Macroeconomics of Racial Disparities: Discrimination, Labor Market, and Wealth

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Abstract

This study examines how racial discrimination in hiring impacts employment, wages, and wealth among black and white workers in the steady state and business cycles. We develop a search-and-matching model that includes both black and white workers and firms with and without racially biased hiring practices. Our results show that labor market search frictions enable the persistence of hiring discrimination in a competitive equilibrium. Firms sustain prejudiced hiring by using their profits while staying competitive. Removing prejudiced firms leads to equal employment rates and reduces income and wealth gaps. However, these firms are not perfect substitutes for non-prejudiced ones. Penalizing prejudiced firms promotes the entry of non-prejudiced firms but does not fully offset the decline in overall economic output and the welfare loss for white workers. Additionally, discriminatory hiring largely explains the higher unemployment and wage volatility among black workers over the business cycles. Eliminating prejudiced firms further boosts black workers' average welfare.

JEL classification: D14, E21, J15, J64, J65

Keywords: search-and-matching, heterogeneous agents, racial inequality, unemployment, wealth distribution, business cycles

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1 Introduction

Research has extensively explored labor market disparities between black and white workers.[1] Empirical evidence demonstrates the persistence of discriminatory practices and the associated racial gaps in the U.S.[2] However, there is a lack of general equilibrium theory that describes the sustaining discriminatory practices, as discrimination is often viewed as inefficient in market competition.[3] This paper proposes a labor search-and-matching framework that sustains hiring discrimination based on race. Moreover, we investigate the consequences of hiring discrimination on racial disparities in the labor market and wealth in the stochastic general equilibrium.

This paper provides three key findings. First, labor market search friction permits discriminatory hiring. Unemployed white workers provide competitive labor to both prejudiced and non-prejudiced firms, and prejudiced firms adjust their retained profit to remain in the market. Second, prejudiced firms compete against non-prejudiced firms in hiring white workers, which not only provides additional employment opportunities for them but also drives up their wages. As a result, black workers are worse off with fewer employment opportunities and lower bargained wage rates as prejudiced firms take up market share. Lastly, with aggregate fluctuations, prejudiced firms exacerbate the wage and unemployment volatility gap between black and white workers. They translate into more volatile consumption and wealth processes for black workers, reducing the average business cycle welfare for black workers.

We construct a heterogeneous agent labor market search-and-matching model with incomplete markets. Firms hire workers to produce. Prejudiced firms only review white workers for hiring, and non-prejudiced firms hire everyone. Individuals are *ex-ante* different

[1] See for example Becker (1957); Couch and Fairlie (2010); Biddle and Hamermesh (2013); Kuhn, Schularick, and Steins (2020); Derenoncourt and Montialoux (2021).

[2] For example, resume studies reveal the persistence of discriminatory practices based on race after controlling for job candidate qualities (e.g. Bertrand and Mullainathan, 2004). The labor income and wealth gaps between black and white households persist, even after the Civil Rights Movement Era (e.g. Cajner, Radler, Ratner, and Vidangos, 2017; Derenoncourt, Kim, Kuhn, and Schularick, 2023). Small and Pager (2020) suggests that discrimination reinforces itself across various domains and is a form of market failure.

[3] See Lang and Spitzer (2020) that summarizes the taste and statistical discrimination theories.

in race, which leads to differences in bargaining power, the possibility of searching for jobs in the two labor markets, and the probability of experiencing a wealth destruction shock. Unemployed workers may qualify for unemployment insurance while matched worker-and-firm pairs bargain for a wage rate to maximize joined matched surplus. Upon calibration, our model endogenously generates a lower job-finding rate, a higher unemployment rate, and a lower bargained wage for black workers. Without further financial frictions, our model produces significant differences in wealth accumulation between black and white workers.

The main message of this paper is that hiring discrimination is sustained as an equilibrium outcome. Consistent with the literature, our calibration shows that prejudiced firms have to pay a higher vacancy posting cost to discriminate against black workers. We gradually raise the posting cost for prejudiced firms. In response, they slowly reduce vacancy posting and employment as their profit adjusts to the higher posting cost. Following the free entry condition, we more than double the benchmark calibrated posting cost so that the future expected value of entering as a discriminatory firm disappears. This suggests that discriminatory firms have enough profit margin to buffer for the higher vacancy posting cost even with the existing market competition.

Moreover, hiring discrimination perpetuates the equilibrium economy through firms' vacancy postings. Though less than half of the vacancy postings compared to non-prejudiced firms, prejudiced firms compete against non-prejudiced firms for each unemployed white worker. As a result, they drive up the wage rates for white workers across the economy. As non-prejudiced firms have to pay higher premiums for white workers, their expected profit drops, hence fewer vacancy postings in the equilibrium, which leaves fewer employment opportunities for black workers. As a consequence, black workers receive lower pay and face a higher unemployment rate, which translates into a more adverse wealth accumulation.

As we remove the prejudiced firms from the economy, non-prejudiced firms pick up the market share to hire workers and produce, providing more job opportunities for black workers. Without the prejudiced sector for white workers, both types of workers compete in

the same non-prejudiced market for work. It equalizes the racial unemployment rate and vastly reduces the wage gap. Prejudiced hiring accounts for over half of the racial wage gap. However, as white workers lose the additional prejudiced sector of employment opportunities, their unemployment rate increases, and welfare declines. Non-prejudiced firms are only imperfect substitutes for prejudiced firms, given the asymmetric calibrated job separation rate and vacancy posting cost. The new vacancy postings from non-prejudiced firms do not fully account for the lost job opportunities from prejudiced firms. As a result, aggregate production drops.

We find that black workers primarily benefit from the removal of discriminatory firms in steady state. High-productive and middle-quintile black workers experience the biggest welfare improvement from removing prejudiced firms. On the contrary, the lowest productive and lowest-wealth white workers suffer the highest average welfare loss.

We further introduce aggregate fluctuations to the economy and show that hiring discrimination creates disparate business cycle dynamics between black and white workers. Particularly, the extra sector of discriminatory firms dampens average wage fluctuations for white workers while exacerbating that for black workers. Consistent with dual sector literature, having both prejudiced and non-prejudiced firms increases unemployment volatility for all workers, particularly for black workers. When we remove prejudiced firms, the racial gap in wage and unemployment rate volatility vastly reduces. The cyclicality gap of racial unemployment and wage differences essentially disappeared. This provides theoretical evidence to Cajner et al. (2017) that non-market demographic differentials cannot explain the cyclical differences between black and white workers.

Lastly, we examine the welfare gap between black and white workers when discriminatory hiring contributes to more volatile labor market outcomes for black workers. We compare the average consumption equivalence of workers during business cycles after removing prejudiced firms. Black workers gain an average of 0.02% in welfare compared to a loss of 0.01% for white workers. Different from steady state welfare value, the high-productive and high-wealth

black workers gain the most while those white workers lose the most.

This paper contributes to the rising discussion on the aggregate impact of inequality by focusing on the disparate conditions and outcomes of white and black workers. Numerous studies have documented racial differences in pay and employment opportunities (e.g. Becker, 1957; Black, 1995; Coate and Loury, 1993; Rosén, 1997; Bertrand and Mullainathan, 2004). Fewer studies examine the patterns between black and white workers over macroeconomic fluctuations. Among the work, Couch and Fairlie (2010) shows that black workers are last hired in the economic upturn and first fired in the downturn. Biddle and Hamermesh (2013) documents that the discriminatory wage gap between black and white workers is procyclical. Cajner et al. (2017) shows much higher unemployment rate volatility and a higher rate of involuntary part-time employment for black workers. Daly, Hobijn, and Pedtke (2020) suggests that the harsh employment opportunities for black workers are driving up the racial earnings gap.

An emerging strand of literature documents the racial disparities in wealth holdings (e.g. Derenoncourt et al., 2023; Derenoncourt, Kim, Kuhn, and Schularick, 2022; Kuhn et al., 2020; Barsky, Bound, Charles, and Lupton, 2002; McIntosh, Moss, Nunn, and Shambaugh, 2020). Recently, Derenoncourt et al. (2023) provide a historical account of wealth segregation between black and white Americans over the past 150 years. Boerma and Karabarbounis (2021) and Aliprantis, Carroll, and Young (2023) examine the impact of discriminatory history on earnings, bequest, and capital returns in a steady-state model without aggregate risks. Given the racial wealth difference, Ganong, Jones, Noel, Greig, Farrell, and Wheat (2020) shows that income risks are transmitted differently to individuals of different racial groups. With such understandings, Bartscher, Kuhn, Schularick, and Wachtel (2021) and Lee, Macaluso, and Schwartzman (2021) discuss the disparate consequences of monetary policy on workers of different race groups.

Germane to our project, Nakajima (2021) creates a search-and-matching model framework examining the role of monetary policies in perpetuating racial differences in the labor

market. Different from Nakajima (2021), our model intentionally differentiates discriminatory firms from nondiscriminatory firms in the labor market hiring process and examines the impact of discriminatory hiring behaviors on black workers and its spillover effects on the rest of the economy. Our analysis establishes the first theoretical understanding of the interplay of hiring discrimination on labor and wealth disparities in the long run and over the business cycles.

In a broader context, this proposed project contributes to the growing discussion on the distributional impact of economic growth and macroeconomic policies by focusing on the heterogeneous outcomes of white and black workers. It joins Caballero and Hammour (1994), Jaimovich and Siu (2020), and Heathcote, Perri, and Violante (2020) in providing evidence that recessions disproportionately hurt disadvantaged individuals. Borella, De Nardi, and Yang (2018) show that introducing gender differences in a theoretical life-cycle model offers a better model fit to the data. This paper will provide insights into how racial difference allows a better fit for search models over the business cycle. Theoretically, Krusell and Smith (1998) conclude that heterogeneity in wealth does not alter business cycle fluctuations. Jang, Sunakawa, Yum, et al. (2020) show that heterogeneity passes to large aggregate fluctuations when introducing non-convexity in budget constraint through progressive tax. This paper identifies that racial wedges in labor search transmit individual risk and heterogeneity to aggregate fluctuations.

The rest of the paper proceeds as follows. Section 2 lays out theoretical framework. Section 3 discusses the calibration strategy. Section 4 examines the steady-state implications of racial discrimination. Section 5 provides business cycle implications. Section 6 concludes the paper.

2 Model

In this section, we present a model of labor market discrimination without aggregate uncertainty. We use this framework to understand the role of hiring discrimination in driving the racial gaps in labor market outcomes and wealth.

2.1 Environment

The model has a unit measure of workers, who are either black or white, $R \in \{bl, wh\}$. Two types of firms post vacancies to hire unemployed workers, subject to search and matching frictions. Prejudiced firms (p) actively discriminate against black workers and hire only white workers. Non-prejudiced firms (np) hire black and white workers without discrimination. Prejudiced and non-prejudiced firms also have type-specific separation rates. To ease exposition, we drop the time subscripts and use a prime symbol (') to denote the variables in the next period.

Workers are either employed (with p or np firm) or unemployed. Those who become unemployed in the current period receive unemployment benefits and continue to receive them in the future with probability P_e. The workers face idiosyncratic productivity shocks s, following an AR(1) process $\log(s') = \rho_s \log(s) + \epsilon_s$, with $\epsilon_s \overset{iid}{\sim} N(0, \sigma_s^2)$. Following Mukoyama (2013), workers also receive race-specific extreme wealth shocks $\epsilon_R \in \{\epsilon_{bl}, \epsilon_{wh}\}$, which gives the probability losing all their wealth. Workers also differ in terms of their asset holdings. They have access to risk-free assets, and the workers can save using these assets to partially insure themselves against the labor market risks. Taken together, workers are heterogeneous across race (R), labor market status (e), idiosyncratic productivity (s), and wealth (a), and the endogenous distribution of workers is given by $\mu(e, R, s, a)$.

2.2 Labor market search and matching

The total number of unemployed workers u is the sum of unemployed black (u_{bl}) and white (u_{wh}) workers. The number of np vacancies available is v_{np}, while number of p firm vacancies is v_p. Since the non-prejudiced firms search among both black and white unemployed workers, the non-prejudiced market tightness is given by $\theta_{np} = v_{np}/u$. On the other hand, prejudiced firms employ only white unemployed workers, and hence the prejudiced market tightness is $\theta_p = v_p/u_{wh}$. Following Den Haan, Ramey, and Watson (2000) and Petrosky-Nadeau, Zhang, and Kuehn (2018), unemployed workers and vacant firms match via a constant return to scale matching function

$$M(u, v) = \frac{uv}{(u^\iota + v^\iota)^{1/\iota}}, \tag{1}$$

with $\iota > 0$. As documented in Den Haan et al. (2000), this matching function ensures that the matching probabilities lie within 0 and 1. The probability for an unemployed worker to match with a np firm is $f(\theta_{np}) = M(u, v_{np})/u = (1 + \theta_{np}^{-\iota})^{-1/\iota}$, while the probability that a white unemployed worker matches with a vacant p firm is $f(\theta_p) = M(u_{wh}, v_p)/u_{wh} = (1 + \theta_p^{-\iota})^{-1/\iota}$. Correspondingly, the probability of filling a vacant np firm is $q(\theta_{np}) = M(u, v_{np})/v_{np} = (1 + \theta_{np}^{\iota})^{-1/\iota}$, while the probability of filling a vacant p firm is $q(\theta_p) = M(u_{wh}, v_p)/v_p = (1+\theta_p^{\iota})^{-1/\iota}$. In addition, non-prejudiced matches get separated with probability λ_{np}, while the prejudiced matches separate at the rate λ_p.

2.3 Unemployment Insurance

Unemployment insurance is characterized by the replacement rate h, probability of eligibility P_e, and maximum eligibility level χ. Following Setty and Yedid-Levi (2021), eligible workers receive unemployment benefits $b(R, s, a) = min\{h\bar{w}(R, s, a), \chi\}$, where $\bar{w}(R, s, a)$ is the counterfactual wage earned by an employed worker with race R, productivity s, and wealth a. We adopt the counterfactual wage to ease the computation burden of tracking wage history. Similar to Mitman and Rabinovich (2015), newly unemployed workers receive unemployment

benefits with certainty and continue to receive benefits next period with probability P_e. If an unemployed worker is ineligible to receive benefits, they remain ineligible. Unemployment benefits are funded through proportional tax τ on the labor income, and the government sets τ to balance its budget.[4]

2.4 Workers

The value function of an employed individual with race R, productivity s, asset a, and working with a np firm is given by $W_{np}(R, s, a)$, while that of a white worker employed with a p firm is given by $W_p(wh, s, a)$. Since the unemployment benefit is indexed to the worker's counterfactual wage, the values of the unemployed workers eligible for benefits depends on whether a non-prejudiced ($U^I_{np}(R, s, a)$) or a prejudiced ($U^I_p(wh, s, a)$) firm employed them previously. An unemployed worker who is not eligible for receiving unemployment benefits earns a value of ($U^N(R, s, a)$) over their lifetime. All the workers discount their future utility by β. Similar to Nakajima (2012) and Setty and Yedid-Levi (2021), we assume that workers cannot borrow. This imposes an exogenous constraint of $a' \geq 0$ on all workers.

2.4.1 Employed with np firm

$$W_{np}(\mu; R, s, a) = \max_{c, a' > 0} \Big\{ u(c) + \beta \mathrm{E}_{\epsilon_R} \sum_{s'} \pi_{ss'} [\underbrace{\lambda_{np} U^I_{np}(\mu'; R, s', a')}_{\text{expected unemployment value}} + \underbrace{(1 - \lambda_{np}) W_{np}(\mu'; R, s', a')}_{\text{expected continuing employed value}}] \Big\} \tag{2}$$

s.t.

$$c + a' = (1 - \tau)\omega_{np}(\mu; R, s, a) + (1 + r)a + d$$

An employed worker of race R with productivity s and asset holdings a, working in an np firm, chooses consumption c and future savings a' to maximize their lifetime discounted utility.

[4] We intentionally model a more realistic and complex unemployment insurance structure to capture the racial disparities in the incidence and take-up of unemployment insurance. This helps us generate racial differences in income and wealth distribution, given the asymmetric labor market and wealth risks.

Their income constitutes of period wage ω_{np} net of payroll tax τ, current savings $(1+r)a$, and dividends d. The expectation of worker's future value is taken over the realizations of race-specific extreme wealth shock ϵ_R and probability of transitioning to a different productivity s'. Additionally, the employed worker may receive a job destruction shock, specific to np firms, and become unemployed with probability λ_{np}, and continue to stay employed with probability $1 - \lambda_{np}$. If unemployed, the worker is eligible to receive unemployment benefits and earns a value of U^I_{np}.

2.4.2 Employed with p firm

Prejudiced firms p hire only white workers. The matched worker receives a job destruction shock specific to p firms, with probability λ_p. A worker losing the job in the current period is eligible for unemployment benefits and earns value U^I_p next period. The rest of the problem is similar to the previous case and is given by

$$\begin{aligned} W_p(\mu; wh, s, a) = \max_{c,a'>0} \Big\{ u(c) + \beta E_{\epsilon_{wh}} \sum_{s'} \pi_{ss'} [\quad & \underbrace{\lambda_p U^I_p(\mu'; wh, s', a')}_{\text{expected unemployment value}} \\ & + \underbrace{(1-\lambda_p) W_p(\mu'; wh, s', a')}_{\text{expected continuing employed value}} \ ] \Big\} \end{aligned} \tag{3}$$

s.t.

$$c + a' = (1-\tau)\omega_p(\mu; wh, s, a) + (1+r)a + d$$

2.4.3 Unemployed and eligible workers

Since unemployment insurance is proportional to the counterfactual wage, the value obtained by an unemployed and eligible worker depends on whether the past employment was in a p or in an np firm. In addition, unemployed white workers can receive job offers from both p and np firms, while black workers can get matched only with np firms.

Black worker from a np firm

$$U^I_{np}(\mu; bl, s, a) = \max_{c,a'>0} \Big\{ u(c) + \beta E_{\epsilon_{bl}} \sum_{s'} \pi_{ss'} \Big[\underbrace{f(\theta_{np}) W_{np}(\mu'; bl, s', a')}_{\text{value of matching with a np job}} + \underbrace{(1 - f(\theta_{np}))[P_e U^I_{np}(\mu'; bl, s', a') + (1 - P_e) U^N(\mu'; bl, s', a')]}_{\text{value of continuing unemployed}} \Big] \Big\} \tag{4}$$

s.t.

$$c + a' = (1 - \tau) b_{np}(bl, s, a) + (1 + r) a + d$$

An unemployed black worker eligible for benefits receives unemployment insurance, $b_{np}(bl, s, a)$, and finds a job with probability $f(\theta_{np})$. If the worker doesn't get matched, they continue to receive unemployment benefits with probability P_e and lose the eligibility with probability $1 - P_e$.

White worker from a np firm

$$\begin{aligned} U^I_{np}(\mu; wh, s, a) = \max_{c,a'>0} \Big\{ u(c) + \beta E_{\epsilon_{wh}} \sum_{s'} \pi_{ss'} \Big[& \underbrace{(1 - f(\theta_{np})) f(\theta_p) W_p(\mu'; wh, s', a')}_{\text{value of matching with a p sector job only}} \\ & + \underbrace{f(\theta_{np})(1 - f(\theta_p)) W_{np}(\mu'; wh, s', a')}_{\text{value of matching with a np sector job only}} \\ & + \underbrace{f(\theta_{np}) f(\theta_p) \max\{W_p(\mu'; wh, s', a'), W_{np}(\mu'; wh, s', a')\}}_{\text{value of matching with both p and np jobs}} \\ & + \underbrace{(1 - f(\theta_p))(1 - f(\theta_{np}))}_{\text{not matching with any job}} \Big[\underbrace{P_e U^I_{np}(\mu'; wh, s', a')}_{\text{value of continuing UI}} + \underbrace{(1 - P_e) U^N(\mu'; wh, s', a')}_{\text{value of losing UI}} \Big] \Big] \Big\} \end{aligned}$$

s.t.

$$c + a' = (1 - \tau) b_{np}(wh, s, a) + (1 + r) a + d \tag{5}$$

Unemployed white workers are recruited by both p and np firms. An unemployed white worker receives a job offer from a p firm with probability $(1 - f(\theta_{np})) f(\theta_p)$, an offer from an np firm with probability $f(\theta_{np})(1 - f(\theta_p))$, and receive both offers together with probability

$f(\theta_{np})f(\theta_p)$. The white worker will remain unemployed if they don't receive any offers (with probability $(1-f(\theta_p))(1-f(\theta_{np}))$) and continue to receive unemployment benefits with probability P_e. In the event that the worker receives both p and np offers, they will choose the job that gives them the higher expected returns.

White worker from a p firm

$$
\begin{aligned}
U_p^I(\mu; wh, s, a) = \max_{c,a'>0} \Big\{ u(c) + \beta E_{\epsilon_{wh}} \sum_{s'} \pi_{ss'} \Big[& \underbrace{(1-f(\theta_{np}))f(\theta_p) W_p(\mu'; wh, s', a')}_{\text{value of matching with a p sector job only}} \\
& + \underbrace{f(\theta_{np})(1-f(\theta_p)) W_{np}(\mu'; wh, s', a')}_{\text{value of matching with a np sector job only}} \\
& + \underbrace{f(\theta_{np}) f(\theta_p) \max\{W_p(\mu'; wh, s', a'), W_{np}(\mu'; wh, s', a')\}}_{\text{value of matching with both p and np jobs}} \\
& + \underbrace{(1-f(\theta_p))(1-f(\theta_{np}))}_{\text{not matching with any job}} \Big[\underbrace{P_e U_p^I(\mu'; wh, s', a')}_{\text{value of continuing UI}} + \underbrace{(1-P_e) U^N(\mu'; wh, s', a')}_{\text{value of losing UI}} \Big] \Big] \Big\}
\end{aligned}
$$

s.t.

$$
c + a' = (1-\tau) b_p(wh, s, a) + (1+r)a + d \tag{6}
$$

The problem faced by a white worker who last worked with a p firm is identical to the previous case, except they earn $b_p(wh, s, a)$ as their unemployment benefit.

2.4.4 Unemployed and ineligible workers

Ineligible workers no longer receive any unemployment benefits. Their income comes only from their past savings and dividends and hence doesn't depend on their previous employment.

Black worker

$$U^N(\mu; bl, s, a) = \max_{c,a'>0} \Big\{ u(c) + \beta E_{\epsilon_{bl}} \sum_{s'} \pi_{ss'} \Big[\underbrace{f(\theta_{np}) W_{np}(\mu'; bl, s', a')}_{\text{value of matching with a np job}} + \underbrace{(1 - f(\theta_{np})) U^N(\mu'; bl, s', a')}_{\text{value of staying unemployed}} \Big] \Big\} \tag{7}$$

s.t.

$$c + a' = (1 + r)a + d$$

White worker

$$\begin{aligned} U^N(\mu; wh, s, a) = \max_{c,a'>0} \Big\{ u(c) + \beta E_{\epsilon_{wh}} \sum_{s'} \pi_{ss'} \Big[& \underbrace{(1 - f(\theta_{np})) f(\theta_p) W_p(\mu'; wh, s', a')}_{\text{value of matching with a p sector job only}} \\ & + \underbrace{f(\theta_{np})(1 - f(\theta_p)) W_{np}(\mu'; wh, s', a')}_{\text{value of matching with a np sector job only}} \\ & + \underbrace{f(\theta_p) f(\theta_{np}) \max\{W_p(\mu'; wh, s', a'), W_{np}(\mu'; wh, s', a')\}}_{\text{value of matching with both np and p sector jobs}} \\ & + \underbrace{(1 - f(\theta_p))(1 - f(\theta_{np})) U^N(\mu'; wh, s', a')}_{\text{value of continuing unemployed}} \Big] \Big\} \end{aligned} \tag{8}$$

s.t.

$$c + a' = (1 + r)a + d$$

Thus, the problem faced by an ineligible worker is analogous to an eligible worker, except that they don't receive unemployment benefits.

2.5 Firms

There are a large number of p and np firms that can post vacancies as long as they pay the vacancy posting costs. The firms are risk-neutral and discount their future profits using

equilibrium real interest rates.

2.5.1 Vacant np firm

Vacant np firms pay a low cost of κ_{np} and search among all unemployed workers irrespective of race. They get matched with an unemployed worker with probability $q(\theta_{np})$. The value of a vacant np firm, V_{np}, is

$$
\begin{aligned}
V_{np} = -\kappa_{np} + \Big(\frac{q(\theta_{np})}{1+r}\Big) \int_a \Big\{ \sum_{s'} \pi_{ss'} \Big[& \underbrace{J_{np}(bl, s', a') \frac{\phi_u(bl, s, a)}{u}}_{\text{value of matching with a type (s,a) black worker}} \Big] \\
+ \sum_{s'} \pi_{ss'} \Big[& \underbrace{\mathbb{1}_{\{W_{np}(\mu'; wh, s', a') \geq W_p(\mu'; wh, s', a')\}}}_{\text{prob of white worker higher value than a p firm}} \Big(\underbrace{J_{np}(wh, s', a') \frac{\phi_u(wh, s, a)}{u}}_{\text{value of matching with (s,a) white worker}} \Big) \\
+ & \underbrace{\mathbb{1}_{\{W_{np}(\mu'; wh, s', a') < W_p(\mu'; wh, s', a')\}}}_{\text{prob of white worker lower value than a p firm}} \Big(\underbrace{J_{np}(wh, s', a') \frac{\phi_u(wh, s, a)}{u}}_{\text{value of matching (s,a) worker without competing p offer}} \Big)(1 - f(\theta_p)) \Big] \Big\} da
\end{aligned}
\tag{9}
$$

where $J_{np}(R, s, a)$ is the value of a producing firm matched with a worker of race R, productivity s, and asset a. A np firm can match with either a black or a white worker from the current unemployment pool. $\phi_u(bl, s, a)$ is the population of unemployed black workers with productivity s and asset a, while $\phi_u(wh, s, a)$ is the corresponding population of white workers. Thus, $\phi_u(bl, s, a)/u$ and $\phi_u(wh, s, a)/u$ are the densities of the unemployed black and white workers over s and a, and these reflect the probabilities that a vacant np firm gets matched with a black and a white unemployed worker respectively. Since the white unemployed workers can potentially receive a competing offer from a p firm, the white worker will accept the np match and begin producing only if it gives them a higher value, or if the worker does not receive a p firm offer.

2.5.2 Vacant p firm

Vacant p firms pay a posting cost of κ_p and restrict their search only among unemployed white workers. The probability of matching with a white unemployed worker is $q(\theta_p)$. The

value of maintaining a p vacancy, V_p, is

$$V_p = -\kappa_p + \Big(\frac{q(\theta_p)}{1+r}\Big)\sum_{s'}\pi_{ss'}\int_a \Big[\underbrace{\mathbb{1}_{\{W_p(\mu';wh,s',a')>W_{np}(\mu';wh,s',a')\}}\Big(J_p(wh,s',a')\frac{\phi_u(wh,s,a)}{u_{wh}}\Big)}_{\text{value of matching with (s,a) white worker, with higher value than np firm}}$$
$$+\underbrace{\mathbb{1}_{\{W_p(\mu';wh,s',a')\leq W_{np}(\mu';wh,s',a')\}}\Big(J_p(wh,s',a')\frac{\phi_u(wh,s,a)}{u_{wh}}\Big)(1-f(\theta_{np}))}_{\text{value of matching with (s,a) white worker without competing np firm}}\Big]da \tag{10}$$

Since the vacant p firm searches only among white workers, the probability of matching with an unemployed white worker having productivity s and asset a is given by $\phi_u(wh,s,a)/u_{wh}$. As the case of np firms, the white worker accepts the p match only if the p offer is more favorable, or if they don't receive a competing np offer.

We assume that there is free entry condition and hence, both p and np firms post vacancies until $V_p = 0$ and $V_{np} = 0$, respectively.

2.5.3 Producing np firm

Upon a successful match with a worker of state (R,s,a), the filled np firm rents capital in order to start production. The value of a producing np firm is

$$J_{np}(\mu;R,s,a) = \max_k\Big\{j(\mu;R,s,a) + \Big(\frac{1-\lambda^{np}}{1+r}\Big)E_{\epsilon_R}\sum_{s'}\pi_{ss'}J_{np}(\mu';R,s',a')\Big\}$$
$$\text{where} \tag{11}$$
$$j(\mu;R,s,a) = sf(k) - (r+\delta)k - \omega_{np}(\mu;R,s,a)$$

The matched firm produces $sf(k)$ units of output, pays the rental and the depreciation cost of capital, $(r+\delta)k$, and the wage cost, $\omega_{np}(\mu;R,s,a)$. The firm discounts their future profits using the interest rate adjusted for the job destruction rate λ_{np}.

2.6 Producing p firm

Similar to a producing np firm, producing p firm hires capital and discounts future profits after accounting for the job destruction rate λ_p.

$$J_p(\mu; wh, s, a) = \max_k \Big\{ j(\mu; wh, s, a) + \Big(\frac{1-\lambda^p}{1+r}\Big) E_{\epsilon_{wh}} \sum_{s'} \pi_{ss'} J_p(\mu'; wh, s', a') \Big\}$$

where

$$j(\mu; wh, s, a) = sf(k) - (r+\delta)k - \omega_p(\mu; wh, s, a) \tag{12}$$

2.7 Wage bargaining

Matched worker-firm pairs bargain for a wage period-by-period. The worker's bargaining power ξ_R depends on the race of the individual, and the firm's bargaining power is $1-\xi_R$. The resulting wage for p and np matches are given by

$$\omega_{np}(\mu; R, s, a) = \arg\max_{\omega} \Big(W_{np}(\mu; R, s, a) - U^I_{np}(\mu; R, s, a) \Big)^{\xi_R} J_{np}(\mu; Ra, s, a)^{1-\xi_R} \tag{13}$$

$$\omega_p(\mu; wh, s, a) = \arg\max_{\omega} (W_p(\mu; wh, s, a) - U^I_p(\mu; wh, s, a))^{\xi_{wh}} J_p(\mu; wh, s, a)^{1-\xi_{wh}} \tag{14}$$

We define the stationary equilibrium in Appendix A.

3 Calibration

A period in the model represents a quarter. We calibrate the baseline model to match the relevant US economy moments. We have two sets of parameters. The first group of parameters is chosen externally based on literature and empirical evidence without using model-generated data, while the second group of parameters is calibrated internally by simulating our model to match a set of relevant data moments. Table 1 shows the internally calibrated parameter values and their targeted moments, as well as the externally chosen parameters and their sources.

Table 1: Calibration and targeted statistics

Parameter	Value	Description	Target statistics	data	model
Chosen internally					
β	0.9943	discount factor	K/Y	10.26	10.26
ι	1.3012	matching elasticity	job finding rate - black	0.4946	0.4946
κ_p	4.2622	p sector vacancy posting cost	job finding rate - white	0.6599	0.6599
κ_{np}	2.7350	np sector vacancy posting cost	market tightness	1	1
λ_p	0.0268	p sector job destruction shock	job separation rate - white	0.0380	0.0380
λ_{np}	0.0644	np sector job destruction shock	job separation rate - black	0.0644	0.0644
ξ_{wh}	0.2110	bargaining power - white	firm profit share	0.033	0.033
ξ_{bl}	0.1397	bargaining power - black	mean wage ratio	0.75	0.75
ϵ_{wh}	0.0086	extreme wealth shock - white	zero wealth share - white	0.07	0.07
ϵ_{bl}	0.0179	extreme wealth shock - black	zero wealth share - black	0.18	0.18
Chosen externally					
α	0.6600	elasticity of labor matching	Nakajima (2012)		
θ_n	0.2890	capital share of output	Nakajima (2012)		
δ	0.0150	quarterly depreciation rate	Nakajima (2012)		
ρ_s	0.9411	persistence of idiosyncratic shock	PSID		
σ_s	0.1680	standard deviation of idiosyncratic shock	PSID		
h	0.4000	UI replacement rate	Mitman and Rabinovich (2015)		
ξ	0.8433	maximum UI coverage	Setty and Yedid-Levi (2021) 48% median wage		
Pe	0.5385	probability of UI eligibility	maximum weeks of eligibility		

Notes: This table reports the parameters, their values, and descriptions. The top panel presents the parameters chosen internally by minimizing the distance between model-generated moments and data. The last two columns of the top panel compare the targeted moments between data and model-simulated values. The bottom panel reports the parameters chosen externally, their values, and descriptions.

3.1 Preferences

We set the period utility function $u(c)$ to be $\log(c)$. The discount factor, β, is calibrated to match the quarterly capital-output ratio of 10.26, the value used by a number of studies including Den Haan, Judd, and Juillard (2010) and Carroll, Slacalek, Tokuoka, and White (2017). The resulting value of β is 0.9943, and the corresponding quarterly real interest rate is 1.3%.

3.2 Production

The worker-firm match produces according to a Cobb-Douglas production function, $f(k) = k^{\alpha}$. We choose α to be 0.289 and set the quarterly capital depreciation rate δ equal to 0.015 following Nakajima (2012).

3.3 Productivity and wealth shocks

We use hourly real wage from the Panel Study of Income Dynamics (PSID) to estimate the persistence, ρ_s, and the standard deviation, σ_s of the productivity process. Our estimation strategy closely follows Setty and Yedid-Levi (2021). We run a standard Mincer wage regression of log wage on the demographic controls, including education, labor market experience, race, marital status, year, and state fixed effects for a sample of males aged 25 years and above. We then apply the obtained residuals to estimate an AR(1) regression by using the panel dimension of the PSID data. The estimated regression is at a biennial frequency, given that the PSID data is available once in two years. We assign the quarterly adjusted coefficient of the AR(1) regression as the persistence of the idiosyncratic productivity process. The standard deviation of the productivity process corresponds to the standard deviation of the residuals from the AR(1) regression after adjusting for the model frequency. We estimate the quarterly persistence, ρ_s, to be 0.9411 and the corresponding standard deviation, σ_s, as equal to 0.1680.

Following Mukoyama (2010), our model also features extreme wealth shocks to capture the mass of people having zero wealth. The race-specific probability of losing one's wealth, ϵ_R, is calibrated to be 0.0179 for black workers and 0.0086 for white workers. They capture the empirical moments that around 18% of black workers and 7% white workers have zero wealth. (Nakajima, 2021).

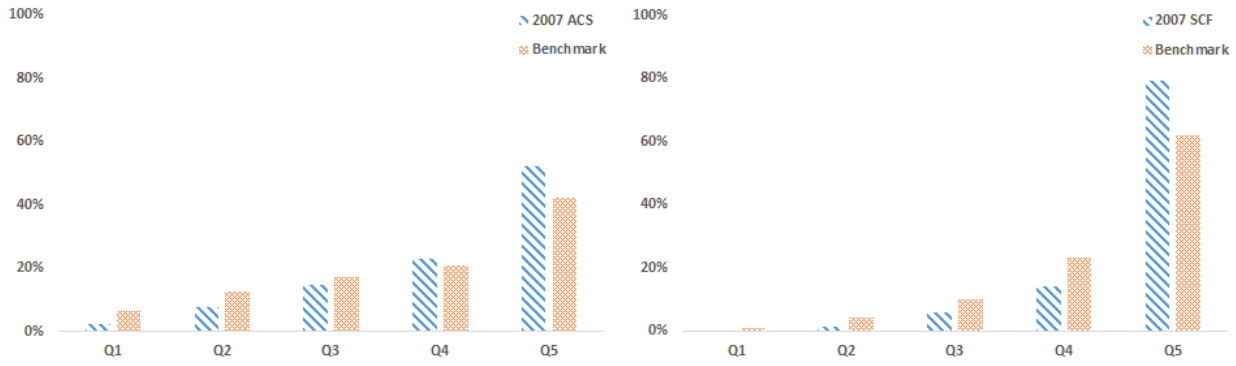
3.4 Unemployment insurance

The unemployment insurance system in our model is characterized by the replacement rate, h, the maximum insurance payout, χ, and the probability of maintaining the eligibility status, P_e. We choose the replacement rate, h, to be 0.4 along the lines of Shimer (2005), Mitman and Rabinovich (2015), and others. Following Setty and Yedid-Levi (2021), we calibrate the maximum payout χ to be 0.8433, which amounts to 48% of the median wage in the model. The eligibility probability P_e is chosen to be 0.5385 to generate an average unemployment benefit duration of 26 weeks, as in Mitman and Rabinovich (2015).

3.5 Labor search and wage bargain

The labor market turnover statistics are obtained from Cajner et al. (2017). The elasticity of the matching function, ι, targets the job finding rate of the black workers. Our calibrated value of 1.3012 is close to that of 1.25 in Den Haan et al. (2000) and Petrosky-Nadeau et al. (2018). We choose firm-type specific job separation rates λ_{np} and λ_p to match the separation rates of black and white workers respectively. The ensuing values for λ_{np} and λ_p are 0.0644 and 0.0268, respectively.[5] The vacancy posting cost of prejudiced firms, κ_p, is chosen to match the job finding rate of white workers, while the posting cost of non-prejudiced firms, κ_{np}, is chosen to target the aggregate labor market tightness, θ, of 1 following Wolcott

[5]All the black workers work only with np firms, and hence λ_{np} is exactly equal to the job separation rate of the black workers. On the other hand, white workers work in both p and np firms, and hence λ_p (0.0268) is smaller than the aggregate separation rate of the white workers (0.0380).



(a) Labor income share

(b) Wealth share

Figure 1: Labor Income and Wealth Distribution

Note: This table compares the steady state model generated wealth and labor income with their empirical analogs. The empirical labor income distribution data comes from the 2007 American Community Survey (ACS), and the empirical wealth distribution data comes from the 2007 Survey of Consumer Finance (SCF).

(2021).[6] We find that the prejudiced firms pay a lot more than non-prejudiced firms to post their vacancies, with κ_p calibrated to be 4.2622, compared to κ_{np} taking a value of 2.735. The bargaining power of black workers, ξ_{bl}, is calibrated to target the average black-to-white racial wage ratio of 0.75 (Derenoncourt and Montialoux, 2021). The white worker's bargaining power, ξ_{wh}, is chosen to generate a firm profit share of 3.3% as in Nakajima (2012). Consistent with our expectations, we find that the black workers have a lower bargaining power compared to the white workers, with ξ_{bl} to be 0.1397 and ξ_{wh} to be 0.211.

3.6 Assessing the model as a quantitative theory of racial disparity

Our calibration successfully captures the racial gaps along three important dimensions: income, wealth, and labor market outcomes. We now discuss each of these dimensions in more detail before proceeding with the quantitative exercises examining the macroeconomic impact of racial discrimination.

First, the model successfully captures the overall household distribution of wealth and labor earnings as shown in Figure 1, even though we don't target these distributions explicitly.

[6] Aggregate labor market tightness $\theta = \frac{v_{np}+v_p}{u_{bl}+u_{wh}}$.

Table 2: Steady State Racial Inequality

Moments	Data	Model
Unemp rate (Black)	0.12	0.12
Unemp rate (White)	0.05	0.05
Mean wealth ratio	0.23	0.28
Median wealth ratio	0.17	0.33

Note: This table compares the steady state wealth and unemployment moments between black and white workers with the corresponding empirical data.

As with the majority of incomplete market models, we also face difficulty in generating the extreme concentration of wealth and labor income in the top quintile. On the other hand, we are much closer to the empirical distributions in the lower quintiles since we target the share of zero-wealth workers in our calibration.

Second, the model is able to capture the disparities in unemployment, labor income, and wealth between black and white workers. As targeted in the calibration, the model replicates the empirical racial labor income gap and the empirical racial difference in the share of people at zero wealth. In addition to the targeted moments, Table 2 demonstrates that our model successfully captures the untargeted employment and wealth moments. Specifically, our model reproduces the 5% unemployment rate among white workers compared to 12% among black workers. Apart from the lower separation rate, white workers have a lower unemployment rate due to their access to the prejudiced sector. Our model results show that the p sector with tightness of 0.4, though smaller than the np market tightness of 0.73, provides an important advantage for white workers by increasing their job-finding rate compared to black workers. Moreover, without targeting, the model generates a mean black-white wealth ratio of 0.28, close to 0.23 as in Kaplan, Violante, and Weidner (2014). However, the model understates the median wealth gap between black and white workers. The median black worker retains 33% of the wealth of the median white worker in our model compared to 17% in the data (Kaplan et al., 2014).

In sum, the model captures the racial inequalities across labor income, wealth, and unemployment outcomes. We explore how racial discrimination in hiring contributes to these

differences.

4 Steady state results

In this section, we first establish how a search framework sustains hiring discrimination in the equilibrium. Then, we examine the steady state impact of racial discrimination by comparing the benchmark economy to one without hiring discrimination. Lastly, we explore the heterogeneous welfare implication associated with eliminating hiring discrimination.

4.1 Sustaining racial discrimination

Our labor search-and-matching framework allows firms to retain profit because of search friction. Prejudiced firms can pay for discrimination using their retained profit. This feature permits the coexistence of prejudiced and non-prejudiced firms in a competitive equilibrium. This is in contrast to a frictionless canonical neoclassical model where prejudiced hiring will be driven out by competition if there is no inherent difference between black and white workers as described in Becker (1957). To demonstrate how a frictional labor market sustains hiring discrimination, we start by gradually penalizing prejudiced hiring to show the extent of the penalty necessary to eliminate the profit retained by prejudiced firms. This exercise also illustrates the interplay between prejudiced and non-prejudiced firms. In particular, we gradually increase the vacancy posting cost κ_p of the p firms until all the prejudiced firms are driven out of the economy. Figure 2 displays the dynamics of employment, vacancy, and profits of the prejudiced and non-prejudiced firms as we increase the vacancy posting cost κ_p. Increasing κ_p disadvantages p firms as their profit gradually declines, which causes a decline in their vacancy postings and employment. Meanwhile, since fewer p firms compete against np firms in the market, np firms experience a gradual increase in their profit, vacancy posting, and employment.

It is worth noting that the dynamics of p and np firms are not symmetric. As p firms'

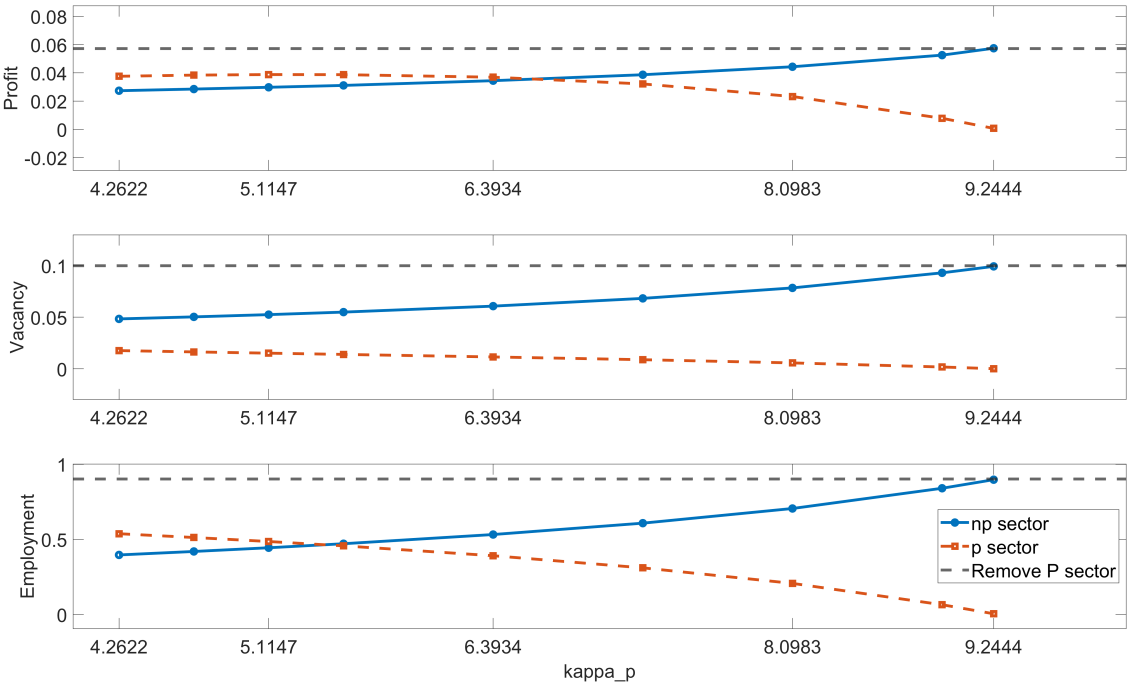


Figure 2: Penalizing Discrimination

Note: This figure displays the dynamics between p and np firms as κ_p increases. The top panel plots the movement in profit, the middle panel plots the movement in vacancy posting, and the bottom panel plots the movement in employment. The red dotted line depicts the dynamics of p firms, the blue solid line depicts the dynamics of np firms, and the grey dotted line depicts the limit where no p firm exists.

profit declines, the profit of np firms increases at a slower rate. This is because np firms face a higher job destruction rate and a lower vacancy posting cost. Moreover, as np firms replace p firms, they recruit from both black and white workers, rather than only white workers displaced from p firms. This is mainly reflected in np firms' more elastic vacancy posting response.

In the limit, when κ_p approaches the entire expected value of the p sector, the p firms almost completely exit the market as it is no longer profitable to post vacancies targeting just the white workers. Meanwhile, np firms nearly become the only employment sector in the economy. The grey dotted lines in Figure 2 depict a counterfactual steady state where we remove p firms from the benchmark model entirely. Increasing κ_p in the limit asymptotically equals the alternative of completely eliminating p firms.

4.2 Impact of hiring discrimination on racial inequality

In the previous subsection, we established the equilibrium outcome of hiring discrimination and that removing it requires non-market forces, such as penalizing prejudiced hiring. In this subsection, we compare the benchmark economy to the one without prejudiced firms to illustrate the aggregate and distributional impact of prejudiced hiring. Table 3 presents the comparison.

The first panel of Table 3 displays the labor market conditions after removing p firms. The labor market tightness of the np sector, θ_{np}, jumps from 0.73 to 1.02 in the equilibrium without p firms. Thus, in response to the p firms exiting, more np firms endogenously enter the market. The ensuing market tightness is higher than the benchmark model aggregate market tightness of 1.

The second panel displays the changes in firm attributes. As discussed in the previous subsection, np firms' profit and vacancy posting double, while their employment level increases from 0.4 to 0.9 when no p firms exist. However, the increase of np employment does not fully compensate for the decline in p employment. Hence, the total employment rate of 90% is still below the aggregate employment rate of 94% in the benchmark case.

The third panel shows the changes in racial wage, unemployment, and wealth disparities after removing prejudiced hiring. Since there is no p sector in the economy, the job finding and separation rates are equalized for both black and white workers. This closes the racial gap in the unemployment rate, with both black and white workers having an unemployment rate of 10%. As np firms retain higher profits, black workers are able to bargain for a higher wage rate. However, white workers no longer have access to p firms, which would have increased their outside option, allowing them to bargain for a higher wage rate with np firms. Their wage rate decreases. As a result, the racial wage gap declines, with black workers, on average, earning 88% of white worker's wages, compared to 75% in the benchmark. The remaining wage gap comes from the bargaining power and extreme wealth shock disparities between black and white workers. Finally, eliminating prejudiced firms also closes the wealth gap,

Table 3: Impact of hiring discrimination

Moments	Benchmark	Eliminate p firms
Labor Market		
np market tightness	0.73	1.02
p market tightness	0.40	-
Firms		
p firm profit	0.04	-
np firm profit	0.03	0.06
p firm vacancy	0.02	-
np firm vacancy	0.05	0.10
p firm employment	0.54	-
np firm employment	0.40	0.90
Households		
unemp rate (Black)	0.12	0.10
unemp rate (White)	0.05	0.10
mean wage ratio	0.75	0.88
mean wealth ratio	0.28	0.33
median wealth ratio	0.33	0.44
Aggregate Outocmes		
Y	3.06	2.95
K/Y	10.26	10.22
average wage	2.04	1.96
unemp rate	0.07	0.10

Note: This table compares the benchmark steady state with a counterfactual steady state with no p firms.

with the mean wealth ratio moving from 0.28 to 0.33 and the median wealth ratio increasing from 0.33 to 0.44.

The last panel of Table 3 describes the aggregate outcomes. Because of the asymmetry between np and p firms, with increased κ_p, despite more np firms entering the market, they don't fully compensate for the exiting p firms. Due to this, aggregate output decreases from 3.06 to 2.95, and the K/Y ratio declines by 0.02. Though black workers' average wage increases, white workers' average wage decreases, in turn causing the overall average wage to decline from 2.04 to 1.96. Even though penalizing p firms leads to equalizing the unemployment rates for black and white workers, the aggregate unemployment rate jumps up from around 6.5% in the benchmark case to 10% in counterfactual equilibrium.

Our results show that the presence of discriminatory firms can explain sizable fractions

of income and wealth inequality. Even though penalizing prejudiced firms improves the outcomes for the black workers, they also worsen the situation for the white workers. Removing p firms reduces the job finding rate, increases the separation rate, and hence the unemployment rate for white workers. In addition, they also lower the value of their outside option in wage bargaining, which, in turn, affects their income and wealth outcomes. In order to quantify the differential effects of removing discrimination, we next calculate the welfare changes experienced by the black and the white workers.

The remaining racial differences come from bargaining power and extreme wealth shock differentials between black and white workers. Though not the primary purpose of this paper, we present a comparison of analysis removing bargaining power and extreme wealth shock in Appendix B.

4.3 Welfare analysis

We further calculate the welfare change measured as average consumption equivalence change by removing discriminatory firms, following Krusell, Mukoyama, and Şahin (2010).[7] We present the average welfare change between black and white workers by productivity types and by wealth quintiles in Table 4. As a comparison, we conduct welfare analysis by imposing a high penalty $\kappa_p = 9.2444$ on discriminatory firms, as in Figure 2, and present the results in Appendix C. It is quantitatively similar to Table 4.

Overall, eliminating discriminatory firms leads to an economy-wide average welfare loss of 5.83% (not shown in the table). Black workers experience an average welfare increase

[7]Under the benchmark model, we let $V(e, R, s, a) = \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t log(c_t)$ be the maximal value of the individual with employment status e, race R, productivity s, and asset a. Under an alternate economy, let $\tilde{V}(e, R, s, a) = \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t log(\tilde{c}_t)$ be the maximal value of individuals with each corresponding state. We examine the welfare change between the two economies through consumption equivalence Ω, following the equation: $\mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t log((1+\Omega)c_t) = \mathrm{E}_0 \sum_{t=0}^{\infty} \beta^t log(\tilde{c}_t)$. With log utility, we derive $\Omega = \exp((\tilde{V} - V)(1-\beta)) - 1$. We sum over individual-level consumption equivalence, Ωs, using the distribution of the counterfactual economy and distribute over the respective population to calculate the average welfare change. We aggregate over the counterfactual distribution rather than benchmark distribution because eliminating p firms in the model removes the distribution of white workers associated with the states of working at and unemployment from p firms. Aggregating over the benchmark distribution overstates welfare change for white workers without accounting for the distribution shift.

of 6.89%. This is driven by the increase in np market tightness and their profit, as more np firms post vacancies after the exit of p firms and without any wage competition from the p sector. On the other hand, white workers experience an average welfare loss of 8.8%. Though the np sector picks up hiring, white workers no longer have a p sector that provides more job stability with a lower job separation rate, which drives down their wage rate.

Productivity types Mid-panels in Table 4 present the heterogeneous welfare change between black and white workers by productivity types. Though the welfare reduction of eliminating prejudiced firms is similar and large across productivities for white workers, the largest loss is for the lowest productive workers. This corresponds to the mechanism that the prejudiced sector provides alternative job sources for displaced white workers from non-prejudiced sectors. Prejudiced firms are likely to offer a more competitive wage to low-productive white workers. In reverse, highly productive black workers have the most welfare gain.

Table 4: Heterogeneous welfare change

Average welfare gain (%)	Black	White
Average	6.89	-8.83
by productivity		
Low	6.30	-9.03
Mid	6.92	-8.83
High	7.41	-8.61
by wealth		
Low 20%	6.85	-9.43
40-60%	6.95	-8.95
Top 20%	6.88	-8.14

Note: This table compares the average consumption equivalence change from the benchmark steady state to the equilibrium where we eliminated p firms. Low, mid, and high productivity corresponds to the lowest, middle, and highest value of idiosyncratic productivity s. The wealth quintiles are based on benchmark steady-state wealth distribution.

Wealth quintiles The bottom panels of Table 4 present the heterogeneous welfare change by wealth quintiles between black and white workers. Removing discriminatory firms benefits

middle-quintile black workers the most - an average welfare gain of 6.95%. After eliminating prejudiced firms, the largest reduction (9.43%) happens to the bottom quintile of white workers.

5 Business cycle dynamics

We introduce aggregate uncertainty through shocks to aggregate productivity in our baseline model to study the impact of labor market discrimination in the short run. Cajner et al. (2017) documents that, compared to white workers, the unemployment rate of black workers is more volatile over the business cycle, and the racial unemployment gap widens during the recessions. Additionally, they show that the differences in demographic factors cannot explain the differential dynamics experienced by black and white workers. In this section, we first augment our baseline model with aggregate uncertainty. We then compare the business cycle properties of the labor market and wealth outcomes between black and white workers with and without prejudiced firms. Lastly, we compare the business cycle welfare implication. Introducing aggregate uncertainty in our baseline model will enable us to quantify the role of prejudiced firms in generating disparate dynamics over the business cycle.

5.1 Augmented model with aggregate shocks

We introduce an aggregate total factor productivity (TFP) shock z to the baseline steady-state model from Section 2. The TFP shocks follows an AR(1) process, $\log(z') = \rho_z \log(z) + \epsilon_z$, with $\epsilon_z \overset{iid}{\sim} N(0, \sigma_z^2)$. The output of the matched firm-worker pairs depends on the realizations of both aggregate and idiosyncratic productivity shocks, and is given by $zsf(k)$.

With the introduction of aggregate shocks, the state space expands to include aggregate states (z, μ), where μ is the distribution of workers across employment status (e), race (R), idiosyncratic productivity (s), and asset (a). The next period's aggregate distribution μ' is determined by (z, μ), and the law of motion is given by $\mu' = \Gamma(z, \mu)$.

We follow Cooley, Prescott, et al. (1995) and Boppart, Krusell, and Mitman (2018) and choose the persistence parameter ρ_z to be 0.95, while the standard deviation σ_z is set to 0.015. All other parameters stay the same as in Table 1. This gives us an aggregate output volatility of 0.02 and a first-order auto-correlation of 0.73.

We obtain the stochastic equilibrium of our model by using the sequence space method of Boppart et al. (2018). We first solve non-linearly for the perfect foresight transitions to a single small MIT shock, i.e., an unexpected shock to the aggregate TFP. We then use the solved impulse responses as the numerical derivatives with respect to the initial TFP shock. Using these derivatives, we simulate the stochastic equilibrium by generating the TFP realizations and calculate the corresponding model moments over the business cycle as a linear combination of the impulse response and the TFP realizations. [8]

5.2 Impulse responses

Figure 3 plots the response of labor market, wealth, and consumption outcomes of both black and white workers after an unanticipated expansionary shock. We compare the benchmark model response to the counterfactual model without p firms to study the impact of hiring discrimination over the business cycle. [9] Overall, our models generate countercyclical unemployment rate and procyclical wage, wealth, and consumption movements. As is standard in the literature on dual labor markets, the single market model (without p firm) reverts to the steady state faster than the dual market model (benchmark) (e.g. Horvath and Yang, 2022). However, in the benchmark model with discriminatory firms, black workers experience more pronounced changes in unemployment rates and consumption in response to an expansionary shock compared to white workers. While average wages and wealth show little difference between models with and without discriminatory firms, the black-white average

[8] This method hinges on the linear-additive property of the business cycle dynamics. In the Appendix D, we demonstrate the validity of this assumption by comparing impulse responses to 1% positive and negative TFP shocks.

[9] For the impulse response function to represent the numerical derivative, the magnitude of the MIT shock should be small. We provide a 1% positive shock to z at the initial period, i.e., $\epsilon_z = 0.01$, and let the TFP return to the steady state deterministically.

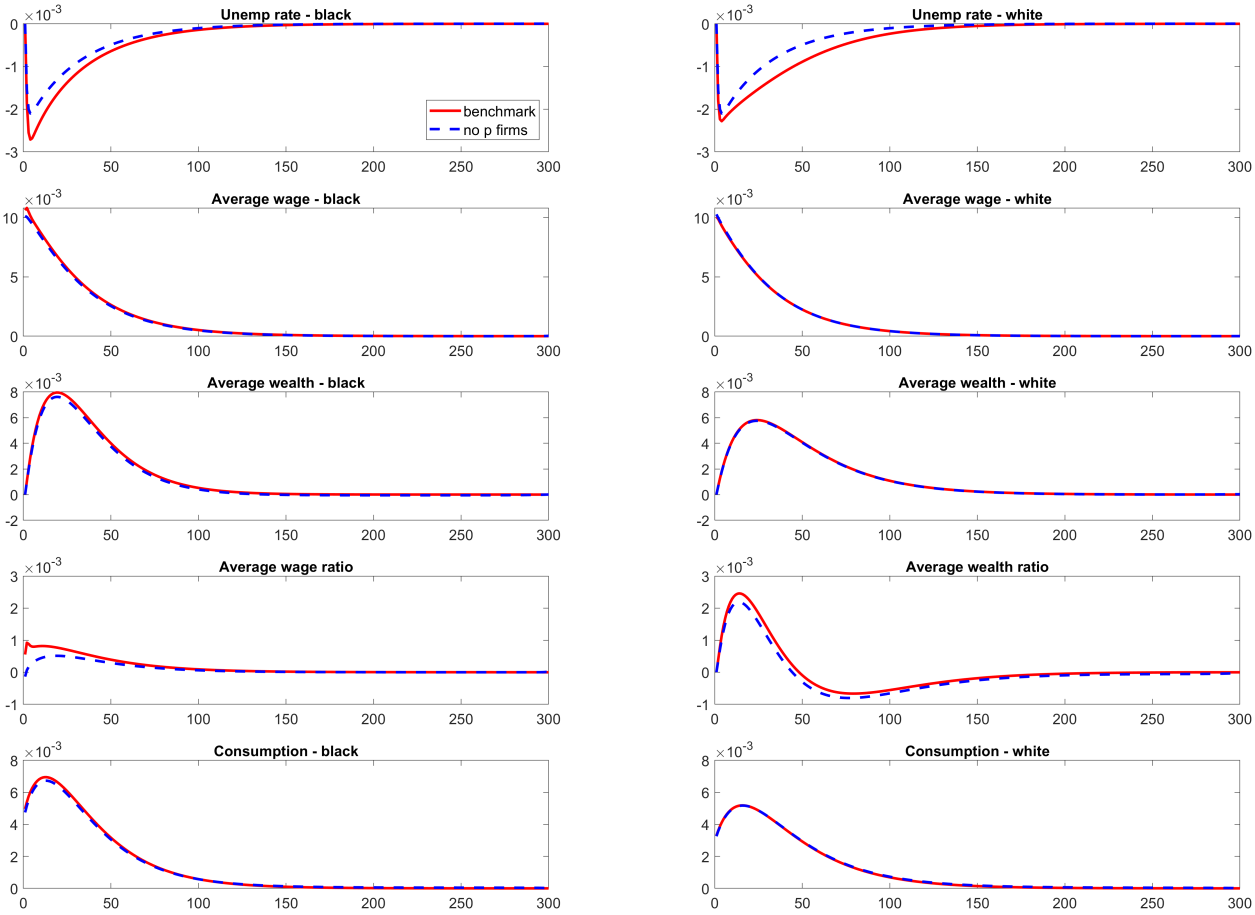


Figure 3: Impulse responses

Note: This figure plots the impulse response functions of unemployment rates, average wage, average wealth, black-white average wage and wealth ratios, and aggregate consumption between black and white workers to a one percent increase in aggregate TFP at date zero. The red solid line denotes the responses from the benchmark model, and the blue dashed line denotes the responses from the counterfactual model without p firms.

wage and wealth ratios are more procyclical in the benchmark model with discriminatory firms.

5.3 Racial disparities over business cycle

In this section, we present the empirical data moments on the racial disparities over the business cycle and contrast them to our model-generated moments in Table 5.[10] We measure the unemployment rate gap as the unemployment rate differentials from black workers to

[10]We present the detailed business cycle moments of each variable from our models in Table E.1.

white workers. The wage ratio is calculated as the average wage ratio of black and white workers. Our data show that the unemployment rate is mildly countercyclical, where it reduces in expansion andÂ increases in recession. On the other hand, the wage ratio is nearly cyclical. This is because our calculation does not account for composition changes during business cycles. Regarding relative volatility, the unemployment rate gap is about 6 times more volatile than the real GDP, while the wage ratio is similar to the real GDP.

Our model successfully recreates the countercyclical unemployment rate gap and procyclical wage ratio, although our produced wage ratio is much more procyclical than the data. Our model also reproduces a more volatile unemployment rate gap and wage ratio than real GDP. However, the unemployment rate gap volatility is much lower in our model than in the data. Nevertheless, the benchmark model contains the business cycle quality of racial gaps.

Table 5: Racial disparity over business cycle

	Cyclicality		Volatility	
	Data	Benchmark	Data	Benchmark
Unemp rate gap	-0.5038	-0.6814	5.6220	1.1977
Wage ratio	0.0136	0.9535	1.1403	1.0791

Note: This table compares the black-white unemployment and wage gaps over the business cycles. The unemployment rate gap is calculated as the quarterly unemployment rate of black workers minus that of white workers. The wage ratio is calculated as the average quarterly wage of black workers over that of white workers. Cyclicality is calculated as the correlation of the series to quarterly real GDP in the US. The volatility is the ratio of the standard deviation of the series to the standard deviation of quarterly real GDP. Data on quarterly real GDP comes from FRED from 1947 Q1 to 2006 Q4. Data on the unemployment rate comes from FRED. The unemployment rate for white workers ranges from 1954 Q1 to 2006 Q4, and for black workers ranges from 1971 Q1 to 2006 Q4. Wage rate information is taken from the average weekly labor earnings from the CPS outgoing rotation sample from 1982 Q1 to 2006 Q4. All variables are logged and HP filtered.

5.4 Impact of hiring discrimination over business cycle

We simulate both the benchmark and counterfactual models without p firms to generate business cycle moments for black and white workers. This allows us to examine the role of

discriminatory hiring in creating racial disparities over the business cycle. Table 6 presents the racial disparities in cyclicality and volatility for the unemployment rate, average wage, and wealth. We also include average consumption, as its fluctuations directly affect consumer welfare for risk-averse agents.

Table 6: Impact of hiring discrimination on business cycle racial gaps

	Cyclicality		Volatility	
	Benchmark	No p firms	Benchmark	No p firms
Unemp rate gap	-0.6814	-0.0393	1.1977	1.0000
Wage ratio	0.9535	0.0286	1.0791	1.0025
Consumption ratio	0.9739	0.9719	1.5096	1.4578
Wealth ratio	0.1513	0.1518	1.6647	1.6090

Note: This table compares the black-white unemployment rate, wage, consumption, and wealth gaps over the business cycles between the benchmark model and model without p firms. The unemployment rate gap is calculated as the quarterly unemployment rate of black workers minus that of white workers. The wage, consumption, and wealth ratio is calculated as the average quarterly series of black workers over that of white workers. Cyclicality is calculated as the correlation of the series to quarterly real GDP in the US. The volatility is the ratio of the standard deviation of the series to the standard deviation of quarterly real GDP. All variables are logged and HP filtered.

Our benchmark model generates countercyclicality of the racial gaps in unemployment, wage, consumption, and wealth, where the gaps widen during the recessions and narrow in the expansions, consistent with the empirical evidence documented by Cajner et al. (2017), Ganong et al. (2020), and Ragusett (2022). With the presence of p firms, we find that the unemployment rate gap is countercyclical, while the wage, consumption, and wealth ratios are procyclical. This reflects that black workers are relatively more affected during recessions compared to white workers, with a higher increase in their unemployment rate and a larger decline in their wages, consumption, and wealth. The counterfactual equilibrium with no p firms does not generate the empirically valid cyclicality of racial gaps along the unemployment rate and wages.

5.5 Welfare disparities in business cycles

We simulate the economy for 10,000 periods and compute the long-run average welfare for each individual type, following Cho and Ma (2023). The welfare measure is calculated as average consumption equivalence described in Section 4.3. We present the results in Table 7. Overall, the economy experiences an average of -0.0076% welfare change (not shown in the table) after removing prejudiced firms. This is much less than the welfare change in a steady state, primarily because white workers also experience a reduction in unemployment rate volatility as in Table E.1. Moreover, all individuals face a minor average welfare change compared to Table 4. Yet, black workers gain 0.02% average welfare compared to white workers losing 0.01%. High-productive black workers gain the most from removing p firms (0.023%), while high-productive white workers lose the most (-0.02%). Top 20% wealth black workers gain the most (0.03% on average), compared to top wealth white workers losing the most (-0.02%).

Table 7: Heterogeneous welfare change in business cycles

Average welfare gain (%)	Black	White
Average	0.018	-0.014
by productivity		
Low	0.004	-0.011
Mid	0.020	-0.014
High	0.023	-0.020
by wealth		
Low 20%	0.015	-0.007
40-60%	0.019	-0.016
Top 20%	0.026	-0.017

Note: This table compares the average consumption equivalence change from the benchmark model to the one without p firms in business cycles. We simulate the economy for 10,000 periods and calculate the long-run average welfare for each individual type. Low, mid, and high productivity corresponds to the lowest, middle, and highest value of idiosyncratic productivity s. The wealth quintiles are based on benchmark steady-state wealth distribution.

6 Conclusion

This study examines the effects of racial discrimination within a frictional labor market on employment, wage disparities, and wealth accumulation between black and white workers in the U.S. We develop a search-and-matching model incorporating firms with and without racial prejudices, alongside race-specific pathways for wealth accumulation. Our findings reveal that racial discrimination in hiring significantly exacerbates wage, unemployment, and wealth gaps in steady state and business cycles. Moreover, discriminatory practices disproportionately consign black workers to the lower end of the wealth spectrum. Contrary to conventional discrimination theories, our analysis suggests that discriminatory hiring practices persist as an equilibrium outcome within frictional markets. Eliminating these discriminatory factors paradoxically results in a decrease in overall welfare, as prejudiced firms inadvertently bolster leverage for white workers and contribute additional economic output, albeit at the expense of black workers. Importantly, our study identifies a pronounced spillover effect of labor market discrimination on wealth accumulation, with a notable, albeit weaker, influence of wealth disparities on negotiated wages. Our findings shed light on the enduring nature of Black-White racial disparities in the U.S., offering insights into the complex interplay between discrimination, labor market dynamics, and wealth accumulation.

Appendix A Defining equilibrium

Appendix B Comparing aggregate implications of bargaining power and extreme wealth shock

Table B.1 compares the benchmark model to models that remove non-market disparities, particularly in equalizing racial bargaining power and extreme wealth shocks. Overall, removing non-market disparities raises black workers' welfare and aggregate outputs. Equalizing black workers' bargaining power to white workers directly raises their bargained wage outcomes. However, non-prejudiced firms retain less profit, hence posting fewer vacancies. On the net, it only has a modicum impact on black workers' welfare. The reduction of non-prejudiced sector vacancy posting spills over to welfare reduction for white workers.

To equalize racial wealth shocks, we assign black workers the same conditions in accumulating wealth as white workers. The effect resembles assigning a higher bargaining power to black workers. This is because of the importance of wealth in self-insuring against uncertain negative outcomes (Nakajima, 2012). Higher personal wealth gives black workers higher reservation value when bargaining with firms. Effectively, black workers can bargain for higher wage outcomes. Similar to assigning a higher bargaining power directly, the more favorable wealth accumulation of black workers also spills over to the firm's unwillingness to post for more vacancies. Indirectly, it reduces white worker's job outcomes and welfare.

Appendix C Comparing welfare change to imposing a high penalty on p firms

Table C.1 presents the welfare change from the benchmark model with a counterfactual of imposing high vacancy posting cost. The result is quantitatively similar to the one removing p sector completely in Table 4.

Table B.1: Aggregate impact of racial disparities from non-market factors

Moments	Benchmark	$\xi_{bl} = \xi_{wh}$	$\epsilon_{bl} = \epsilon_{wh}$
Labor Market			
np market tightness	0.73	0.69	0.78
p market tightness	0.40	0.27	0.26
job finding rate (Black)	0.50	0.46	0.48
job finding rate (White)	0.66	0.64	0.65
unemp rate (Black)	0.12	0.12	0.12
unemp rate (White)	0.05	0.05	0.05
Income			
mean wage ratio	0.75	0.82	0.78
average wage	2.04	2.05	2.06
Wealth			
mean wealth ratio	0.28	0.21	0.76
median wealth ratio	0.33	0.27	0.82
share of zero wealth (Black)	0.18	0.18	0.06
share of zero wealth (White)	0.06	0.06	0.06
Aggregate Outcomes			
Y	3.06	3.05	3.08
K/Y	10.26	10.25	10.45
unemp rate (%)	0.07	6.78	6.64
Average welfare gain (%)			
Average		0.66	1.10
black		6.27	8.69
white		-0.66	-0.69

Note: This table compares the benchmark steady state to the model with equal bargaining power $\xi_{bl} = \xi_{wh}$ and a model with equal extreme wealth shock $\epsilon_{bl} = \epsilon_{wh}$.

Table C.1: Heterogeneous welfare change to imposing a high penalty on p firms

Average welfare gain (%)	Black	White
Average	6.93	-8.60
by productivity		
Low	6.34	-8.78
Mid	6.96	-8.61
High	7.45	-8.38
by wealth		
Low 20%	6.89	-9.15
40-60%	6.99	-8.74
Top 20%	6.92	-7.95

Note: This table compares the average consumption equivalence change from the benchmark steady state to the high κ_p equilibrium where p firms have exited the market. κ_p is recalibrated from the benchmark value of 4.26 to 9.24 in the high κ_p equilibrium. Low, mid, and high productivity corresponds to the lowest, middle, and highest value of idiosyncratic productivity s. The wealth quintiles are based on benchmark steady-state wealth distribution.

Appendix D Comparing impulse responses in recession and expansion

Figure D.1 presents the impulse responses functions to a 1% positive and negative TFP shock at date 0. The shock gradually returns to a steady state with a persistence of 0.95. Our model produces symmetric impulse responses across all variables.

Appendix E Business cycle moments

Table E.1 present business cycle moments for all variables of interest between the benchmark model and the model without p firms. Our model suffers from the Shimer Puzzle, generating highly volatile market tightness, wage rates, and low volatile unemployment rates (Shimer, 2005). However, our model focuses on describing the racial gaps between black and white workers, as in Section 5.3. We consider the relevant moments to be a success of our model.

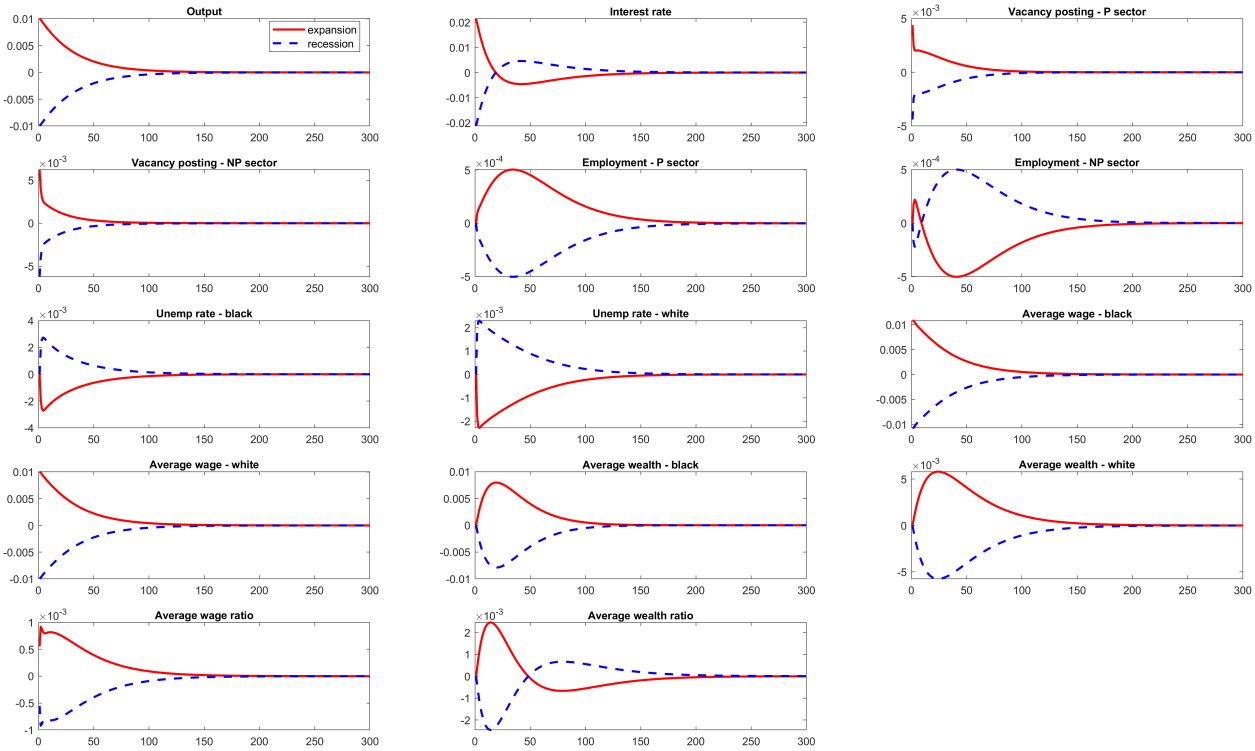


Figure D.1: Comparing impulse responses

Note: This figure plots the impulse response functions of the benchmark economy to a one percent increase and a one percent decrease in aggregate TFP at date zero. The red solid line denotes the responses to the expansionary shock, and the blue dashed line denotes the responses to the recessionary shock.

Table E.1: Business cycle moments

	Cyclicality		Volatility	
	Benchmark	No p firms	Benchmark	No p firms
		Labor Market		
p market tightness	0.9960	-	0.4317	-
np market tightness	0.9945	0.9991	0.5851	0.5116
		Households		
Unemp rate (Black)	-0.6935	-0.7046	0.2575	0.2008
Unemp rate (White)	-0.7071	-0.7046	0.2150	0.2008
Average wage (Black)	0.9996	0.9994	1.0779	1.0144
Average wage (White)	0.9999	0.9999	0.9989	1.0119
Average wealth (Black)	0.0760	0.0720	0.3714	0.3543
Average wealth (White)	0.0285	0.0253	0.2231	0.2202
Consumption (Black)	0.9475	0.9451	0.5412	0.5165
Consumption (White)	0.9294	0.9286	0.3585	0.3543

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