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Sectoral Shocks, Reallocation, and Labor Market Policies

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Abstract

Unemployment insurance and wage subsidies are key tools to support labor markets in recessions. We develop a multi-sector search and matching model with on-the-job human capital accumulation to study labor market policy responses to sector-specific shocks. Our calibration accounts for structural differences in labor markets between the United States and the euro area, including a lower job-finding rate in the latter. We use the model to evaluate unemployment insurance and wage subsidy policies in recessions of different duration. After a temporary sector-specific shock, unemployment insurance improves reallocation toward productive sectors at the cost of initially higher unemployment and, thus, human capital destruction. By contrast, wage subsidies reduce unemployment and preserve human capital at the cost of limiting reallocation. In the United States, unemployment insurance is preferred to wage subsidies when it does not distort job creation for too long. In the euro area, wage subsidies are preferred, given the lower job-finding rate and reallocation.

Keywords: Labor Market Policies, Search and Matching Frictions, Reallocation.

JEL Classification: E24, J64, J68.

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1 Introduction

Recent recessions—including the 2009 Global Financial Crisis (GFC) and the more recent COVID-19 pandemic—had heterogeneous effects across sectors. Interestingly, policy responses to these recessions varied across countries. While the United States largely supported unemployed workers by extending unemployment insurance (UI), several European countries expanded short-time work subsidies (WS) to prevent rapid job destruction in affected sectors (Giupponi, Landais and Lapeyre, 2021). The issue of how to best support labor markets received substantial attention in the policy debate, especially in the outburst of the COVID-19 pandemic.[1]

These different approaches to fighting recessions raise natural questions: Which labor market policy, UI or WS, is preferable during recessions, and why did different countries opt for different policies? While both policies support workers during recessions, they also have costs. On the one hand, generous unemployment benefits can deter employment, thus generating human capital losses from permanent separations—estimated to be significant and persistent, especially during recessions (Davis and von Watcher, 2011). On the other hand, subsidizing declining sectors might prevent an efficient sectoral reallocation of workers, thus weighing on aggregate productivity (Restuccia and Rogerson, 2008). Intuitively, the tradeoff of these costs crucially depends on how quickly workers can reallocate across sectors and how persistent the recession is expected to be.

In this paper, we develop a multi-sector search and matching model to study labor market policy responses to sector-specific shocks. We focus on UI and WS policies, the two labor market policies most commonly used in recent years. The model incorporates key features to address the policy tradeoffs just discussed. We argue that labor market flexibility, measured by labor market flows, is crucial in determining which policy is preferred.

Our model extends an off-the-shelf search and matching model in a few dimensions. We assume that workers accumulate job-specific human capital when employed, which is lost upon permanent separation. Firms and workers can endogenously decide to terminate a match, and thus a match duration responds to UI and WS policies. Similarly, workers can only sluggishly reallocate across

[1] See for instance the work of Bluedorn, Caselli, Chen, Hansen, Mondragon, Shibata and Tavares (2021) for the IMF April 2021 World Economic Outlook, the OECD (2020) Employment Report, or the Federal Reserve June 2020 Monetary Policy Report, https://www.federalreserve.gov/monetarypolicy/2020-06-mpr-part1.htm.).

sectors, making the persistence of the recession key for reallocation gains. Additionally, we assume wage rigidity, which yields inefficient separations and, thus, possible welfare gains from labor market policies. Finally, we add temporary lay-offs and recall, a ubiquitous feature in the U.S. labor market (Fujita and Moscarini, 2017).

We use key labor market statistics to calibrate two versions of the model: one matched to the U.S. economy and a second one matched to the euro-area economy. We label the U.S. calibration as a *flexible* economy, as it features high job-finding rates, and the euro-area calibration as a *rigid* economy, as it exhibits lower job-finding rates. We show that both calibrations deliver a good fit for each respective economy and are consistent with the key empirical evidence we present in this paper. In particular, we document that sectoral labor reallocation, measured as proposed by Chodorow-Reich and Wieland (2020), is higher in the United States during recessions compared to the euro area.

We use the model to evaluate UI and WS policies in a short-lived recession induced by a sector-specific shock. In particular, we aim to recreate the initial shock to the services sector during the first half of 2020, when public health restrictions led to a rapid closure of high-contact services.

Our main finding is that, in response to a short-lived sectoral shock, the UI policy is preferable in the flexible economy, while the WS policy is preferable in the rigid economy. In the flexible economy, the UI policy generates a larger initial economic contraction but also a faster recovery. With higher job-finding rates, the UI policy promotes necessary labor reallocation to unaffected sectors, thus achieving a faster recovery. In contrast, with lower job-finding rates, as in the rigid economy, the UI policy does not generate such a fast recovery, making the WS policy more appealing. The WS policy provides a continuous support for firms' profits which proves beneficial also to workers. We compute the welfare gains of each policy, measured as the present discounted value of workers' consumption and firms' profits, net of the policy cost. Our welfare analysis shows that UI benefits consumers at the expense of firms, while WS improve the welfare of firms and, to some extent, that of consumers. In the United States, UI is preferable as consumers' gains more than offset firms' losses. In the euro area, firms' losses from UI deteriorate welfare, making WS preferred. Thus, our results rationalize the difference in policies usually implemented in the United States versus the euro area.

Finally, we show that while some UI policies may boost labor reallocation, they may also have the opposite effect if the UI increase is too generous. Generous benefits lead to increased wages and, thus, lower profits for firms, which may reduce vacancy postings and job creation. This distortion is particularly strong in persistent recessions, as firms are less willing to pay higher wages for an extended period. We argue that front-loading UI may ameliorate this distortion.

Related Literature Our analysis is related to several strands of the literature that study the macroeconomic effects of labor market policies.

Regarding modeling strategy, we follow standard search and matching models of the labor market in the spirit of Shimer (2005). In addition, we introduce recall and temporary lay-offs as in Fujita and Moscarini (2017), allowing firms to recall furloughed workers. We depart from these models by introducing an important inefficiency in terms of wage rigidities, in line with evidence from Gertler, Huckfeldt and Trigari (2020). Finally, we introduce different economic sectors that lead to labor market segmentation. This assumption results in different sectoral job-finding rates that depend on sector-specific productivity and will prove to be key in understanding the effect of labor market policies on labor reallocation in response to sectoral shocks. While several papers in the literature have used multi-sector search models (see, for instance, Chodorow-Reich and Wieland (2020) and Visschers and Carrillo-Tudela (2021)) to study the role of sectoral shocks in driving aggregate fluctuations, this paper aims to study the effectiveness of labor market policies in the presence of sectoral shocks.

Our paper directly speaks to the literature that analyzes the role of labor market policies over the business cycle (see, for example, Gnocchi, Lagerborg and Pappa (2015) and Mitman and Rabinovich (2015)). For instance, Cacciatore and Fiori (2016) and Cacciatore, Duval, Fiori and Ghironi (2016) discuss the effects of labor market regulations in the short run, such as reducing firing costs and unemployment benefits. Our analysis provides a framework to study various policies not only at the aggregate level but also by sector. It is important to mention two recent papers that discuss the implications of labor market policies during the recent COVID-19 recession. Gertler, Huckfeldt and Trigari (2021) consider the effect of the Paycheck Protection Program in the U.S. labor market during the COVID-19 recession and find that this program facilitated hiring and worker recall. Birinci, Karahan, Mercan and See (2021) derives the optimal labor market policy mix in response to the COVID-19 shock and find that a joint intervention of UI and payroll subsidies is optimal. Nevertheless, neither of these papers considers the tradeoff generated by these policies in facilitating labor reallocation across industries at the cost of destroying match-specific productivity, which we model explicitly and show its importance in the aftermath of a sectoral shock.

Empirically, there have been many studies that separately analyzed WS and UI policies. Studies on WS predominantly use European data during the 2009 financial crisis. Using Italian data, Giupponi and Landais (2018) find that when the shock is persistent, adverse selection of low productivity firms prevents labor reallocation. In a related manner, using French data Cahuc, Kramarz and Nevoux (2018) show that WS policies successfully supported employment in firms that faced strong but temporary adverse revenue shocks. Cooper, Meyer and Schott (2017) also find positive effects in supporting employment, but at the cost of allocative efficiency using German data. Finally, Balleer, Gehrke, Lechthaler and Merkl (2016) argue that WS policies successfully support employment provided they are part of the automatic stabilizer toolkit. A more recent paper by Gehrke and Hochmuth (2021) studies the non-linear effects of WS over the business cycle, finding that these policies are not as effective outside of recessions. Concerning UI, an extensive literature has tried to quantify its effects on unemployment and workers' incentives to take jobs, finding in many cases that extending UI can lead to longer unemployment episodes (see, for instance, Nakajima (2012) and Pei and Xie (2021)). Relative to UI design, Mitman and Rabinovich (2015) study the optimal level and duration of UI during recessions of different persistence. In a COVID-19 application, Mitman and Rabinovich (2021) assess the U.S. policy, finding that a large, transitory, and front-loaded policy, similar to the one implemented in early 2020, is optimal. Finally, Ganong, Greig, Liebeskind, Noel, Sullivan and Vavra (2021) study the 2020 expansion of UI, finding that larger benefits did not lead to a substantial decrease in employment.

In this paper, we take stock of both the empirical and theoretical literature to provide a structural analysis of labor market policies focusing on the selection and reallocation effects and the importance of recessions' persistence in evaluating the policy response.

Section 2 documents empirical evidence on sectoral labor reallocation across countries, section 3 presents the structural model, and section 4 provides the calibration for the flexible and rigid economies. Section 5 describes the simulation of a short-lived recession for the flexible and rigid economies and the model predictions on reallocation and welfare under WS and UI for these economies. Section 7 discusses the role of recession persistence and policy design in our findings. Section 8 concludes.

2 Sectoral Reallocation: Cross-Country Evidence

In this section, we empirically document how labor reallocation behaves over the business cycle and how it relates to unemployment and productivity changes. We present our results for both the euro area and the United States.

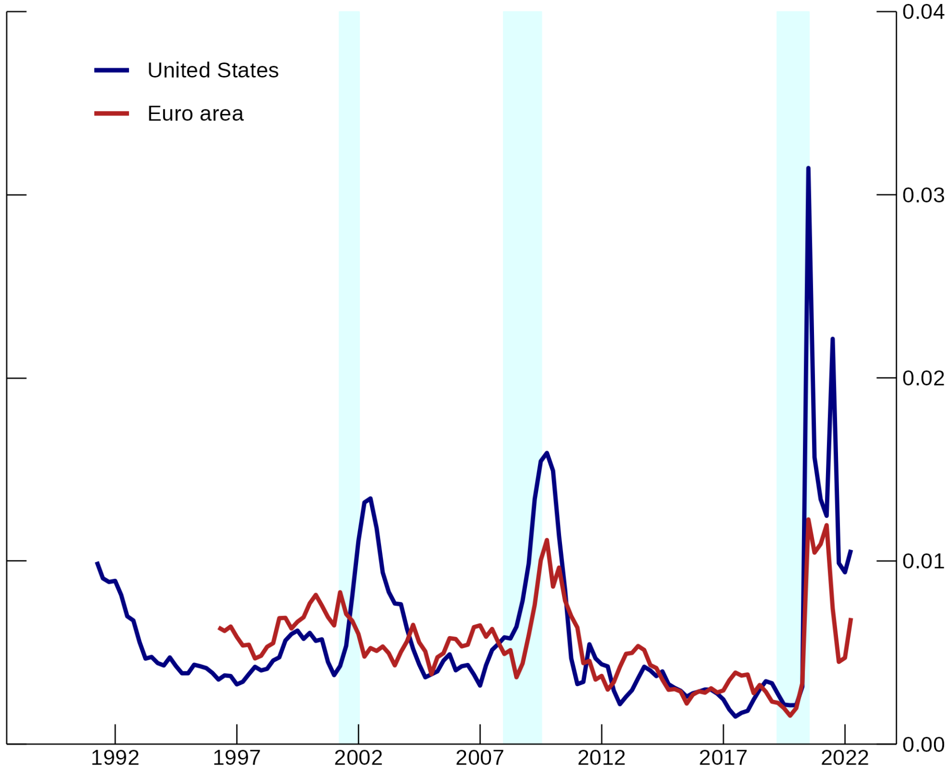
We analyze labor reallocation, relying on the reallocation index proposed by Chodorow-Reich and Wieland (2020) (hereafter, CRW index) based on employment growth dispersion across industries. In particular, reallocation across a number I of industries between t and $t+j$ is given by

$$R_{t,t+j} = \frac{1}{2}\sum_{i}^{I} s_{i,t}\left|\frac{1+g_{i,t,t+j}}{1+g_{t,t+j}} - 1\right|. \tag{1}$$

In equation (1), g and g_i represent the aggregate and sectoral growth rates of employment e and e_i, respectively, and $s_i = \frac{e_i}{e}$ is the share of employment in sector i relative to the aggregate.[2] The index can take values between 0 and 1. $R_{t,t+j} = 0$ implies that the employment growth rate in every industry between t and $t+j$ is identical. The index takes the value $R_{t,t+j} = 1$ when all employment in existing industries at t disappears by $t+j$, and new industries with zero employment at t account for all the employment in $t+j$. We compute the index using aggregate data from 10 industries, following the Standard Industrial Classification (SIC), and homogenizing industries across the United States and the euro area. Data from the United States come from the Bureau of Labor Statistics and for the euro area from Eurostat. We compute year-over-year employment

[2] As argued in Visschers and Carrillo-Tudela (2021), the pre-multiplication of the index by 0.5 aims to avoid double counting from net inflows into some industries that are net outflows from other industries.

Figure 1 Chodorow-Reich and Wieland's Reallocation Index



Note: The reallocation index is calculated using year-over-year growth rates of employment from SIC industry classification. The shading indicates recessions as determined by the NBER. Source: NBER, Statistical Office of European Communities, and Bureau of Labor Statistics via Haver Analytics.

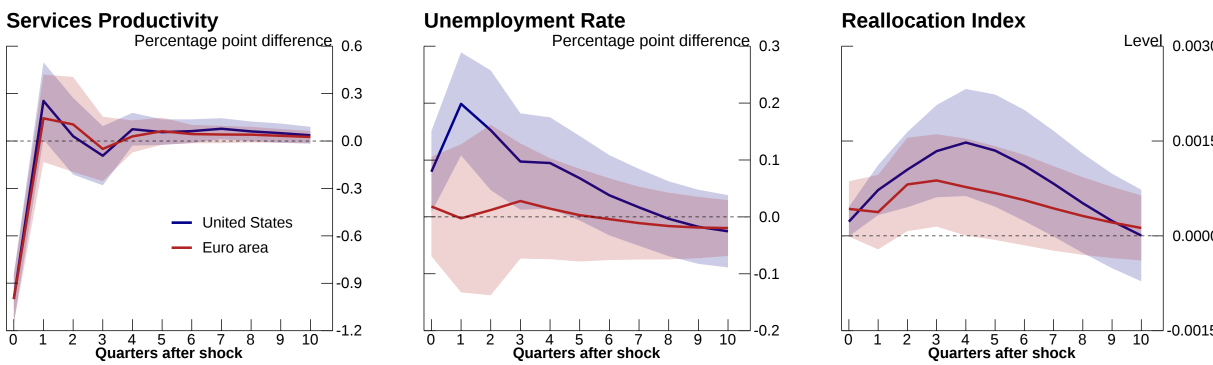
growth rates.[3]

Figure 1 compares reallocation indexes in the United States and the euro area. While both economies present low industry reallocation during expansions, reallocation increases during a recession. The reallocation increase is more significant in the United States, relative to the euro area, and particularly sharp in the COVID-19 recession when unemployment reached historically high peaks in the United States. Thus, the reallocation data suggest that the U.S. labor market appears more dynamic than its euro-area counterpart.

[3]We exclude employment in agriculture from these calculations. We have performed robustness in calculating this index. In particular, we have used the NAICS 19-industry classification instead of the SIC's 10-industry classification. As expected, the reallocation index implied by a higher disaggregation is slightly larger but comes at the cost of a shorter time span. We also calculated the index with quarterly growth rates instead of yearly, leading to similar, although slightly noisier, results. These findings can be found in Appendix A.1.

We confirm these findings when estimating a structural vector autoregression (SVAR) model, which provides a more systematic analysis of the relation between labor reallocation, sectoral productivity, and unemployment. We use manufacturing productivity, services productivity, unemployment, and reallocation, as variables in an SVAR model which we estimate separately for the United States and the euro area. We identify manufacturing and service productivity shocks by ordering them first, followed by unemployment and reallocation. Additionally, we set zero restrictions on the impact response of one sector's productivity to an exogenous change in another sector's productivity. The data are quarterly and are between 2005:Q1 and 2019:Q4 for both the United States and the euro area.[4] We are interested in the average responses of unemployment and reallocation to exogenous changes in manufacturing and services productivity.[5] The results are presented in Figure 2 and Figure 3.

Figure 2 Impulse Responses to a 1 Percentage Point Shock to Services Productivity



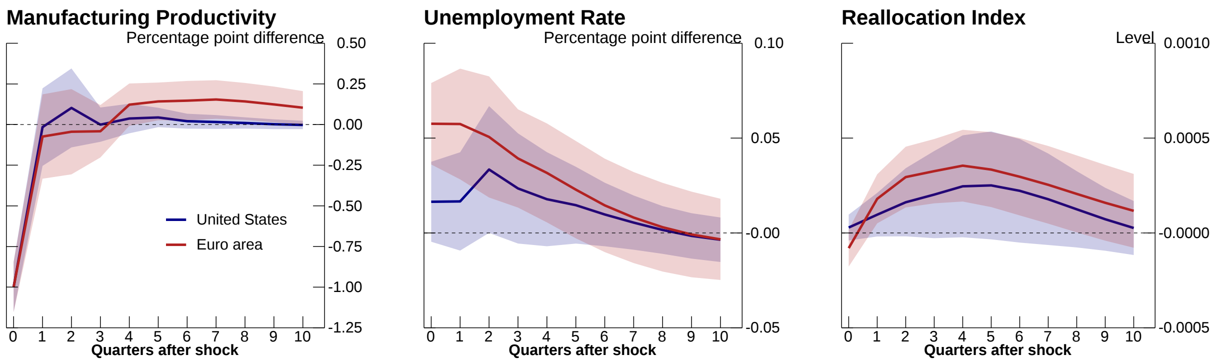
Note: Shading represents the 90% confidence interval. Productivity is defined as output per employee, and reallocation is constructed following Chodorow-Reich and Wieland's (2020) methodology. It is calculated using SIC industry classification with year-over-year changes.

A negative shock to either sectoral productivity results in a persistent increase of unemployment accompanied by higher reallocation. Response of reallocation is hump-shaped as it takes a couple of quarters to reach its peak level (consistent with its behavior during past recessions as evidenced in Figure 1). The response of reallocation is much larger for services productivity shock, which is

[4]Due to the size of the shock and large swings in the measurement of the data, we exclude COVID-19 pandemic period from our sample. See Appendix A.1 for more details on data sources and computations.

[5]In the Appendix A.2, we also show impulse responses of sectoral productivities and reallocation to an exogenous shock to unemployment. Similarly to services productivity shock, we find that reallocation in the United States increases much more than in the euro area.

Figure 3 Impulse Responses to a 1 Percentage Point Shock to Manufacturing Productivity



Note: Shading represents the 90% confidence interval. Productivity is defined as output per employee and reallocation is constructed following Chodorow-Reich and Wieland's (2020) methodology. It is calculated using SIC industry classification with year over year changes.

in line with the services sector being approximately twice the size of the manufacturing sector in both regions.

We find that a negative shock to services productivity leads to a stronger response of both unemployment and reallocation in the United States than in the euro area. In the case of shocks to manufacturing productivity, we see a stronger response in unemployment and reallocation in the euro area. Yet, this difference is not statistically significant due to a high level of uncertainty surrounding mainly estimates for the United States.[6]

Our empirical results, thus, provide supportive evidence of a stronger reallocation and unemployment response in the United States than in the euro area after a service productivity shock, very much in line with the realization during the COVID-19 pandemic. These differences between the United States and the euro area could be due to different labor institutions or labor market policies. UI policies, typically implemented in the United States, tend to boost unemployment and reallocation more than the WS policies, usually preferred in the euro area. In order to understand the exact role of both institutions and policies, we develop a structural model in the next section. Our goal is to assess the effectiveness of the WS and UI policies in response to sector-specific shocks and quantify the winners and losers from the two policy choices in labor markets with different institutions.

[6]Uncertainty surrounding our estimates is mainly due to the short sample used given limited data availability.

3 Model

This section presents a multi-sector search and matching model of the labor market. We assume workers accumulate job-specific human capital while employed, and they can decide whether to leave or stay with the match at any time. Firms can also decide whether to temporarily or permanently separate from workers. Job-specific human capital is preserved when firms recall workers from temporary lay-off but lost when the separation is permanent. Workers can move across sectors, but reallocation is sluggish due to matching frictions and because searching in a different sector only occurs with a certain probability. Finally, matches are subject to wage rigidity, and thus productivity changes do not immediately pass through to wages. We provide a more detailed description in the following subsections.

3.1 Environment

Time is discrete, infinite, and indexed by $t = 1, 2, \ldots$. The economy is populated by a continuum of workers and firms. Firms post vacancies in order to find workers. The cost of a vacancy is κ, and the probability of contacting a worker is q_t. Firms belong to a sector indexed by s, and we assume there are two sectors in the economy: $s = 1, 2$. Upon forming a match, the firm and the worker draw match-specific productivity z_0 distributed according to $G(z_0)$. We consider deterministic transition dynamics where agents have perfect foresight, and we use time t to denote the aggregate state of the economy.

A match can be either active or idle. We refer to a worker in an idle match as in temporary unemployment or furlough. The match-specific productivity evolves stochastically following a Markov chain: $z' \sim P^a(z'|z)$ for active matches and $z' \sim P^i(z'|z)$ for idle matches. Under both processes $P^a(z'|z)$ and $P^i(z'|z)$, the productivity of $z = 0$ is an absorbing state—akin to an exogenous separation. When the match dissolves permanently, either exogenously or endogenously, z is lost. The output of an active firm produces a match at is given as $y_t(s, z) = x_t(s)z$, where $x_t(s)$ is the sector-specific productivity.

Active matches re-set wages subject to a Calvo-style friction. New matches have flexible wages given initial productivity z_0 and sectoral productivity $x(s)$. After observing the realized match and sectoral productivity, z and x; a match re-sets wages with probability λ. After the wage-setting stage, the worker decides whether to stay in the match or quit. If the worker decides to stay, the firm has the next move and has three options: to be active, to be idle, or to terminate the match. If the match is active, the output is produced, the worker gets wage w, and the operating cost c_o must be paid. If the match is idle, the worker goes into temporary unemployment, no wages are paid, and the firm faces a cost c_i of keeping the idle match. At any point, a furloughed worker can be either recalled or terminated at no cost to the firm. If the match is terminated, the firm ceases to exist.

Unemployed workers can be either on furlough or unmatched. They are attached to the last sector where they worked, s, and search for a job in sector $\tilde{s}$ with probability $\pi_u(s, \tilde{s}) \leq \pi_u(s, s)$—which may differ across furloughed and unmatched workers, $u = U, F$. The probability that a worker contacts a firm is sector-specific and given by $f_t(s)$. There is no cost of searching while unemployed, and job offers can be rejected. Unemployed workers receive benefits b_t that do not expire.

The timing of events is as follows: (1) productivity shocks are realized, (2) unemployed and furloughed workers search for jobs and matching occurs, (3) wage renegotiation occurs with probability λ, (4) employed and furloughed workers decide whether to stay in the match or quit, (5) remaining matches decide whether to be active, idle, or exit, and (6) production and consumption takes place. All of the value functions below are written at point (6).

3.2 Search and Matching Technologies

Firms direct vacancies toward each sector s—that is, markets are segmented. Let v be the number of vacancies posted in sector s, and n the number of workers searching for a job in that sector—including unmatched and furloughed workers. The total number of matches is then given by the constant-return-to-scale matching function with matching efficiency ϕ (as in den Haan, Ramey and Watson, 2000):

$$m = \frac{\phi n v}{[n^\eta + v^\eta]^{\frac{1}{\eta}}}. \tag{2}$$

The worker's job-contact probability f and the firm's worker-contact rate q are given by

$$f(s) = \frac{m}{n} \qquad q(s) = \frac{m}{v}. \tag{3}$$

Market tightness $\theta(s)$ is defined as the ratio of vacancies to searchers: $\theta(s) = v/n$.

3.3 Firms

Let $J_t(z, w, s)$ be the maximal attainable value for a firm in an active match with productivity z, wages w, and sector s, at time t. Analogously define $V_t(z, w, s)$ as the value for a firm in an idle match. The value for an active firm is

$$J_t(z, w, s) = \Pi + \beta \mathbb{E}_t \left[\left(1 - \eta^a_{t+1}(z', w', s)\right) \max \left\{ J_{t+1}(z', w', s), V_{t+1}(z', w', s), 0 \right\} | z \right] \tag{4}$$

$$\Pi = y_t(z, s) - (1 - \sigma_t)w - c_o$$

$$w' = \begin{cases} w & \text{w.p. } \lambda \\ w^*_{t+1}(z', s) & \text{w.p. } 1 - \lambda \end{cases} \tag{5}$$

where $\eta^a_t(\cdot)$ is the quitting decision of a worker in an active match. The firm's profits, Π, are given by output net of wages and operating costs, including the subsidy to the wage bill σ_t. The continuation value in (4) shows an active firm's three options each period: continue the match, set the match to be idle, or terminate the match. The next-period wage w' adjusts with probability $1 - \lambda$, given by the rule $w^*_t(\cdot)$, which we discuss in more detail below.

The value for a firm in an idle match is

$$V_t(z, w, s) = -c_i + \beta \mathbb{E}_t \left[\left(1 - f^i_{t+1}(z', w, s)\right) \left(1 - \eta^i_{t+1}(z', w, s)\right) \max \left\{ J_{t+1}(z', w, s), V_{t+1}(z', w, s), 0 \right\} | z \right] \tag{6}$$

where $\eta^i_t(\cdot)$ is the quitting decision of a worker in an idle match, and $f^i_t(\cdot)$ is the probability that an idle/furloughed worker will find and accept another job—which we derive later with the workers' problem. Note that the continuation value for an idle firm in equation (6) is the same as for an active firm, although the stochastic process for z may be different.

Let $e_t^a(z,w,s)$ be the decision of a firm to exit an active match, and $d_t(z,w,s)$ the decision to set a match to be idle. Similarly, let $e_t^i(z,w,s)$ be the decision to exit an idle match and $r_t(z,w,s)$ the decision to recall an idle worker. These decisions are given as

$$e_t^a(z,w,s) = \begin{cases} 0 & \text{if } \max\{J_t(z,w,s), V_t(z,w,s)\} \geq 0 \\ 1 & \text{otherwise} \end{cases} \tag{7}$$

$$d_t(z,w,s) = \begin{cases} 0 & \text{if } J_t(z,w,s) \geq V_t(z,w,s) \\ 1 & \text{otherwise} \end{cases} \tag{8}$$

$$e_t^i(z,w,s) = e_t^a(z,w,s) \tag{9}$$

$$r_t(z,w,s) = 1 - d_t(z,w,s). \tag{10}$$

That is, a firm terminates the match if the values of being active or idle are both below zero, and the firm turns a match idle when the value is larger than being active.

3.4 Workers

Let $W_t(z,w,s)$ be the maximal attainable value for a worker in an active match with productivity z, wage w, and sector s, at time t. Analogously define $F_t(z,w,s)$ as the value of a worker in an idle match. Let $U_t(s)$ be the value of being unemployed when attached to sector s. The value of being in an active match is given as

$$W_t(z,w,s) = w + \beta \mathbb{E}_t \left[\max \left\{ \hat{W}_{t+1}(z',w',s), U_{t+1}(s) \right\} |z \right] \tag{11}$$

where next-period wages, w', are given as in equation (5). The continuation value in equation (11) is the maximum between quitting (being unemployed) or staying in the match. The value of staying in the match, $\hat{W}_t(z,w,s)$, is given as

$$\begin{aligned} \hat{W}_t(z,w,s) = & (1 - e_t^a(z,w,s)) \{(1 - d_t(z,w,s)) W_t(z,w,s) + d_t(z,w,s) F_t(z,w,s)\} \\ & + e_t^a(z,w,s) U_t(z,w,s). \end{aligned} \tag{12}$$

Thus, the value of staying in a match accounts for the exit and idle decisions, $e_t^a(\cdot)$ and $d_t(\cdot)$, which the firm will make after the workers' decisions.

While idle, a furloughed worker receives unemployment benefit b and searches for jobs at intensity $\zeta < 1$. The probability of finding a job in sector $\tilde{s}$ is the compound of the job-finding probability $f_t(\tilde{s})$ times the probability of switching sectors $\pi_F(s, \tilde{s})$. Upon receiving and accepting an offer, the worker starts with initial productivity z_0 and wages w_0. When recalled, the worker returns to the same wage w they had before. Thus, the value $F_t(z, w, s)$ of being in an idle match is given as

$$\begin{aligned} F_t(z,w,s) = b_t + \beta \mathbb{E}_t \Bigg[\sum_{\tilde{s}} \pi_F(s,\tilde{s}) \Bigg(& (1 - \zeta f_{t+1}(\tilde{s})) \max \left\{ U_{t+1}(s), \hat{F}_{t+1}(z', w, s) \right\} \\ & + \zeta f_{t+1}(\tilde{s}) \int \max \left\{ W_{t+1}(z_0, w_{0t}^*, \tilde{s}), \max\{\hat{F}_{t+1}(z', w, s), U_{t+1}(s)\} \right\} dG(z_0, \tilde{s}) \Bigg) | z \Bigg] \end{aligned} \tag{13}$$

where $w_{0t}^* = w_t^*(z_0, s)$ is the initial wage of a newly formed match, and $\hat{F}_t(z, w, s)$ is the value of staying in the idle match as

$$\begin{aligned} \hat{F}_t(z,w,s) = & (1 - e_t^i(z,w,s)) \left[r_t(z,w,s) W_t(z,w,s) + (1 - r_t(z,w,s)) F_t(z,w,s) \right] \\ & + e_t^i(z,w,s) U_t(s) \end{aligned} \tag{14}$$

which incorporates the exit and recall decisions, $e_t^i(\cdot)$ and $r_t(\cdot)$, taken by the firm later in the period.

We can now compute $f_t^i(\cdot)$, the probability that a furloughed worker will find and accept a job offer, which we use in equation (6) to define the value of a firm in an idle match. In particular, the probability $f_t^i(\cdot)$ is given as

$$f_t^i(z,w,s) = \sum_{\tilde{s}} \pi_F(s,\tilde{s}) \zeta f_t(\tilde{s}) \int \mathbb{I} \left\{ W_t(z_0, w_{0t}^*, \tilde{s}) > \max\{\hat{F}_t(z', w, s), U_t(s)\} \right\} dG(z_0, \tilde{s}) \tag{15}$$

where $\mathbb{I}\{\cdot\}$ is an indicator function. Thus, $f_t^i(\cdot)$ compounds the probability that a worker searches in sector $\tilde{s}$ and receives an offer better than staying furloughed.

Finally, the value of being unemployed for a worker attached to sector s is given as

$$U_t(s) = b_t + \beta \sum_{\tilde{s}} \pi_U(s, \tilde{s}) \bigg(f_{t+1}(\tilde{s}) \int \max \left\{ W_{t+1}(z_0, w^*_{0t}, \tilde{s}), U_{t+1}(s) \right\} dG(z_0, \tilde{s}) \qquad (16)$$
$$+ (1 - f_{t+1}(\tilde{s})) U_{t+1}(s) \bigg).$$

The quit decisions for workers in an active and idle match, $\eta^a_t(\cdot)$ and $\eta^i_t(\cdot)$, are given as

$$\eta^a_t(z, w, s) = \begin{cases} 0 & \text{if } \hat{W}_t(z, w, s) \geq U_t(s) \\ 1 & \text{otherwise} \end{cases} \qquad (17)$$

$$\eta^i_t(z, w, s) = \begin{cases} 0 & \text{if } \hat{F}_t(z, w, s) \geq U_t(s) \\ 1 & \text{otherwise.} \end{cases} \qquad (18)$$

Note that the quit decisions of the worker use the value $\hat{W}_t(\cdot)$ and $\hat{F}_t(\cdot)$(instead of $W_t(\cdot)$ and $F_t(\cdot)$) as to take into account the separation/furloughed decisions the firm makes later in the period.

3.5 Wage Setting

Wages are set following a simple rule that splits the (discounted) per-period flows of profits and unemployment benefits. In particular, the re-set wage $w^*_t(z, s)$ function is given as

$$w^*_t(z, s) = \omega \bar{\Pi}_t(z, s) + (1 - \omega) \bar{b}_t \qquad (19)$$

where $\bar{\Pi}_t(z, s)$ and $\bar{b}_t$ are given as

$$\bar{\Pi}_t(z, s) = \sum_{j=0}^{n} \mathbb{E}_t \left[\Omega_{t+j} (y_{t+j}(z_{t+j}, s) - c_o) | z \right]$$
$$\bar{b}_t = \sum_{j=0}^{n} \Omega_{t+j} b_{t+j}$$

where weights $\Omega_{t+j} \geq 0 \; \forall j$ and $\sum_{j=0}^{n} \Omega_{t+j} = 1$.

This wage rule is similar to a static Nash bargain that splits current profits, with ω akin to the worker's bargaining power. However, because wages are re-set infrequently, the values $\bar{\Pi}_t$ and $\bar{b}_t$

also incorporate expected future paths for productivity and benefits. As in Cooper *et al.* (2017), we assume the subsidy does not enter the division of surplus between the firm and worker. However, current or expected increases in benefits do pass through to wages.

Our wage specification is an alternative to setting wages via Nash bargaining over the firm's and worker's value functions. With wage rigidity, Nash bargaining over values would be computationally intensive, especially with heterogeneous productivity across workers and multiple sectors. Our simple rule is meant to ease the computational burden in an economically intuitive manner.

3.6 Free Entry

Let $\mu_t^W(z,w,s)$ be the measure of workers in an active match with productivity z and wages w in sector s at time t. Analogously define $\mu_t^F(z,w,s)$ as the measure of workers in an idle match, and let $\mu_t^U(s)$ be the measure of unmatched workers.

Let $n_t(s)$ be the number of workers searching for a job in sector s. Let $\mathcal{M}_t^F(s)$ and $\mathcal{M}_t^U(s)$ be the number of furloughed and unmatched workers who would accept a job offer if they were to receive one. Then

$$\begin{aligned} n_t(s) &= \sum_{\tilde{s}} \left\{ \pi_U(\tilde{s},s)\mu_t^U(\tilde{s}) + \pi_F(\tilde{s},s)\zeta \int d\mu_t^F(z,w,\tilde{s}) \right\} \\ \mathcal{M}_t^F(z_0,s) &= \sum_{\tilde{s}} \pi_F(\tilde{s},s)\zeta \int \mathbb{I}\left(W_t(z_0,w_{0t}^*,s) \geq \hat{F}_t(z,w,\tilde{s}) \right) d\mu_t^F(z,w,\tilde{s}) \\ \mathcal{M}_t^U(z_0,s) &= \sum_{\tilde{s}} \pi_U(\tilde{s},s)\mathbb{I}\left(W_{t+1}(z_0,w_{0t}^*,s) \geq U_t(\tilde{s}) \right) \mu_t^U(\tilde{s}) \end{aligned}$$

where we set w_{0t}^* as a function of z_0.

The free entry condition for job creation is given as

$$\kappa = q_t(s) \left[\int_{z_0} \max\left\{ J_t(z_0,w_{0t}^*,s), 0 \right\} p_t(z_0,s) dG(z_0,s) \right] \tag{20}$$

where $p_t(z_0,s) = \frac{\mathcal{M}_t^F(z_0,s) + \mathcal{M}_t^U(z_0,s)}{n_t(s)}$ is the probability that the worker accepts an offer. Expression (20) equates the cost of creating a vacancy to the expected profit of finding a worker. Note that, upon the realization of the initial productivity z_0, the firm can decide not to create the position.

3.7 Equilibrium

We define a *recursive equilibrium* in this model as (i) a set of value functions: J, V, W, F, and U; (ii) separation, idle, and recall decisions for the firm: e^a, d, e^i, and r; (iii) a quitting decision for the workers: η^a, and η^i; and (iv) a distribution of workers across states and sectors μ^W, μ^F, and μ^U such that the firm's and worker's decisions are optimal and the free entry condition is satisfied.

4 Quantitative Analysis: Flexible versus Rigid Labor Markets

For the quantitative analysis, we extend the model from the previous section by including a set of Gumbel shocks for firm and worker decisions. These decisions resemble those in discrete choice models, and the shocks help smooth the computational burden. We describe the full model with Gumbel shocks in Appendix B.1 and proceed to the calibration next.

4.1 Calibration and Model Assessment

In this section, we assess the ability of the model to replicate standard labor market features and to account for structural differences in labor markets across countries. For this reason, we provide two calibrations for the steady-state economy: one that aims at replicating the most prominent features of the U.S. (*flexible*) labor market, and a second one for the euro-area's (*rigid*) labor market. Next, we describe these two economies' common parameters and the labor market-specific calibration.

4.1.1 Common Parameters across Labor Markets

The calibration is monthly. Common parameter choices across labor markets are summarized in Table 1 and described next. Firms and workers discount the future at a monthly rate of $\beta = 0.99^{1/3}$, consistent with a 4 percent annual interest rate. We assume there are two sectors that are symmetric in the steady state. There exists an exogenous separation probability for active matches of 1.4 percent at a monthly frequency in each sector. Moreover, furloughed and unemployed workers continue searching in the same sector with a monthly probability of $\pi_F(s, s) = 0.75$ and $\pi_U(s, s) = 0.50$, respectively, in line with empirical findings (see, for instance, supplemental appendix B in Visschers and Carrillo-Tudela (2021)). We set furloughed workers' search efficiency to $\psi = 0.75$

relative to unemployment to account for the lower effort exerted by those furloughed. For wages, we set $n = 8$ and the forward-looking weights in the wage function $\Omega_{t+j} \quad \forall j \in (0, n)$ to be 1/9. We set the firm's bargaining power $\omega = 0.55$, which generates an elasticity of wages relative to a change in unemployment benefit b as reported in Mitman and Rabinovich (2015). We set the matching function elasticity η to be 1.50, in line with Schaal (2017) and Blanco and Navarro (2017).

We assume match-specific productivity z follows an AR(1) process with long-run productivity $\bar{z}$, persistence ρ^z, and variance σ^z, as

$$\ln z_t = (1 - \rho^z)\bar{z} + \rho^z \ln z_{t-1} + \sigma^z \epsilon_t. \tag{21}$$

We follow Kehoe, Midrigan and Pastorino (2019) and set $\bar{z} = 2.7$, $\rho^z = 0.995$, and $\sigma^z = 0.065$. We discretize the process for z into a Markov process with 90 points using Tauchen's method. We calibrate the initial productivity value z_0 as $0.65 \times \bar{z}$.

Table 1 Calibration: Common External Parameters

Parameter	Description	Value
β	Discount factor	$0.99^{1/3}$
δ	Monthly exogenous separation rate: Active	0.014
η	Matching function elasticity	1.50
ω	Firm's bargaining power	0.55
π_F	Rate of sectoral persistence: Furloughed	75%
π_U	Rate of sectoral persistence: Unemployed	50%
ψ	Search efficiency idle	0.75
$\bar{\mu}$	Long-run match productivity	2.7
ρ_z	Persistence match productivity	0.995
σ_z	Std. dev match productivity	0.065

4.1.2 Calibration: Parameterizing Two Distinct Labor Markets

Next, we describe the choice of parameters that will characterize two economies with structural differences in their labor markets: the United States (which we refer to as a flexible economy) and the euro area (rigid economy). For each economy, there are two sets of parameters, some externally set, shown in Table 2, and the remaining internally calibrated by solving the model to target some distinct moments of each labor market, shown in Table 7. We set five external parameters to characterize each economy: the monthly workers' job contact rate (f) and firms' contact rate (q) in each sector, the probability of re-bargaining wages every period (λ), and the baseline labor market policies for UI (b) and WS (σ) in the steady state.[7]

Table 2 Calibration: External Parameters - Flexible and Rigid Economies

Parameter	Description	Flex value	Rigid value
f	Worker's job contact rate	45%	20%
q	Firm's contact rate	70%	50%
λ	Probability of wage adjustment	1/9	1/13
b	Unemployment insurance	0.40	0.65
σ	Wage subsidy to firms	0%	0%

The seven remaining parameters are set to match eight data moments. These parameters are all jointly estimated. In particular, we estimate the monthly separation rate from furlough into unemployment, δ_F, as well as the variance of the Gumbel shocks received by: firms when making their active/idle/separation decisions $\rho_{J,V}$ and $\rho_{M,0}$; active and furloughed workers' quitting decisions $\rho_{W,U}$ and $\rho_{F,U}$; and furloughed and unemployed workers decisions to accept new jobs ρ_{H,W_0} and ρ_{U,W_0}, respectively. In terms of data moments, we present the full set of moments and associated values in Table 3 and briefly describe them next. We target the average unemployment rate for each economy (5.8 percent for the United States and 9.5 percent for the euro area) and the stock of workers in permanent unemployment and those in temporary lay-offs.[8] We also target transitions in and out of furlough, and, particularly for the United States, we target the reported transitions in Gertler *et al.* (2021). For the last two moments, we target the monthly transition rates from unemployment to employment, standard in the literature for the United States (Shimer (2012) and Gertler *et al.* (2021)), and we take the mid-range of the estimates presented by Balleer

[7] Given the values for f and q, we obtain a value for matching efficiency ψ and vacancy cost κ in each labor market. We estimate ψ to be 0.92 and 0.58, and κ to be 5.31 and 4.75 in the flexible and rigid markets, respectively.

[8] These moments are calculated from the Current Population Survey (CPS) averages between 1990 and 2019 for the United States and from Eurostat averages during the 1998-2019 period for the euro area, and pulled via Haver Analytics.

et al. (2016) and Hobijn and Şahin (2009) for the euro area. Finally, we target a pure recall rate from furlough of 76 percent in both economies, which is in the mid-range of the non-imputed and imputed values reported by Fujita and Moscarini (2017) for temporary lay-off workers in the United States (we use recall rates excluding permanent separators, as, in our model, these workers do not have a recall option). The estimated parameters are presented in Appendix C in Table 7.

4.1.3 Model Assessment: Flexible Labor Market

We next assess the predictions of the calibrated flexible labor market model in the steady state. The results are presented in Table 3. The calibrated model provides a good fit for the U.S. labor market. In terms of targeted moments, the model replicates the total unemployment rate and decomposition between permanently unemployed and furloughed workers. We find a monthly transition probability from furlough to employment of 60.1 percent, slightly higher than in the data, but we do a good job in matching that, among furloughed workers returning to active employment, recalls drive 78.5 percent of those transitions. Given the job-contact rate and search effectiveness, this result implies that actual job-to-job transitions account for only 21.5 percent of furlough transitions to employment. We find a transition probability from unemployment to employment of 45 percent; hence, there are virtually no rejections of employment offers from unemployed workers in the steady state, as all workers start with the same initial productivity z_0 and wage w_0. The model also successfully matches the data when inspecting non-targeted moments. In particular, the rate of monthly total transitions in each sector from employment to unemployment is 2.3 percent, in line with Kehoe *et al.* (2019) using CPS data. Given our calibrated exogenous separation rate, the monthly rate for endogenous separations is 0.9 percent. We obtain a replacement rate of UI relative to newly employed workers' wage of about 35 percent (Shimer, 2005), as is regularly assumed for the United States, and the profit share for the newly hired, w_0/Π, accounts for about 51 percent of the profit of the firm.

Table 3 Model Assessment: Flexible and Rigid Economies Targeted Moments

Moment	Description	Flex data	Flex model	Rigid data	Rigid model
$U+I$	Total unemployment rate	5.84%	5.82%	9.52%	9.52%
U	Permanent unemployment rate	5.09%	5.11%	9.47%	9.48%
I	Temporary unemployment rate	0.75%	0.71%	0.05%	0.04%
$U-E$	Job acceptance rate	30.00%	45.00%	20.00%	20.00%
$F-E$	Furlough-to-employment rate	48.10%	60.10%	10.00%	15.13%
$F-U$	Furlough-to-unemployment rate	20.70%	22.78%	80.00%	74.70%
$F-F$	Furlough-to-furlough rate	31.20%	17.12%	10.00%	10.17%
Recall	Recall rate from furlough	75.70%	78.48%	75.70%	57.10%

4.1.4 Calibration: Rigid Labor Market

We next describe the calibration and model assessment of a more rigid labor market, targeting the euro-area economy. As in the previous economy, we have two sets of parameters: one is set externally to common values in the literature and data, and we estimate the other set internally to match some data moments. The five externally set parameters are displayed in the right column of Table 2. The monthly job contact rates for workers and firms are set to 20% and 50%, respectively, implying longer unemployment episodes in European economies relative to the United States, and in line with empirical findings by Hobijn and Şahin (2009). We assume the wage duration is also longer—meaning higher rigidity—and set $\lambda = 1/13$. This is in line with the evidence presented by Lamo and Smets (2010), which documents an average duration of wages of 15 months. Regarding policies, UI is more generous, so we set $b = 0.65$, and there are no WS in the steady state.

The seven remaining parameters are set to match the same data objects as in the U.S. calibration, with some taking different values compared to the United States. In this case, we target an average unemployment rate that matches the average euro-area unemployment rate of 9.52 percent during the 1998–2019 period. We put virtually all the unemployed workers in permanent unemployment (9.47 percent) to match the infrequent use of temporary lay-offs in the euro area, where employment protection usually requires consensus between firms and workers' representatives for these types of separations. We target monthly transition rates from furlough to employment of 10 percent and from furlough to unemployment of 80 percent. This calibration increases employment rigidity by not allowing furloughs to be a realistic option a firm can use to manage their workforce in the euro area compared to the United States. Finally, we target an unemployment-to-employment monthly flow rate of 20 percent, in the mid-range of the estimates presented by Balleer *et al.* (2016) and Hobijn and Şahin (2009). We assume the same recall rate as in the U.S. exercise. The estimated parameters for the rigid calibration are presented in Appendix C in the last column of Table 7.

4.1.5 Model Assessment: Rigid Labor Market

As can be seen in the last two columns of Table 3, the model does a good job of replicating the main labor market outcomes from the euro-area economy. Precisely, we match the unemployment rate very well, and there is an almost negligible fraction of workers in temporary unemployment. We also assess the performance of the model relative to non-targeted moments. The sectoral monthly separation rate is 2.1 percent, which is very similar to the U.S. estimate and in line with the findings from Hobijn and Şahin (2009) that most unemployment differences between these economies arise from differences in job-finding rates, not separation rates. It is important to highlight that the replacement rate of UI relative to newly employed workers is higher compared with the flexible economy, resulting in wages representing a larger fraction of a firm's output and reduced profit margins for firms.

5 Model Simulation: A Crisis Experiment

We analyze a short-lived recession that results in an abrupt decrease in output and a rapid increase in unemployment. We aim to recreate the initial shock to the services sector and the initial policy response observed in the first half of 2020 when public health restrictions aimed at containing the spread of the COVID-19 virus led to a rapid closure of high-contact services. That is, we do not target the whole COVID-19 recession, as many other factors and subsequent closures played a role in the economy's recovery, but just the initial sectoral shock. In turn, we assume that sectoral productivity x in only one of the sectors falls by Δ_x and returns at rate ρ: $x_1 = \mu_x(1 - \Delta_x)$, and $x_t = (1 - \rho)\mu_x + \rho x_{t-1}$ $\forall t \geq 2$. The other sector's productivity remains unaffected. In the flexible labor market, we set $\Delta_x = 0.225$ and $\rho = 0.75$, generating a nine percentage point unemployment increase, as observed at the start of the COVID-19 recession in the United States. The flexible labor market calibration includes an increase for about four months in UI that more than doubles the replacement rate for new workers and then returns to the steady-state amount.[9] This type of UI extension is similar to the policy adopted in the United States at the start of the COVID-19 recession, with the cost of the policy amounting to about 1% of GDP both in model and data.[10] In the rigid labor market, we set $\Delta_x = 0.37$ and $\rho = 0.75$ to target an unemployment increase of about 0.9 percent. The calibration of the rigid labor market economy includes a WS policy in the affected sector for 12 months, also amounting to a cost of 1 percent of GDP both in model and data.[11] The calibration of the rigid economy aims at mimicking the dynamics of a euro-like labor market and policies adopted at the beginning of the COVID-19 recession.[12]

We consider the predictions of the model under three cases. First, a "Benchmark" case in which there is the standard steady-state UI policy. Second, an "Extended UI" case, in which UI replacement rates increase for 4 months, as explained above. Third, a "Wage Subsidy" case, in which we provide a 12-month WS policy to the affected sector, as explained above. We consider these three experiments both for the flexible and the rigid economy.

5.1 Policy Alternatives in a Flexible Labor Market

As seen in Figure 4, a negative productivity shock results in a strong contraction in output accompanied by a spike in unemployment, increasing both permanent and temporary lay-offs. Notably, the UI extension (light blue line) leads to the strongest contraction on impact but to the fastest

[9]In the figures and the remainder of the paper, we denote this policy as a UI extension, but we acknowledge that this policy is a temporary increase in UI.

[10]Our calibration intends to mimic the introduction of the extension, which took place in mid-April and lasted through the end of July 2020. Therefore, we give workers only half of the more generous extension during the first month and the complete, twice-as-large replacement rate in the next three months. The reported cost of the extended policy (see Ganong *et al.*, 2021) is about 1 percent of annual GDP.

[11]For comparability across exercises, we also use 1 percent as the relevant policy cost. Moreover, this is in line with expenditures during the first 12 months after the COVID-19 shock in countries such as Spain (see "https://www.lamoncloa.gob.es/serviciosdeprensa/notasprensa/trabajo14/Paginas/2021/050521-paroregistrado.aspx") and Germany, as reported in "https://www.economist.com/business/2021/06/26/german-firms-are-conflicted-about-the-kurzarbeit-furlough-scheme". This leads to an implicit subsidy of 4 percent to the wage bill for all active firms.

[12]In Appendix C, we present an additional quantitative example of a prolonged recession with a smaller initial shock, which is more similar to the 2008–09 crisis.

recovery afterward among the three policy alternatives considered.

The UI extension raises workers' outside option, and thus, wages. Higher wages increase the measure of firms who decide to separate from workers permanently or temporarily (furloughed). Additionally, in the presence of rigid wages, many employed workers quit to find higher-wage jobs. Quits are more significant in the affected sector but also occur in the unaffected sector. These factors result in an initial strong economic contraction, shown in the top-right panel of Figure 4.

The job-finding rate decreases sharply in the affected sector, reflecting its lower productivity. Interestingly, the job-finding rate declines in the unaffected sector, though much less sharply. As a result of the shock, a larger share of unemployed workers is furloughed, leading job offer rejections, in hope of being recalled.

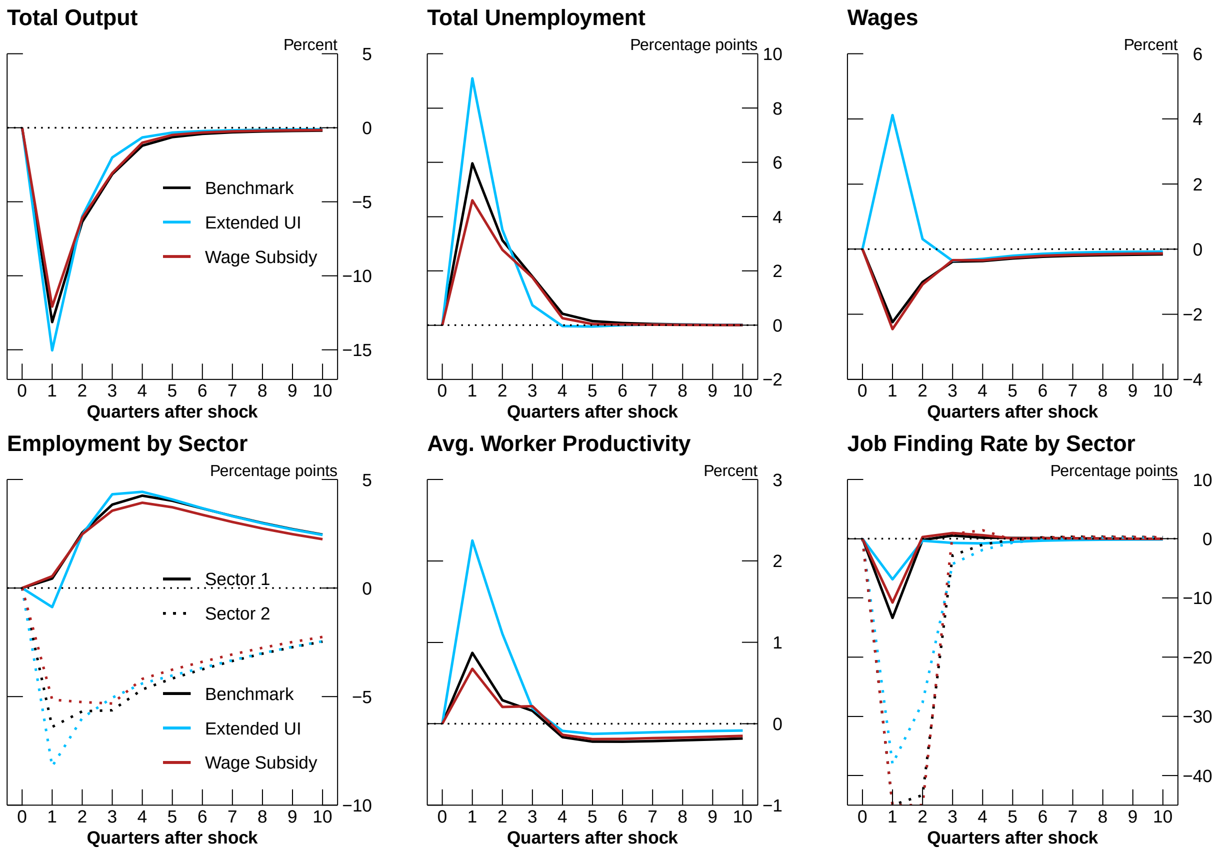
The UI extension leads to the smallest decline in the job-finding rate. The UI extension front-loads quits initially but later decreases them below the steady state as the economy recovers. As such, firms' expected value of a new job is higher; thus, the number of job postings is higher than in the benchmark policy. At the same time, the average match productivity increases (in line with the cleansing effect), which further helps to speed up the recovery, even as new matches are formed.

The WS policy reduces temporary lay-offs and prevents permanent job destruction, resulting in the smallest increase in unemployment (red line in upper-middle panel of Figure 4).[13] The WS policy leads to a shallower path for output and unemployment, but at the cost of a somewhat slower recovery and lower labor productivity (red line, lower-middle panel of Figure 4). As low-wage, low-productivity jobs are profitable under the wage subsidy, there is less of a cleansing effect associated with the recession, and both wages and match productivity fare worse than under both the UI and benchmark policies. Overall, the differences between benchmark and WS policies are small, as in this economy, firms can always recall furloughed workers as the shock wanes.

To sum up, the UI extension and WS policies produce tradeoffs between the speed of the recovery, higher/lower unemployment, and lower/higher productivity. At the same time, as we show in more detail in the following section, the UI policy benefits consumers at the expense of firms, while the WS policy protects firms' profits.

[13] We set the wage subsidy to 4.5, which delivers the same cost as the extended UI policy in the flexible economy.

Figure 4 Flexible Economy: Policy Alternatives in the Short-Lived Recession



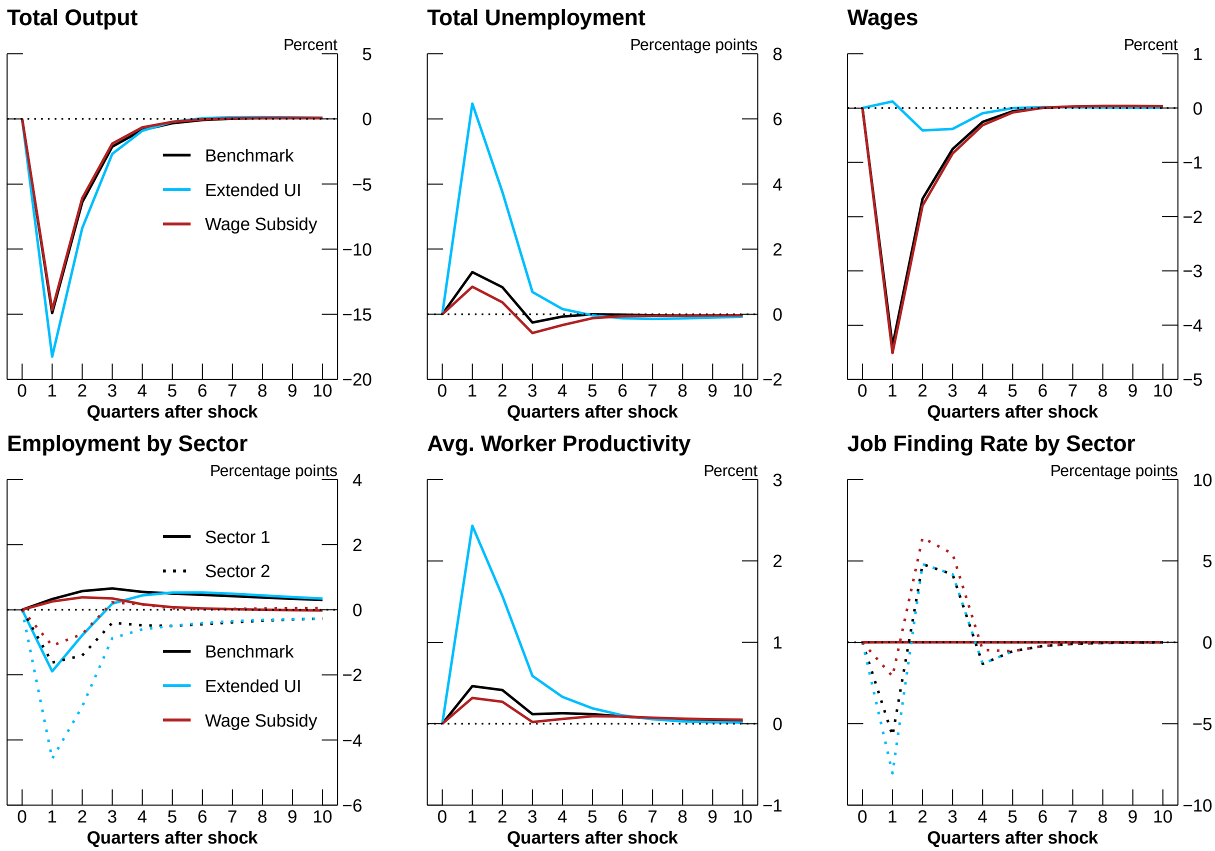
Note: Sector 1 refers to the unaffected sector, and sector 2 is the sector affected by the shock. All variable responses are expressed as deviations from the steady state.

5.2 Policy Alternatives in a Rigid Labor Market

Figure 5 shows the rigid economy response. While the output contraction is similar to that in the flexible economy, unemployment increases less in the rigid economy. However, it takes about the same time to return to its steady-state level. In this economy with low job-finding rates, small increases in unemployment can have persistent effects (Duval and Vogel, 2008). Recall that, in the rigid economy, unemployment is mainly composed of permanent separators since temporary lay-offs and subsequent recall are not possible.

The WS policy (red line) produces a contraction in output similar to the benchmark policy but succeeds in stemming persistent increases in unemployment. Under this policy, unemployment

Figure 5 Rigid Economy: Policy Alternatives in the Short-Lived Recession



Note: Sector 1 refers to the unaffected sector, and sector 2 is the sector affected by the shock. All variable responses are expressed as deviations from the steady state.

increases for only a few quarters relative to the steady state, but it overshoots and temporarily declines below its long-run value. The overshoot occurs because, despite the productivity shock, the WS policy increases firms' profits, thus leading to more vacancy postings and higher job-finding rates. Note that in this economy, where furloughs are unavailable, WS alleviate firms' wage bill while keeping workers employed.

Compared to the flexible economy, the UI policy leads to a more substantial output contraction but does not result in a faster recovery.[14]. Unemployment in particular, takes longer to recover because of a lower job-finding rate and the absence of a recall option. As in the flexible economy,

[14]The calibrated UI policy in the rigid economy that accounts for 1 percent of GDP is given by a 21 percent increase in the replacement rate during the first month, followed by a 42 percent increase in the subsequent three months.

the unemployment–productivity tradeoff still exists under the considered policies. However, firms' losses from permanent separations in the rigid economy will become larger and more persistent.

5.3 Assessing Model Implications

As discussed above, the model has different implications for several variables, depending on labor market features (flexible vs. rigid) and labor policies in place (UI vs. WS). This section contrasts some of the key model implications with data. In particular, Section 5.3.1 discusses the implications for unemployment, productivity, and wages, while Section 5.3.2 discusses the implications for sectoral reallocation.

5.3.1 The response of labor market variables

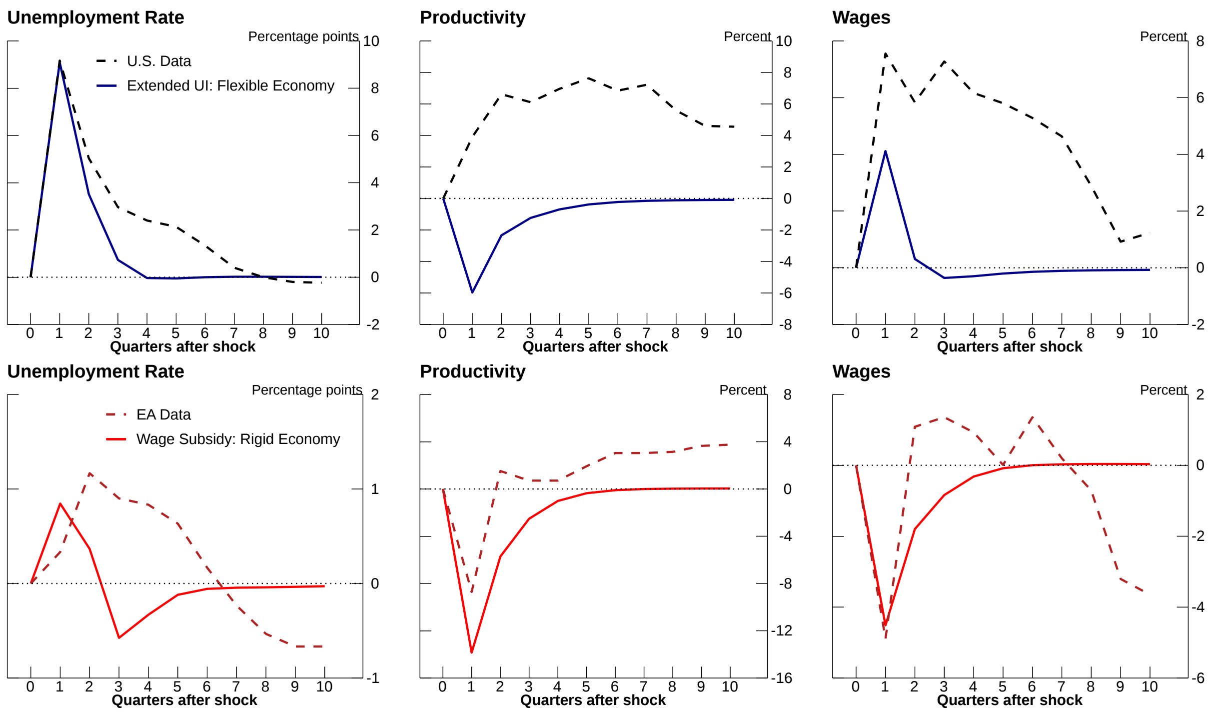
Figure 6 compares the response of unemployment, productivity, and wages during the COVID-19 pandemic with the paths implied by our model crisis experiment. We compare the data outcomes in the United States with the flexible economy under the UI extension, and the euro-area data with the rigid economy under the WS policy.

The left panel shows the path for unemployment dynamics. By construction, the model matches the peak increase in the unemployment rate, although it occurred with a delay in the euro area. The data exhibits slightly more persistence for both countries, as there were subsequent health-related closures that we did not include in our experiment. Interestingly, our model also predicts an undershoot of unemployment as observed in the euro area economy.

The middle panel illustrates the path for productivity, measured as output per employee. The model response of output per employee captures two effects. First, the sectoral productivity shock leads to a significant decline in output per employee. Second, there is a cleansing effect, given that productive matches, and those in the unaffected sector, are more likely to survive. Quantitatively, the first effect dominates in both the rigid and flexible calibrations. This decline in productivity is observed in the euro area, where wage subsidies dampen the cleansing effect. At the same time, the United States exhibited a surprising productivity increase, reflecting a stronger cleansing effect and some distortions in measurement, as discussed in Gordon and Sayed (2022).

The right panel depicts the path for wages.[15] The model successfully replicates the qualitative path for wages, a non-targeted moment, both for the rigid and flexible economies. In particular, consistent with empirical evidence, the model predicts an increase in wages in the flexible economy—as seen in the United States—and an initial decline in wages in the rigid economy—as seen in the euro area. Note that the response of wages signals the stark differential effects of UI and WS policies, and the model successfully captures this feature.

Figure 6 Unemployment, Productivity, and Wages: Data and Model Simulation



Note: Productivity is defined as output per employee and wage is real compensation per employee.
Source: Bureau of Labor Statistics and Statistical Office of European Communities via Haver Analytics.

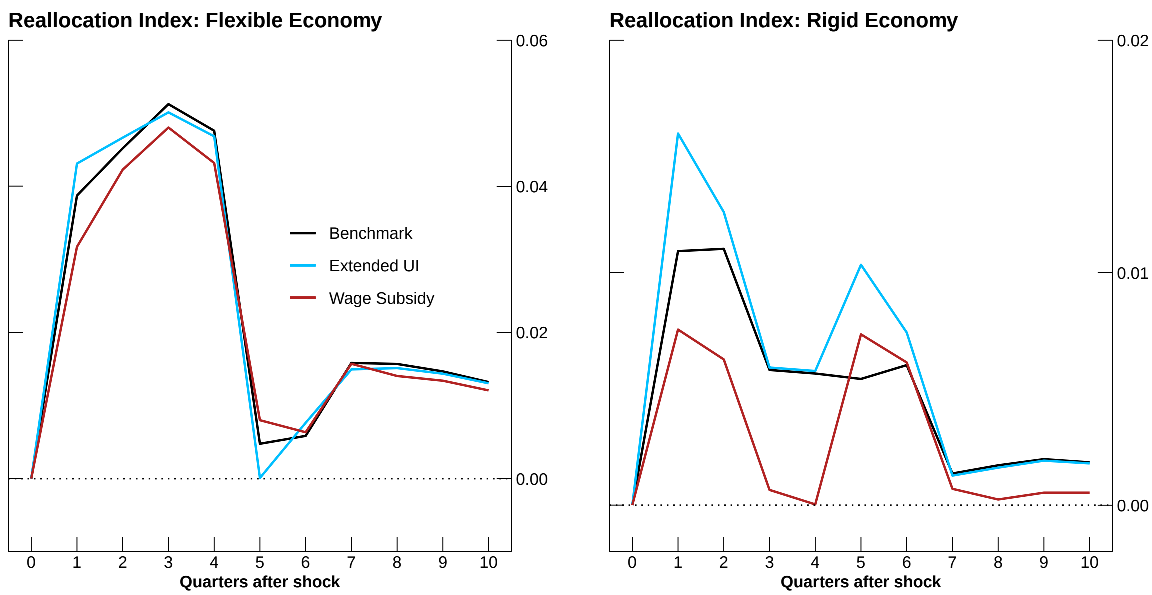
5.3.2 CRW Reallocation index

Next, we apply the CRW reallocation index to our model simulated data for the flexible and rigid economies. As Figure 7 shows, our crisis experiment leads to higher reallocation in both economies. Moreover, the model predicts a smaller increase in reallocation in the rigid economy compared to the flexible economy, which is in line with the evidence presented in Section 2.

[15] We define wages in the data and the model as average compensation per employee

As discussed earlier, UI and WS policies have opposite effects on unemployment, with the former encouraging quits and separations and preventing job destruction. Consistently, the UI policy leads to larger initial reallocation, while the WS policy does the opposite. Yet, the reallocation increase using UI policies would be smaller in the rigid economy than in the flexible one, showing that both policies and labor market features explain the difference in reallocation found empirically between the United States and the euro area.

Figure 7 Chodorow-Reich and Wieland's Index: Model with a Short-Lived Recession



Note: The reallocation index is calculated using year over year growth rates of quarterly sectoral employment.

6 Welfare Quantification

This section discusses the welfare performance of UI and WS policies. We define overall welfare ($\mathcal{W}$) as a sum of workers' welfare ($\mathcal{P}(C)$), measured by the present discounted value of their consumption, and firms' welfare ($\mathcal{P}(\Pi)$), measured by the present discounted value of their profits, net of policy cost $\mathcal{P}(P)$.[16] Formally,

$$\mathcal{W} = \mathcal{P}(C) + \mathcal{P}(\Pi) - \mathcal{P}(P), \tag{22}$$

with

$$\mathcal{P}(C) = \sum_{t=0}^{\infty} \beta^t \sum_s \left\{ \int w d\mu_t^W(z,w,s) + \int b_t d\mu_t^F(z,w,s) + b_t \mu_t^U(s) \right\}$$
$$\mathcal{P}(\Pi) = \sum_{t=0}^{\infty} \beta^t \sum_s \left\{ \int \Pi d\mu_t^W(z,w,s) - \int c_i d\mu_t^F(z,w,s) \right\}$$
$$\mathcal{P}(P) = \sum_{t=0}^{\infty} \beta^t \sum_s \left\{ \int \sigma_t w d\mu_t^W(z,w,s) + \int b_t d\mu_t^F(z,w,s) + b_t \mu_t^U(s) \right\}.$$

Table 4 reports the overall welfare cost $\Delta\mathcal{W} = \mathcal{W} - \mathcal{W}_{ss}$ for three cases: the no-policy case (benchmark), the UI policy, and the WS policy in response to the shock, net of the steady state welfare–that is, equation (22) with no shocks. In each case, we also report welfare components: $\mathcal{P}(C)$, $\mathcal{P}(\Pi)$, and $\mathcal{P}(P)$. We report welfare numbers in terms of annual GDP, a natural measure since all agents are risk neutral in the economy.

Table 4 Welfare Comparison: Percentage Loss Relative to Steady State

	Flexible economy			Rigid economy		
	Benchmark	UI	WS	Benchmark	UI	WS
$\mathcal{P}(C)$	−1.94%	−0.42%	−1.70%	−1.04%	−0.51%	−0.93%
$\mathcal{P}(\Pi)$	−4.34%	−4.52%	−3.16%	−4.60%	−5.26%	−3.49%
$\mathcal{P}(P)$	0.42%	1.10%	1.32%	0.10%	1.13%	1.03%
$\Delta\mathcal{W}$	−6.69%	−6.04%	−6.19%	−5.74%	−6.90%	−5.45%

Note: Welfare gains $\Delta\mathcal{W}$ relative to steady-state. We report the components of $\Delta\mathcal{W}$: workers' consumption ($\mathcal{P}(C)$), firms' profits ($\mathcal{P}(\Pi)$), and policy cost ($\mathcal{P}(P)$). All numbers are expressed in terms of annual steady-state GDP. Columns may not add up due to rounding.

In the flexible economy, the welfare loss due to the shock is large, at 6.69% of output. Interestingly, UI and WS policies produce similar and non-negligible welfare gains relative to the

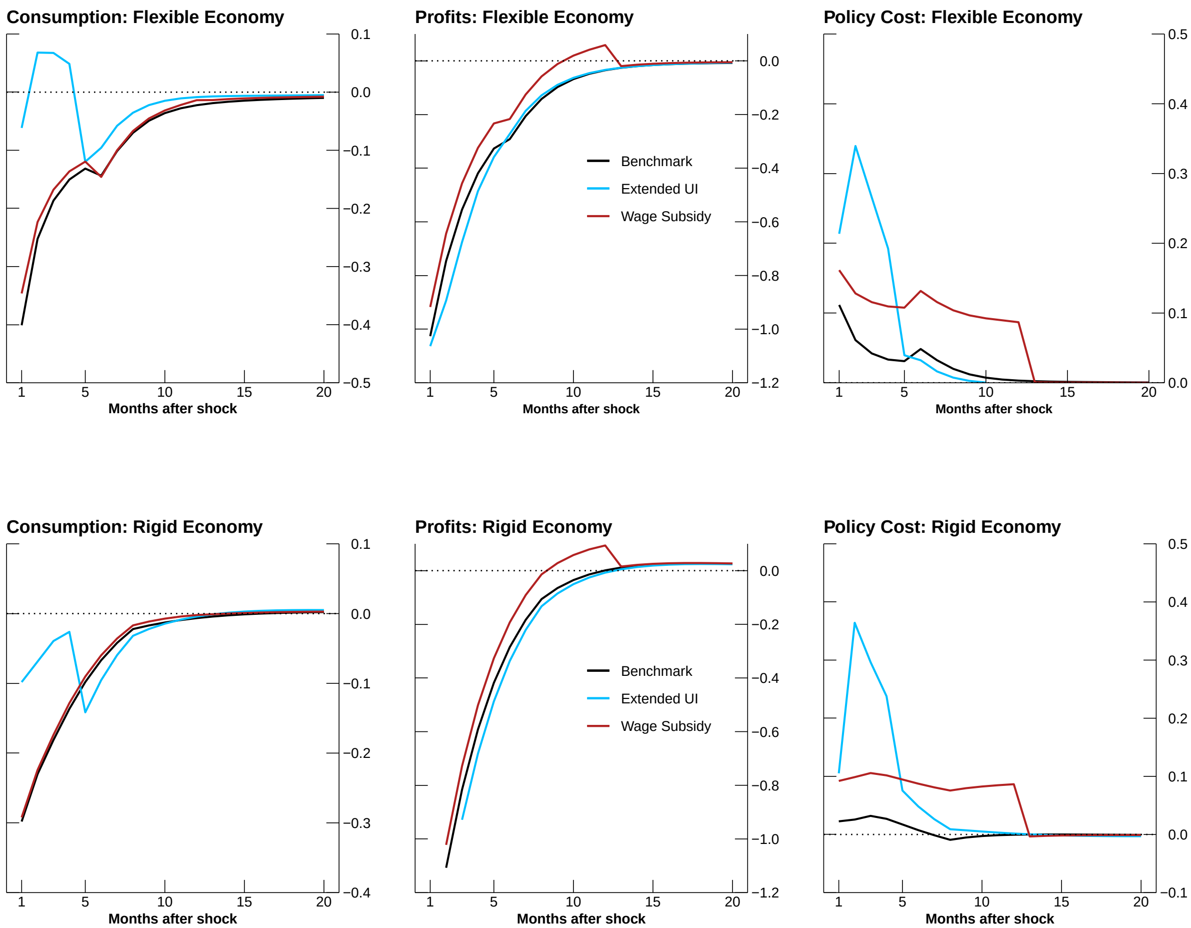
[16] The value $\mathcal{P}(C)$ measures the consumption of employed, furloughed, and unemployed workers, while the value $\mathcal{P}(\Pi)$ measures the firm's profit Π—defined for the active firm value in equation (4)—net of idle matches costs.

benchmark case. However, the decomposition of gains into workers' consumption and firms' profits differs significantly. WS mainly improve profits and, to a lesser extent, consumption, while the UI policy improves consumption at the expense of lower profits. The WS policy aims to prevent significant profit losses, thus benefiting firms more. Despite protecting jobs and dampening consumption losses, WS maintain low-productivity/low-wages matches. On the contrary, the UI policy, by construction, insures consumption and increases wages in both sectors, thus delivering the highest consumption gains. Consumers are better off under the UI policy as even the least productive ones get higher benefits than what they would get in terms of wages under the WS policy. Overall, the UI policy is preferred in the flexible economy and generates a substantial welfare gain of 0.65% (= 6.69% − 6.04%) of (annual) GDP relative to the benchmark.

Welfare tradeoffs are similar in the rigid economy, although their quantification changes. The UI policy prevents consumption losses, but less than in the flexible economy, as the rigid economy already starts with high replacement rates. Even so, the UI policy produces higher profit losses than under the flexible economy, as the profit share of firms is lower, reducing the scope to increase wages and still keep productive matches. As such, the WS policy becomes the only welfare-improving option, despite being less preferred by consumers than the UI policy. WS prevent the persistent losses from job destruction and, compared to the flexible economy, generate more modest welfare gains of 0.29% (= 5.74% − 5.45%) of (annual) GDP relative to no policy. Notably, the UI policy generates a large welfare loss of −1.16% (= 5.74% − 6.90%) of (annual) GDP relative to the benchmark scenario.

We also analyze welfare evolution over periods after the shock hits. As can be seen in Figure 8, the WS policy supports firms' profits through the first year after the shock which benefits also workers through lower unemployment and thus slighlty higher consumption compared to the benchmark policy. Instead, UI delivers much higher initial payoff for workers at a cost of lower firms' profits in the first months after the shock. The increase in payoff under the UI policy is weaker in the case of the rigid economy as not as many workers get unemployed. Finally, the UI costs are concentrated in the first months after the shock, while for the WS policy the costs are spread much more evenly over the first year.

Figure 8 Welfare Evolution: Flexible and Rigid Economies



Note: All variable responses are expressed as deviations from the steady state aggregates and in terms of percent of annual output.

Overall, these welfare results rationalize why the United States typically relies on UI policies, whereas the euro area relies more on WS policies. Next, we discuss how the benefits of UI and WS policies may vary with the persistence of the recession and firms' capacity to recall workers.

7 Robustness Analysis

In this section, we discuss robustness of our findings to two important assumptions: 1) the furlough option in the flexible economy and 2) the persistence of the shock. First, so far we concluded that the UI policy is preferred in the flexible economy. Yet, one could argue that this result is dependent on furlough allowing firms to keep workers and preserve match-specific human capital. Thus, we exclude furlough option in Section 7.1 and revisit the performance of UI and WS policies. Second, so far we only discussed a short-lived recession. But a more persistent shock could make reallocation even more desirable, affecting the preferred policy choice. Consistently, in Section 7.2, we look at policies' performance as shocks get more persistent.

7.1 The role of furlough and the policy performance

In a flexible economy with the furlough option and high job-finding rates, we argue that UI is preferred to WS, although both policies are welfare-improving. In a sense, recalling furloughed workers acts similarly to a WS policy: the firm does not have to pay wages during low productivity periods, but it can eventually recall workers without losing their job-specific human capital. In turn, we analyze the performance of UI and WS policies in a flexible economy when recalling furloughed workers is not an option.

In particular, we set all parameters as in the flexible economy calibration, except that we impose a separation rate from furlough as in the rigid economy, $\delta_F = 0.987$, making furlough and recall harder. The resulting moments of the new calibration are in Table 5, including the moments of the baseline calibration. Increasing δ_F results in slightly lower aggregate unemployment, as the number of furloughed workers is a third of those in the baseline, but an uptick in permanent unemployment. This fact suggests that, compared to the baseline economy, firms still employ most of the workers. Only the least productive workers would be permanently separated from the firm.[17]

Table 5 Model moments: Flexible Economy - Baseline and No Furlough

Moment	Description	Flex baseline	Flex no furlough
$U + I$	Total unemployment rate	5.82%	5.49%
U	Permanent unemployment rate	5.11%	5.22%
I	Temporary unemployment rate	0.71%	0.28%
$U - E$	Job acceptance rate	45.00%	45.00%
$F - E$	Furlough-to-employment rate	60.10%	33.77%
$F - U$	Furlough-to-unemployment rate	22.78%	52.73%
$F - F$	Furlough-to-furlough rate	17.12%	13.50%
Recall	Recall rate from furlough	78.48%	8.59%

Table 6 presents welfare in the no-furlough economy for the same three policies as in the baseline scenario.[18] Both UI and WS remain welfare-improving relative to the no-policy scenario. Yet, the benchmark scenario with no furlough has a lower policy cost than the baseline economy. Firms are now more selective when firing than when furlough is available, which results in lower unemployment. For this reason, UI produces even higher gains while WS gains are diminished.

Importantly, wage subsidies and recall only prevent *inflows* into permanent unemployment via separation rates. The persistence of unemployment is also determined by *outflows* from unemployment to employment, which depend on job-finding rates. As job-finding rates are high in the flexible economy, unemployment remains low even without a furlough option.

7.2 UI policy design and the persistence of shocks

Our previous analysis shows that an increase in UI benefits promotes reallocation at the start of the recession. Thus, a UI policy could be beneficial in a long-lived recession when reallocation to the unaffected sector is more desirable. However, as discussed, a generous UI policy can increase

[17]This is confirmed by looking at transitions from furlough to employment. These transitions are half of those in the baseline economy. Still, they remain sizable, reflecting the fact that job-finding rates give the possibility to transition to new jobs. Overall, recall rates drop and are a negligible fraction of transitions out of furlough.

[18]In this exercise, all parameters remain the same as in the baseline economy. Hence it is not imposed that the cost of policies will be 1 percent of GDP.

Table 6 Welfare Comparison – No Furlough in Flexible Economy

	Flexible economy: No furlough		
	Benchmark	UI	WS
$\mathcal{P}(C)$	-1.29%	0.16%	-1.24%
$\mathcal{P}(\Pi)$	-3.79%	-3.89%	-2.71%
$\mathcal{P}(P)$	0.15%	0.61%	1.15%
$\Delta\mathcal{W}$	-5.23%	-4.34%	-5.10%

Note: Welfare gains $\Delta\mathcal{W}$ relative to steady-state. We report the components of $\Delta\mathcal{W}$: workers' consumption ($\mathcal{P}(C)$), firms' profits ($\mathcal{P}(\Pi)$), and policy cost ($\mathcal{P}(P)$). All numbers are expressed in terms of annual steady-state GDP. Columns may not add up due to rounding.

wages, lower firms' profits, and, thus, discourage job creation. In this section, we discuss the effects of UI and WS in more detail by considering shocks of different persistence.

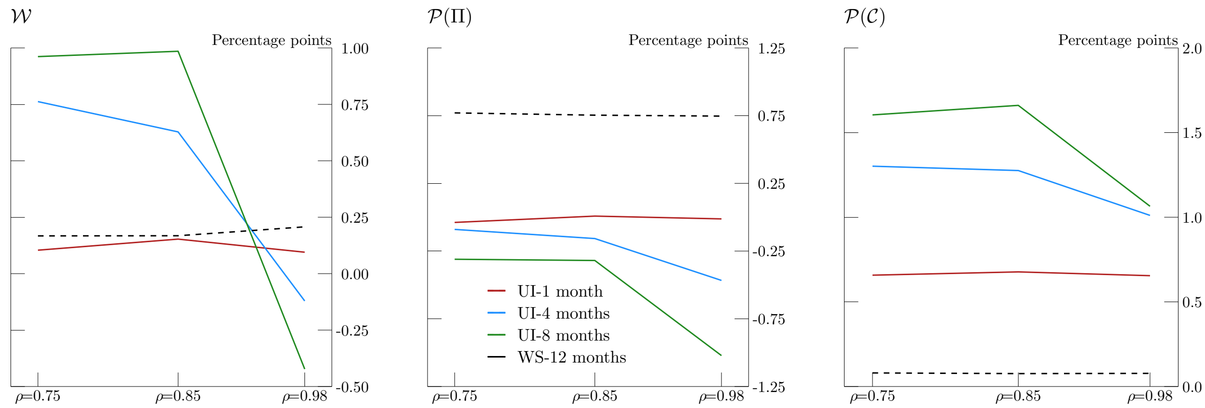
As before, we analyze a sector-specific shock that drops productivity by Δ_x. We consider three different levels of shock persistence: $\rho = [0.75, 0.85, 0.98]$. For this comparison, we feed a shock of $\Delta_x = 0.10$.[19] For each persistence level, we analyze three different durations of the UI policy: (1) a front-loaded one-month UI policy such that $b_{new} = 3.75 \times b$, (2) a four-month policy such that $b_{new} = 1.9 \times b$, and (3) an eight-month policy such that $b_{new} = 1.4 \times b$. The three policy durations generate a similar fiscal cost. We compare these policies with a twelve-month WS policy subsidizing 3 percent of a firm's wage bill.

Figure 9 shows the welfare values $\mathcal{W}$ for each UI and the WS policies and for the different recession persistence levels, given by ρ. We present the three welfare measures discussed earlier: worker's consumption $\mathcal{P}(C)$, firms' profits $\mathcal{P}(\Pi)$, and total welfare by netting out the policy cost $\mathcal{P}(P)$–that is, $\mathcal{W} = \mathcal{P}(C) + \mathcal{P}(\Pi) - \mathcal{P}(C)$. The welfare values are presented relative to the benchmark so that a positive number means it is preferred to the benchmark. As before, we report welfare values in terms of annual steady-state GDP.

Front-loading UI extensions (one-month UI policy; red line, left panel) is the safest option: it helps workers' consumption while not depressing firms' profits, regardless of the recession's per-

[19] This shock is smaller than the estimated $\Delta_x = 0.225$ in Section 5. We use a smaller shock because, as we increase the persistence of the shock, it would produce unrealistic results.

Figure 9 Welfare Differences between Policies and Benchmark Policy



Note: All variable responses are expressed as deviations from the steady state aggregates and in terms of percent of annual output.

sistence. At the same time, such a policy does not produce significant welfare gains relative to the benchmark policy, as consumers' gains are almost offset by the cost of the policy (not shown). Increasing UI duration can improve total welfare when the recession persistence is shorter, although larger firms' losses offset the higher consumer welfare gains. Yet, in persistent recessions, front-loading becomes the best option, as a larger UI duration hurts firms' profits and diminishes worker gains. This result aligns with Mitman and Rabinovich (2015), who study the optimal design of UI policy and find that front-loading UI in long-lived recession minimizes job creation distortions.

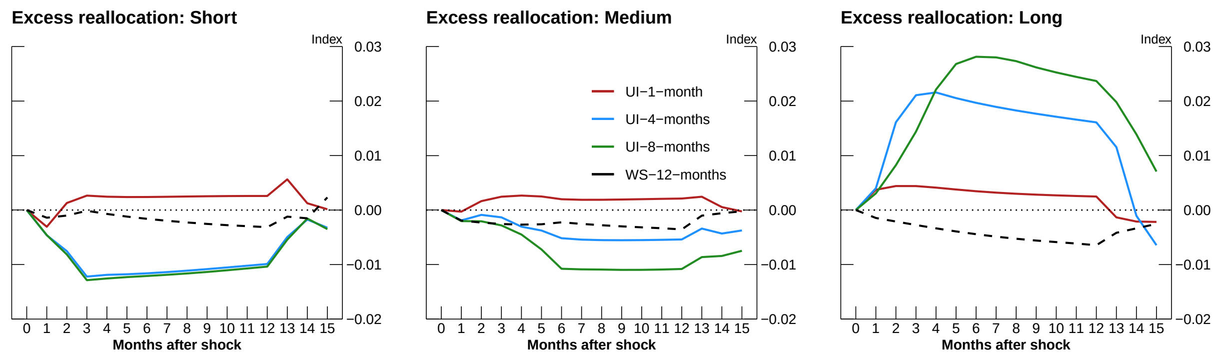
Contrary to UI, we find that welfare gains under WS do not change much with the persistence of the recession (dashed line) and the policy's design (not show, available upon request). WS preserve firms' profits relative to the benchmark policy and do not change workers' outside option, thus leading to fewer distortions in vacancy posting irrespective of the length of the recession.[20]

The relation between UI duration and reallocation is also complex. While WS always reduce reallocation relative to the benchmark scenario, a more extensive UI duration does not necessarily lead to more reallocation, as Figure 10 shows. The one-month UI duration leads to higher realloca-tion for most recession persistence levels, except for the very persistent one. That is, the distortion

[20]Consistently, front-loading WS does not necessarily improve welfare under more persistent recessions, as with-drawing firm support early in the recession can lead to job destruction when sector productivity remains low. While we have not analyzed subsidies for longer than a year, prolonged subsidizing of industries could lead to labor misal-location, especially when the decline in productivity is persistent or even permanent.

effect of a more generous UI policy could lead to lower reallocation. Moreover, higher reallocation does not necessarily mean higher welfare: higher reallocation occurs with longer UI duration in a persistent recession, but welfare is higher under the one-month UI duration.

Figure 10 Policies Excess Reallocation by Persistence of the Recession



Note: Excess reallocation is the difference between reallocation under a given policy and the benchmark policy.

8 Conclusions

In this paper, we developed a multi-sector search and matching model of the labor market subject to sector-specific shocks and wage rigidity. We calibrated the model to match key labor market features of the United States (*flexible* economy) and the euro area (*rigid* economy). We used the model to evaluate UI and WS policies, the two labor market policies most commonly used in recent years. We focused on sector-specific shocks to account broadly for the nature of recent recessions, such as the COVID-19 recession. We showed that, in such recessions, UI policies are preferred in a flexible economy, whereas WS policies are preferred in a rigid economy. Thus, our results provide a rationale for the different policies usually implemented in the United States versus the euro area.

We argued that UI extensions could lead to higher sectoral reallocation, which can be desirable in the presence of sector-specific shocks. However, UI extensions can also distort job creation, as larger benefits increase wages and thus decrease firms' profits. Overall, UI extensions trade welfare gains for workers with profit losses for firms. We found that front-loading UI extensions may help make this trade-off more favorable when designing policies. Notably, WS policies lead to fewer distortions in vacancy posting irrespective of the length of the recession. Thus, their performance does not significantly improve with a front-loaded subsidy.

We focused on simple labor market policies that resemble those implemented by several countries. Going forward, we believe there are several paths in which our analysis could be enriched. First, the model could include within-sector firm heterogeneity, worker-specific human capital, and sector-specific business cycle shocks. Second, one could compute the optimal UI-WS policies mix in this extended model. Third, one could derive what optimal reallocation should be in the presence of sector-specific shocks. We consider the optimal design of labor market policies in such a rich model a top priority for future research.

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A Empirical Analysis

A.1 Data Description and Additional Evidence on Reallocation

Our main data sources are pulled from Haver Analytics and described next. For the United States, we use the Bureau of Labor Statistics for aggregate and industry employment and the Current Population Survey (CPS) for the unemployment rate. We construct sectoral productivity as output per employee using sectoral gross value-added series from the National Accounts. The period for these variables is 2005:Q1–2019:Q4.

For the euro area, the primary data source is Eurostat, as they aggregate national country data for employment, unemployment, and national accounts. We construct sectoral output per employee series similar to the United States series. The period covered is 2005:Q1–2019:Q4.

In the estimation of SVAR, productivity enters the system in log differences, the unemployment rate in percentage point differences, and the CRW reallocation index in levels.

A.2 Structural VAR Analysis: unemployment shock

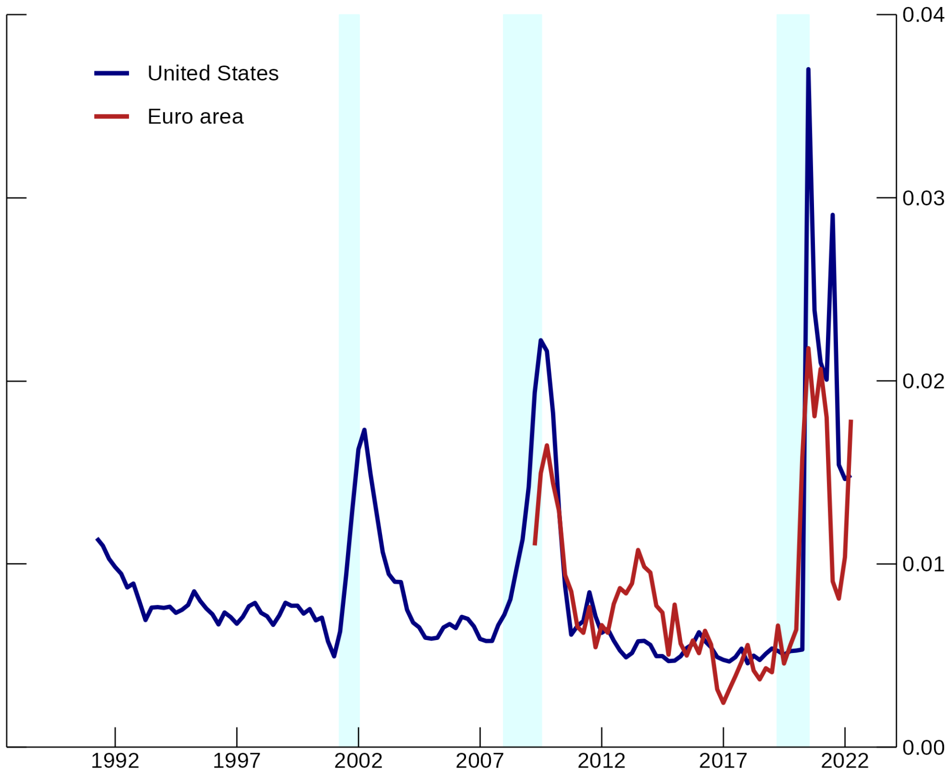
We analyze average responses of sectoral productivities and reallocation to an exogenous unemployment shock (identified as any shock to unemployment that does not affect contemporaneously sectoral productivities). We find that reallocation in the United States increases strongly in response to the unemployment shock while it moves up only slightly in the euro area. Sectoral productivities does not react strongly to the shock in either economy. Though with time, we see a slight increase in both sectoral productivities in the United States, which contrasts with the euro area where sectoral productivities decline.

B Quantitative model: Extension and solution

B.1 Model extension with Gumbel shocks

In this appendix, we describe the model's details with Gumbel shocks. As discussed in the text, the firm and worker decisions resemble those in discrete choice models, and adding shocks helps ease the computational burden. Appendix B.2 contains some useful formulas for solving the model

Figure 11 Chodorow-Reich and Wieland's Reallocation Index



Note: The reallocation index is calculated using year-over-year growth rates of employment from NAICS industry classification. The shading indicates recessions as determined by the NBER. Source: NBER, Statistical Office of European Communities, and Bureau of Labor Statistics via Haver Analytics.

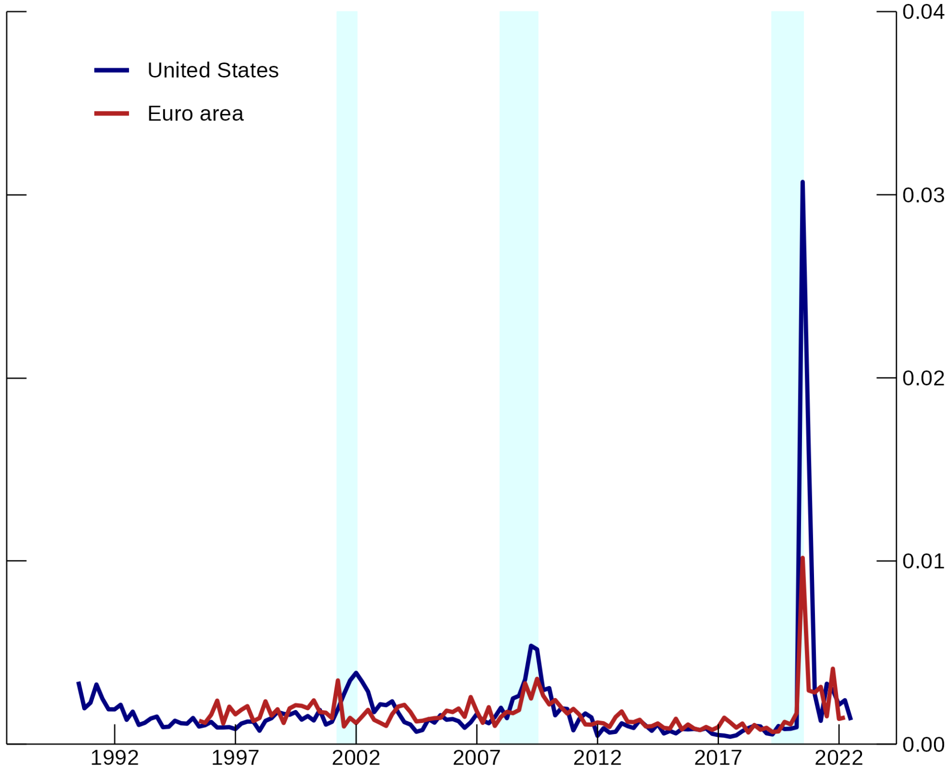
with Gumbel shocks, and Appendix B.3 contains details on the model solution.

B.1.1 Firms

Let $J_t(z, w, s)$ be the maximal attainable value for an active firm in a match with productivity z, wages w, and sector s at time t. Analogously define $V_t(z, w, s)$ as the value of an idle match. We assume a Gumbel shock for each value, respectively denoted ϵ^J and ϵ^V, both with variance $\rho_{J,V}$. Let $M_t(z, w, s)$ be the expected value over the maximum of $J_t(z, w, s)$ and $V_t(z, w, s)$ integrated over the Gumbel shocks:

$$M_t(z, w, s) = \mathbb{E}\left[\max\left\{J_t(z, w, s) + \epsilon^J, V_t(z, w, s) + \epsilon^V\right\}\right]. \tag{23}$$

Figure 12 Chodorow-Reich and Wieland's Reallocation Index



Note: The reallocation index is calculated using quarter-over-quarter growth rates of employment from SIC industry classification. The shading indicates recessions as determined by the NBER. Source: NBER, Statistical Office of European Communities, and Bureau of Labor Statistics via Haver Analytics.

The value for an active firm is

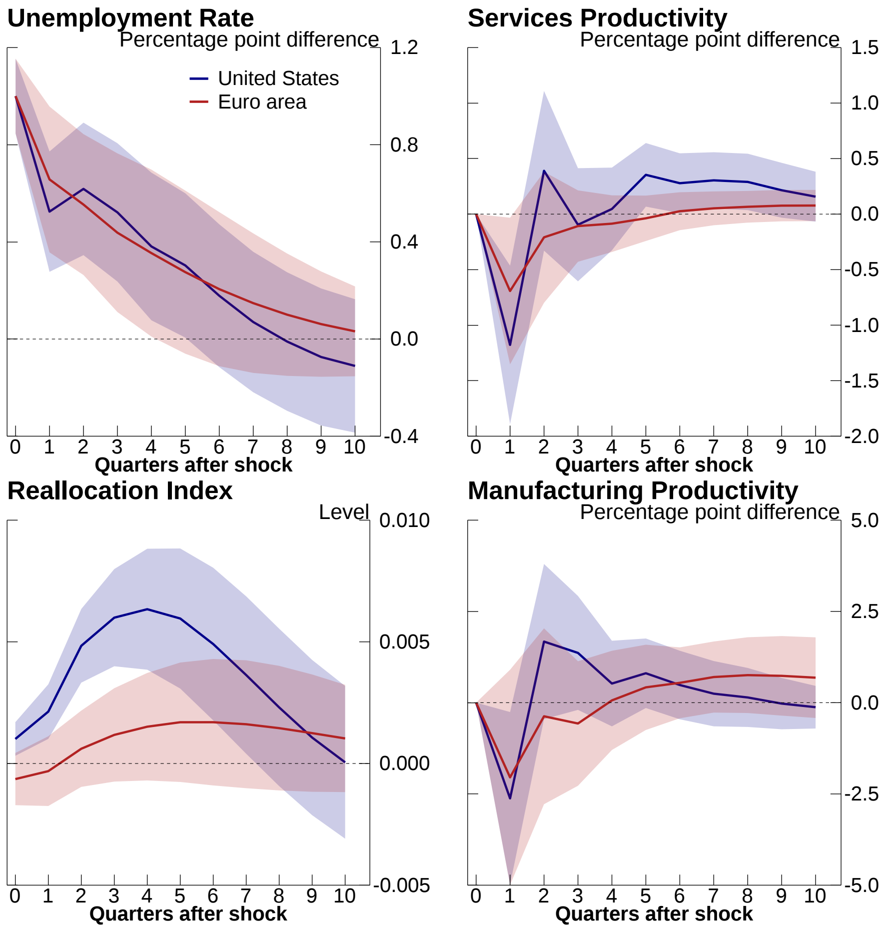
$$J_t(z, w, s) = \Pi + \beta \mathbb{E}_t \left[\left(1 - \eta^a_{t+1}(z', w', s)\right) \max \left\{ M_{t+1}(z', w', s) + \epsilon^M, 0 + \epsilon^0 \right\} |z \right] \tag{24}$$

$$\Pi = y_t(z, s) - (1 - \sigma_t) w - c_o$$

$$w' = \begin{cases} w & \text{w.p. } \lambda \\ w^*_{t+1}(z', s) & \text{w.p. } 1 - \lambda \end{cases}$$

where $\eta^a_t(\cdot)$ is the probability that a worker in an active match will quit, and the wage $w^*_t(\cdot)$ is given as in (19). In equation (24), we add a Gumbel shocks for the continuation value and another for exit value, respectively denoted ϵ^M and ϵ^0, both with variance $\rho_{M,0}$.

Figure 13 Impulse Responses to 1 Percentage Point Unemployment Shock



Note: Shading represents the 90% confidence interval. Productivity is defined as output per employee, and reallocation is constructed following Chodorow-Reich and Wieland's (2020) methodology. It is calculated using SIC industry classification with year-over-year changes.

The value for an idle match is

$$V_t(z,w,s) = -c_i + \beta \mathbb{E}_t \left[\left(1 - f^i_{t+1}(z',w,s)\right) \left(1 - \eta^i_{t+1}(z',w',s)\right) \max \left\{ M_{t+1}(z',w',s) + \epsilon^M, 0 + \epsilon^0 \right\} |z \right] \tag{25}$$

where $f^i_t(\cdot)$ is the probability that an idle/furloughed worker will find and accept another job offer (more on this below). Note that the continuation value for an idle firm in equation (25) is the same as for an active firm, including the Gumbel shocks ϵ^M and ϵ^0, although the stochastic process for

z may be different.

Let $e_t^a(z,w,s)$ be the decision of a firm to exit an active match, and $d_t(z,w,s)$ the decision to set a match to be idle. Similarly, let $e_t^i(z,w,s)$ be the decision to exit an idle match and $r_t(z,w,s)$ the decision to recall an idle worker. In the presence of Gumbel shocks, these decisions are probabilities given as

$$e_t^a(z,w,s) = \mathbb{P}\left(M_t(z,w,s) + \epsilon^M \leq 0 + \epsilon^0\right) \tag{26}$$

$$d_t(z,w,s) = \mathbb{P}\left(J_t(z,w,s) + \epsilon^J \leq V_t(z,w,s) + \epsilon^V\right) \tag{27}$$

$$e_t^i(z,w,s) = e_t^a(z,w,s) \tag{28}$$

$$r_t(z,w,s) = 1 - d_t(z,w,s) \tag{29}$$

B.1.2 Workers

Let $W_t(z,w,s)$ be the maximal attainable value for an active worker in a match with productivity z, wages w, and sector s at the beginning of period t. Analogously define $F_t(z,w,s)$ as the value of a worker in an idle match. Let $U_t(s)$ be the value of being unemployed in sector s at time t. Recall our assumption is that workers make decisions first, and then the firm moves. In turn, let $\hat{W}_t(z,w,s)$ and $\hat{F}_t(z,w,s)$ be the values of being active and idle, respectively, just after a worker made decisions but before the firm moves. Then

$$\begin{aligned}\hat{W}_t(z,w,s) = {} & (1 - e_t^a(z,w,s))\left[(1 - d_t(z,w,s))W_t(z,w,s) + d_t(z,w,s)F_t(z,w,s)\right] \\ & + e_t^a(z,w,s)U_t(s)\end{aligned} \tag{30}$$

$$\begin{aligned}\hat{F}_t(z,w,s) = {} & \left(1 - e_t^i(z,w,s)\right)\left[r_t(z,w,s)W_t(z,w,s) + (1 - r_t(z,w,s))F_t(z,w,s)\right] \\ & + e_t^i(z,w,s)U_t(s)\end{aligned} \tag{31}$$

We assume Gumbel shocks for the value of being active, $\hat{W}_t(\dot{c})$, being idle, $\hat{F}_t(\dot{c})$, and being unemployed, $U_t(\cdot)$. Let $H_t^a(z,w,s)$ be the expected value to a worker of being active at the beginning of the period, before the Gumbel shocks are realized and decisions are made. Similarly define

$H_t^i(z,w,s)$ as the expected value of an idle worker before shocks/decisions. Then

$$H_t^a(z,w,s) = \mathbb{E}\left[\max\left\{\hat{W}_t(z,w,s) + \epsilon^{\hat{W}}, U_t(s) + \epsilon^{U,W}\right\}\right] \tag{32}$$

$$H_t^i(z,w,s) = \mathbb{E}\left[\max\left\{\hat{F}_t(z,w,s) + \epsilon^{\hat{F}}, U_t(s) + \epsilon^{U,F}\right\}\right] \tag{33}$$

where $\epsilon^{\hat{W}}$ and $\epsilon^{U,W}$ are Gumbel shocks with variance $\rho_{W,U}$, and $\epsilon^{\hat{F}}$ and $\epsilon^{U,F}$ are Gumbel shocks with variance $\rho_{F,U}$.

The value of an active worker $W_t(\cdot)$ is then

$$W_t(z,w,s) = w + \beta\mathbb{E}_t\left[H_{t+1}^a(z',w',s)|z\right]. \tag{34}$$

where $H_{t+1}^a(\cdot)$ already encodes the next period optimal decisions of the firm and worker. Similarly, the value to an idle worker $F_t(\cdot)$ is given as

$$\begin{aligned} F_t(z,w,s) = b_t + \beta\mathbb{E}\Bigg[\sum_{\tilde{s}}\pi_F(s,\tilde{s})\Bigg\{&(1-\zeta f_{t+1}(\tilde{s}))H_{t+1}^i(z',w,s) \\ &+ \zeta f_{t+1}(\tilde{s})\int \max\left\{H_{t+1}^i(z',w,s) + \epsilon^H, W_{t+1}(z_0, w_{0t}^*, \tilde{s}) + \epsilon^{W,F}\right\} dG(z_0,\tilde{s})\Bigg\}|z\Bigg]. \end{aligned} \tag{35}$$

An idle worker receives a job offer in sector $\tilde{s}$ with probability $\zeta f_{t+1}(\tilde{s})$ and must decide whether to stay idle or accept the new job, as the second line in equation (35) shows. In this case, we assume the worker receives a shock ϵ^H to the value of being idle, and a shock $\epsilon^{W,F}$ to the value of accepting a new job. Both ϵ^H and ϵ^W follow a Gumbel distribution with variance ρ_{H,W_0}. Note that, conditional on remaining on an idle match, the value $H_{t+1}^i(\cdot)$ encodes the next period optimal decisions of the firm and worker. Consequently, the probability that an idle worker finds and accepts a new job, $f_t^i(\cdot)$, is given as

$$f_t^i(z,w,s) = \sum_{\tilde{s}}\pi_F(s,\tilde{s})\zeta f_t(\tilde{s})\int \mathbb{E}\left[\mathbb{I}\left\{H_t^i(z,w,s) + \epsilon^H < W_t(z_0, w_{0t}^*, \tilde{s}) + \epsilon^{W,F}\right\}\right] dG(z_0,\tilde{s}) \tag{36}$$

Finally, the value of being unemployed $U_t(s)$ is given as

$$U_t(s) = b_t + \beta \sum_{\tilde{s}} \pi_U(s,\tilde{s}) \Bigg\{ (1 - f_{t+1}(\tilde{s}))\, U_{t+1}(s) \\ + f_{t+1}(\tilde{s}) \int \mathbb{E}\left[\max\left\{W_{t+1}(z_0, w^*_{0t}, \tilde{s}) + \epsilon^W, U_{t+1}(s) + \epsilon^U\right\}\right] dG(z_0,\tilde{s}) \Bigg\} \tag{37}$$

An unemployed worker receives a job offer in sector $\tilde{s}$ with probability $f_{t+1}(\tilde{s})$ and must decide whether to stay unemployed or accept the new job, as the second line in equation (37) shows. In this case, we assume the worker receives a shock ϵ^U to the value of being unemployed, and a shock ϵ^W to the value of accepting a new job. Both ϵ^U and ϵ^W follow a Gumbel distribution with variance ρ_{U,W_0}.

Given the worker's value functions, we can compute the quit decisions, $\eta^a(\cdot)$ and $\eta^i(\cdot)$, as

$$\eta^a(z,w,s) = \mathbb{P}\left(\hat{W}_t(z,w,s) + \epsilon^{\hat{W}} < U_t(s) + \epsilon^{U,W}\right) \tag{38}$$

$$\eta^i(z,w,s) = \mathbb{P}\left(\hat{F}_t(z,w,s) + \epsilon^{\hat{F}} < U_t(s) + \epsilon^{U,F}\right) \tag{39}$$

Finally, let $p^F_t(z,w,s,z_0,\tilde{s})$ be the probability that a furloughed worker with productivity z and wage w in sector s will accept a job in sector $\tilde{s}$ when drawing an initial productivity z_0. Similarly, let $p^U_t(s,z_0,\tilde{s})$ be the probability that an unemployed worker attached to sector s will accept a job in sector $\tilde{s}$ when drawing an initial productivity z_0. Formally,

$$p^F_t(z,w,s,z_0,\tilde{s}) = \mathbb{P}\left(H^i_t(z,w,s) + \epsilon^H < W_t(z_0, w^*_{0t}, \tilde{s}) + \epsilon^{W,F}\right) \tag{40}$$

$$p^U_t(s,z_0,\tilde{s}) = \mathbb{P}\left(U_t(s) + \epsilon^U < W_t(z_0, w^*_{0t}, \tilde{s}) + \epsilon^W\right) \tag{41}$$

B.1.3 Measure evolution and equilibrium

We next discuss the measure evolution. To do so, we assume that productivity z and wages w are discrete variables that belong to grids $\vec{z} = \{z_1, z_2, \ldots, z_{N_z}\}$ and $\vec{w} = \{w_1, w_2, \ldots, w_{N_w}\}$, respectively. We assume discrete variables for two reasons: first, it simplifies the exposition, and, second, it is useful for the solution algorithm of the model, as we explain in Appendix B.3.

Let $\mu_t^W(z,w,s)$ be the measure of workers in an active match with productivity z, wages w, in sector s, at time t. Analogously define $\mu_t^F(z,w,s)$ to the measure of workers in an idle match. Let $\mu_t^U(s)$ be the measure of unemployed workers attached to sector s.

The measure of active workers $\mu_t^W(\cdot)$ evolves as

$$\begin{aligned}\mu_{t+1}^W(z,w,s) = &\sum_{\tilde z} \lambda \left(1-\eta_{t+1}^a(z,w,s)\right)\left(1-e_{t+1}^a(z,w,s)\right)\left(1-d_{t+1}(z,w,s)\right) P^a(z|\tilde z)\mu_t^W(\tilde z,w,s) \\ &+ \sum_{\tilde z,\tilde w}(1-\lambda)\left(1-\eta_{t+1}^a(z,w,s)\right)\left(1-e_{t+1}^a(z,w,s)\right)\left(1-d_{t+1}(z,w,s)\right)\mathbb{L}\left(w_{t+1}^*(z,s),w\right)P^a(z|\tilde z)\mu_t^W(\tilde z,\tilde w,s) \\ &+ \sum_{\tilde z}\left(1-f_{t+1}^i(z,w,s)\right)\left(1-\eta_{t+1}^i(z,w,s)\right)\left(1-e_{t+1}^i(z,w,s)\right) r_{t+1}(z,w,s)P^i(z|\tilde z)\mu_t^F(\tilde z,w,s) \\ &+ \sum_{\tilde z,\tilde w,\tilde s,\tilde z_-} \pi_F(\tilde s,s)\zeta f_{t+1}(s)p_{t+1}^F(\tilde z,\tilde w,\tilde s,z_0,s)\mathbb{I}\left(z_0=z\right)\mathbb{L}\left(w_{0t}^*,w\right)G(z_0,s)P^i(\tilde z|\tilde z_-)\mu_t^F(\tilde z_-,\tilde w,\tilde s) \\ &+ \sum_{\tilde s}\pi_U(\tilde s,s)f_{t+1}(s)p_{t+1}^U(\tilde s,z_0,s)\mathbb{I}\left(z_0=z\right)\mathbb{L}\left(w_{0t}^*,w\right)G(z_0,s)\mu_t^U(\tilde s)\end{aligned} \tag{42}$$

where function $\mathbb{L}$ computes a linear interpolation between grid pints in $\vec{w}$: $\mathbb{L}(x,w_i) = \mathbb{I}\left(x\in(w_{i-1},w_i]\right)\frac{x-w_{i-1}}{w_i-w_{i-1}}$ $\forall i=1,\ldots,N_w$. The first line in equation (42) is the measure of active workers who don't adjust wages, transition from productivity $\tilde z$ to z, and are in a match that remains active—that is, the worker doesn't quit ($\eta_{t+1}^a(\cdot)=0$), and are not fired neither furloughed ($e_{t+1}^a(\cdot)=0$ and $d_{t+1}(\cdot)=0$). The second line is the measure of active workers who adjust wages to w and also remain active. The third line is the measure of furloughed workers who don't find (or don't accept) a new job, don't leave their idle match ($\eta_{t+1}^i=0$) and recalled by the firm ($e_{t+1}^i(\cdot)=0$ and $r_{t+1}(\cdot)=1$). The fourth line is the measure of idle workers who find and accept a new job after transitioning from productivity $\tilde z$ to z. Finally, the fifth line is the measure of unemployed workers who find and accept a new job.

The measure of idle workers $\mu_t^F(\cdot)$ evolves as

$$\begin{aligned}\mu_{t+1}^F(z,w,s) = &\sum_{\tilde z}\lambda\left(1-\eta_{t+1}^a(z,w,s)\right)\left(1-e_{t+1}^a(z,w,s)\right)d_{t+1}(z,w,s)P^a(z|\tilde z)\mu_t^W(\tilde z,w,s) \\ &+ \sum_{\tilde z,\tilde w}(1-\lambda)\left(1-\eta_{t+1}^a(z,w,s)\right)\left(1-e_{t+1}^a(z,w,s)\right)d_{t+1}(z,w,s)\mathbb{L}\left(w_{t+1}^*(z,s)=w\right)P^a(z|\tilde z)\mu_t^W(\tilde z,\tilde w,s) \\ &+ \sum_{\tilde z}\left(1-f_{t+1}^i(z,w,s)\right)\left(1-\eta_{t+1}^i(z,w,s)\right)\left(1-e_{t+1}^i(z,w,s)\right)\left(1-r_{t+1}(z,w,s)\right)P^a(z|\tilde z)\mu_t^F(\tilde z,w,s)\end{aligned} \tag{43}$$

The first line in equation (43) is the measure of active workers who don't adjust wages, transition from productivity $\tilde z$ to z, and are in a match that turns idle—that is, the worker doesn't quit

($\eta^a_{t+1}(\cdot) = 0$), and the worker is furloughed ($e^a_{t+1}(\cdot) = 0$ and $d_{t+1}(\cdot) = 1$). The second line is the measure of workers who adjust their wage and are in a match that turns idle. The third line is the measure of furloughed workers who don't find (or don't accept) a new job, don't leave their idle match ($\eta^i_{t+1} = 0$) and are kept furloughed by the firm ($e^i_{t+1}(\cdot) = 0$ and $r_{t+1}(\cdot) = 0$).

The measure of unemployed workers $\mu^U_t(\cdot)$ evolves as

$$\begin{aligned}
\mu^U_{t+1}(s) = & \sum_{z,\tilde{z},w} \lambda \left[\eta^a_{t+1}(z,w,s) + (1-\eta^a_{t+1}(z,w,s))\, e^a_{t+1}(z,w,s)\right] P^a(z|\tilde{z})\mu^W_t(\tilde{z},w,s) \\
& + \sum_{z,\tilde{z},\tilde{w}} (1-\lambda)\left[\eta^a_{t+1}(z,w^*_{t+1}(z,s),s) + (1-\eta^a_{t+1}(z,w^*_{t+1}(z,s),s))\, e^a_{t+1}(z,w^*_{t+1}(z,s),s)\right] P^a(z|\tilde{z})\mu^W_t(\tilde{z},\tilde{w},s) \\
& + \sum_{z,\tilde{z},w} \Big(1 - f^i_{t+1}(z,w,s)\Big) \Big[\eta^i_{t+1}(z,w,s) + \Big(1-\eta^i_{t+1}(z,w,s)\Big)\, e^i_{t+1}(z,w,s)\Big] P^i(z|\tilde{z})\mu^F_t(\tilde{z},w,s) \\
& + (1 - f^u_t(s))\,\mu^U_t(s)
\end{aligned} \tag{44}$$

where $f^u_t(s)$ is the probability that an unemployed worker finds and accepts a job:

$$f^u_t(s) = \sum_{\tilde{s},z_0} \pi_U(s,\tilde{s}) f_t(\tilde{s}) p^U_t(s,z_0,\tilde{s}) G(z_0,s) \tag{45}$$

The first line equation (44) is the measure of active workers who don't adjust wages, transition from productivity $\tilde{z}$ to z, and are in a match that is terminated—that is, either the worker quits ($\eta^a_{t+1}(\cdot) = 1$), or the firm exits ($e^a_{t+1}(\cdot) = 1$). The second line is the measure of workers who adjust their wage and are in a match that is terminated. The third line is the measure of furloughed workers who don't find (or don't accept) a new job, and are in a match that is terminated—that is, either the worker quits ($\eta^i_{t+1}(\cdot) = 1$), or the firm exits ($e^i_{t+1}(\cdot) = 1$). Finally, the fourth line is the measure of unemployed workers who don't find a job.

B.2 Gumbel shocks: Some useful formulas

We layout some useful formulas when using Gumbel shocks in discrete choice models. In particular, assume there are $n = 1, \ldots, N$ choices with values $\{v_n\}_n$. The actual utility derived of choice n is $v_n + \epsilon_n$, where ϵ_n is a Gumbel shock with variance ρ. Let v^e be the expected value of the maximal choice, and p_n the probability of selecting choice n, that is

$$v^e = \mathbb{E}\left[\max_n \{v_n + \epsilon_n\}\right]$$
$$p_n = \mathbb{P}\left(v_n + \epsilon_n \geq \max_j \{v_j + \epsilon_j\}\right)$$

The values v^e an p_n have closed-form solution

$$v^e = \rho \ln\left(\sum_n \exp(v_n/\rho)\right) \tag{46}$$
$$p_n = \frac{\exp(v_n/\rho)}{\sum_j \exp(v_j/\rho)} \tag{47}$$

We use equations (46)-(47) to compute expected values and probability of outcomes in the model of Appendix B.1

B.3 Model solution

In this appendix we provide more details on the model solution.[21] We start by discussing the steady-state solution algorithm and then discuss the transition computation. Throughout the appendix, we drop the sub-index t when referring to steady-state objects.

B.3.1 Steady-State computation

To solve for the steady-state, we need to find the finding rate $f(s)$ that is consistent with free-entry condition. We explain how we do this next.

0. Set grid for wages $\vec{w} = \{w_1, w_2, \ldots, w_{N_w}\}$ and for productivity $\vec{z} = \{z_1, z_2, \ldots, z_{N_z}\}$. We use $N_w = 35$ and $N_z = 90$. Compute transition matrices $P^a(z'|z)$ and $P^i(z'|z)$ from discretizing the productivity process using Tauchen's method.

1. Guess the firm's value functions, $J(z, w, s)$ and $V(z, w, s)$, and the worker's value functions, $W(z, w, s)$, $F(z, w, s)$, and $U(s)$.

[21] All codes are available upon request.

2. Given value functions, compute firm's policies $e^a(z,w,s)$, $d(z,w,s)$, $e^a(z,w,s)$, and $r(z,w,s)$ using equations (26), (27), (28), and (29). Similarly, compute the worker quit decisions, $\eta^a(z,w,s)$ and $\eta^i(z,w,s)$, using equations (38) and (39). We can also compute the job-finding probability for an idle worker, $f^i(z,w,s)$, using equation (36).

3. Given the policies of step 2., update value functions. In particular, compute: the implied value of an active firm, $J^{\text{new}}(z,w,s)$, using equation (24); the implied value of an idle firm, $V^{\text{new}}(z,w,s)$, using equation (25), the implied value of an active worker; $W^{\text{new}}(z,w,s)$, using equation (34); the implied value of an idle worker, $F^{\text{new}}(z,w,s)$, using equation (35); and the implied value of being unemployed, $U^{\text{new}}(s)$, using equation (37). This step will require value functions outside the wage grid $\vec{w}$. We use linear interpolation when this occurs.

4. Compute the errors between value functions guessed and implied ones: $\mathcal{E}(J) = \max_{z,w,s}|J(z,w,s) - J^{\text{new}}(z,w,s)|$, $\mathcal{E}(V) = \max_{z,w,s}|V(z,w,s) - V^{\text{new}}(z,w,s)|$, $\mathcal{E}(W) = \max_{z,w,s}|W(z,w,s) - W^{\text{new}}(z,w,s)|$, $\mathcal{E}(F) = \max_{z,w,s}|F(z,w,s) - F^{\text{new}}(z,w,s)|$, and $\mathcal{E}(U) = \max_s|U(s) - U^{\text{new}}(s)|$. We determined that value functions converged if $\mathcal{E}(J)$, $\mathcal{E}(V)$, $\mathcal{E}(W)$, $\mathcal{E}(F)$, and $\mathcal{E}(U)$ are all below 1e-8. If value functions didn't converge, we go back to step 1. If value functions converged, we move to step 5.

5. Compute the stationary measures $\mu^W(z,w,s)$, $\mu^F(z,w,s)$, and $\mu^U(s)$. In particular, take an initial guess for the measures, and iterate iterate using equations (42), (43), and (44) until the measures converge. Denote $\mathcal{E}(\mu^W) = \max_{z,w,s}|\mu^W(z,w,s) - \mu^{W,\text{new}}(z,w,s)|$, $\mathcal{E}(\mu^F) = \max_{z,w,s}|\mu^F(z,w,s) - \mu^{F,\text{new}}(z,w,s)|$, and $\mathcal{E}(\mu^U) = \max_s|\mu^U(s) - \mu^{U,\text{new}}(s)|$. We determine measures converged if $\mathcal{E}(\mu^W)$, $\mathcal{E}(\mu^F)$, and $\mathcal{E}(\mu^U)$ are all below 1e-12.

6. Compute the implied finding probability $f^{\text{new}}(s)$. In particular, given $J(z,w,s)$, compute the probability of filling a vacancy $q(s)$ using equation (20). Given $q(s)$, compute market tightness using the matching function in equation (2). This yields, $\theta(s) = \left(-1 + \left(\frac{q(s)}{\phi}\right)\right)^{1/\eta}$. Finally, obtain the implied finding probability as $f^{\text{new}}(s) = q(s)\theta(s)$. We determined the model converged if the initial guess $f(s)$ is similar to the implied $f^{\text{new}}(s)$. In particular, the model converged if $|f(s) - f^{\text{new}}(s)| < $ 1e-5.

In practice, we calibrate the cost of posting vacancies κ and the matching efficiency ϕ, to match our targeted job-filling rate q and job-finding rate f. In turn, for the steady-state computation, we do not need to iterate on the job-finding rate, but only to solve firms' and workers' value functions.

B.3.2 Transition computation

To solve for the transition, we need to find the sequence of finding rates $\{f(s)\}_{s,t}$ that is consistent with free-entry condition each period. We do this using a shooting algorithm. In particular, we assume all equilibrium objects in the model are back to steady-state by period $\bar{T} = 120$. This gives enough periods for the model to converge, given that we assume all shocks disappear after 70 periods. Details follow.

1. Guess a sequence of finding rates $\{f(s)\}_{s,t}$.

2. Solve for value functions and policies backwards. In particular, we set value functions in the last period to the steady-state values: $J_{\bar{T}}(z,w,s) = J(z,w,s)$, $V_{\bar{T}}(z,w,s) = V(z,w,s)$, $W_{\bar{T}}(z,w,s) = W(z,w,s)$, $F_{\bar{T}}(z,w,s) = F(z,w,s)$, and $U_{\bar{T}}(s) = U(s)$. Then, given $t+1$ functions $\{J_{t+1}(\cdot), V_{t+1}(\cdot), W_{t+1}(\cdot), F_{t+1}(\cdot), U_{t+1}(\cdot)\}$, compute $t+1$ policies $\{e^a_{t+1}(\cdot), d_{t+1}(\cdot), e^i_{t+1}(\cdot), r_{t+1}(\cdot), \eta^a_{t+1}(\cdot),$ and the probability $f^i_{t+1}(\cdot)$. Then, we can solve for period t functions $\{J_t(\cdot), V_t(\cdot), W_t(\cdot), F_t(\cdot), U_t(\cdot)\}$ using equations (24), (25), (34), (35), and (37). This backward iteration yields values and policy functions for periods $t = 0, 1, \dots, \bar{T}$.

3. Compute measure forward. In particular, we initialize measures at $t = 0$ at their steady-state values: $\mu^W_0(z,w,s) = \mu^W(z,w,s)$, $\mu^F_0(z,w,s) = \mu^F(z,w,s)$, and $\mu^U_0(s) = \mu^U(s)$. The we solve $\{\mu^W_t(\cdot), \mu^F_t(\cdot), \mu^U_t(\cdot)\}$ forward using equations (43), (42), and (44).

4. Compute implied finding probability $f^{\text{new}}_t(s)$. In particular, given $J_t(z,w,s)$, compute the probability of filling a vacancy $q_t(s)$ using equation (20). Given $q_t(s)$, compute market tightness using the matching function in equation (2). This yields, $\theta_t(s) = \left(-1 + \left(\frac{q_t(s)}{\phi}\right)\right)^{1/\eta}$. Finally, obtain the implied finding probability as $f^{\text{new}}_t(s) = q_t(s)\theta_t(s)$.

5. Compute the error with the new finding rate: $\mathcal{E}(f) = \max_{t,s}|f_t(s) - f^{\text{new}}_t(s)|$. We determine

the transition converged if $\mathcal{E}(f) < $ 1e-4. Otherwise, update the guess $\{f(s)\}_{s,t}$ and go to step 2.

C Model Simulation: Additional Results

Table 7 Calibration: Internal Parameters

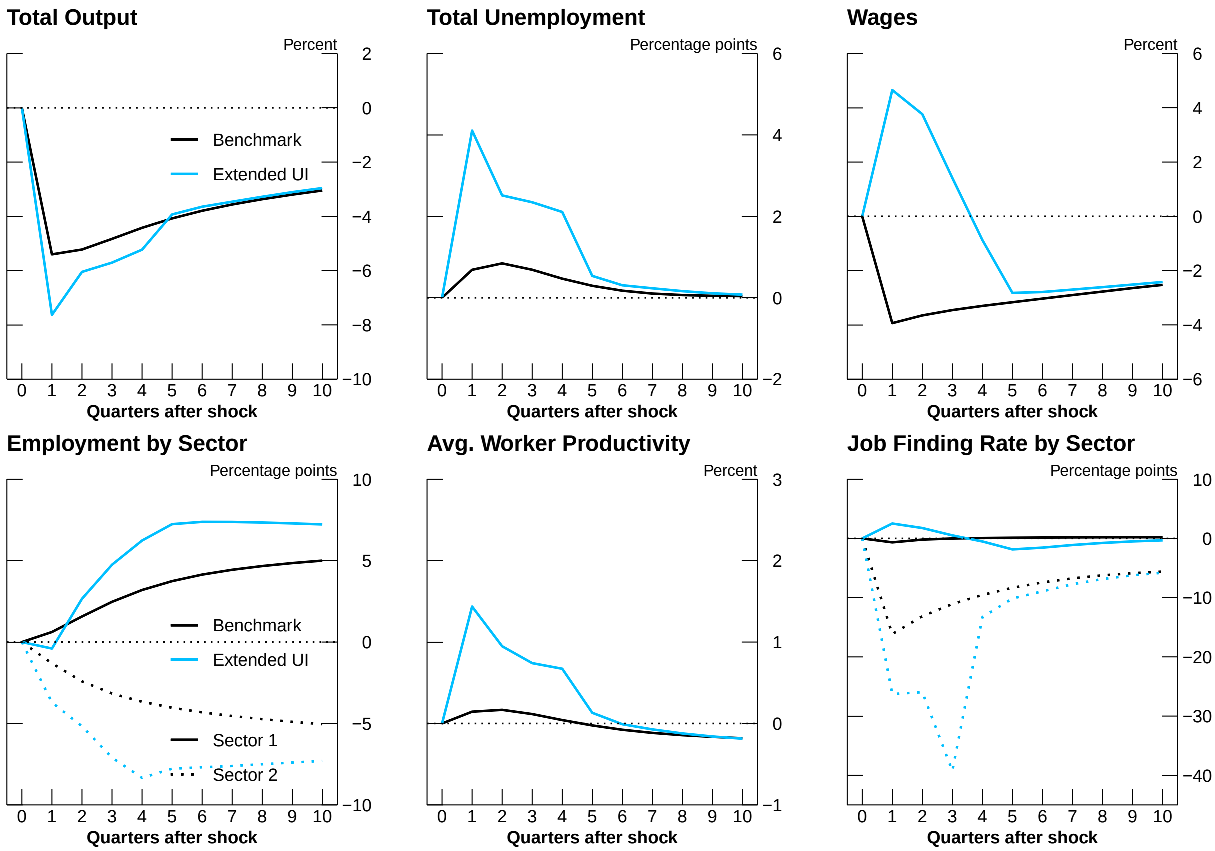
Parameter	Description	Flex value	Rigid value
δ_F	Monthly exogenous separation rate: furlough	0.061	0.987
$\rho_{J,V}$	Gumble shock firm: active/inactive	0.075	0.020
$\rho_{M,0}$	Gumble shock firm: remain open/close	0.066	0.071
$\rho_{W,U}$	Gumble shock worker: remain employed/quit	0.078	0.017
$\rho_{F,U}$	Gumble shock worker: remain furloughed/quit	0.120	0.044
ρ_{H,W_0}	Gumble shock worker: remain employed/accept new job	0.073	0.027
ρ_{U,W_0}	Gumble shock worker: remain unemployed/accept new job	0.113	0.027

C.1 Experiment 2: Long-Lived Recession

C.1.1 Long-Lived Recession: UI Extension in a Flexible Labor Market

Our second experiment explores how the persistence of the shock interacts with the policies. We set $\Delta_x = 0.10$ and $\rho = 0.983$ so the drop is much smaller but with a sluggish recovery. We compare the response of the economy under a smaller increase in the replacement rate compared to the short-lived recession but for equal expenditures (as it now lasts for 12 months) and a benchmark economy with no additional policies. The cost of the policy still accounts for around 1 percent of the annual GDP in the steady state. We present the results in Figure 14. As in the short-lived recession, the UI policy continues to increase unemployment and leads to a larger contraction in output, though it does not produce a faster recovery. Reallocation is rapid and persistent. A WS policy (shown in Figure 15) would continue to limit the increase in unemployment but limit reallocation when an industry experiences a long-lasting shock. The welfare analysis, presented in Table 8, confirms our analysis in section 7 that the UI extension generates significant profit losses that result in welfare loss compared with the benchmark policy.

Figure 14 Benchmark and UI Policy Response in a Flexible Economy (Long-Lived recession)

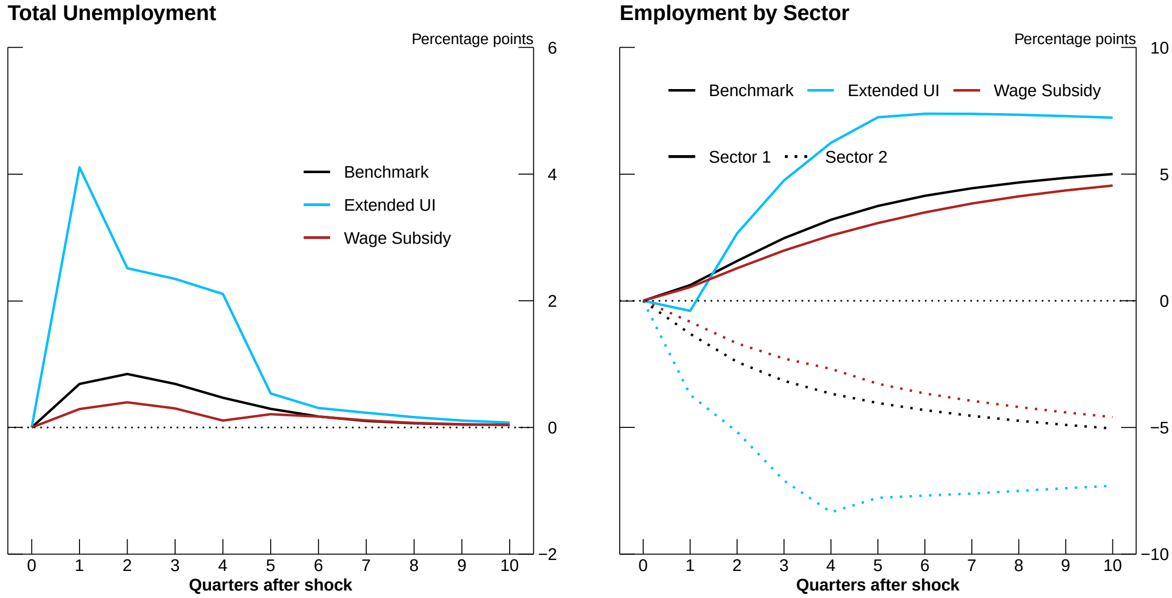


Note: Sector 1 refers to the unaffected sector, and sector 2 is the sector affected by the shock. All variable responses are expressed as deviations from the steady state.

C.1.2 Long-Lived Recession: WS in a Rigid Labor Market

We now analyze the differences for a similar recession in a rigid labor market. We set $\Delta_x = 0.125$ and $\rho = 0.983$, and in this case, we compare the economy's response under a 12-month WS policy in the affected sector and the benchmark economy with no additional policies. The policy's cost accounts for around 1 percent of the annual GDP. Figures for these results are presented in Figure 16 and Figure 17. As in the short recession, the WS policy limits job destruction, leading to a smaller contraction in output and a contained unemployment rate. However, the lower job-finding rate makes the recession even more persistent despite a smaller increase in unemployment relative to the flexible economy. Reallocation toward the unaffected sector is more sluggish relative to the

Figure 15 Flexible Economy: Counterfactual Policies in the Long-Lived Recession



Note: Sector 1 refers to the unaffected sector, and sector 2 is the sector affected by the shock. All variable responses are expressed as deviations from the steady state.

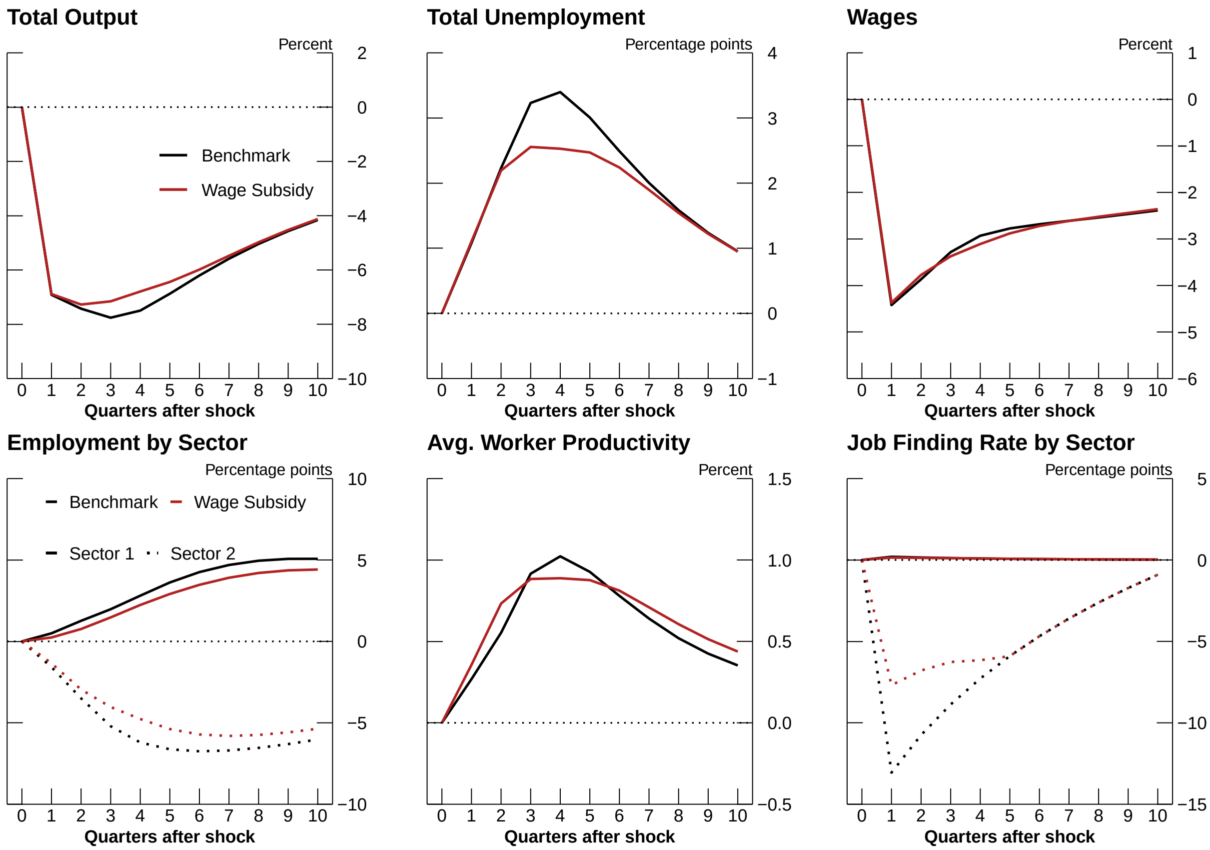
benchmark policy. A counterfactual UI policy initially produces higher unemployment but induces a faster recovery than the benchmark. Overall, firms' losses under the UI policy are higher, making the WS policy a preferred option.

Table 8 Welfare Comparison: Percentage Loss Relative to Steady State

	Flexible economy			Rigid economy		
	No Policy	UI	WS	No Policy	UI	WS
$\mathcal{P}(C)$	−7.16%	−4.39%	−7.05%	−7.87%	−6.44%	−7.62%
$\mathcal{P}(\Pi)$	−9.46%	−11.70%	−8.34%	−10.29%	−10.88%	−8.97%
$\mathcal{P}(P)$	0.24%	1.17%	1.17%	1.07%	1.41%	1.90%
$\mathcal{W}$	−16.85%	−17.27%	−16.56%	−19.23%	−18.72%	−18.50%

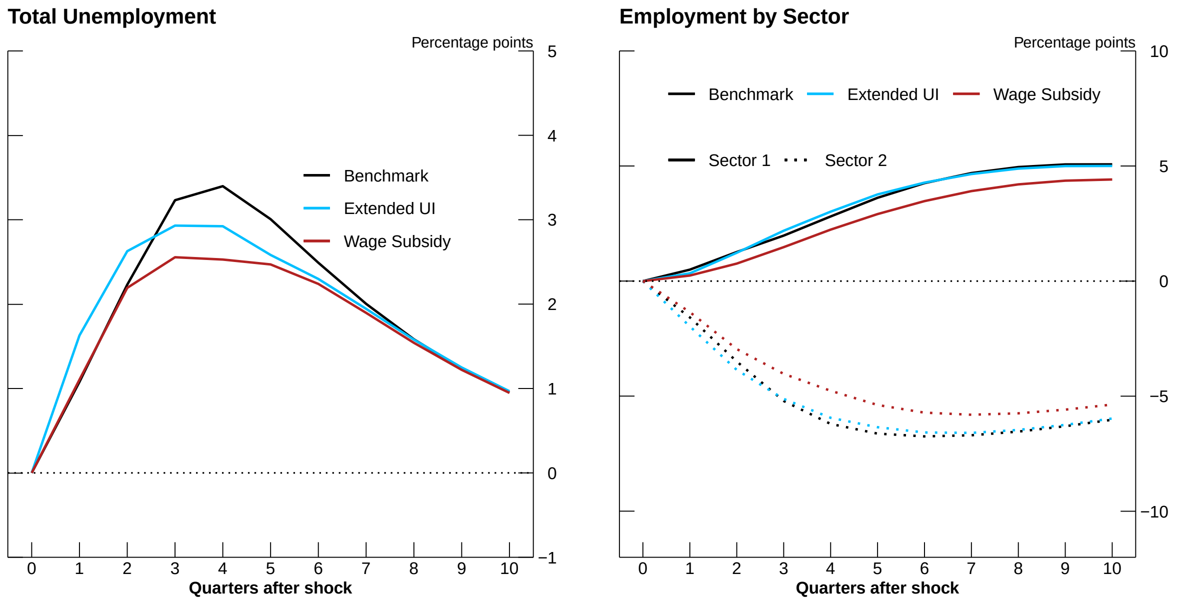
Note: Welfare gains $\Delta\mathcal{W}$ relative to steady-state. We report the components of $\Delta\mathcal{W}$: workers' consumption ($\mathcal{P}(C)$), firms' profits ($\mathcal{P}(\Pi)$), and policy cost ($\mathcal{P}(P)$). All numbers are expressed in terms of annual steady-state GDP. Columns may not add up due to rounding.

Figure 16 Benchmark and WS Response in a Rigid Economy (Long-Lived Recession)



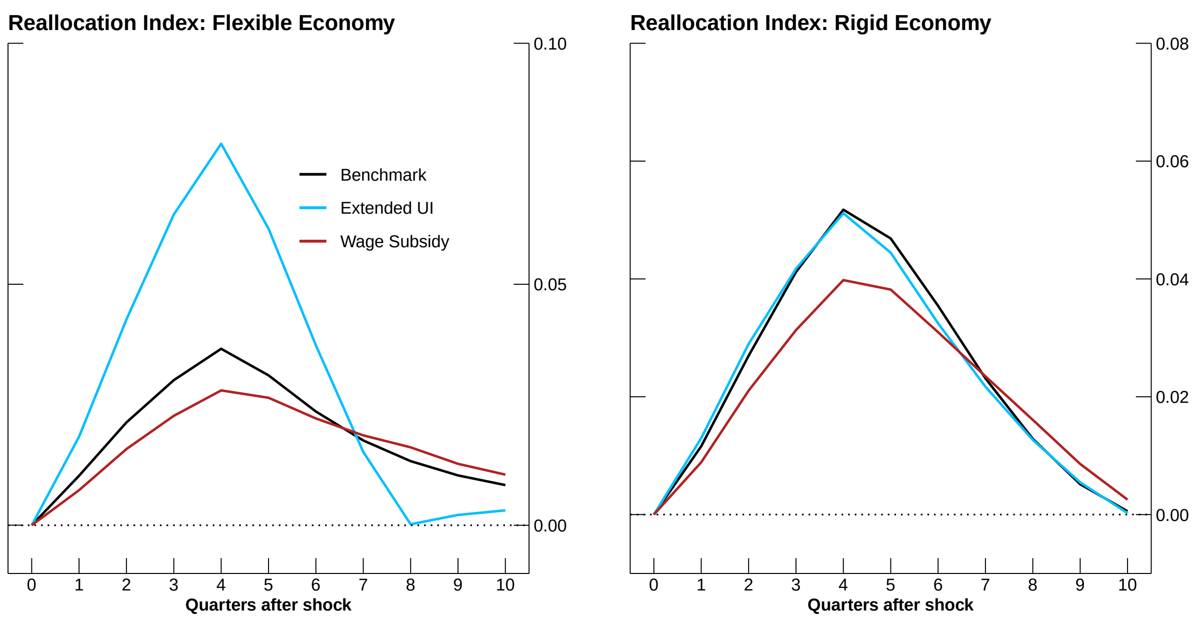
Note: Sector 1 refers to the unaffected sector, and sector 2 is the sector affected by the shock. All variable responses are expressed as deviations from the steady state.

Figure 17 Rigid economy: Counterfactual Policies in the Long-Lived Recession



Note: Sector 1 refers to the unaffected sector, and sector 2 is the sector affected by the shock. All variable responses are expressed as deviations from the steady state.

Figure 18 Chodorow-Reich and Wieland's Index: Model with a Long-Lived Recession



Note: The reallocation index is calculated using year-over-year growth rates of quarterly sectoral employment.

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