%, unlike other racial groups, which implies that the median earnings of Asian workers are significantly affected by a rising college premium. On average, median weekly earnings of Asian workers are about 20% higher than the overall median earnings.

B Additional Facts about Racial Wealth Inequality

The upper block of Table A.1 contains the fractions of hand-to-mouth based on alternative definitions. In the first line, I define hand-to-mouth as households whose net worth is zero or negative. Net worth is a similar but more comprehensive measure than total wealth, which I employ in Section 2. On top of all the items included in total wealth, net worth includes other managed financial assets (annuities and trusts), other miscellaneous financial assets, net equity of vehicles (the value of vehicles minus the outstanding value of car loans), the value of businesses, other miscellaneous non-financial assets, net of education loans and other installment loans, and other debt. Overall, 10.8% of households have a zero or negative net worth position. Among White households, the fraction is lower, at 7.9%. The fraction among Asian households is exactly the same as the overall fraction (10.8%). Among Hispanic (18.7%) and Black (21.8%) households, more households have a zero or negative net worth position. If I use a zero or negative total wealth position to define hand-to-mouth, the fractions are similar to the previous case. Overall, again, 10.8% of households are hand-to-mouth by holding a zero or negative total wealth position. The fraction based on total wealth position is higher for Hispanic households (25.2%, compared with 18.7%) but similar for other racial groups. If I define

Table A.1: U.S. Wealth Distribution for Four Racial Groups: Alternative Measures

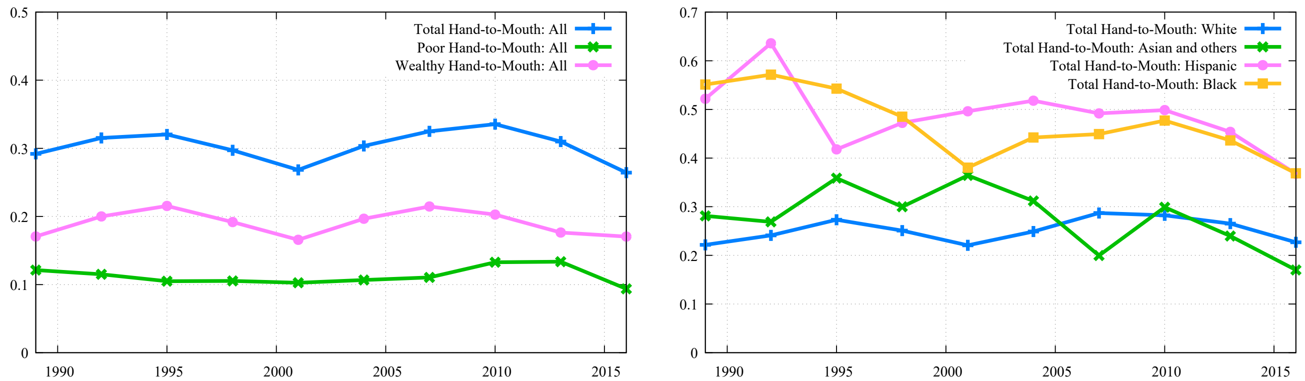
	Overall	White	Asian	Hispanic	Black
Alternative Measures of Hand-to-Mouth					
% with Non-Positive Net Worth	10.8	7.9	10.8	18.7	21.8
% with Non-Positive Total Wealth	10.8	7.4	11.0	25.2	20.3
% with Total Wealth $\leq$ 1-Week Earnings	15.7	11.1	16.1	33.9	28.5
Alternative Measures of Wealth Holding					
Mean Net Worth	529,315	656,489	527,478	143,386	115,538
Relative to White	80.6	100.0	80.3	21.8	17.6
Median Net Worth	110,527	159,885	101,924	18,824	20,687
Relative to White	69.1	100.0	63.7	11.8	12.9
Home Ownership Rate	66.5	73.5	56.8	45.3	46.1
Vehicle Ownership Rate	86.7	91.0	83.2	79.1	69.2

Note: The source is the the Survey of Consumer Finances (SCF). I use the average of 1989 to 2016 waves (10 waves, since the SCF is available every three years). I use the Extract Public dataset. Following Kaplan et al. (2014), households whose head is between 22 and 79 years old and whose non-financial income is strictly positive are included. Since the SCF over-samples wealthier households, I use the sample household weights provided by the SCF. With the Extract Public dataset, Asian households are bunched together with all the other (other than White, Hispanic, or Black) racial groups. Dollar amounts are shown in 2010 dollars.

hand-to-mouth as total wealth of less than half of non-financial income per the pay period (2 weeks), the fraction of hand-to-mouth is obviously higher. Overall, 15.7% of households are hand-to-mouth, compared with 10.8% when zero is used as the threshold. Not surprisingly, all racial groups exhibit a higher fraction of hand-to-mouth. The fractions for White, Asian, Hispanic, and Black households are 11.1%, 16.1%, 33.9%, and 28.5%, respectively.

The lower block of Table A.1 contains alternative measures of wealth holding. Both mean and median net worth holding for the four racial groups are as unequally distributed as total wealth. The last two rows show the fraction of households with housing and that with vehicles. In general, minority groups exhibit a lower homeownership rate, which shows up as smaller illiquid wealth holding as well as smaller total wealth holding for minority groups. The homeownership rate for White households is 73.5%, while the homeownership rates for Asian, Hispanic, and Black households are 56.8%, 45.3%, and 46.1%, respectively. Vehicle ownership is also higher among White households compared with minority households. For White households, the vehicle ownership rate is 91.0%, while it is 83.2% for Asian households, 79.1% for Hispanic households, and 69.2% for Black households.

While I show the average of the 10 waves of the SCF in Tables 3 and A.1, Figure A.2 shows the time series of the overall fraction of total, poor, and wealthy hand-to-mouth (Panel (a)) and the fraction of total hand-to-mouth for the four racial groups (Panel (b)), both from 1989 to 2016. Panel (a) confirms the finding of Kaplan et al. (2014); the fraction of hand-to-mouth households remained stable throughout the period covered by the SCF. As for the fraction of hand-to-mouth households for each racial group, the fraction remained stable or slightly increased among White households. On the other hand, for the three minority groups (Hispanic, Black,



(a) Hand-to-Mouth: Overall (b) Total Hand-to-Mouth: Four Racial Groups

Figure A.2: Proportion of Hand-to-Mouth: 1989-2016

and Asian and others), there is no discernible trend, but the fraction of total hand-to-mouth is lower in the recent years compared with earlier years.

C Note on the Definition of Hand-to-Mouth

This Appendix summarizes the definition of poor and wealthy hand-to-mouth, following Kaplan et al. (2014). According to their definition, a household is poor hand-to-mouth if one of the following two holds:

$$a \leq 0 \quad \text{and} \quad 0 \leq m \leq \frac{y}{2} \tag{A.1}$$

$$a \leq 0 \quad \text{and} \quad m < 0 \quad \text{and} \quad m \leq -\underline{m} + \frac{y}{2} \tag{A.2}$$

The first case is when a household has a positive liquid asset position. a and m are a household's illiquid and liquid wealth holding, respectively, and y is a household's income in pay period. y is divided by half because y could be received anytime during the period. $a < 0$ rarely happens in the data. It happens only if a house price decline makes the home equity negative. The second case is when a household has a negative liquid asset position. Then a household is assumed to be able to borrow up to $-\underline{m}$. If the liquid asset position is less than the borrowing limit plus half of income in the pay period, the household is considered liquidity constrained, as the household is too close to the borrowing limit.

Similarly, a household is wealthy hand-to-mouth if one of the following two holds:

$$a > 0 \quad \text{and} \quad 0 \leq m \leq \frac{y}{2} \tag{A.3}$$

$$a > 0 \quad \text{and} \quad m < 0 \quad \text{and} \quad m \leq -\underline{m} + \frac{y}{2} \tag{A.4}$$

Total hand-to-mouth is the sum of poor hand-to-mouth and wealthy hand-to-mouth. Kaplan et al. (2014) set y to be two weeks' of earnings, based on the pay frequency in CEX from 1990 to 2010. According to their calculation, during the period, 32% of respondents are paid weekly, 52% are paid bi-weekly, and the rest are paid at a lower frequency. In terms of $\underline{m}$, Kaplan et al. (2014) set the borrowing limit as one month's equivalent of non-financial income as their baseline case. They also try an alternative case with one year's equivalent of non-financial income and self-reported borrowing limit in the Survey of Consumer Finances (SCF). According to their calculation (Table 3 of their paper), between 1989 and 2010 in the SCF, 31.2% of households are hand-to-mouth. Among those, about 1/3 (12.1% of total) are poor hand-to-mouth, and 2/3 (19.2% of total) are wealthy hand-to-mouth.

In the model constructed in the paper, since there is no liquid debt, only the first condition for both poor and wealthy hand-to-mouth is used. In order to be consistent with the definition of poor hand-to-mouth of Kaplan et al. (2014), I set the second grid (the first grid represents zero assets) to be equal to two weeks' equivalent of earnings. By doing this, the threshold on average between the first grid (zero assets) and the second grid is half of two weeks' equivalent of earnings. In other words, the first grid captures those with equal or less than half of two weeks' equivalent of earnings on average, which is consistent with the definition of poor hand-to-mouth in Kaplan et al. (2014). When I calculate the fraction of hand-to-mouth for each racial group, shown in Table 3, I use the same definition.

As for the wealthy hand-to-mouth, I assume that there is an i.i.d. shock with probability π_h^s. With probability $1 - \pi_h^s$, a worker of type-s is not hit by the wealthy hand-to-mouth shock, and their liquidity constraint is the standard one ($a_{t+1} \geq 0$). With probability π_h^s, a worker is hit by the wealthy hand-to-mouth shock, and the liquidity constraint becomes $a_{t+1} \geq (1 - \delta_h)a_t$. δ_h is calibrated to be the median credit card limit divided by median total wealth. In the SCF, the credit card limit for each household is defined as equivalent to one month of earnings, following Kaplan et al. (2014). I assume that δ_h is common across all racial groups. The i.i.d. probability of wealthy hand-to-mouth shock, π_h^s, is calibrated such that the proportion of wealthy hand-to-mouth ($a > 0$ and hit by the shock) is equal to the data for each type-s. The fraction of wealthy hand-to-mouth for each racial group is reported in Table 3.

The assumption that households with a positive amount of illiquid assets can use the value of illiquid assets up to the amount of the median credit card limit can be considered tight, as households probably could use the value of illiquid assets as well in case they need more liquidity. However, notice that, even with the liquidity constraint for the wealthy hand-to-mouth that can be considered tight, the aggregate MPC implied by the model is at the lower end of available estimates.

D Race and Education

In the paper, I build a model in which workers of different racial groups differ in terms of labor market risks, liquidity, and the rate of return of savings. This is a parsimonious way to capture the differences across racial groups in the data presented in this section while assuming that the preferences are the same, and could be justified for short-run analysis like the current paper. However, the approach is admittedly ad-hoc in the sense that deeper causes which create racial differences in labor market outcomes and wealth holding are not explicitly modeled. The differences across racial groups could be a manifestation of heterogeneity in education, skills, sector or type of jobs, etc. In this appendix, I investigate how much of the racial differences presented in this section can be attributed to differences in education attainment. Specifically, Table A.2 shows the unemployment rate and the proportion of hand-to-mouth across different

Table A.2: Race and Education

	Overall	White	Asian	Hispanic	Black
Labor Force Composition (%)					
Less than high school	10.9	6.7	7.7	31.3	10.9
High school diploma	28.2	27.5	17.8	30.6	33.8
Some college	28.6	29.7	19.2	23.7	32.7
Bachelor's degree or more	32.2	36.2	55.3	14.3	22.6
Total	100.0	100.0	100.0	100.0	100.0
Unemployment Rate (%)					
Less than high school	13.9	14.4	7.8	11.0	24.8
High school diploma	8.1	7.1	5.9	8.4	13.5
Some college	5.9	5.1	5.9	6.6	9.6
Bachelor's degree or more	3.2	2.8	3.8	4.1	4.9
Total	6.5	5.4	4.9	8.2	11.5
Hypothetical	–	6.3	5.3	6.5	10.0
% accounted for	–	13.6	70.3	62.0	25.3
Proportion of Hand-to-Mouth: Less than Bachelor's Degree (%)					
Total hand-to-mouth	37.3	31.4	41.8	52.2	51.6
Poor hand-to-mouth	15.4	10.1	19.7	30.9	26.2
Wealthy hand-to-mouth	21.9	21.3	22.1	21.2	25.5
Proportion of Hand-to-Mouth: Bachelor's Degree or More (%)					
Total hand-to-mouth	17.1	15.3	14.9	30.5	30.1
Poor hand-to-mouth	3.5	2.6	4.7	11.6	8.5
Wealthy hand-to-mouth	13.6	12.8	10.2	18.8	21.6
Proportion of Hand-to-Mouth (%)					
Total hand-to-mouth	30.3	25.2	27.9	48.7	47.0
Hypothetical	–	27.7	32.1	44.3	43.8
% accounted for	–	11.7	-150.1	18.8	14.7

Note: The source for the labor force composition and the unemployment rate is the CPS, Annual Social and Economic Supplement. Averages from 2003 to 2018 are shown. The source for the fraction of hand-to-mouth is the SCF, averaged across 10 waves between 1989 and 2016. For non-White workers, the *hypothetical* unemployment rate is computed by using the non-White unemployment rate for each education level and the education composition among the White labor force. For White workers, the Black educational composition and the White unemployment rate for each education level are used to compute the hypothetical unemployment rate. The fraction of the difference in the unemployment rate between non-White and White workers that can be accounted for by the difference in the education composition is shown in *Fraction accounted for*. The definition of hand-to-mouth follows Kaplan et al. (2014). The *hypothetical* fractions of hand-to-mouth are computed similar to the *hypothetical* unemployment rate.

racial groups and different education attainment.

The first block of Table A.2 shows the composition of educational attainment in the labor force for different racial groups. Asian workers tend to have higher educational attainment than White workers. The fraction with at least a bachelor's degree among White workers is 36.2%, while more than half (55.3%) of Asian workers have at least a bachelor's degree. On the other hand, Hispanic workers exhibit the opposite tendency. The fraction of workers without a high school diploma is 6.7% among White workers but 31.3% among Hispanic workers. Meanwhile, the proportion with at least a bachelor's degree among Hispanic workers is only 14.3%, significantly lower than that of White workers. The educational attainment of Black workers is somewhere between those of White and Hispanic workers. The proportion without a high school diploma among Black workers is 10.9%, higher than that of White workers, while the proportion of Black workers with a bachelor's degree (22.6%) is lower than that of White workers.

One might think that the difference in the composition of educational attainment could explain racial differences — for example, in the unemployment rate. However, even the unemployment rate with the same educational attainment is different across racial groups, as shown in the second block of Table A.2. Among White workers without a high school diploma, the unemployment rate is 14.4%. Asian (7.8%) and Hispanic (11.0%) workers without a high school diploma have a lower unemployment rate. For Hispanic workers, it is probably because of the type of jobs or the sectors they search for a job. On the other hand, the unemployment rate is 24.8% among Black workers without a high school diploma. Among workers with a bachelor's degree, Asian (3.8%), Hispanic (4.1%) and Black (4.9%) workers exhibit higher unemployment rates than White workers (2.8%). There is a similar tendency among workers with some college.

Since the unemployment rates associated with the same educational attainment are different across racial groups, it is not likely that controlling for the differences in the composition of educational attainment is enough to account for all the racial differences. But let's try. The results are shown in the bottom two lines of the second block. For a minority racial group, the "Hypothetical" unemployment rate is computed by combining the composition of educational attainment among White workers and the unemployment rate associated with the different educational attainment of the minority racial group. The row labeled "% accounted for" represents the fraction of the difference in the unemployment rate between White and non-White workers that can be accounted for by controlling for the composition of educational attainment. The hypothetical Black unemployment rate is 10.0%, which is only slightly lower than the actual Black unemployment rate (11.5%). Therefore, only about a quarter of the difference in the unemployment rate between Black and White workers can be accounted for by the difference in educational attainment. If I do the opposite hypothetical, combining the educational composition of Black workers and the unemployment rate associated with different educational attainment among White workers, the hypothetical unemployment rate is 6.3%, slightly higher than the actual unemployment rate among White workers (5.4%) but far lower than that of Black workers (11.5%). In the end, only 14% of the Black-White difference in the unemployment rate can be accounted for by the difference in educational attainment. In short, the difference in the educational attainment between White and Black workers can explain only up to 1/4 of the difference in the overall unemployment rate. However, a larger fraction of the difference in the unemployment rate can be accounted for by the difference in educational attainment for Asian and Hispanic workers. The hypothetical unemployment rate for Hispanic workers is 6.5%, which is sizably lower than the actual Hispanic unemployment rate (8.2%). This implies that the difference in the educational attainment between White and

Hispanic workers can account for 62% of the difference in their unemployment rate. For Asian workers, the Asian unemployment rate is lower than the White unemployment rate, but if the educational composition of White workers is used, the hypothetical Asian unemployment rate goes up, to 5.3%, which is close to the White unemployment rate. Indeed, the difference in educational attainment can account for 70% of why the Asian unemployment rate is lower than that of White workers. In sum, for Hispanic and Asian workers, the difference in the composition of educational attainment can account for a large part of the difference in the unemployment rate between them and White workers, although the difference is smaller from the beginning. These results echo the findings of Cajner et al. (2017), who also use the CPS and control for differences in age, marital status, and state of residence on top of educational attainment and reach the same conclusion; they find that the Black-White difference in the unemployment rate cannot be explained by differences in observable characteristics, while the Hispanic-White differences in the unemployment rate can be explained largely by differences in educational attainment.

The third block of Table A.2 shows the proportion of hand-to-mouth households for different racial groups without a bachelor's degree. There are three main takeaways. First, even among households with the same education attainment (without a bachelor's degree), the fraction of hand-to-mouth is higher among Asian (41.8%), Hispanic (52.2%) and Black households (51.6%) than among White households (31.4%). Second, interestingly, the difference is mainly due to a higher proportion of poor hand-to-mouth households among Asian (19.7%), Hispanic (30.9%) and Black households (26.2%) compared with White households (10.1%). Third, on the other hand, the proportion of wealthy hand-to-mouth households is similar across White (21.3%), Asian (22.1%), Hispanic (21.2%), and Black (25.5%) households. The fourth block shows the proportion of hand-to-mouth for each racial group with a bachelor's degree. Again, even if we restrict our attention to households with a bachelor's degree, there are large racial differences in the proportion of hand-to-mouth, although the proportions are lower for all groups compared with those without a bachelor's degree. The proportion of total hand-to-mouth is higher among Hispanic (30.5%) and Black households (30.1%) compared with White (15.3%) and Asian households (14.9%). This is true for both poor hand-to-mouth and wealthy hand-to-mouth.

The last block of Table A.2 contains the actual and "Hypothetical" fractions of total hand-to-mouth and the percentage of the difference in hand-to-mouth that can be accounted for by the differences in educational composition for each racial group. The hypothetical fraction of hand-to-mouth is constructed in a similar way as the hypothetical unemployment rate shown in the second block of the table. Specifically, the hypothetical fraction of hand-to-mouth for Black households is computed by combining the proportion of hand-to-mouth for two educational groups among Black households and the composition of educational attainment among White households. The hypothetical fraction of hand-to-mouth among Black households is 43.8%, which is close the actual fraction among Black households (47.0%). In other words, accounting for the Black-White difference in educational composition cannot explain much of the Black-White difference in the fraction of hand-to-mouth. The last row states that only 15% of the difference can be accounted for by the difference in educational attainment. If the hypothetical fraction of hand-to-mouth is constructed in the opposite way, by combining the educational composition of Black households and the proportion of hand-to-mouth for two education groups among White households, the hypothetical fraction of hand-to-mouth is 27.7%, instead of 25.2% among White households, implying that the difference in the educational attainment can only account for 12% of the Black-White difference in the fraction of hand-to-mouth. The proportion of the White-Hispanic difference in hand-to-mouth that can be accounted for by educational attainment is slightly larger, at 19%. For Asian households, the actual fraction of hand-to-mouth is already close to that of White households, and if the educational composition among White households is applied for Asian households, the fraction of hand-to-mouth among Asian households becomes even higher than the actual proportion of hand-to-mouth.

E Solving the Equilibrium

This Appendix describes how to solve the equilibrium of the model. Appendix E.1 obtains the set of equations that characterize the equilibrium of the model. Appendix E.2 organizes these equations into the framework of Schmitt-Grohé and Uribe (2009) so that their first-order (linear) perturbation method can be applied to solve the model.

E.1 Characterizing the Equilibrium

A worker's optimal saving decision is characterized by the following equations:

$$u'(c_t) = \beta_t \mathbb{E}_t \frac{(1 + r_{t+1} + \iota_s) p^a_{t+1}}{p^a_t} u'(c_{t+1}) \tag{A.5}$$

where

$$a_{t+1} = \max\{((1 + r_t + \iota_s) p^a_t a_t + tr(earn_t) + (1 - \mathbb{1}_{e_t=1}\tau_{ui,t} - \tau_{tr,t}) earn_t - c_t)/p^a_t, \underline{a}_t\} \tag{A.6}$$

$$\underline{a}_t = \begin{cases} 0 & \text{if } h_t = 1 \\ (1 - \delta_h) a_t & \text{if } h_t = 2 \end{cases} \tag{A.7}$$

As for investment firms, taking the first-order condition yields the following equilibrium condition:

$$z^{MEI}_t p^i_t = 1 + \frac{z^{MEI}_t \psi_i}{2} \left[3\frac{i^2_t}{i^2_{t-1}} - 4\frac{i_t}{i_{t-1}} + 1 \right] - \mathbb{E}_t Q_{t+1} z^{MEI}_{t+1} \psi_i \frac{i^2_{t+1}}{i^2_t} \left[\frac{i_{t+1}}{i_t} - 1 \right] \tag{A.8}$$

Notice that, if we impose the steady-state conditions ($i_{t-1} = i_t = i_{t+1}$ and $z^{MEI}_t = z^{MEI}_{t+1} = 1$), the above equation becomes $p^i_t = 1$.

Capital firms decide the utilization rate and the capital accumulation. Taking the first-order condition with respect to utilization rate h_t in the problem of capital firms yields:

$$r^k_t = p^i_t \delta_0 \delta_1 n^{\delta_1 - 1}_t \tag{A.9}$$

The first order condition with respect to k_{t+1} yields:

$$p^i_t = \mathbb{E}_t Q_{t+1} \left[r^k_{t+1} n_{t+1} + (1 - \delta_0 n^{\delta_1}_{t+1}) p^i_{t+1} \right] \tag{A.10}$$

As for the intermediate good firms and final good firms, I focus on a symmetric equilibrium in which all intermediate good firms choose the same price in period t. Therefore $P_t = P_t(j)$ and $y_t = y_t(j)$ for all j in equilibrium. The Lagrangian for an intermediate good firm j is as follows:

$$\mathbb{E}_0 \sum_{t=0}^{\infty} \left(\prod_{\tilde{t}=0}^{t} Q_{\tilde{t}} \right) \left[\frac{P_t(j)}{P_t} y_t(j) - \frac{R_t^k}{P_t}(k_t(j)n_t(j)) - \frac{X_t}{P_t}\ell_t(j) - \frac{\psi_1}{2}\left(\frac{P_t(j)}{P_{t-1}(j)} - \overline{\pi} \right)^2 y_t \right.$$
$$\left. -\psi_0 + \lambda_t^f \left\{ y_t(j) - \left(\frac{P_t(j)}{P_t} \right)^{-\epsilon_p} y_t \right\} + mc_t \left\{ z_t^{TFP}(k_t(j)n_t(j))^{\theta} \ell_t(j)^{1-\theta} - y_t(j) \right\} \right] \quad \text{(A.11)}$$

where mc_t is the Lagrange multiplier for production technology, and can be interpreted as the marginal cost of producing one unit of an intermediate good. The first-order conditions are:

$$\frac{P_t(j)}{P_t} + \lambda_t^f - mc_t = 0 \quad \text{(A.12)}$$
$$\frac{R_t^k}{P_t} - mc_t z_t^{TFP} \theta (k_t(j)n_t(j))^{\theta-1} \ell_t(j)^{1-\theta} = 0 \quad \text{(A.13)}$$
$$\frac{X_t}{P_t} - mc_t z_t^{TFP} (1-\theta)(k_t(j)n_t(j))^{\theta} \ell_t(j)^{-\theta} = 0 \quad \text{(A.14)}$$

$$\left[\frac{1}{P_t} y_t(j) - \psi_1 \left(\frac{P_t(j)}{P_{t-1}(j)} - \overline{\pi} \right) y_t \frac{1}{P_{t-1}(j)} + \lambda_t^f \epsilon_p P_t(j)^{-\epsilon_p - 1} P_t^{\epsilon_p} y_t \right]$$
$$+ \mathbb{E}_t Q_{t+1}(-\psi_1) \left(\frac{P_{t+1}(j)}{P_t(j)} - \overline{\pi} \right) y_{t+1} P_{t+1}(j)(-P_t(j)^{-2}) = 0 \quad \text{(A.15)}$$

Substituting in $r_t^k = R_t^k/P_t$, $x_t = X_t/P_t$, $\pi_t = P_t/P_{t-1}$, $P_t(j) = P_t$, $y_t(j) = y_t$, $k_t(j)n_t(j) = k_t n_t$, and $\ell_t(j) = \ell_t$, the above conditions become:

$$1 + \lambda_t^f - mc_t = 0 \quad \text{(A.16)}$$
$$r_t^k = mc_t z_t^{TFP} \theta (k_t n_t)^{\theta-1} \ell_t^{1-\theta} \quad \text{(A.17)}$$
$$x_t = mc_t z_t^{TFP} (1-\theta)(k_t n_t)^{\theta} \ell_t^{-\theta} \quad \text{(A.18)}$$
$$\left[y_t - \psi_1 \left(\pi_t - \overline{\pi} \right) y_t \pi_t + \lambda_t^f \epsilon_p y_t \right] + \mathbb{E}_t Q_{t+1} \left[\psi_1 \left(\pi_{t+1} - \overline{\pi} \right) y_{t+1} \pi_{t+1} \right] = 0 \quad \text{(A.19)}$$

By substituting out λ_t^f:

$$r_t^k = mc_t z_t^{TFP} \theta (k_t n_t)^{\theta-1} \ell_t^{1-\theta} \quad \text{(A.20)}$$
$$x_t = mc_t z_t^{TFP} (1-\theta)(k_t n_t)^{\theta} \ell_t^{-\theta} \quad \text{(A.21)}$$
$$\left[y_t - \psi_1 \left(\pi_t - \overline{\pi} \right) y_t \pi_t + (mc_t - 1) \epsilon_p y_t \right] + \mathbb{E}_t Q_{t+1} \left[\psi_1 \left(\pi_{t+1} - \overline{\pi} \right) y_{t+1} \pi_{t+1} \right] = 0 \quad \text{(A.22)}$$

Notice that $P_{t-1}(j)$ is eliminated from the system of equations characterizing the optimal decision of intermediate good firms, which means that we do not need to keep track of past price levels. The amount of dividends from intermediate good firms, d_t^{INT}, can be computed as follows:

$$d_t^{INT} = y_t - r_t^k n_t k_t - x_t \ell_t - \frac{\psi_1}{2} \left(\pi_t - \overline{\pi} \right)^2 y_t - \psi_0 \quad \text{(A.23)}$$

Total number of mutual fund shares and aggregate labor supply are obtained by aggregating up individual worker's share holding and labor supply:

$$\overline{a} = \int a \, d\, m_{t+1} \tag{A.24}$$

$$\ell_t = \int \mathbb{1}_{e=1} p \eta_s \, d\, m_{t+1} \tag{A.25}$$

Aggregating up the budget constraints of individual households yields the following:

$$c_t = d_t + w_t \ell_t \tag{A.26}$$

Substituting the dividends yields the following aggregate resource constraint:

$$y_t = c_t + i_t + z_t^{MEI} i_t \frac{\psi_i}{2} \left(\frac{i_t}{i_{t-1}} - 1 \right)^2 + \sum_s \kappa_s v_{s,t} + \frac{\psi_1}{2} (\pi_t - \overline{\pi})^2 y_t + \psi_0 \tag{A.27}$$

The left-hand side is total output. The right-hand side consists of aggregate consumption expenditures, investment, investment adjustment cost, vacancy posting cost, nominal price adjustment cost, and fixed cost of production.

Although the aggregate bond supply is assumed to be zero in equilibrium by assumption, no arbitrage condition between mutual fund shares and nominal bonds has to hold, which is characterized as follows:

$$R_t = \mathbb{E}_t \frac{1}{Q_{t+1}} \pi_{t+1} \tag{A.28}$$

Notice that R_t is the return of nominal bonds from period t to $t+1$, so is determined in period t, while the discount factor Q_{t+1} and the inflation rate π_{t+1} are realized in period $t+1$.

E.2 Computing the Equilibrium

Below I organize the equations characterizing the equilibrium of the model so that the model can be solved with the first-order (linear) perturbation method developed by Schmitt-Grohé and Uribe (2009). In particular, we need to organize the equations characterizing the solution of the model in the following manner:

$$\mathbb{E}_t \mathbf{f}(\mathbf{x}_t, \mathbf{x}_{t+1}, \mathbf{y}_t, \mathbf{y}_{t+1}) = 0, \tag{A.29}$$

where $\mathbf{x}_t$ is a size-n_x vector of state variables in period t, meaning that $\mathbf{x}_t$ are predetermined at the beginning of period t. $\mathbf{y}_t$ is a size-n_y vector of control variables, which are not determined at the beginning of period t but determined before period $t+1$. Denote $n = n_x + n_y$. $\mathbf{f}$ is a function that characterizes the equilibrium and has to be a function which takes $2n$ variables ($\mathbf{x}_t$, $\mathbf{x}_{t+1}$, $\mathbf{y}_t$, and $\mathbf{y}_{t+1}$) and maps into n conditions.

What should be $\mathbf{x}_t$ and $\mathbf{y}_t$ in the model developed in this paper? Let's start with $\mathbf{x}_t$. First, the shocks z_t^{TFP}, z_t^{MEI}, and z_t^{MP} are included. Second, other variables predetermined at the beginning of period t are k_t, i_{t-1}, and R_{t-1}. Finally, the type distribution of heterogeneous workers

m_t is a part of $\mathbf{x}_t$. How do we store the type distribution? I use the simplest method and store the distribution of wealth holding by n_a-grid histograms. This is also used by the bare-bone version of the algorithm proposed by Reiter (2009). A type distribution can be stored by a vector of length $n_s \times n_b \times n_p \times n_e \times n_a$. Notice that, since the wealthy hand-to-mouth shock, h, is i.i.d., there is no need to keep track of the type distribution in terms of h, allowing me to reduce the dimension of the type distribution. Moreover, the probability measure at one of the asset grids (I use the lowest grid point) for each of type-s is not necessary since this can be backed up using the measure of type-s workers (which is fixed). In the end, $\mathbf{x}_t$ is a vector of length $n_x = 6 + n_s \times n_b \times n_p \times n_e \times n_a - n_s$.

Let's move on to $\mathbf{y}_t$. Aggregate variables that are not predetermined are the following $17+3\times n_s$: y_t, c_t, i_t, ℓ_t, n_t, p^a_t, d_t, mc_t, $\tau_{ui,t}$, $\tau_{tr,t}$, δ_t, x_t, w_t, r_t, r^k_t, p^i_t, π_t, $u_{s,t}$, $v_{s,t}$, and $f_{s,t}$. Moreover, the optimal consumption function by heterogeneous workers and the value of labor firms are a part of $\mathbf{y}_t$. Using the same grids as those for storing the distribution of assets, the optimal consumption function can be stored by $n_s \times n_b \times n_p \times n_e \times n_a \times n_h$ points. Notice that we need to store the optimal decision rule for each realization of the wealthy hand-to-mouth shock h. The value of labor firms can be stored by $n_s \times n_p$ points. In sum, $\mathbf{y}_t$ is a vector of length $n_y = 17 + 3 \times n_s + n_s \times n_b \times n_p \times n_e \times n_a \times n_h + n_s \times n_p$.

The $n = n_x + n_y = 23 + 3 \times n_s + n_s \times n_b \times n_p \times n_e \times n_a - n_s + n_s \times n_b \times n_p \times n_e \times n_a \times n_h + n_s \times n_p$ equations included in $\mathbf{f}(.)$ are as follows:

$$\log z^{TFP}_{t+1} = \rho_{TFP} \log z^{TFP}_t + \epsilon^{TFP}_{t+1} \tag{A.30}$$
$$\log z^{MEI}_{t+1} = \rho_{MEI} \log z^{MEI}_t + \epsilon^{MEI}_{t+1} \tag{A.31}$$
$$\log z^{MP}_{t+1} = \rho_{MP} \log z^{MP}_t + \epsilon^{MP}_{t+1} \tag{A.32}$$
$$k_{t+1} = (1-\delta_t)k_t + i_t z^{MEI}_t \tag{A.33}$$
$$\ell_t = \int \mathbb{1}_{e=1} p \eta_s \, d\, m_{t+1} \tag{A.34}$$
$$i_{(t-1)+1} = i_t \tag{A.35}$$

$$\log R_t = (1-\rho_R)\log \overline{R} + \rho_R \log R_{t-1} + (1-\rho_R)[\phi_\pi(\log \pi_t - \log \overline{\pi}) + \phi_y(\log y_t - \log \overline{y})] + \log z^{MP}_t \tag{A.36}$$

$$\tau_{ui,t} \int \mathbb{1}_{e=1} w_t p \eta_s \, d\, m_{t+1} = \int \mathbb{1}_{e=2} \min(\phi_0 w_t p \eta_s, \phi_1 \overline{wp\eta}_s) \, d\, m_{t+1} \tag{A.37}$$
$$\tau_{tr,t} \int earn_t \, d\, m_{t+1} = \int tr(earn_t) \, d\, m_{t+1} \tag{A.38}$$
$$y_t = c_t + i_t + z^{MEI}_t i_t \frac{\psi_i}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 + \sum_s \kappa_s v_{s,t} + \frac{\psi_1}{2}(\pi_t - \overline{\pi})^2 y_t + \psi_0 \tag{A.39}$$
$$\overline{a} = \int a \, d\, m_{t+1} \tag{A.40}$$
$$c_t = d_t + w_t \ell_t \tag{A.41}$$

$$w_t = \omega_0 \overline{x} + \omega_1(\log x_t - \log \overline{x}) + \omega_2(\log \pi_t - \log \overline{\pi}) \tag{A.42}$$

$$z_t^{MEI} p_t^i = 1 + \frac{z_t^{MEI}\psi_i}{2}\left[3\frac{i_t^2}{i_{t-1}^2} - 4\frac{i_t}{i_{t-1}} + 1\right] - \mathbb{E}_t \frac{p_t^a}{p_{t+1}^a + d_{t+1}} z_{t+1}^{MEI}\psi_i \frac{i_{t+1}^2}{i_t^2}\left[\frac{i_{t+1}}{i_t} - 1\right] \tag{A.43}$$

$$y_t = z_t^{TFP}(k_t n_t)^\theta \ell_t^{1-\theta} \tag{A.44}$$

$$r_t^k = mc_t z_t^{TFP}\theta(k_t n_t)^{\theta-1}\ell_t^{1-\theta} \tag{A.45}$$

$$x_t = mc_t z_t^{TFP}(1-\theta)(k_t n_t)^\theta \ell_t^{-\theta} \tag{A.46}$$

$$\left[y_t - \psi_1(\pi_t - \overline{\pi})\, y_t \pi_t + (mc_t - 1)\epsilon_p y_t\right] + \mathbb{E}_t \frac{p_t^a}{p_{t+1}^a + d_{t+1}}\left[\psi_1(\pi_{t+1} - \overline{\pi})\, y_{t+1}\pi_{t+1}\right] = 0 \tag{A.47}$$

$$\delta_t = \delta_0 n_t^{\delta_1} \tag{A.48}$$

$$r_t^k = p_t^i \delta_0 \delta_1 n_t^{\delta_1 - 1} \tag{A.49}$$

$$R_t = \mathbb{E}_t \pi_{t+1}\frac{p_{t+1}^a + d_{t+1}}{p_t^a} \tag{A.50}$$

$$p_t^i = \mathbb{E}_t \frac{p_t^a}{p_{t+1}^a + d_{t+1}}\left[r_{t+1}^k n_{t+1} + (1 - \delta_0 n_{t+1}^{\delta_1}) p_{t+1}^i\right] \tag{A.51}$$

$$r_t + \int \iota_s a_t \, m_{t+1} = \frac{d_t}{p_t^a} \tag{A.52}$$

The following gives $n_s \times n_b \times n_p \times n_e \times n_a \times n_h$ equations characterizing the optimal consumption function.

$$c_t = \left[\beta_t \mathbb{E}_t \frac{(1 + r_{t+1} + \iota_s)p_{t+1}^a}{p_t^a} c_{t+1}^{-\sigma}\right]^{-1/\sigma} \tag{A.53}$$

Using the type distribution at the beginning of period t, m_t, optimal decision rules, and transition probabilities of shocks, the type distribution can be updated to $\hat{m}_{t+1}$. Since m_{t+1} is a part of $\mathbf{x}_{t+1}$, we have:

$$m_{t+1} = \hat{m}_{t+1} \tag{A.54}$$

This gives $n_s \times n_b \times n_p \times n_e \times n_a$ conditions. But n_s conditions can be dropped, since they can be backed up by the fixed measure of each s-type. $u_{s,t}$, $v_{s,t}$, and $f_{s,t}$ are characterized by the following equations for each s:

$$u_{\overline{s},t} = \int \mathbb{1}_{e=2}\mathbb{1}_{s=\overline{s}} d\, m_t \tag{A.55}$$

$$\kappa_s = \mu v_{s,t}^{\alpha-1} u_{s,t}^{1-\alpha} \sum_p \pi_{p|s,e=2} \sum_{p'} \pi_{p'|p,2,1} J_{s,p,t} \tag{A.56}$$

$$f_{s,t} = \mu v_{s,t}^\alpha u_{s,t}^{-\alpha} \tag{A.57}$$

Finally, the following recursive definition of the firm's value gives $n_s \times n_p$ equations.

$$J_{s,p,t} = (x_t - w_t)p\eta_s + \mathbb{E}_t \frac{p_t^a}{p_{t+1}^a + d_{t+1}}(1 - \lambda_s)\sum_{p'} \pi_{p'|p,1,1} J_{s,p',t+1} \tag{A.58}$$

F Variables in the Steady State

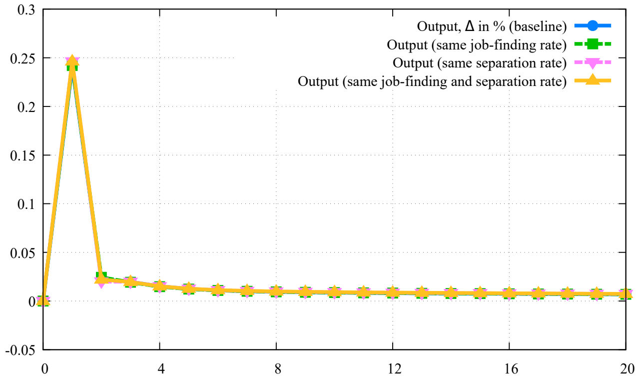
By imposing steady-state conditions to equations characterizing the equilibrium, steady-state variables can be characterized. They are summarized in Table A.3. I omit time scripts to denote variables in the steady state.

Table A.3: Steady-State Values and Conditions

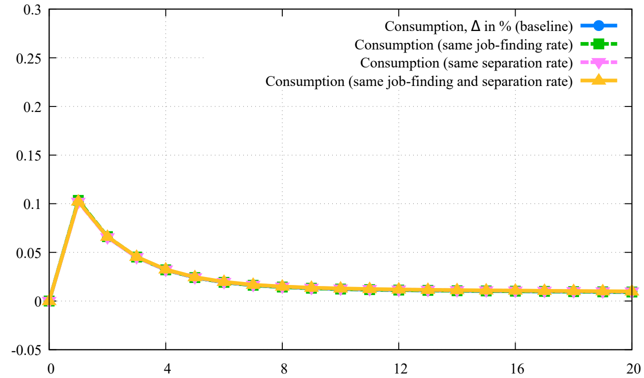
Variable	Value	Condition
z^{TFP}	1.0000	From law of motion.
z^{MEI}	1.0000	From law of motion.
z^{MP}	1.0000	From law of motion.
k	27.480	$=(k/y\, z^{TFP} n^{\theta})^{1/(1-\theta)}\ell$
ℓ	0.7895	$=\int \mathbb{1}_{e=1} p\eta_s \, d\, m$
i	0.4122	$=\delta k$
R	1.0138	$=\pi(1+r)$
y	2.2900	$=z^{TFP}(kn)^{\theta}\ell^{1-\theta}$
c	1.7264	$=d+w\ell$
n	1.0000	By assumption.
p^a	28.485	$=d/r$
d	0.2492	$=rk-\sum_s \kappa_s v_s$
mc	0.9500	$=1-\frac{1}{\epsilon_p}$
τ_{ui}	0.0206	From the government budget constraint for UI.
τ_{tr}	0.0344	From the government budget constraint for transfers.
δ	0.0150	$=\delta_0$
x	1.9290	$=mc(1-\theta)z(kn)^{\theta}\ell^{-\theta}$
w	1.8711	$=\omega_0 x$
r	0.0088	$=r_k-\delta$
r^k	0.0238	$=mc\theta z(kn)^{\theta-1}\ell^{1-\theta}$
p^i	1.0000	From the first-order condition of investment firms.
π	1.0050	$=\overline{\pi}$
f_s	Table 5	From Cajner et al. (2017).
u_s	Table 5	$=\lambda_s/(f_s+\lambda_s)$
v_s	Table 5	$=(f_s/\mu)^{1/(\alpha-1)}u_s$

Note: Quarterly frequency.

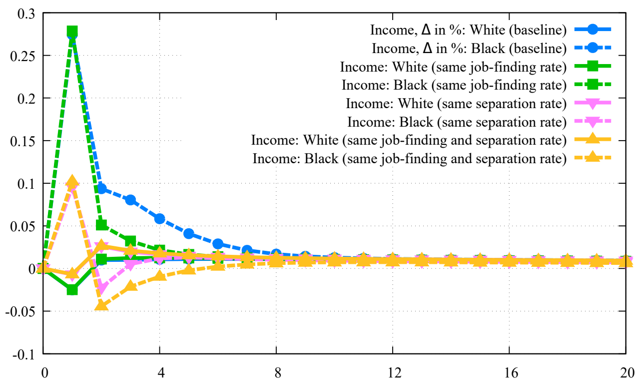
G Additional Results: Effects of Accommodative Monetary Policy Shock



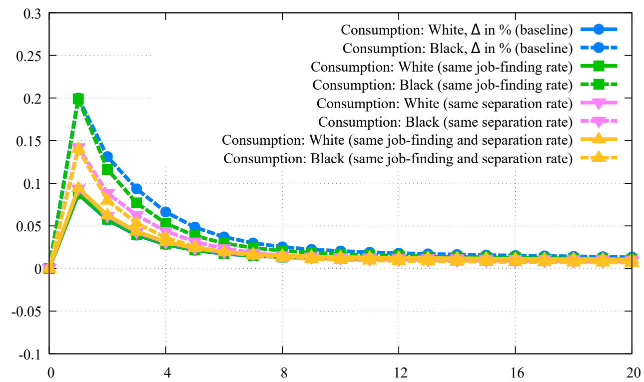
(a) Output



(b) Aggregate Consumption

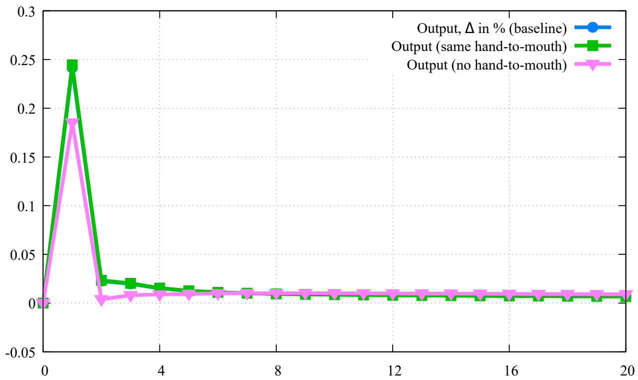


(c) Income of White and Black Workers

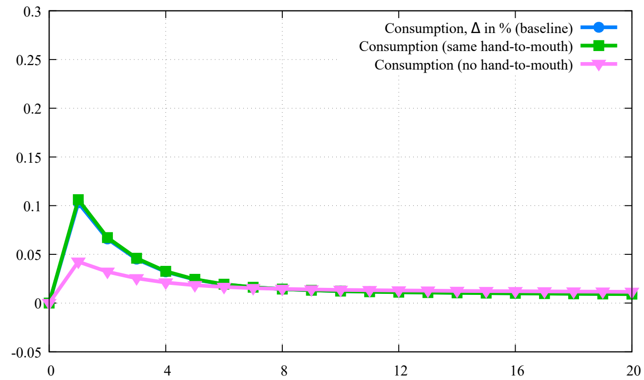


(d) Consumption of White and Black Workers

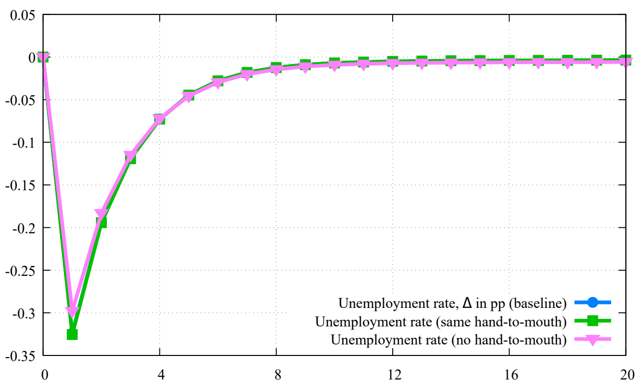
Figure A.3: Role of Labor Market Risk Heterogeneity



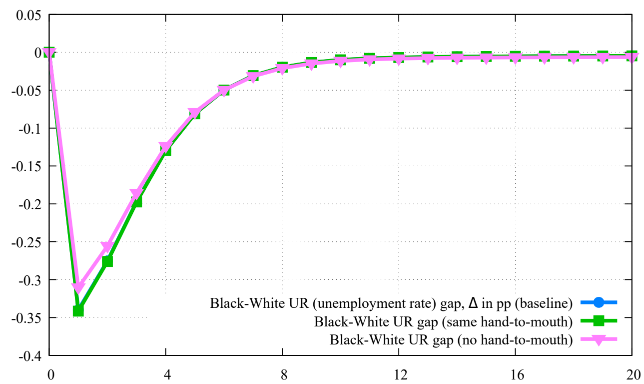
(a) Output



(b) Aggregate Consumption

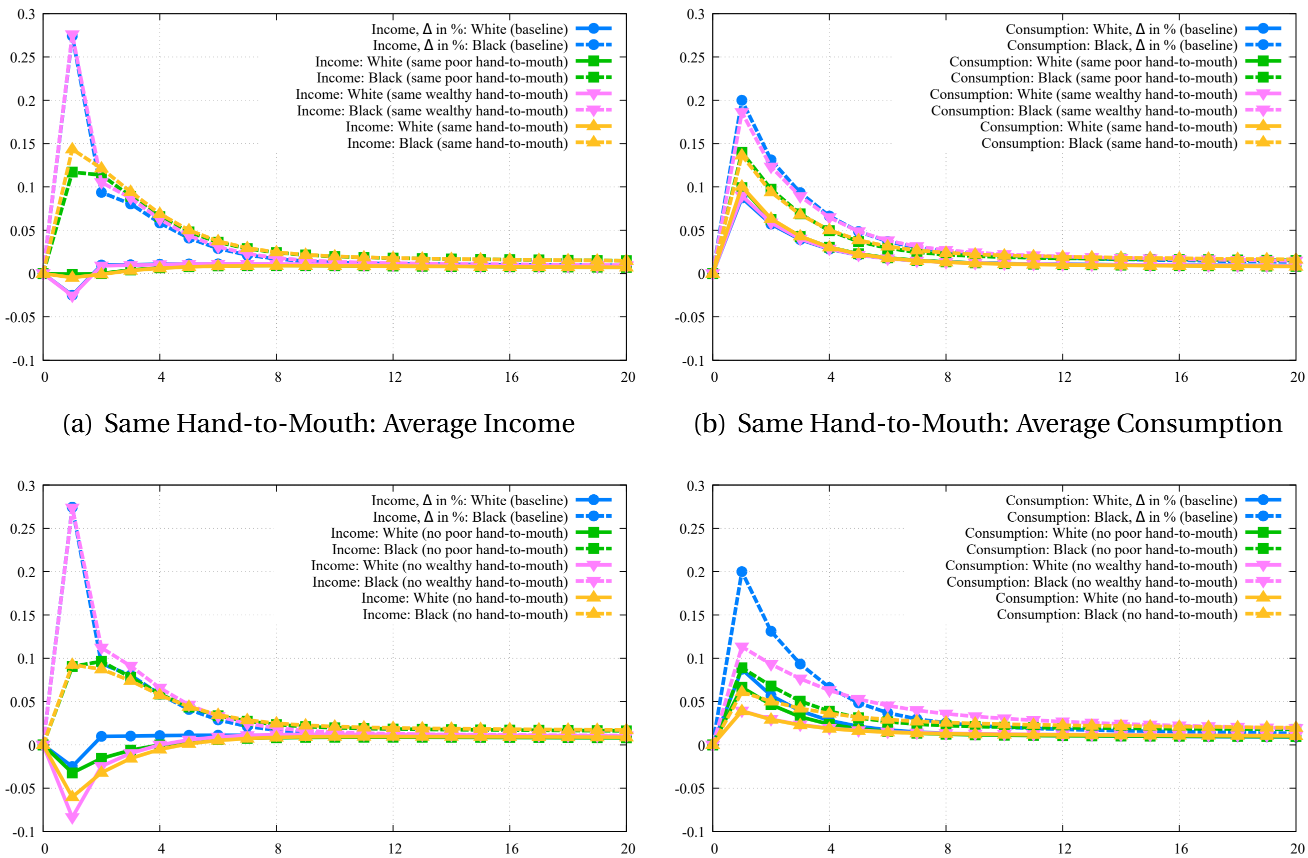


(c) Unemployment Rate



(d) Black-White Unemployment Rate Gap

Figure A.4: Role of Hand-to-Mouth Heterogeneity



(a) Same Hand-to-Mouth: Average Income

(b) Same Hand-to-Mouth: Average Consumption

(c) No Hand-to-Mouth: Average Income

(d) No Hand-to-Mouth: Average Consumption

Figure A.5: Decomposing the Role of Hand-to-Mouth Heterogeneity