Optimal Unemployment Insurance with Multiple Applications*

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Abstract

This paper examines how unemployment transfers should be allocated over the business cycle. When risk-averse workers can submit multiple applications, the optimal UI policy is countercyclical. In contrast, optimal policy in a standard search model featuring one-to-one matching is procyclical. In the latter, more generous UI during a downturn discourages search effort, dampening job creation. In the former, decreased search effort aids job creation. Because firms cannot coordinate and commit to not making the same worker an offer, lower search effort by reducing the number of applications sent mitigates this coordination friction. This in turn boosts job creation incentives, supporting employment outcomes.

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1 Introduction

Economists have long debated the optimal allocation of unemployment insurance (UI). Despite the extensive literature covering this topic, there is little consensus on the optimal cyclicality of unemployment benefits. At the heart of this disagreement are the two-fold effects from increasing unemployment benefits. When unemployment risk is uninsurable and workers are risk-averse, increasing UI helps with consumption smoothing. Increasing UI, however, also affects workers' job search incentives and can discourage workers from exerting high levels of search effort. The degree of search by workers can affect the firm's incentive to create jobs through its impact on the firm's ability to hire workers. The form that search effort takes, however, is crucial for whether the optimal allocation of benefits is procyclical or countercyclical. In this paper, I highlight that when increased worker search effort takes the form of submitting more applications and contacting more vacancies, the optimal allocation of UI over the business cycle is countercyclical. Notably, this optimal countercyclicality of UI is derived in a parsimonious random search model where the only difference from the standard Diamond-Mortensen-Pissarides (DMP) model is that workers can submit multiple applications.

In my model, workers can submit multiple applications. Each application is sent to a different vacancy. The amount of search effort exerted positively affects the number of applications a worker can send on average. More applications submitted naturally imply more vacancies contacted by the worker, and thus also a higher likelihood of receiving more than one offer, holding all else constant. Search effort, however, is costly and workers face higher disutility when they apply to more jobs. Firms, at the same time, can receive multiple applicants. Because a job is a single-firm worker pair, a firm selects and makes one offer to a candidate from its applicant pool. At the time of making offers, firms are unable to coordinate and cannot avoid the risk of making offers to the same candidate. Because a worker can only work at one job, this means that a worker approached by more than one firm rejects some offers. The acceptance rate of workers then plays a key role in affecting the firm's hiring probability. While greater search effort by workers leads to more applications sent, and thus improves the firm's probability of meeting at least one applicant, a higher number of applications submitted can also reduce the worker's acceptance probability as the worker rejects offers more often when she can choose from more options. Consequently, job creation incentives by the firm can actually be diminished when workers exert high levels of search effort and lower their acceptance probabilities.

Crucially, this coordination failure and inability of firms to not make offers to the same candidate is key for optimal UI to be countercyclical. In my model, the utilitarian Ramsey planner solves a date 0 problem and seeks to maximize expected discounted lifetime utility of all households. The key instrument that the planner has at its disposal to affect welfare is the generosity of unemployment insurance. Workers are risk-averse and are exposed to uninsurable unemployment risk. The planner, thus chooses the level of UI so as to 1) provide insurance to workers, 2) affect job search incentives and 3) boost job creation by balancing the opposing effects that search effort has on firms' hiring probabilities. In response to a negative productivity shock, the planner raises UI in a recession and keeps the level of UI elevated for the duration of the shock. Because higher levels of UI help to close the consumption gap between the employed and unemployed, workers do not need to self-insure as much against unemployment, and thus they reduce search effort. Lower levels of search effort not only reduce the disutility faced by the unemployed, but help to mitigate the aforementioned coordination failure among firms that are making offers. This in turn bolsters job creation incentives among firms and mitigates the

decline in the job-finding rate. Despite the fact that increases in UI discourage search effort, the planner precisely chooses to raise unemployment benefits during a downturn as it achieves both the dual goal of providing insurance and supporting employment outcomes.

These results stand in stark contrast to what a planner would choose when workers can only submit one application and firms can only receive one applicant. Solving the same planner's problem but in an economy where meetings are only one-to-one, I show that the optimal UI policy in a DMP economy[1] is largely procyclical. The planner in this case only raises benefits on impact but cuts them immediately thereafter and keeps them persistently depressed for the duration of the recession. The persistent cut in UI hastens the recovery in search effort and thus boosts vacancy creation, as firms observe a higher rate of meeting workers when workers search harder. This result echoes the findings of previous papers such as Nakajima (2012), Mitman and Rabinovich (2015) and Gervais et al. (2022) who find that optimal UI policy is procyclical. A key difference between these papers and my model concerns the fact that in the previous papers, workers always accept the offers they receive. This is because in the standard DMP model, if a worker rejects an offer, her alternative is unemployment. In my model, a worker can be presented with multiple offers at the same time. Rejecting one offer does not necessarily send her back into unemployment. Since acceptance rates are always equal to 1 in the standard DMP model, higher search effort by the worker only has the effect of raising the rate at which firms meet workers and thus the firm's hiring probability. In comparison, higher search effort in my model has two opposing effects on the firm's ability to hire through its impact on both firm meeting rates *and* worker acceptance probabilities.

Finally, I verify how the results change in the baseline model (where workers can submit multiple applications) and the DMP model (where meetings are one-to-one) when wages are assumed to be more flexible. Notably, greater flexibility in wages implies that the consumption gap is smaller during a downturn, as deeper wage declines help to absorb a larger part of the negative productivity shock in a recession. When consumption gaps are smaller, the insurance motive of the planner is reduced, and as such the focus turns more toward supporting employment outcomes. In the baseline model, higher degrees of wage flexibility reduce the magnitude of the increase in UI provided during a downturn but do not alter the direction of unemployment benefits. Optimal UI is still countercyclical. In the DMP model, greater wage flexibility not only reduces the magnitude of the *initial* increase in UI provided on impact, but also reverses the sign at date 1. In this case, when wages are highly flexible, the reduced consumption gap between the employed and unemployed, and thus the reduced need for insurance, actually leads the planner to cut benefits from the very beginning and to keep benefits depressed throughout the entire recession. In other words, optimal UI policy in the DMP model becomes completely procyclical as the planner chooses to cut benefits to order to induce more search effort to raise employment outcomes. In contrast, the optimal policy in our baseline model remains countercyclical even as the degree of wage flexibility increases. Again, this result is driven by the fact that more search effort need not beget higher job-creation when worker acceptance rates vary negatively with search effort.

That higher search effort by a worker results in more applications being sent is a natural starting point. In recent work, Birinci et al. (2024) show that the median number of applications submitted by workers has doubled over time. While the literature has traditionally modeled that increases in search effort raise the probability of contacting a vacancy, most workers submit

[1] I use the term DMP economy to refer to the standard search model where meetings are one-to-one.

applications to more than one vacancy at a time.[2] Thus, modeling search effort as affecting the number of applications submitted allows me to present a microfounded framework to analyze how the allocation of UI impacts the welfare of individuals. Further, Davis and de la Parra (2024) not only document that job-seekers tend to contact many vacancies at a time, they also note that vacancy durations are fairly inresponsive to measures of labor market tightness, where the latter is measured as either vacancies per job-seeker or the ratio of total vacancies to total applications. This finding is inconsistent with the predictions of the standard DMP model. The framework with multiple applications and the consequential role of worker acceptance rates provides an avenue for rationalizing why vacancy durations are not observed to lengthen with tighter labor markets. Given the pertinent role of many-to-many meetings in the search process in data, I argue that it is important to examine optimal UI policy in an environment where workers can submit multiple applications.

Related Literature A large and extensive literature has focused on the optimal allocation of UI. In a seminal paper, Baily (1978) characterized the optimal UI allocation and showed how an optimal UI policy is one that balances the marginal benefit of consumption smoothing against the marginal cost of discouraged search and higher unemployment. The optimal UI policy in Baily (1978) was derived under a partial equilibrium setting with exogenous job-finding rates. Since then, papers such as Nakajima (2012), Mitman and Rabinovich (2015), Landais et al. (2018), Pei and Xie (2021) and Gervais et al. (2022) have re-visited this question through a search-and-matching framework, allowing the job-finding rate to respond to the level of UI. In these models, higher UI diminishes search effort and thus the likelihood that a firm meets a worker. A lower meeting rate reduces the incentive to create jobs. Notably, Nakajima (2012), Mitman and Rabinovich (2015), and Gervais et al. (2022) all find optimal UI policy to be procyclical. Pei and Xie (2021) relax the assumption of perfect commitment by the government and also find a role for procyclical UI. Separately, Landais et al. (2018) examine optimal UI through a job-rationing model with decreasing returns to scale in production, and find optimal UI to be countercyclical. My paper adds to this discussion on the optimal cyclicality of UI by allowing endogenous search effort to affect the number of applications a worker can send. The previous literature thus far has examined this question exclusively under the lens of one-to-one matching models.

This paper is also related to the growing literature on multiple applications. Many papers within this literature have highlighted that the decentralized search economy is typically inefficient. Fixing the number of applications a worker can send, Albrecht et al. (2006) and Galenianos and Kircher (2009) highlight that in these models, firms tend to create too many vacancies. In doing so, they fail to recognize that the more vacancies available for a worker to contact, the greater the likelihood that the worker may have more than one offer and this worsens the coordination problem among firms. Gautier et al. (2016) and Gautier and Moraga-Gonzalez (2018) endogenize the number of applications sent by workers and depending on the size of the application cost, workers can search too much or too little relative to the social planner's outcome. Similarly, Gautier and Wolthoff (2009) highlight that the number of matches formed is non-monotonic in the number of applications sent. This non-monotonicity makes it non-obvious when increases in applications weighs on employment and when it instead supports employment outcomes. Worker application behavior is inefficient as workers do not internalize congestion externalities, nor the coordination problem they impose on firms in the offer process. Notably,

[2] Faberman and Kudlyak (2019) document that workers send about 1.9 applications per week. Depending on the time period, Birinci et al. (2024) document that workers send between 2.7 to 7 applications per month.

much of the analysis in search models with multiple applications tends to focus on steady state analysis. Wolthoff (2018) is an exception as he focuses on how hiring standards vary over the business cycle when workers can submit multiple applications. To my knowledge, however, this is the first paper to analyze how optimal UI should be conducted over the business cycle when workers can send multiple applications. Further, this paper provides a novel reason for why optimal UI should be countercyclical beyond the usual need to provide insurance to workers during a downturn. In trying to balance insurance provision and supporting employment outcomes, optimal policy must take into consideration the non-monotonic relationship between matches formed and the number of applications sent.

The rest of the paper is organized as follows. Section 2 outlines the model and planning problem. Section 3 calibrates the decentralized economy to standard labor market moments while Section 4 discusses the quantitative findings. Section 5 provides some sensitivity analysis while Section 6 concludes.

2 Model

2.1 Environment

Time is discrete. The economy comprises of a unit mass of infinitely-lived workers who discount the future with discount factor β. There are three types of agents in the economy: workers, firms and a government. Workers are risk-averse, and can be either employed or unemployed. If employed, workers earn a wage $w(y_t)$ which varies exogenously with productivity, y_t. If unemployed, workers engage in home production and produce $z(y_t)$. Both wages, $w(y_t)$, and home production, $z(y_t)$, are increasing in productivity. Further, employed individuals are subject to a proportional labor income tax τ_t, while unemployed workers received a transfer b_t. There is no savings technology implying that individuals consume their income.

A job is a single firm-worker pair. Output per employed worker is equal to aggregate productivity y_t, which evolves according to the following process:

$$\ln y_t = \rho \ln y_{t-1} + \epsilon_t \tag{1}$$

where the shock ϵ_t is drawn from a normal distribution with mean 0 and standard deviation σ_ϵ. Let $y^t = \{y_0, y_1, \ldots, y_t\}$ denote the history of shocks up to date t. Matched firm-worker pairs continue to produce until they experience an exogenous separation shock that occurs with probability δ^s.

Search Search is random. Every period, firms can choose to enter the labor market by posting a vacancy at cost κ. Similarly, at a cost of $\chi(\xi_t)$, unemployed individuals can in every period choose how much effort, ξ_t, to expend searching the labor market. Search effort is unobservable, and the amount of effort, ξ_t, affects the number of applications a worker can submit, and thus the number of vacancies a worker can contact. The number of applications, a, that a worker can send, is a random variable drawn from a Poisson distribution where the parameter governing the distribution is given by the worker's search effort ξ_t. Since the average number of applications drawn from a Poisson distribution is equal to ξ_t, this implies that higher search effort on average leads to more applications being submitted and more vacancies being contacted. Consequently, the probability that a worker sends exactly a applications given that she expands search effort ξ_t is given by:

$$p\left(a; \xi_t\right) = \frac{1}{a!} \xi_t^a \exp\left(-\xi_t\right) \tag{2}$$

I assume that each application submitted by a worker goes to a separate vacancy.

In the same vein, the number of applicants that visit a firm is also a random variable. Note that on average, the probability that a worker sends an application to a particular firm is given by ξ_t/v_t where v_t is the measure of vacancies. Let n_t be the measure of employed individuals at the start of period t and $1-n_t$ the measure of unemployed at the beginning of t. Define the mean number of applicants per vacancy as $\lambda_t = \xi_t(1-n_t)/v_t$. Since λ_t represents the average queue length at a vacancy, it follows that the number of applicants j that a firm receives is drawn from a Poisson distribution with parameter λ_t. Thus, the probability that a firm receives j applicants in period t is given by:

$$q(j;\lambda_t) = \frac{1}{j!}(\lambda_t)^j \exp(-\lambda_t)$$

Accordingly, the probability a firm has zero applicants is given by $q(0;\lambda_t) = \exp(-\lambda_t)$ and the probability that the firm has at least one applicant is given by its complement $1-q(0;\lambda_t) = 1-\exp(-\lambda_t)$.

Timing At the beginning of each period, productivity y_t is realized. Firms choose whether or not to post a vacancy, and workers choose how much search effort, ξ_t, to expend. Next, separation shocks occurs. Workers newly separated from their jobs must wait at least one period before they can search the labor market. Following this, workers realize the number of applications a they can submit and contact separate vacancies with each of their applications. Contacted firms then choose and make an offer to a candidate from their pool of applicants. A firm can only make one offer at a time and all firms make offers simultaneously. I assume there is no recall as is standard in the literature.[3] This implies that firms who choose to make an offer to a particular candidate cannot return to their applicant pool if their offer is rejected. Workers who receive offers can choose whether to accept or reject these offers. If the worker accepts an offer, the firm and worker form a match and move to the production stage.

2.2 Worker value functions

Unemployed At the start of period t, an unemployed worker who observes aggregate productivity y_t must choose how much search effort ξ_t to exert that period. Denote the probability the worker finds a job as $f(\xi_t,\lambda_t)$, the details of which I will elaborate on in Section 2.2.1. While all values and choice variables depend on the history of shocks y^t, for ease of exposition, I will suppress the dependence on y^t. Then the value of an unemployed worker can be written as:

$$\begin{aligned} V_t^U &= \max_{\xi_t} -\chi(\xi_t) + f(\xi_t,\lambda_t)\left[u\left([1-\tau_t]w(y_t)\right) + \beta\mathbb{E}_t V_{t+1}^E\right] \\ &\quad + [1-f(\xi_t,\lambda_t)]\left[u\left(z(y_t)+b_t\right) + \beta\mathbb{E}_t V_{t+1}^U\right] \end{aligned}$$

With probability $f(\xi_t,\lambda_t)$, the unemployed worker finds a job and becomes employed. In this case, she enjoys current utility from after-tax wage income, $u([1-\tau_t]w(y_t))$, and gets the expected value of an employed worker, represented by $\mathbb{E}_t V_{t+1}^E$. With probability $1-f(\xi_t,\lambda_t)$, the worker remains unemployed and in this case, she enjoys current utility from home-production and the transfer, $u(z(y_t)+b_t)$, and gets the expected continuation value from being unemployed.

[3] See for example Albrecht et al. (2006), Galenianos and Kircher (2009),Gautier and Wolthoff (2009),Gautier and Moraga-Gonzalez (2018),Albrecht et al. (2020) and Birinci et al. (2024).

Employed At the start of period t, the employed individual suffers a separation shock with probability δ^s, and becomes unemployed. With probability $1-\delta^s$, she remains employed and receives utility from after-tax income and the continuation value of being employed. The value of an employed worker is thus given by:

$$V_t^E = (1-\delta^s)\left[u\left(\left[1-\tau_t\right]w(y_t)\right)+\beta\mathbb{E}_t V_{t+1}^E\right]+\delta^s\left[u\left(z(y_t)+b_t\right)+\beta\mathbb{E}_t V_{t+1}^U\right]$$

2.2.1 Probability of finding a job

At this point, it is useful to elucidate how the worker's probability of finding a job is derived. All jobs in our model pay a wage $w(y_t)$. Then so long as the after-tax wage is greater than the income from being unemployed, i.e., $(1-\tau_t)w(y_t) \geq z(y_t)+b_t$, a worker finds a job as long as at least one of her applications yields an offer.

What is the probability a worker receives an offer? Consider first a worker who has applied to a firm with j other applicants. Since all workers are identical, the firm randomizes when it chooses a candidate and the worker at this particular firm receives an offer with probability $1/(j+1)$. Since the mean number of applicants per vacancy is given by λ_t, this implies that the number of other competitors a worker can expect to face at a vacancy is also drawn from a Poisson distribution with parameter λ_t. Aggregating across all the possible numbers of other applicants at a firm, the probability that a single application yields a job offer is given by:[4]

$$\mathcal{P}(\lambda_t) = \frac{1}{\lambda_t}\left[1-\exp\left(-\lambda_t\right)\right] \tag{3}$$

Further, let $\phi(a;\lambda_t)$ be the probability a worker who submitted a applications finds a job:

$$\phi(a;\lambda_t) = 1-\left[1-\mathcal{P}(\lambda_t)\right]^a$$

where $1-\mathcal{P}(\lambda_t)$ is the probability of no offer and thus $\phi(a;\lambda_t)$ represents the probability of at least one offer from a worker's a applications. Since $\phi(a;\lambda_t)$ only represents the job-finding probability of a worker who has submitted a applications, to derive the aggregate job-finding probability, I take a weighted sum across all the possible number of applications a worker can submit, where the weights are given by $p(a;\xi_t)$.

$$f(\xi_t,\lambda_t) = \sum_{a=0}^{\infty} p(a;\xi_t)\phi(a;\lambda_t) \tag{4}$$

Equation 4 makes clear that the job-finding probability depends on both how hard an individual searches, ξ_t, and also on how congested the labor market is, as represented by the mean number of applicants per vacancy, λ_t.

2.3 Firm value functions

Operating firm At the start of period t, the operating firm experiences a separation shock with probability δ^s and separates from the worker. In this case, the firm is vacant in the current period and produces zero output. He continues into the next period with the expected value of a vacancy. With probability $1-\delta^s$, the firm retains the worker, produces current profit $y_t - w(y_t)$ and continues into the next period as an operating firm. Thus, the value of the firm is given as:

$$V_t^J = (1-\delta^s)\left[y_t - w(y_t) + \beta\mathbb{E}_t V_{t+1}^J\right] + \delta^s\beta\mathbb{E}_t V_{t+1}^V$$

[4]Using Maclaurin's expansion, one can show that $\mathcal{P}(\lambda_t) = \sum_{j=0}^{\infty}\frac{1}{j+1}q(j;\lambda_t) = \frac{1}{\lambda_t}\left[1-\exp\left(-\lambda_t\right)\right]$

Vacancy A firm that posts a vacancy pays κ. Unlike the standard DMP model, hiring probabilities depend not just on meeting rates, but also acceptance probabilities. The meeting rate is given by the probability that the firm has at least one applicant, i.e., $1 - q(0; \lambda_t)$. To derive the acceptance probability, consider first an individual who has submitted a applications. Further, let i denote the number of other offers the individual has received. The firm does not know how many other offers a worker has received. Thus, the acceptance probability of an individual who has submitted a applications is equal to:

$$\Gamma(a; \lambda_t) = \sum_{i=0}^{a-1} \binom{a-1}{i} \mathcal{P}(\lambda_t)^i [1 - \mathcal{P}(\lambda_t)]^{a-1-i} \frac{1}{i+1}$$

In words, the number of offers the worker receives out of her a applications follows a binomial distribution. The first term $\binom{a-1}{i}\mathcal{P}(\lambda_t)^i [1 - \mathcal{P}(\lambda_t)]^{a-1-i}$ describes the probability that the worker has received i other offers. Since all firms pay workers the same wage, the worker randomizes and accepts this particular firm's offer with probability $1/(i+1)$. The sum over $i = 0$ to $i = a - 1$ considers all the possible other offers a worker who submitted a applications might receive. Applying the binomial theorem, the acceptance probability of a worker who submitted a applications can be re-written as:

$$\Gamma(a; \lambda_t) = \frac{(1 - [1 - \mathcal{P}(\lambda_t)]^a)}{a\mathcal{P}(\lambda_t)} \tag{5}$$

At the time of vacancy posting, a firm does not know how many applications a worker might submit, thus in expectation, the acceptance probability of a worker is given by:

$$\Gamma(\xi_t, \lambda_t) = \sum_{a=1}^{\infty} p(a, \xi_t)\Gamma(a; \lambda_t) \tag{6}$$

Equation 6 shows that the acceptance probability depends on both the worker's search effort and the mean number of applicants per vacancy, as search effort affects the number of applications a worker can send submit while the average queue length affects the probability of offers. Both the ability to contact many vacancies and the likelihood of having other offers affects the rate at which individuals accept a job.[5]

Having derived the meeting and acceptance probabilities, the value of a vacancy is given by:

$$V_t^V = -\kappa + \Gamma(\xi_t, \lambda_t)[1 - q(0; \lambda_t)]\left[y_t - w(y_t) + \beta\mathbb{E}_t\left(V_{t+1}^J - V_{t+1}^V\right)\right] + \beta\mathbb{E}_t V_{t+1}^V$$

With probability $\Gamma(\xi_t, \lambda_t)[1 - q(0; \lambda_t)]$, the firm hires a worker and becomes an operating firm. With probability $1 - \Gamma(\xi_t, \lambda_t)[1 - q(0; \lambda_t)]$, the firm remains vacant, produces nothing in the current period and continues into next period with the value of a vacancy. There is free entry of firms into the labor market, firms enter until value of a vacancy is equal to zero.

[5]The reader might wonder why the acceptance probability does not show up in the job-finding probability in Equation 4. An alternative way of characterizing the worker's job-finding probability, is to note that for a single application, a worker who submitted a applications is hired into that particular job with probability $\Gamma(a; \lambda_t)\mathcal{P}(\lambda_t)$, where $\mathcal{P}(\lambda_t)$ represents the probability the worker was offered that job, and $\Gamma(a; \lambda_t)$ is the probability she accepts that job given that she has submitted a applications. Since $\Gamma(a; \lambda_t)\mathcal{P}(\lambda_t)$ is the probability she was hired for a particular application, a worker who sent a applications, could have been hired at any one of those a applications. Thus the aggregate job-finding probability is given by $\sum_{a=0}^{\infty} p(a; \xi_t)a\Gamma(a; \lambda_t)\mathcal{P}(\lambda_t) = \sum_{a=0}^{\infty} p(a)\phi(a; \lambda_t) = f(\xi_t, \lambda_t)$. The two definitions are equivalent.

2.4 Government

The government runs a balanced budget every period. It collects tax revenue from a proportional tax on wage income and uses this revenue to finance unemployment benefits. The labor income tax is only levied on those employed at the end of the period. Similarly, unemployment benefits are only issued to those unemployed at the end of period. Since n_t is the measure of employed at the start of period t, then n_{t+1} denotes the measure of employed at the end of period t (start of period $t+1$). Thus the government's budget constraint is given by:

$$\tau_t w_t n_{t+1} = (1 - n_{t+1})\, b_t \tag{7}$$

2.5 Decentralized economy equilibrium

Thus far, I've described the individual problems of the worker, the firm and the government. Equilibrium in this model can be characterized by the following lemma:

Lemma 1. *Given the history of shocks y^t, the initial stock of employed and exogenous wage and home production functions $\{w(y_t), z(y_t)\}$, the following equations determine the equilibrium $\{\xi_t, \lambda_t, \tau_t, b_t, n_{t+1}\}$:*

Free entry

$$\frac{\kappa}{\Gamma(\xi_t, \lambda_t)\left[1 - q(0; \lambda_t)\right]} = y_t - w(y_t) + \beta\left(1 - \delta^s\right)\mathbb{E}_t \frac{\kappa}{\Gamma(\xi_{t+1}, \lambda_{t+1})\left[1 - q(0; \lambda_{t+1})\right]} \tag{8}$$

Optimal search effort

$$\begin{aligned} \frac{\chi'(\xi_t)}{f_\xi(\xi_t, \lambda_t)} &= u\left(\left[1 - \tau_t\right] w[y_t]\right) - u\left(z[y_t] + b_t\right) \\ &\quad + \beta\mathbb{E}_t\left(\chi(\xi_{t+1}) + \frac{\left[1 - \delta^s - f(\xi_{t+1}, \lambda_{t+1})\right]}{f_\xi(\xi_{t+1}, \lambda_{t+1})}\chi'(\xi_{t+1})\right) \end{aligned} \tag{9}$$

Law of motion of employed

$$n_{t+1} = f(\xi_t, \lambda_t)(1 - n_t) + (1 - \delta^s)\, n_t \tag{10}$$

as well as the government budget constraint as characterized by equation 7.

Proof. See Appendix A. □

Intuitively, Equation 8 represents the free entry condition and states that the marginal cost of creating a vacancy weighted by the probability of hiring a worker is equal to benefit of gaining profits today and continuing as an operating firm tomorrow. Equation 9 characterizes the unemployed worker's optimal search effort and balances the marginal cost of exerting more effort today $\chi'(\xi_t)$ - weighted by the rate of change in job-finding from one more unit of search effort $f_\xi(\xi_t, \lambda_t)$ - against the marginal benefit of exerting more effort. The latter of which is represented by the gain in current utility from becoming employed and the benefit from saving on future search costs. Equation 10 is the law of motion of the employed and states that tomorrow's employed consists of the $f(\xi_t, \lambda_t)$ fraction of the unemployed at the start of t who find a job by the end of period t and become employed, as well as all the employed at the start of period t who retained their jobs $(1-\delta^s)n_t$. Closing the model, the government budget constraint, Equation 7, holds in every period.

2.6 Ramsey planner problem

Thus far, I have characterized equilibrium in the decentralized economy. To understand how unemployment benefits should optimally vary over the business cycle, I consider a utilitarian Ramsey planner who solves a date 0 problem and puts equal weight on the expected discounted lifetime utility of all households. The planner's objective function can be written as:

$$\max \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ n_{t+1} u\left(\left[1 - \tau_t \right] w[y_t] \right) + \left(1 - n_{t+1} \right) u\left(z[y_t] + b_t \right) - \left(1 - n_t \right) \chi\left(\xi_t \right) \right\} \tag{11}$$

The planner maximizes average expected lifetime utility, subject to the balanced government budget constraint (7), the free entry condition (8), the worker's privately optimal choice of search effort (9), the evolution of employment (10), and the evolution of aggregate productivity (1). Let $\beta^t \psi_t$, $\beta^t \zeta_t$, $\beta^t \mu_t$ and $\beta^t \sigma_t$ be the Lagrange multipliers on constraints 7, 8, 9, and 10 respectively.[6] Appendix B.1 shows the optimality conditions from the planner's problem. Notably, the planner's optimal choice of unemployment benefits when workers can send multiple applications differs differs from what she would allocate when workers can only meet one vacancy at a time. Section 2.6.1 highlights the differences between the two models.

2.6.1 Optimal policy

A key difference between optimal policy in the standard search model with one-to-one meetings and the current model with multiple applications is that the planner has to take into account how varying unemployment benefits can not only affect the firm's job creation incentives through meeting rates but also through the worker's probability of accepting a job. To see this, consider the planner's optimality condition with respect to λ_t, the mean number of applicants per vacancy, in the multiple applications model, and with respect to θ, the ratio of vacancies to effective jobseekers, in the standard search model with one-to-one meetings.

In the baseline model, the planner's optimality condition with respect to λ_t can be characterized as:

$$\begin{aligned} \left[\zeta_t - \zeta_{t-1} \left(1 - \delta^s \right) \right] \frac{\kappa}{\Gamma\left(\xi_t, \lambda_t \right) \left[1 - q\left(0; \lambda_t \right) \right]} \left[\frac{\Gamma_\lambda\left(\xi_t, \lambda_t \right)}{\Gamma\left(\xi_t, \lambda_t \right)} - \frac{q_\lambda\left(0; \lambda_t \right)}{\left[1 - q\left(0; \lambda_t \right) \right]} \right] &= 0 \\ + \left\{ \mu_t - \mu_{t-1} \left[1 - \delta^s - f\left(\xi_t, \lambda_t \right) \right] \right\} \frac{\chi'\left(\xi_t \right)}{f_\xi\left(\xi_t, \lambda_t \right)} \frac{f_{\xi\lambda}\left(\xi_t, \lambda_t \right)}{f_\xi\left(\xi_t, \lambda_t \right)} - \mu_{t-1} f_\lambda\left(\xi_t, \lambda_t \right) \frac{\chi'\left(\xi_t \right)}{f_\xi\left(\xi_t, \lambda_t \right)} & \\ + \sigma_t f_\lambda\left(\xi_t, \lambda_t \right) \left(1 - n_t \right) & \end{aligned} \tag{12}$$

The first line in Equation 12 highlights how a higher value of λ_t affects the shadow value of job creation in period t and $t-1$ - as represented by the multiplier ζ_t and ζ_{t-1} - through its impact on meeting rates *and* worker acceptance rates. The former is represented by how the probability of meeting zero applicants in period t, $q_\lambda(0; \lambda_t)$, is reduced when λ_t increases while the latter is represented by how acceptance probabilities change when λ_t rises, $\Gamma_\lambda(\xi_t, \lambda_t)$. The backward-looking multiplier, ζ_{t-1}, features in the planner's optimality condition as the planner solves a date 0 planning problem and internalizes that raising λ_t in t affects the value of job-creation in the previous period, ζ_{t-1}. The second line in Equation 12 shows how raising the value of λ_t affects the shadow value of exerting more search effort both in period t and $t-1$ – as represented

[6] Appendix B details the Lagrangian formulation of the planner's maximization problem.

by μ_t and μ_{t-1} – through its impact on job-finding rates. Finally, the last line takes into account how a higher λ_t affects the measure of employed through its impact on job-finding.

A similar expression exists in the search model with one-to-one matching. Appendix B.2 outlines the Ramsey planner's problem and optimality conditions for the DMP model. For ease of reference, the optimality condition with respect to θ, the ratio of vacancies to effective job-seekers, is outlined here:

$$\begin{aligned} \left[\zeta_t - \zeta_{t-1}\left(1-\delta^s\right)\right] \frac{\kappa}{\widetilde{q}\left(\theta_t\right)} \frac{\widetilde{q}'\left(\theta_t\right)}{\widetilde{q}\left(\theta_t\right)} &= 0 \\ + \left[\mu_t - \mu_{t-1}\left(1-\delta^s\right)\right] \frac{\chi'\left(s_t\right)}{g'\left(s_t\right)\widetilde{f}\left(\theta_t\right)} \frac{\widetilde{f}'\left(\theta_t\right)}{\widetilde{f}\left(\theta_t\right)} & \\ + \sigma_t g\left(s_t\right)\widetilde{f}'\left(\theta_t\right)\left[1-n_t\right] & \end{aligned} \tag{13}$$

where $g(s_t)$ is the search efficiency of the unemployed worker given her search effort s_t, with the properties, $g(0) = 0$, $g(1) = 1$ and $g'(s_t) > 0$. In the DMP model, workers find jobs with probability $g(s_t)\widetilde{f}(\theta_t)$. Further, $\widetilde{q}(\theta_t)$ is the firm's probability of filling a vacancy which is equivalent to the rate at which firms meet workers. A comparison of equations 12 and 13 reveals that a key difference in the optimality conditions between the two models stems from the fact that the planner in the baseline model internalizes how changing the mean number of applicants per vacancy – which is the analogue to the reciprocal of tightness, $1/\theta$, and thus a measure of congestion – affects not just meeting rates but also acceptance rates when considering its impact on job creation. Intuitively, increasing the mean number of applicants per vacancy affects the offer probability $\mathcal{P}(\lambda_t)$, as λ_t informs the number of workers competing at the same vacancy on average. The likelihood of getting other offers in turn affects the odds that a worker would accept her current offer. This impact on acceptance probabilities is missing in the standard DMP model as workers always accept the offer that they receive.

The optimality conditions on search effort reveal similar forces at play. Equations 14 and 15 are the optimality conditions with respect to search effort ξ_t in the baseline model and s_t in the DMP model, respectively. The first line in both equations relates to the marginal cost of exerting more search effort which directly affects the utility of unemployed households. The second line in Equation 14 highlights shows how the choice of search effort ξ_t affects the shadow value of job creation directly both in t and $t-1$ through its impact on the acceptance rate, i.e., through $\Gamma_\xi(\xi_t, \lambda_t)$. This direct impact of search effort on the shadow value of job creation is absent in the DMP model. The third line in Equation 14 and second line in Equation 15 show how the choice of search effort affects the shadow value of relaxing the constraint on worker's search behavior both in t and $t-1$ through 1) its impact on how quickly the marginal cost of search is rising with additional effort and 2) through its impact on job-finding rates. Finally the last line in both Equations 14 and 15 reflects how search effort affects the measure of employed.

$$
\begin{aligned}
-\left(1-n_t\right)\chi'\left(\xi_t\right) &= 0 \qquad (14)\\
+\left[\zeta_t-\zeta_{t-1}\left(1-\delta^s\right)\right]\frac{\kappa}{\Gamma\left(\xi_t,\lambda_t\right)\left[1-q(0;\lambda_t)\right]}\frac{\Gamma_\xi\left(\xi_t,\lambda_t\right)}{\Gamma(\xi_t,\lambda_t)}&\\
+\left\{\mu_t-\mu_{t-1}\left[1-\delta^s-f\left(\xi_t,\lambda_t\right)\right]\right\}\left\{\frac{\chi'\left(\xi_t\right)}{f_\xi\left(\xi_t,\lambda_t\right)}\frac{f_{\xi\xi}\left(\xi_t,\lambda_t\right)}{f_\xi\left(\xi_t,\lambda_t\right)}-\frac{\chi''\left(\xi_t\right)}{f_\xi\left(\xi_t,\lambda_t\right)}\right\}&\\
+\sigma_t f_\xi\left(\xi_t,\lambda_t\right)\left(1-n_t\right)&
\end{aligned}
$$

$$
\begin{aligned}
-\left(1-n_t\right)\chi'\left(s_t\right) &= 0 \qquad (15)\\
+\left\{\mu_t-\mu_{t-1}\left[1-\delta^s-g\left(s_t\right)\widetilde{f}\left(\theta_t\right)\right]\right\}\left\{\frac{\chi'\left(s_t\right)}{g'\left(s_t\right)\widetilde{f}\left(\theta_t\right)}\frac{g''\left(s_t\right)}{g'\left(s_t\right)}-\frac{\chi''\left(s_t\right)}{g'\left(s_t\right)\widetilde{f}\left(\theta_t\right)}\right\}&\\
+\sigma_t g'\left(s_t\right)\widetilde{f}\left(\theta_t\right)\left[1-n_t\right]&
\end{aligned}
$$

Crucially, a key difference between these equations concerns the fact that additional search directly affects the shadow value of job creation in the economy where workers can send multiple applications. While higher search effort raises the probability that a worker contacts at least one vacancy, higher search effort can also affect the firm's hiring probability by changing acceptance rates. To see this, note that search effort ξ_t in our model is also equal to the mean number of applications a worker can submit in period t. Intuitively, when a worker can contact more vacancies, she can potentially receive more than one offer. The ability to select from more than one option affects the worker's likelihood of accepting the current offer as she can only accept and work at one job at a time. This impact of search effort on acceptance rates is noticeably absent in the DMP model since higher search effort only raises the probability of contacting a single vacancy, which if contacted, the worker always accepts with probability 1.

The differences between equations 12 and 13, as well as between equations 14 and 15 highlight the additional coordination problem firms face when workers can submit multiple applications. Beyond taking into the usual congestion externalities that workers impose on each other when they increase their search effort, the planner in the economy where workers can submit multiple applications also recognizes that firms cannot coordinate and commit to not making the same worker an offer. That is, firms do not know if they are making offers to the same applicant and offers are potentially wasted since a worker can only work at one job at a time and thus can only accept one offer. In the standard search model with one-to-one matching, a firm who contacts a worker never has his offer 'wasted'. All his offers are always accepted. Thus there is no additional coordination friction among firms beyond the usual congestion externalities. This additional coordination friction among firms has been highlighted in the earlier literature on multiple applications (see for example Albrecht et al. (2006) and Gautier and Moraga-Gonzalez (2018)). While the earlier literature has highlighted how this inefficiency exists in the decentralized economy, this paper focuses on the optimal policy over the business cycle where the planner chooses benefits to balance both the provision of insurance and supporting employment outcomes. A key difference relative to the DMP model, is that the planner in our model recognizes that changing benefits to encourage more search need not raise employment outcomes as more applications submitted can lower the likelihood of offers being converted into hires.

2.7 Understanding the acceptance rate

Since a key consideration present in the planner's optimality conditions in the economy with multiple applications – but missing in the standard search model – concerns the worker's acceptance rate , it is useful to understand how $\Gamma(\xi_t, \lambda_t)$ responds to changes in its arguments. The planner's choice of a tax and transfer system affects the marginal utility of being employed vs. unemployed, which in turn has an impact on the resultant level of search effort and average number of applicants per vacancy in the economy. Thus, understanding how $\Gamma(\xi_t, \lambda_t)$ responds to changes in ξ_t and λ_t can help inform us of the trade-offs the planner may face in choosing its optimal tax and transfer system. Since the acceptance probability also depends on how many other offers a worker might have, this section outlines how offer and acceptance probabilities vary in ξ_t or λ_t or both. For expositional purposes, I will treat ξ_t and λ_t as exogenous objects, however, it should be noted that in the model, these are endogenous variables in the planner's problem and are affected by the planner's choice of taxes and transfers.

Lemma 2. *The offer probability, $\mathcal{P}(\lambda_t)$ is decreasing in mean applicants per vacancy, λ_t, while the acceptance probability, $\Gamma(\xi_t, \lambda_t)$, is increasing in λ_t. Further, the acceptance probability observes a non-monotonic relationship with search effort, ξ_t.*

Proof. See Appendix C. □

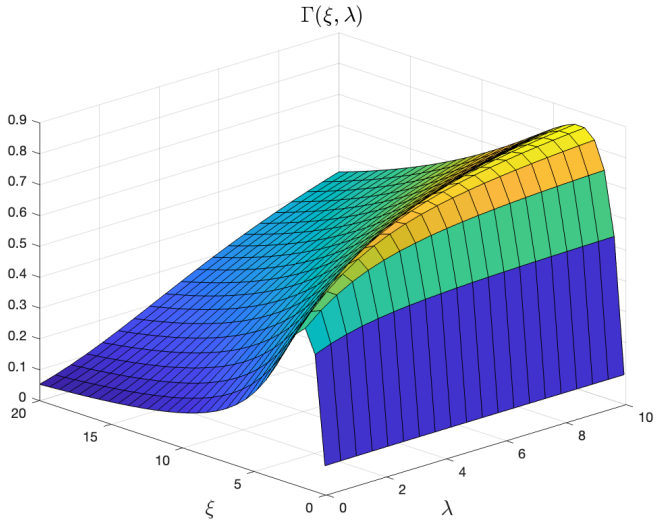
Intuitively, a higher λ_t represents, on average, more competitors a worker has to compete with at a vacancy. Since all workers have the same productivity at a job, the firm randomizes when choosing a candidate. A higher number of other competitors thus lowers the chance a worker gets an offer and thus offer probabilities are declining in λ_t, as shown in Equation 26 in Appendix C.

The opposite is true for acceptance probabilities. Equation 27 in Appendix C shows that $\Gamma(\xi_t, \lambda_t)$ is increasing in λ_t. If λ_t increases, and offer probabilities fall, then workers have a lower likelihood of having more than one offer. This in turn then raises the probability that the worker will accept the current offer at hand. Unlike the offer probability, the worker's acceptance probability is also affected by her search effort ξ_t. The effect of search effort on acceptance rates is non-monotonic as shown in Equation 28 in Appendix C. To illustrate this non-monotonicity, Figure 1 shows that acceptance probabilities increase with ξ up to a point and then decline with higher ξ, holding all else constant. Initially, increasing search effort raises the acceptance probability as the worker is more likely to draw at least one application and thus contact a vacancy. At some point, higher and higher levels of search effort however, weigh negatively on $\Gamma(\xi_t, \lambda_t)$, as more search effort, ξ_t, raises the likelihood that the worker has more than one offer for the same λ_t. Despite having more offers, the worker can only work at one job. Thus, the worker is more likely to reject a job when she has more offers, causing her acceptance probability to be lower. Thus far, I've outlined how the acceptance probability responds to changes in search effort and the mean number of applicants per vacancy. However, as aforementioned, both ξ_t and λ_t are equilibrium objects. As such, I now turn to the quantitative model to illustrate how the planner allocates benefits in steady state and over the business cycle, and how this affects the resulting choice of ξ_t and λ_t.

3 Calibration

In this section, I calibrate the deterministic steady state of the decentralized economy to match labor market moments observed in the data. Using the parameters obtained from the calibrated

Figure 1: Variation of $\Gamma(\xi, \lambda)$ in ξ and λ



Note: This figure plots how the worker acceptance probability, $\Gamma(\xi, \lambda)$ varies with search effort ξ and congestion as measured by the mean number of applicants per vacancy, λ.

decentralized economy, I then solve the Ramsey planner's problem.

A period is a month in the model. Utility of consumption is given by log utility. The discount factor, β, is set to 0.995, while aggregate productivity is normalized to be 1 in steady state. In Section 4.2 which focuses on optimal policy over the business cycle, the persistence on log aggregate productivity, ρ, is assumed to be 0.8878 and the standard deviation of shocks σ_ϵ to be 0.0056. Using data from the Bureau of Labor Statistics (BLS) for the period spanning 1947 to 2024, these numbers are derived from an AR(1) regression on the cyclical component of log labor productivity where the latter is measured by output per hour in the non-farm business sector. In steady state, aggregate productivity, y_t is normalized to be 1. Further, the job separation probability is set to be 0.03, as standard in the literature.[7] Following Shimer (2005) who assumes a replacement rate of 0.4, I set the unemployment transfer in the the steady state of the decentralized economy to be $b = 0.4$. Note that while this assumed to be the steady state transfer in the decentralized economy, it is not necessarily the transfer that would result in the planner's problem in every state, especially when there are aggregate shocks. In Section 4.1 and 4.2, b_t is endogenous and state-dependent.

The following choices are made with regards to the exogenous wage and home production functions. The wage is assumed to take the form of $\overline{w}y_t^\gamma$,[8] while home production is assume to be linear in productivity $z(y_t) = zy_t$. Following Hall and Milgrom (2008), I assume that the wage is equal to 0.985 of the marginal product of labor. Since y_t is labor productivity in our model and equal to 1 in steady state, this means setting $\overline{w} = 0.985$. Further, following Mitman and Rabinovich (2015), γ is set to match the elasticity of wages to productivity which implies a value of 0.449.[9] The remaining parameter z is calibrated to match the fall in consumption upon

[7] See Hall and Milgrom (2008) and Shimer (2005) for example.

[8] This is the same exogenous wage function used in Landais et al. (2018) and also in the discussion section of Mitman and Rabinovich (2015).

[9] In recent work, Fukui (2020) using BLS data, records that the elasticity of wages with respect to productivity is about 0.38. Landais et al. (2018) report an elasticity of 0.5. The value reported in Mitman and Rabinovich (2015) of 0.449 falls between these two values. Section 5 shows some sensitivity results when the degree of wage

unemployment. Gruber (1997) estimates that a 10 percentage point increase in unemployment insurance lowers the decline in consumption in unemployment by 2.65 percentage points and that in an economy without unemployment insurance, consumption in unemployment is 22.2 percent lower than consumption in employment. Given our assumed transfer of $b = 0.4$, this implies a ratio of consumption of the unemployed to consumption of the employed of 0.884.[10] I calibrate z to target this ratio.

I further assume that the search cost function is quadratic and takes the form of $\chi(\xi) = \chi\xi^2$. The assumption of a quadratic search cost function has been found to be empirically relevant, and has been adopted in papers with endogenous search effort such as Yashiv (2000), Lise (2013), and Gomme and Lkhagvasuren (2015). The scaling parameter χ is calibrated to match the average number of applications. There are two sources of information on applications, the Employment Opportunity Pilot Project (EOPP) and the Federal Reserve Bank of New York Survey of Consumer Expectations (SCE) Labor Market Survey. The former covers the period 1979 to 1980 while the latter is an on-going survey that began in 2013. Birinci et al. (2024) note that in both surveys that the mean number of applications is far above the median, suggesting there are a few outliers who send many applications. As such, I measure average applications as the average of the medians recorded across the two surveys. This implies choosing χ to match an average of 4.85 applications.[11]

Finally, I choose κ to target an unemployment rate of 5 percent in steady state. Table 1 provides a summary of the parameters. While only the unemployment rate, average applications and the drop in consumption upon unemployment were targeted, the model also predicts that the fraction of individuals without offers is about 0.43, close to the average fraction of individuals without offers of about 0.405.[12] Further, the ratio of vacancies to unemployed in our model is about 0.85, fairly close to the 0.7 recorded in data.[13] Overall, our model provides a fairly good fit of both targeted and untargeted moments.

4 Quantitative Results

4.1 Decentralized economy vs. Ramsey planner

Steady State Before focusing on the differences in optimal policy between the DMP economy and the baseline model with multiple applications, I compare how the planner's choices deviate from that of the decentralized economy in steady state. Table 2 summarizes the outcomes.

In the model, the planner's only instrument to implement optimality is the level of unemployment benefits since Equation 7 reveals that labor income tax rates are simply a function of the unemployment benefit transfer given wages – which are exogenous in our baseline model – and the level of employment, which in steady state is simply a function of search effort and the mean

flexibility γ is increased above the baseline value of 0.449.

[10] This number is calculated as $100 - 22.2 + 4 * 2.65$.

[11] This number is calculated as $0.5(2.7 + 7)$ where the median number of applications recorded in the EOPP is 2.7, and the median number of applications recorded in the SCE for the period 2013-2019 is 7.

[12] Conditional on applying for at least one job, Birinci et al. (2024) document that the fraction of unemployed job-seekers without a job offer in the EOPP is equal to 0.38, while the fraction of unemployed job-seekers without an offer in the SCE for the period 2013-2019 is 0.43. Thus the average fraction of individuals without offers is computed as $0.5(0.38 + 0.43) = 0.405$.

[13] Using data on vacancies from Job Openings and Labor Turnover Survey (JOLTS) and data on unemployment from the Current Population Survey (CPS), the average ratio of vacancies to unemployed is about 0.7 for the period 2000m12 to 2024m9.

Table 1: Calibrated Parameters

Fixed Parameters

Parameter	Value	Description	Source
β	0.995	Discount factor	
ρ	0.888	Persistence in y	BLS
σ_ϵ	0.006	Standard deviation of shock	BLS
δ^s	0.03	Exogenous separation rate	Shimer (2005)
$\overline{w}$	0.985	0.985 MPL	Hall and Milgrom (2008)
γ	0.449	Elasticity of w wrt y	Mitman and Rabinovich (2015)
b	0.4	Steady state UI	Shimer (2005)

Calibrated Parameters

Parameter	Value	Targets	Model	Data
κ	0.310	Unemployment rate	0.05	0.05
χ	0.0023	Average applications	4.85	4.85
z	0.452	Consumption drop	0.884	0.884

Note: This table lists the set of externally and internally calibrated parameters.

Table 2: Differences between decentralized and Ramsey planner outcomes

Outcomes

Variable	Decentralized	Ramsey
b	0.4	0.45
ξ	4.85	3.52
λ	5.73	4.28
$\Gamma(\xi, \lambda)$	0.72	0.73
$\mathcal{P}(\lambda)$	0.17	0.23
v	0.04	0.04
$1 - n$	0.05	0.05

Note: This table lists how key variables affecting firm and worker outcomes vary across the decentralized economy and the Ramsey planner solution in steady state.

number of applicants per vacancy. Denote by superscript $\mathcal{R}$ the outcomes from the Ramsey planner solution and by superscript $\mathcal{D}$ the outcomes observed in the decentralized economy. In contrast to the decentralized economy where $b^{\mathcal{D}}$ was set to 0.4, the planner chooses a more generous unemployment transfer of $b^{\mathcal{R}} = 0.45$. More generous transfers in turn affect the worker's choice of search effort. Intuitively, when transfers are more generous, the difference in utilities from being employed and unemployed are smaller. From Equation 9, this smaller difference has an impact on the level of search effort chosen. In fact, the planner chooses to implement a much lower level of search effort, $\xi^{\mathcal{R}} < \xi^{\mathcal{D}}$, than that observed in the decentralized economy. Given that increased search effort causes 1) higher disutility among the unemployed, 2) increased congestion among workers and 3) lower acceptance probabilities when workers have more options to choose from, holding all else constant, it is perhaps unsurprising that the constrained optimal level of search effort is lower than that observed in the decentralized economy in steady state. Interestingly, $\xi^{\mathcal{R}} > 1$, suggesting that the planner does not want workers to send one application on average. Since the number of applications also affects the likelihood that the firm has at least one applicant and thus their ability to hire, the planner optimally sets $1 < \xi^{\mathcal{R}} < \xi^{\mathcal{D}}$.

The lower value of $\xi^{\mathcal{R}}$ naturally contributes towards a lower value of mean applicants per vacancy $\lambda^{\mathcal{R}}$ since $\lambda = \xi u/v$. In both models, the planner roughly chooses the same level of vacancies, $v = 0.04$. Nonetheless, by offering more generous benefits and thus lowering search effort without substantively changing the level of vacancies, the planner's economy features a higher acceptance rate of 0.73, compared to 0.72 in the decentralized economy. This increase in the acceptance rate is key to keeping job creation relatively unchanged between the planner's solution and the decentralized economy outcomes. To understand why this occurs, consider the free entry condition Equation 8 but evaluated at steady state:

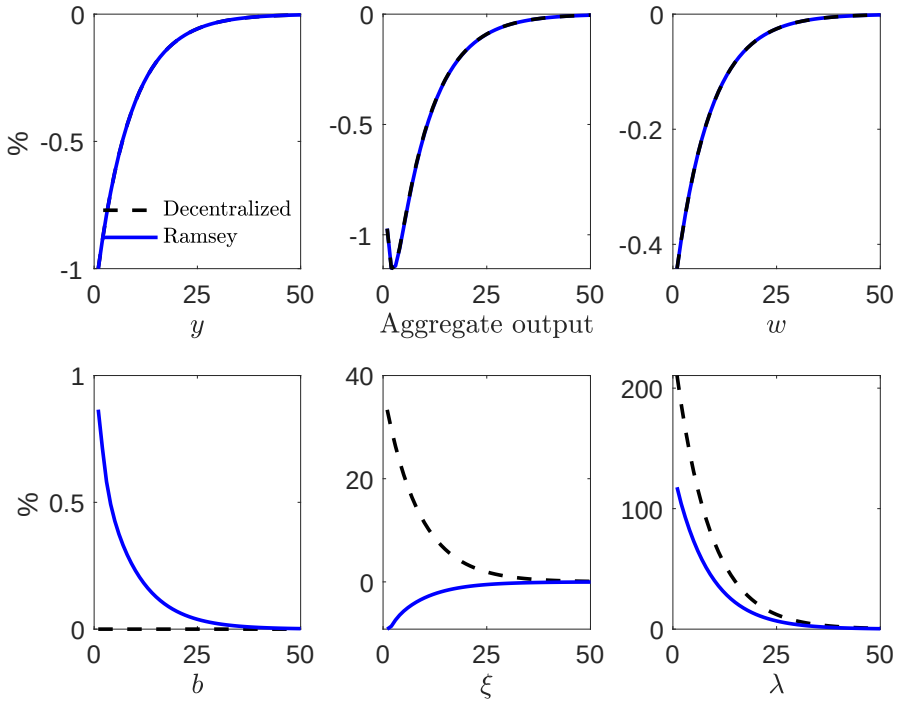
$$\frac{\kappa}{\Gamma(\xi, \lambda)[1 - q(0; \lambda)]} = \frac{y - w}{1 - \beta(1 - \delta^s)}$$

The RHS of the above equation is constant. Given that a decline in ξ contributes to a fall in λ, this leads the probability of the firm having at least 1 applicant, $1 - q(0; \lambda)$, to decrease. The decline in meeting rates as captured by $1-q(0; \lambda)$ is counteracted by the rise in acceptance rates, $\Gamma(\xi, \lambda)$, causing the number of vacancies created to be roughly the same in the two economies.

Further, offer probabilities are declining in λ as highlighted in Lemma 2. Thus, the lower level of $\lambda^{\mathcal{R}}$ causes the offer probability $P(\lambda^{\mathcal{R}})$ to be higher in the Ramsey planner's solution at 0.23, compared to 0.17 in the decentralized economy. Thus, job-finding rates are also relatively unchanged, despite a lower number of vacancies contacted on average when workers reduce their search effort. From Equation 4, the shift in application probabilities, $p(a; \xi)$, towards lower a levels of applications is compensated by the rise in $\phi(a; \lambda)$, the latter being increasing in offer probabilities. Relatively unchanged job-creation and job-finding rates imply that unemployment is about 5 percent in both economies despite workers searching less in the planner's solution.

With aggregate shocks Turning to the dynamics outside of steady state, Figure 2 shows how the decentralized economy (dashed black line) and the planner's economy (solid blue line) responds to a negative 1 percent shock in aggregate productivity. In both economies, aggregate output – which includes both market and home production – and wages fall on impact to the same extent. In response to this negative shock, however, the planner increases UI while in the decentralized economy, the level of UI is held constant. These differential changes in UI cause search effort in the two economies to respond differently. With no change in UI, workers in the decentralized economy increase their search effort in an attempt to self-insure against increased

Figure 2: Impulse response: Decentralized economy vs. Ramsey planner



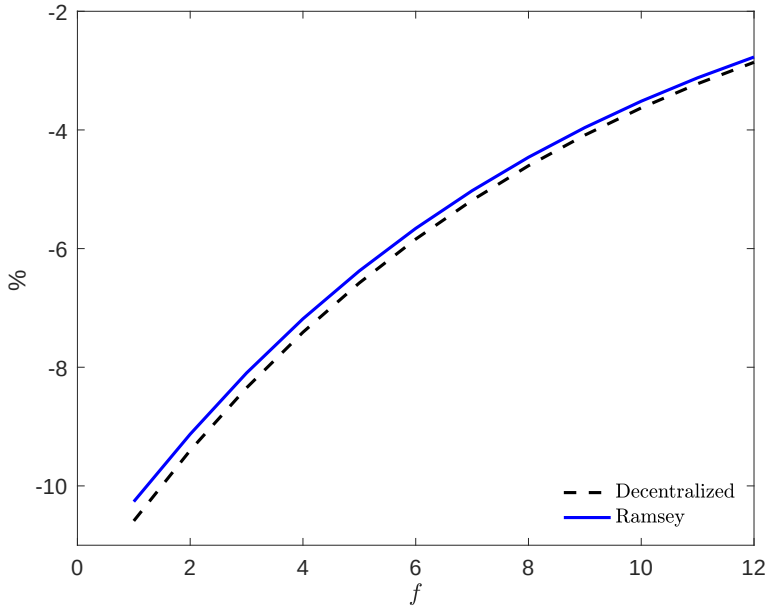
Note: The top row of the figure plots the IRF for productivity, y, aggregate output which includes both market and home production, and wages. The bottom row plots the IRF for unemployment insurance b, and its impact on search effort, ξ, and congestion, λ. The blue solid line shows the Ramsey planner solution in the economy where workers submit multiple applications, while the black dashed line shows the outcomes in the decentralized economy. For the decentralized economy, b is assumed to be fixed over the cycle.

unemployment risk. As such, search effort increases by 33 percent on impact and stays elevated throughout the recession. In contrast, the planner, by raising the level of UI, provides insurance to the worker during the downturn. From equation 9, the smaller consumption gap implies that the worker need not apply as much search effort to smooth consumption. Thus, search effort falls in the Ramsey planner economy as shown by the blue line in the bottom middle panel of Figure 2. I elaborate on these changes in more detail in Section 2.6.1 when I compare the optimal policy in the economy with multiple applications against its counterpart in the DMP economy.

In addition, the differences in ξ lead congestion among workers – as captured by λ, the mean number of applicants per vacancy – to increase by more in the decentralized economy. This larger increase in λ in the decentralized economy is mainly due to the increase in ξ.[14] Notably, both the increase in λ and ξ causes the job-finding rate to fall by a slightly larger amount in the decentralized economy than in the Ramsey planner economy as shown in Figure 3. The job-finding rate in the decentralized economy only performs slightly worse than that of the Ramsey planner economy because both the acceptance rate and firm meeting rate rise by more with the large increase in λ in the decentralized economy, mitigating the decline in vacancy creation and leading there to be roughly the same drop in vacancies as observed in the Ramsey planner economy. Nonetheless, the decentralized economy, by observing an increase in search effort implies that the roughly same drop in vacancy creation and marginally worse decline in workers' job-finding rates comes at the expense of workers bearing a larger disutility from search. In

[14]This is not the case for the Ramsey planner's economy as I elaborate in Section 2.6.1. In the Ramsey planner solution, λ rises despite ξ falling.

Figure 3: Marginally larger decline in job-finding rate in decentralized economy



Note: This figure plots the IRF for the job-finding rate for the first few periods. The blue line plots the response under the Ramsey planner solution while the black dashed line plots the outcome in the decentralized economy.

contrast, the Ramsey planner achieves a marginally smaller decline in the job-finding rate while improving workers' welfare and economizing on the disutility from search.

4.2 Optimal policy in a recession

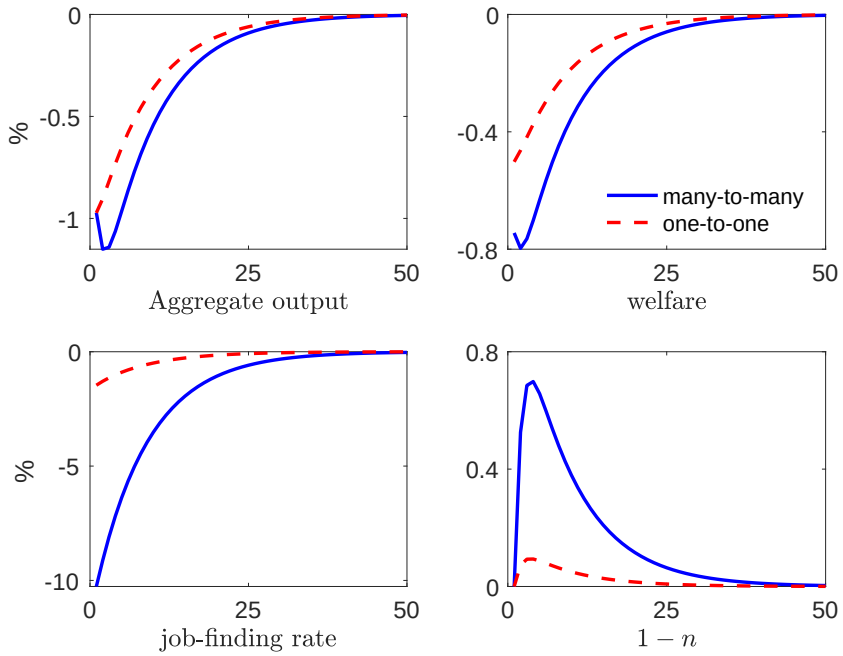
Thus far, I've discussed how the Ramsey planner's solution differs from the decentralized economy with multiple applications. The key questions of this paper, however, concern how the optimal allocation of benefits over the business cycle when workers can send multiple applications differs from what a planner would choose in a DMP model where meetings are only one-to-one. To investigate how the optimal policy differs between the economy with multiple applications and the DMP economy, I calibrate the DMP model to match similar labor market moments as documented in Section 3, with the exception that the target of average applications is swapped out with the percentage of unemployed who applied to at least one vacancy in the last month.[15] Appendix C.1 shows the calibrated parameters for the DMP model. Because both models are calibrated to largely the same moments, the assumption that the two economies start in steady state and are then exposed to the same productivity shock implies that both economies have the same starting points in terms of unemployment, output and wages.

Figures 4 and 5 summarize the outcomes in key aggregate variables. The blue solid lines refer to outcomes in the economy with multiple applications while the red dashed lines refer to the outcomes in the DMP economy. Figure 4 shows the impulse responses in aggregate output, current welfare, job-finding rates and unemployment.[16] Notably, the planner's solution in the economy with multiple applications features more volatile movements in aggregate output and unemployment in response to a one percent negative productivity shock, relative to the planner's

[15]Using data from the SCE, Faberman et al. (2022) report that 92.8 percent of the unemployed apply to at least one vacancy in the last four weeks.

[16]Current welfare is calculated as the average utility in the economy at time t.

Figure 4: Response in key labor market variables: multiple applications vs DMP



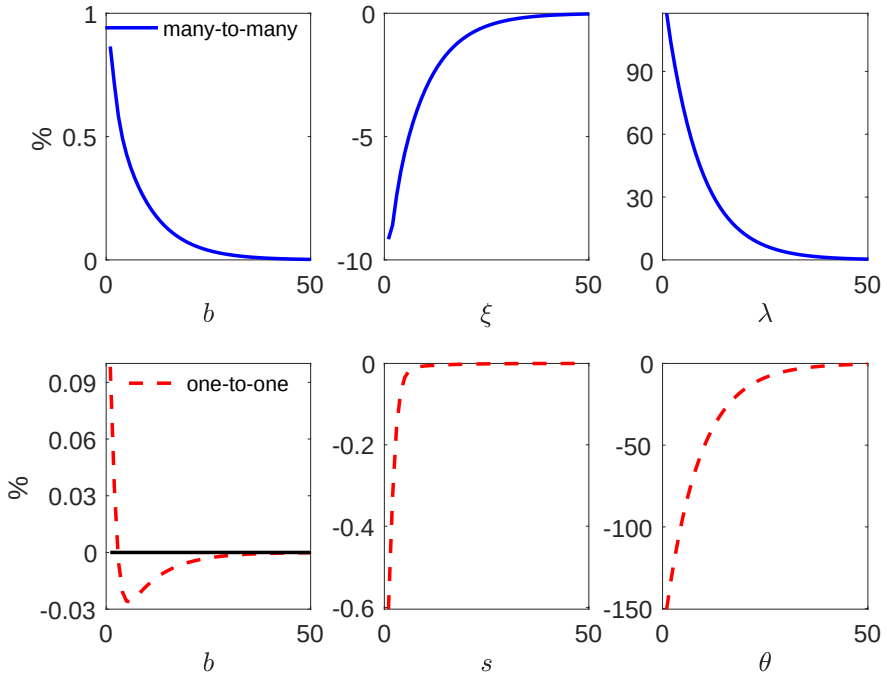
Note: This figure plots the impulse response in key labor market variables to a 1 percent negative productivity shock. The blue solid line shows the Ramsey planner solution in the economy where workers submit multiple applications, while the red dashed line shows the Ramsey planner solution for the DMP economy where meetings are one-to-one.

solution in the DMP economy. This greater response in unemployment and output to a negative productivity shock is an artefact of the matching technology (many-to-many matching vs. one-to-one matching) and not due to the planner's choices itself. Appendix C.2 shows that the more volatile response in output and unemployment also features in the decentralized economy with multiple applications relative to the outcomes in the DMP decentralized economy. This greater volatility is in part due to the fact that in the multiple applications model, search effort affects the average number of applications sent and the number of applications is only bounded below by zero and unbounded above. Variations in ξ can induce substantive changes in congestion among workers. In the DMP model, search effort s affects the search efficiency of workers, $g(s)$, where the latter is bounded between 0 and 1. There is thus a limit to how much increases in search effort can affect tightness, θ.

How does the planner respond to the decline in productivity and rise in unemployment? Focusing first on the economy with multiple applications, recall that the main instrument our planner has to affect outcomes is merely the level of unemployment insurance. The first column of the top panel of Figure 5 highlights that in response to a 1 percent negative productivity shock, the planner raises benefits by 0.87 percent on impact. This change in the level of UI is almost proportional to the shock, albeit in the opposite direction. Further, the increase in UI is persistent and lasts until the negative productivity shock completely dissipates, implying that the optimal UI policy in the economy with multiple applications is countercyclical.

This rise in benefits together with the fall in wages imply a smaller consumption gap between the employed and unemployed, reducing the need for the worker to self-insure by searching harder. Consequently, ξ falls by 9 percent on impact. Despite the fall in search effort, the fewer

Figure 5: Impulse response in key choice variables: multiple applications vs DMP



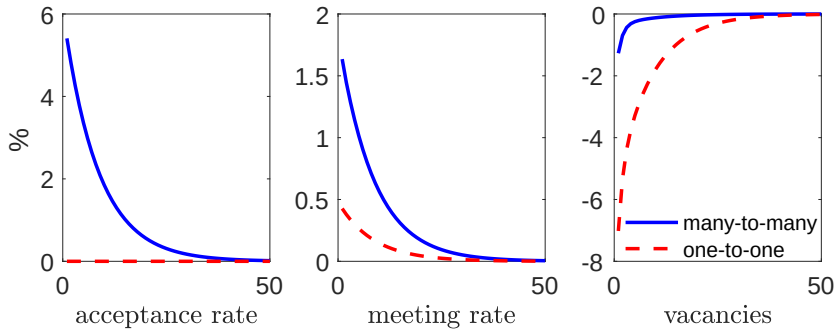
Note: This figure plots the impulse response in the planner's main instrument b, and its impact on key equilibrium variables concerning search effort (ξ, s) and congestion (λ, θ). The blue solid line shows the Ramsey planner solution in the economy where workers submit multiple applications, while the red dashed line shows the Ramsey planner solution for the DMP economy where meetings are one-to-one.

number of applications sent is not enough to cause a decrease in the mean number of applicants per vacancy, λ. Rather, λ increases on impact as firms create less vacancies when aggregate productivity and thus output per employed worker, y, falls.

The results of the baseline model stand in stark contrast to the choices made by a Ramsey planner in an economy where there are only one-to-one meetings. In the DMP model, the planner initially increases UI but from the third period onwards, cuts them below their steady state level. Further, this subsequent cut in benefits is persistent and lasts until the negative shock completely dissipates. This result is similar to that observed in Mitman and Rabinovich (2015) who concludes that the optimal allocation of benefits over the business cycle is largely procyclical.[17] Any increase in benefits in the DMP model is limited to the initial period when the shock first occurs, and thereafter, the planner optimally cuts benefits. The planner initially raises benefits to insure the unemployed but thereafter cuts benefits to promote job creation. The cut in benefits hastens the recovery in search effort, s, as shown in the bottom middle panel of Figure 5. Because the gap in marginal utilities is larger between the employed and unemployed when benefits are cut, individuals apply more search effort to insure themselves in the DMP model. This in turn induces a faster recovery in the unemployment rate as shown by the red dashed line in the bottom right panel of Figure 4 relative to that observed in the

[17] Although the baseline model in Mitman and Rabinovich (2015) features Nash Bargaining, they conduct the same exercise with the same exogenous wage function as in this paper, and find that optimality within the DMP model features procyclical benefits even with exogenous wages. This paper establishes that a search economy with many-to-many meetings reverses this result.

Figure 6: Acceptance rate, firm meeting rates, and vacancies



Note: This figure plots the impulse response in the worker's acceptance probability, the firm's meeting rate and the level of vacancy creation. The blue solid line shows the Ramsey planner solution in the economy where workers submit multiple applications, while the red dashed line shows the Ramsey planner solution for the DMP economy where meetings are one-to-one.

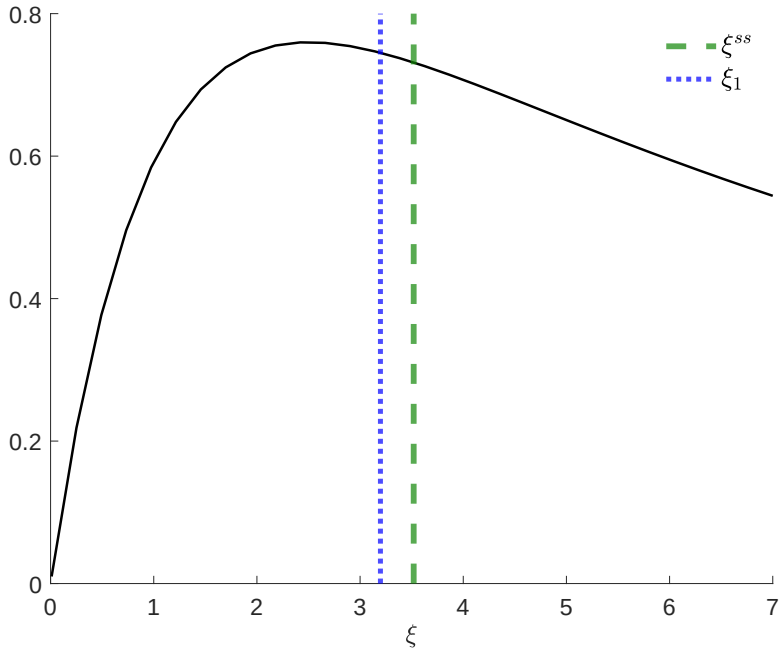
economy with multiple applications, as depicted by the blue solid line.[18]

Why then does the planner choose to raise benefits and keep them persistently elevated until the shock dissipates in the economy where workers can send multiple applications? Note that in both the DMP search economy and the economy with multiple applications, the planner chooses to raise benefits on impact to provide insurance against the negative productivity shock. Subsequently, however, the evolution of job creation affects their differential choices of benefits. Equations 12 to 15 highlight that the key difference in the planner's optimality conditions stem from the fact that the acceptance rate in the model with multiple applications also responds to the planner's choices. Because the persistent rise in benefits under the planner's economy with multiple applications reduces the gap in utilities between being unemployed and employed, search effort recovers slowly and the average number of applications, ξ, remains low. Fewer applications sent, together with the rise in mean applicants per vacancy, λ, contribute towards increasing the acceptance rate, as shown by the blue line in the first panel of Figure 6. The flat red-dashed line at zero represents the percentage change in the DMP model, which is unvarying as workers always accept an offer in the standard DMP model. As highlighted in Lemma 2, the acceptance rate, $\Gamma(\xi, \lambda)$ is increasing in λ and non-monotonic in ξ. Figure 7 however shows that, holding λ constant at its steady state level, a fall in ξ on impact (depicted by the dotted blue line) from its steady state level, ξ^{ss} (depicted by the dashed green line) works towards raising the acceptance rate. Because ξ^{ss} is above the level of applications that would give a peak acceptance rate given λ^{ss}, small decreases in ξ actually work towards raising the acceptance rate. Intuitively, this is because when workers apply to many jobs, this raises the coordination failure among firms as it heightens the likelihood that more than one firm may make the same worker an offer. Thus, by keeping benefits elevated, the planner actually helps to mitigate this coordination friction among firms by reducing the likelihood of workers having multiple offers and thus, raising their acceptance probability.

The second panel of Figure 6 shows that the meeting rate in both models rise, with the

[18] Appendix C.3 shows that even if we were to impose the same parameters on the DMP model as the baseline model, the Ramsey planner solution in the DMP model features completely procyclical benefits. In this case, the planner in the DMP model chooses to cut benefits on impact in a recession, and keeps benefits persistently lower. This is the complete opposite of the Ramsey planner's choices in the economy with multiple applications, where benefits are raised on impact and are kept persistently higher throughout the shock.

Figure 7: Acceptance rate higher with planner's lower ξ



Note: Holding constant λ at its steady state level, this figure show the acceptance rate changes as search effort ξ changes from its steady state level ξ^{ss} – indicated by the green dashed line – to its level ξ_1 on impact of the shock, where the latter is depicted by the dotted blue line.

meeting rate rising by less in the DMP model. Intuitively, more applicants per vacancy on average, i.e., a higher λ, and a lower ratio of vacancies to effective job seekers, a lower θ, both increase the probability that the firm meets applicants. In the standard DMP model, the meeting rate is the sole object which affects the firm's hiring probability while in the model with multiple applications, both the acceptance rate and meeting rate matter for the firm's ability to hire. Since both the acceptance rate and the meeting rate both move in the same direction, this bolsters the firm's hiring probability and thus, their incentive to create jobs. Consequently, vacancy creation falls by less in the planner's economy with multiple applications. This can be seen in the third panel of Figure 6 which shows the percentage change in vacancies following the negative productivity shock. The blue solid line for the economy where workers send multiple applications falls by less relative to the red dashed line which depicts the standard DMP search economy.

In summary, the inclusion of multiple applications changes the cyclicality of optimal policy. In the DMP model, the planner only increases benefits in the beginning and cuts them almost immediately thereafter to stimulate search effort and boost job creation. In contrast, in the economy where workers send multiple applications, the planner increases benefits on impact and keeps them elevated throughout the shock. The additional margin the planner takes into account is that too much search effort can actually exacerbate the coordination friction among firms. Reducing search effort via higher benefits can raise workers' acceptance rates and thus further mitigate the decline in job creation.

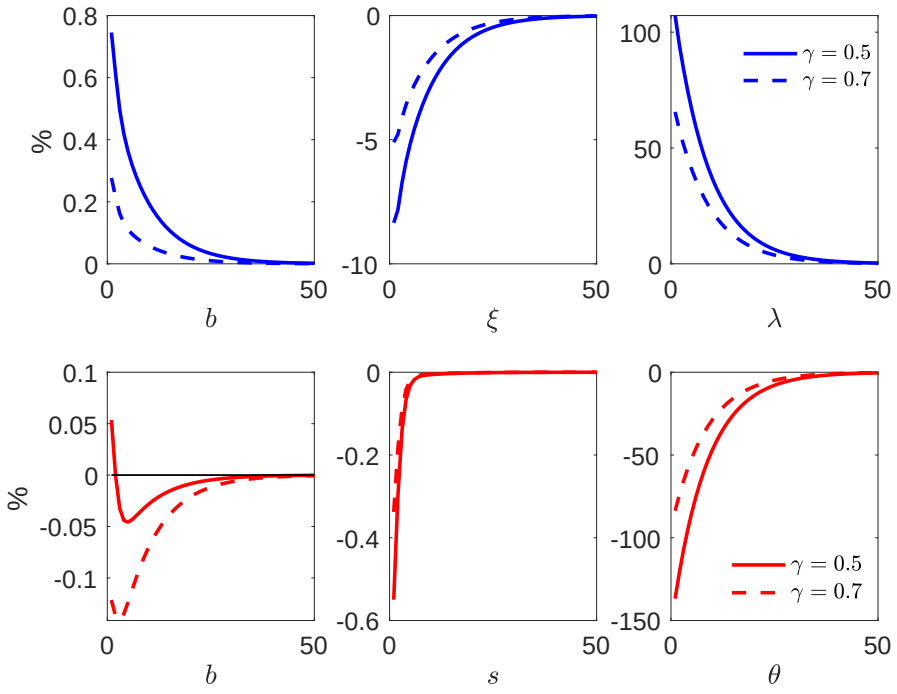
5 Sensitivity Analysis

5.1 Response under more flexible wages

In the baseline model, the elasticity of wages with respect to productivity is assumed to be 0.449. This value falls within the range of estimates the literature has used from 0.38 to 0.50. In this section, I show how the results differ if wages become more flexible.

The top row of Figure 8 shows how the Ramsey planner's solution differs as when wages are more flexible in the economy where workers can send multiple applications while the bottom row shows the counterpart for the economy where meetings are one-to-one. The solid lines represent the outcomes when wage elasticity $\gamma = 0.5$, and the dashed lines represent the outcomes when the wage elasticity $\gamma = 0.7$. Focusing first on the economy where workers submit multiple applications, the Ramsey planner increases benefits by less during a recession when wages are more flexible. Intuitively, when wages are more flexible and fall during a recession, the gap between the utility of the employed and that of the unemployed is smaller. As such, the planner need not raise benefits as much to smooth consumption between the two employment states. Relative to our baseline model where $\gamma = 0.449$ and the planner increased benefits by 0.87 percent on impact, the Ramsey planner here increases benefits by 0.75 and 0.28 percent for the economies where the wage elasticity is 0.5 and 0.7, respectively.

Figure 8: Optimal benefits, search effort and congestion under different wage elasticities



Note: This figure plots the impulse response in the planner's main instrument b, and its impact on key equilibrium variables concerning search effort (ξ, s) and congestion (λ, θ) for different degrees of wage rigidity. The top row in blue shows the Ramsey planner solution in the economy where workers submit multiple applications, while the bottom row in red shows the Ramsey planner solution for the DMP economy where meetings are one-to-one. Solid lines represent the outcomes when $\gamma = 0.5$ while dashed line represent the outcomes for when $\gamma = 0.7$. Higher γ implies more wage flexibility.

This smaller increase in benefits also then leads to a smaller decline in search effort as depicted by the lesser fall in the blue dotted line for $\gamma = 0.7$ relative to the solid blue line for $\gamma = 0.5$ in

the top middle panel of Figure 8. Despite the smaller reduction in search effort when wages are more flexible, λ increases by less in the economy where $\gamma = 0.7$ as depicted in the top rightmost panel of Figure 8. This occurs because vacancies fall by less during a recession when wages are more flexible. That is, although a smaller fall in ξ implies that the numerator of λ is declining by less, the simultaneous smaller fall in v implies that the denominator of λ is also not shrinking as much when wages are more flexible. The latter force dominates the former and overall, λ increases when $\gamma = 0.7$.

The bottom row shows the result for the Ramsey planner's solution in the DMP model when wages elasticities are 0.5 (given by the red solid line) and 0.7 (given by the red dashed line), respectively. Notably, when wages are more flexible, the planner not only a lower increase in benefits on impact, but in some cases may choose to even cut benefits at the very beginning of the shock. Relative to the case where $\gamma = 0.449$ and the Ramsey planner in a DMP economy raised benefits by 0.1 percent on impact, the planner here chooses either a lower increase of 0.05 percent for $\gamma = 0.5$ or cuts benefits by 0.12 percent for $\gamma = 0.7$. In other words, greater flexibility in wages in the DMP model, by reducing the need for insurance provision drives the optimal benefit allocation to be more procyclical. Lower provision or a cut in benefits at the same time makes search effort, s, decline by less. Finally, θ, the ratio of vacancies to effective job-seekers, also falls by less as more flexible wages absorb some of the negative productivity shock and make it more profitable for firms to enter the labor market.

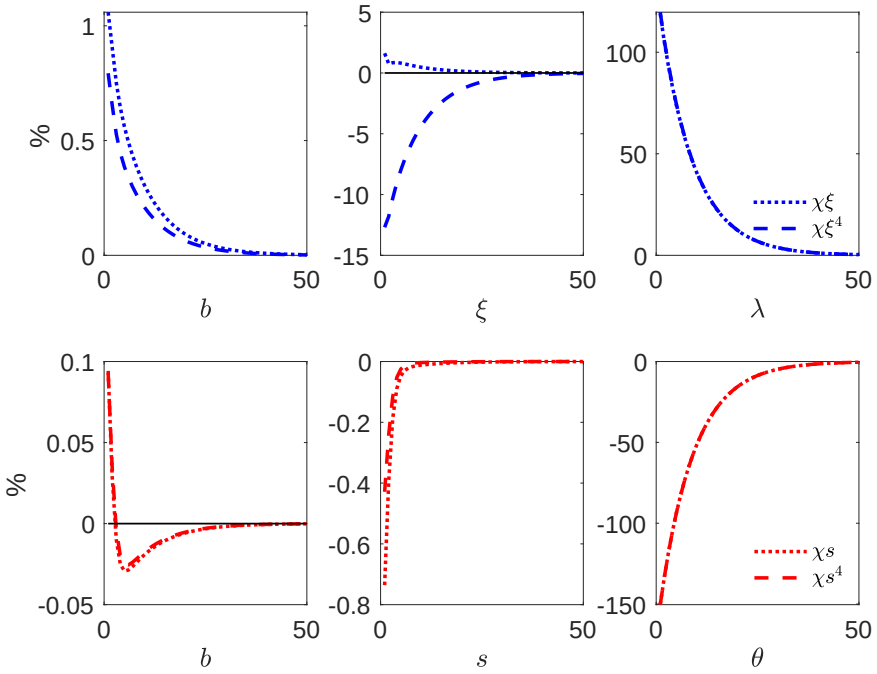
It is important to note that the inclusion of more flexible wages does not change the direction of the planner's optimal allocation of benefits in the economy with multiple applications. It only changes the magnitude of the increase in benefits. The planner in this economy always takes into account that search effort not only affects job search incentives but also the likelihood that a firm can hire a worker that it meets, via search effort's impact on the worker's acceptance rate. By increasing benefits during a recession, the planner can reduce the number of applications a worker sends and reduce the coordination friction among firms of making the same applicant an offer. In contrast, the degree of wage flexibility in a DMP economy can change whether a planner wants to increase benefits at all. Since the planner in the DMP economy does not need to resolve this additional coordination friction among firms regarding offers to the same applicant, increased wage flexibility and the reduced need to provide insurance makes the planner focus increasingly instead on raising employment outcomes. The planner achieves the latter by reducing benefits to encourage more search.

5.2 Response under different curvature in search costs

A quadratic search cost function is assumed in the baseline model. In this section, I show how the results vary if marginal costs are instead constant, i.e., $\chi(\xi) = \chi\xi$, or if instead the curvature in the search cost function is doubled from its baseline level, i.e., $\chi(\xi) = \chi\xi^4$. In changing the curvature of the cost function, I re-calibrate the model each time to match the same labor market moments as before. Appendix C.4 contains the details of the re-calibrated models. Thus, all economies have the same starting point in terms of unemployment and wages. Figure 9 summarizes the results. The dashed lines represent the outcomes when the search cost function is given by $\chi\xi^4$ (χs^4 in the DMP model) while the dotted lines represent the search cost function when marginal costs are constant.

Focusing first on the economy with multiple applications, the top row of Figure 9 shows that the planner still chooses to optimally raises benefits during a recession. The extent to which which the planner raises benefits is declining in the curvature of the search cost function. On

Figure 9: Optimal benefits, search effort and congestion under different search cost functions



Note: This figure plots the impulse response in the planner's main instrument b, and its impact on key equilibrium variables concerning search effort (ξ, s) and congestion (λ, θ) for different search cost functions. The top row in blue shows the Ramsey planner solution in the economy where workers submit multiple applications, while the bottom row in red shows the Ramsey planner solution for the DMP economy where meetings are one-to-one. Dashed lines represent the outcomes when the curvature on the cost function is raised to the power 4 while dotted lines represent the outcomes for when marginal costs are constant.

impact, the planner raises 1.06 percent when the marginal cost of search is constant and by 0.79 percent when the curvature of the search cost function is raised to the power 4. For reference, the baseline model with a quadratic search cost function observes the planner raising benefits on impact by 0.87 percent. Why do benefits rise by less with greater curvature in the search cost function? Intuitively, the planner here is using benefits not only to provide insurance but to tamp down the worker's desire to increase search effort during a recession. In the absence of any change in benefits, the worker always has an incentive to search harder during a recession to help smooth her consumption. When the marginal cost of search effort is constant and not increasing in effort, it becomes less costly for the worker to search harder to self-insure. To counteract this increased insurance motive, the planner purposefully raises benefits by a larger amount when the cost of exerting search effort is constant. The planner seeks to tamp down the amount of search effort exerted by workers during a downturn as increased search effort reduces acceptance rates and dampens the firm's incentive to create jobs. Despite these larger benefits, constant marginal cost of search still leads workers in the model with multiple applications to increase search effort and their average number of applications sent, as the private benefit of finding a job outweighs the private cost of searching. In contrast, when search costs are of the form $\chi\xi^4$, increasing marginal costs of search lead workers to find it costly to exert effort. As such, a lower rise in benefits is needed to curb the desire to increase search effort. In fact, search effort ξ falls by close to 12.7 percent on impact when search costs take the form of $\chi\xi^4$. The differential change in ξ leads to only slight differences in the mean number of applicants per vacancy as increases in λ are largely driven by declines in vacancy creation.

The bottom row of Figure 9 features the planner's outcomes in the DMP economy. In this

case, optimal UI is still largely procyclical, with the planner increasing benefits in the beginning to provide insurance but cutting them soon after to stimulate a faster recovery in search effort. In this case, the increase in benefits on impact are marginally higher in the model with constant marginal costs, leading there to be a larger fall in search effort s on impact, as shown by the dotted line. Despite the more generous benefit initially provided, the model with constant marginal search costs actually observes benefits being cut by a slightly deeper extent. Five periods after the shock, benefits are cut by 2.9 percent in the model with constant marginal search costs as opposed to 2.5 percent in the model with search cost function equal to χs^4. These slightly deeper cuts stimulate a faster recovery in search effort in the constant marginal cost model, which in turn contributes towards improved hiring probabilities for the firm as it raises the rate at which the firm can meet workers. Intuitively, the cut in benefits in the model with search cost function equal to χs^4 is smaller as encouraging a faster recovery in search effort is costly in this model. Finally, changes in θ are swamped by changes in vacancy creation, leading there to be little difference between the two models with different search costs functions.

6 Conclusion

In this paper, I show that in an economy where workers can submit multiple applications, the optimal allocation of unemployment insurance is countercyclical. This is in stark contrast to the planner's choice in a DMP economy, where benefits are largely pro-cyclical. Importantly, an additional consideration exists in the planner's problem when workers can submit multiple applications. In particular, the planner takes into account that while raising the search effort of workers may make it easier for firms to meet workers, this does not necessarily improve firms' hiring probability. When workers search harder and submit more applications, the likelihood that they have more than one offer increases. Because a worker can only work at one job, a higher likelihood of more than one offer than translate into a lower worker acceptance probability. The latter reduces the firm's hiring probability and weakens the value of creating a vacancy. Even when wages are more flexible and the need for insurance provision declines, the planner still does not want to cut benefits during a recession as employment outcomes are not necessarily maximized when workers search a lot. Rather, the planner raises benefits to reduce search and bolster vacancy creation by raising worker acceptance rates.

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Appendix

A Proof of Lemma 1

This section derives the equilibrium conditions detailed in Lemma 1. Under free entry, the value of a vacancy is driven to zero, implying:

$$\kappa = \Gamma(\xi_t, \lambda_t) \left[1 - q\left(0; \lambda_t\right)\right] \left[y_t - w(y_t) + \beta \mathbb{E}_t V_{t+1}^J\right]$$

From the value of an operating firm, we know that:

$$V_t^J = (1-\delta^s)\frac{\kappa}{\Gamma(\xi_t,\lambda_t)[1-q(0;\lambda_t)]}$$

Iterating forward one period, we get:

$$V_{t+1}^J = (1-\delta^s)\frac{\kappa}{\Gamma(\xi_{t+1},\lambda_{t+1})[1-q(0;\lambda_{t+1})]}$$

and plugging the expression for V_{t+1}^J into the free entry condition, we get Equation 8.

From the unemployed worker's problem, optimal search effort is implicitly given by:

$$\frac{\chi'(\xi_t)}{f_\xi(\xi_t,\lambda_t)} = u\left([1-\tau_t]\,w[y_t]\right) - u\left(z[y_t]+b_t\right) + \beta\mathbb{E}_t\left(V_{t+1}^E - V_{t+1}^U\right)$$

where the LHS of the above equation represents the marginal cost of exerting more effort weighted by the rate of change in job-finding with respect to one more unit of effort, and the RHS represents the change in value from finding a job. Subtracting V_t^U from V_t^E and using the fact that the change in value from finding a job is equal to $\frac{\chi'(\xi_t)}{f(\xi_t,\lambda_t)}$, we have:

$$V_t^E - V_t^U = \chi(\xi_t) + (1-\delta^s - f(\xi_t,\lambda_t))\,\frac{\chi'(\xi_t)}{f_\xi(\xi_t,\lambda_t)}$$

Iterating forward one period and plugging the expression of $V_{t+1}^E - V_{t+1}^U$ into the unemployed worker's first order condition with respect to ξ, we get Equation 9.

Equation 10 is the law of motion for the employed, and follows from the fact that $f(\xi_t,\lambda_t)$ fraction of the unemployed at the start of period t, $1-n_t$, will find jobs and become employed by the end of period t, while $(1-\delta^s)$ of the employed at the start of t, n_t, will remain employed by the end of period t. Finally, Equation 7 is the balanced government budget constraint.

B Lagrange formulation of planner's problem

The planner's problem can be written as:

$$\begin{aligned}
\mathcal{L} \;=\; & \mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\Big\{n_{t+1}u\left([1-\tau_t]\,w[y_t]\right) + (1-n_{t+1})\,u\left(z[y_t]+b_t\right) - (1-n_t)\,\chi(\xi_t)\Big\} \\
& + \mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\zeta_t\left\{y_t - w(y_t) + \beta(1-\delta^s)\frac{\kappa}{\Gamma(\xi_{t+1},\lambda_{t+1})\left[1-q(0;\lambda_{t+1})\right]} - \frac{\kappa}{\Gamma(\xi_t,\lambda_t)\left[1-q(0;\lambda_t)\right]}\right\} \\
& + \mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\mu_t\Big\{u\left([1-\tau_t]\,w[y_t]\right) - u\left(z[y_t]+b_t\right) \\
& \qquad + \beta\left(\chi(\xi_{t+1}) + \frac{[1-\delta^s - f(\xi_{t+1},\lambda_{t+1})]}{f_\xi(\xi_{t+1},\lambda_{t+1})}\chi'(\xi_{t+1})\right) - \frac{\chi'(\xi_t)}{f_\epsilon(\xi_t,\lambda_t)}\Big\} \\
& + \mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\sigma_t\Big\{f(\xi_t,\lambda_t)(1-n_t) + (1-\delta^s)\,n_t - n_{t+1}\Big\} \\
& + \mathbb{E}_0\sum_{t=0}^{\infty}\beta^t\psi_t\Big\{\tau_t w(y_t)n_{t+1} - (1-n_{t+1})b_t\Big\}
\end{aligned}$$

B.1 Optimality Conditions

The following equations characterize the planner's optimality conditions

FOC wrt λ_t The first order condition with respect to λ_t is:

$$\begin{aligned}\frac{\left[\zeta_t-\zeta_{t-1}\left(1-\delta^s\right)\right]\kappa}{\Gamma\left(\xi_t,\lambda_t\right)\left[1-q\left(0;\lambda_t\right)\right]}\left[\frac{1}{\Gamma\left(\xi_t,\lambda_t\right)}\frac{d\Gamma\left(\xi_t,\lambda_t\right)}{d\lambda_t}-\frac{1}{\left[1-q\left(0;\lambda_t\right)\right]}\frac{dq\left(0;\lambda_t\right)}{d\lambda_t}\right] &= 0 \\ +\left\{\mu_t-\mu_{t-1}\left[1-\delta^s-f\left(\xi_t,\lambda_t\right)\right]\right\}\frac{\chi'\left(\xi_t\right)}{f_\xi\left(\xi_t,\lambda_t\right)}\frac{f_{\xi\lambda}\left(\xi_t,\lambda_t\right)}{f_\xi\left(\xi_t,\lambda_t\right)} & \\ -\mu_{t-1}f_\lambda\left(\xi_t,\lambda_t\right)\frac{\chi'\left(\xi_t\right)}{f_\xi\left(\xi_t,\lambda_t\right)} & \\ +\sigma_t f_\lambda\left(\xi_t,\lambda_t\right)\left(1-n_t\right) &\end{aligned} \tag{16}$$

The first line in Equation 16 highlights how a higher value of λ_t affects the shadow value of job creation in period t and $t-1$ - as represented by the multiplier ζ_t and ζ_{t-1} - through its impact on meeting rates *and* worker acceptance rates. The former is represented by how the probability of meeting zero applicants in period t, $dq(0;\lambda_t)/d\lambda_t$, is reduced when λ_t increases while the latter is represented by how acceptance probabilities change when λ_t rises, $\Gamma(\xi_t,\lambda_t)/d\lambda_t$. The backward-looking multiplier, ζ_{t-1}, features in the planner's optimality condition as the planner solves a date 0 planning problem and internalizes that raising λ_t affects the value of job-creation in the previous period, ζ_{t-1} The second and third line represent how raising the value of λ_t affects the shadow value of exerting more search effort both in period t and $t-1$, through its impact on job-finding rates. Finally, the last line takes into account how a higher λ affects the measure of employed through its impact on job-finding.

FOC wrt ξ_t The first order condition with respect to ξ_t is:

$$\begin{aligned}-\left(1-n_t\right)\chi'\left(\xi_t\right) &= 0 \\ +\left[\zeta_t-\zeta_{t-1}\left(1-\delta^s\right)\right]\frac{\kappa}{\Gamma\left(\xi_t,\lambda_t\right)\left[1-q(0;\lambda_t)\right]}\frac{1}{\Gamma(\xi_t,\lambda_t)}\frac{d\Gamma\left(\xi_t,\lambda_t\right)}{d\xi_t} & \\ +\left\{\mu_t-\mu_{t-1}\left[1-\delta^s-f\left(\xi_t,\lambda_t\right)\right]\right\}\left\{\frac{\chi'\left(\xi_t\right)}{f_\xi\left(\xi_t,\lambda_t\right)}\frac{f_{\xi\xi}\left(\xi_t,\lambda_t\right)}{f_\xi\left(\xi_t,\lambda_t\right)}-\frac{\chi''\left(\xi_t\right)}{f_\xi\left(\xi_t,\lambda_t\right)}\right\} & \\ +\sigma_t f_\xi\left(\xi_t,\lambda_t\right)\left(1-n_t\right) &\end{aligned} \tag{17}$$

The first line in Equation 17 captures the marginal cost of exerting more effort multiplied by the total unemployed. The second line highlights how a higher value of ξ_t affects the shadow value of job creation in t and $t-1$ through its impact on acceptance rates only. The third line shows that higher search effort impacts the shadow value of exerting more search effort in t and $t-1$ through its impact on the costs of search as well as impact on job-finding rates. The last line shows how higher search effort in t impacts the measure of employed through in impact on job-finding rates.

FOC wrt b_t The first order condition with respect to z is:

$$\left(1-n_{t+1}-\mu_t\right)u'\left(z(y_t)+b_t\right)-\psi_t\left(1-n_{t+1}\right)=0 \tag{18}$$

Intuitively, a higher b_t raises marginal utility of the unemployed. It also affects the shadow value of search effort in period t as the fall in consumption while unemployed is now smaller when b_t is larger and hence this impacts the worker's incentive to search for a job. Finally, it affects the shadow value of relaxing the government budget constraint by changing the amount of transfers sent to the unemployed

FOC wrt τ_t The first order condition with respect to τ is:

$$\psi_t w_t n_{t+1} - (n_{t+1} + \mu_t) w_t u' ([1 - \tau_t] w[y_t]) = 0 \tag{19}$$

The first term captures how higher tax rates affect the shadow value of relaxing the government budget constraint by changing the amount of tax revenues. The second term captures how the marginal utility of the employed as well as the shadow value of search effort in t is affected by higher labor income tax rates.

FOC wrt n_{t+1} The first order condition with respect to n_{t+1} is:

$$\begin{aligned} u ([1 - \tau_t] w[y_t]) - u (z[y_t] + b_t) + \psi_t \{\tau_t w_t + b_t\} &= 0 \\ -\sigma_t + \beta \mathbb{E}_t \sigma_{t+1} [1 - \delta^s - f (\xi_{t+1}, \lambda_{t+1})] & \end{aligned} \tag{20}$$

The first two terms show how a marginal increase in n_{t+1} changes welfare by the gain in utility from having an individual employed. The third term shows how an increase in n_{t+1} affects the shadow value of relaxing the government budget constraint by increasing tax revenues and also reducing the amount of transfers. The last line captures how the planner is forward looking and internalizes that one more individual employed today affects the evolution of employed tomorrow.

Equations 16,17,18,19 and 20, together with constraints 7, 8, 9 and 10 characterize the Ramsey problem's equilibrium allocations.

B.2 Ramsey problem in a standard DMP search model

Because meetings are one-to-one in the DMP model, search effort affects the likelihood of contacting a vacancy, rather than the number of vacancies contacted. Let s_t be the amount of search effort an unemployed worker can choose to exert given cost of search $\chi(s_t)$. Each unit of search effort scales the worker's job-finding probability by $g(s_t)$ where $0 \leq g(s_t) \leq 1$ and $g'(s_t) \geq 0$ and $g''(s_t) \leq 0$. Further, let $\theta = \frac{v}{g(s)u}$ denote the labor market tightness, defined as the ratio of vacancies to effective job-seekers, where the effective number of job-seekers takes into account the search efficiency of the unemployed. Note that the counter-part to tightness in our baseline model is given by the reciprocal of mean applicants per vacancy, i.e., $1/\lambda_t$. Matches follow a Den-Haan matching function as in Den Haan et al. (2000), i.e.,

$$\text{matches}_t = \frac{g(s_t) u_t v_t}{[(g(s_t) u_t)^\alpha + v_t^\alpha]^{1/\alpha}}$$

We will denote the individual worker's job-finding rate as $g(s_t)\widetilde{f}(\theta_t)$ and the firm's job-filling rate as $\widetilde{q}(\theta_t)$. Beyond those differences in definitions, the Ramsey planner problem in the DMP model is similar to that of our baseline model. The utilitarian planner solves a date 0 problem and maximizes expected discounted lifetime utility taking as constraints the equilibrium conditions in the decentralized economy. The Lagrangian formulation of this problem is given by:

$$
\begin{aligned}
\mathcal{L} \;=\; & \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \left\{ n_{t+1} u\left([1-\tau_t]\, w\left[y_t \right] \right) + \left(1-n_{t+1}\right) u\left(z[y_t] + b_t \right) - \left(1-n_t\right) \chi\left(s_t \right) \right\} \\
& + \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \zeta_t \left\{ y_t - w(y_t) + \beta \mathbb{E}_t \left(1-\delta^s\right) \frac{\kappa}{\widetilde{q}\left(\theta_{t+1}\right)} - \frac{\kappa}{\widetilde{q}\left(\theta_t\right)} \right\} \\
& + \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \mu_t \Bigg\{ - \frac{\chi'(s_t)}{g'(s_t)\widetilde{f}(\theta_t)} + u\left([1-\tau_t]\, w[y_t] \right) - u\left(z[y_t] + b_t \right) \\
& \qquad + \beta \mathbb{E}_t \left[\left(1 - \delta^s - g\left(s_{t+1}\right) \widetilde{f}\left(\theta_{t+1}\right) \right) \frac{\chi'\left(s_{t+1}\right)}{g'\left(s_{t+1}\right) \widetilde{f}\left(\theta_{t+1}\right)} + \chi(s_{t+1}) \right] \Bigg\} \\
& + \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \sigma_t \left\{ g\left(s_t\right) \widetilde{f}\left(\theta_t\right) \left[1-n_t\right] + \left(1-\delta^s\right) n_t - n_{t+1} \right\} \\
& + \mathbb{E}_0 \sum_{t=0}^{\infty} \beta^t \psi_t \left\{ \tau_t w(y_t) n_{t+1} - \left(1-n_{t+1}\right) b_t \right\}
\end{aligned}
$$

The following first order conditions together with the constraints contained in lines 2 to 5 of the above Lagrangian characterize equilibrium in the DMP planner's problem:

FOC wrt θ_t

$$
\begin{aligned}
0 \;=\; & \left[\zeta_t - \zeta_{t-1}\left(1-\delta^s\right) \right] \frac{\kappa}{\widetilde{q}\left(\theta_t\right)} \frac{q'\left(\theta_t\right)}{\widetilde{q}\left(\theta_t\right)} \\
& + \left[\mu_t - \mu_{t-1}\left(1-\delta^s\right) \right] \frac{\chi'\left(s_t\right)}{g'\left(s_t\right) \widetilde{f}\left(\theta_t\right)} \frac{\widetilde{f}'\left(\theta_t\right)}{\widetilde{f}\left(\theta_t\right)} \\
& + \sigma_t g\left(s_t\right) \widetilde{f}'\left(\theta_t\right) \left[1-n_t\right]
\end{aligned} \tag{21}
$$

FOC wrt s_t

$$
\begin{aligned}
0 \;=\; & -\left(1-n_t\right) \chi'\left(s_t\right) \\
& + \left\{ \mu_t - \mu_{t-1} \left[1 - \delta^s - g\left(s_t\right) \widetilde{f}\left(\theta_t\right) \right] \right\} \left\{ \frac{\chi'\left(s_t\right)}{g'\left(s_t\right) \widetilde{f}\left(\theta_t\right)} \frac{g''\left(s_t\right)}{g'\left(s_t\right)} - \frac{\chi''\left(s_t\right)}{g'\left(s_t\right) \widetilde{f}\left(\theta_t\right)} \right\} \\
& + \sigma_t g'\left(s_t\right) \widetilde{f}\left(\theta_t\right) \left[1-n_t\right]
\end{aligned} \tag{22}
$$

FOC wrt b_t

$$
0 = \left(1 - n_{t+1} - \mu_t\right) u'\left(z[y_t] + b_t \right) - \psi_t \left(1 - n_{t+1}\right) \tag{23}
$$

FOC wrt τ_t

$$
0 = -\left(n_{t+1} + \mu_t\right) w(y_t) u'\left([1-\tau_t]\, w[y_t] \right) + \psi_t w_t n_{t+1} \tag{24}
$$

FOC wrt n_{t+1}

$$\begin{aligned} 0 &= u\left(\left[1-\tau_t\right] w\left[y_t\right]\right) - u\left(z[y_t]+b_t\right) + \psi_t\left(\tau_t w[y_t]+b_t\right) \\ &\quad -\sigma_t + \mathbb{E}\beta\sigma_{t+1}\left[1-\delta^s - g\left(s_{t+1}\right)\widetilde{f}\left(\theta_{t+1}\right)\right] \end{aligned} \tag{25}$$

Equations 21, 22, 23, 24 and 25 are the analogues to equations 16, 17, 18, 19 and 20 in the baseline model.

C Proof of Lemma 2

Consider the probability a worker receives an offer for a particular application. First note that we can rewrite equation 3 as

$$\mathcal{P}(\lambda_t) = \frac{1}{\lambda_t}\left[1-\exp\left(-\lambda_t\right)\right] = \frac{\left[\exp\left(\lambda_t\right)-1\right]}{\lambda_t \exp\left(\lambda_t\right)}$$

Differentiating the above with respect to λ_t, we get:

$$\mathcal{P}'(\lambda_t) = -\frac{\exp(\lambda_t)-(1+\lambda_t)}{\lambda_t^2\exp(\lambda_t)} = -\frac{\sum_{i=2}^{\infty}\frac{\lambda_t^i}{i!}}{\lambda_t^2\exp(\lambda_t)} < 0 \tag{26}$$

where the second equality uses the fact that $\exp(\lambda) = \sum_{i=0}^{\infty}\frac{\lambda^i}{i!}$. Thus, Equation 26 shows that the offer probability is declining in λ_t. Intuitively, the higher the mean number of applicants per vacancy, the more competitors a worker has to compete with at a vacancy, and thus the lower the offer probability.

Turning to the acceptance probability, differentiating Equation 6, we have:

$$\Gamma_\lambda(\xi_t,\lambda_t) = \sum_{a=1}^{\infty} p(a;\xi_t)\Gamma_\lambda(a;\lambda_t) \geq 0$$

where $\Gamma_\lambda(a;\lambda_t) \geq 0$ as shown below:

$$\Gamma_\lambda(a;\lambda_t) = \left\{\left[1-\mathcal{P}\left(\lambda_t\right)\right]^{a-1} - \frac{\left(1-\left[1-\mathcal{P}\left(\lambda_t\right)\right]^a\right)}{a\mathcal{P}\left(\lambda_t\right)}\right\}\frac{\mathcal{P}'\left(\lambda_t\right)}{\mathcal{P}\left(\lambda_t\right)} \geq 0 \tag{27}$$

Note that the second term on the right hand side of equation 27, $\frac{\mathcal{P}'(\lambda_t)}{\mathcal{P}(\lambda_t)}$, is negative, since we have already established that the numerator $\mathcal{P}'(\lambda_t) < 0$ and the denominator $\mathcal{P}(\lambda_t)$ is bounded between zero and 1. To understand why the first term is also non-positive, note that for $a = 1$, the first term in parentheses in equation 27 becomes 0. For any $a > 1$, the first term in parentheses in equation 27 can be characterized by:

$$\left\{\left[1-\mathcal{P}\left(\lambda_t\right)\right]^{a-1} - \frac{\left(1-\left[1-\mathcal{P}\left(\lambda_t\right)\right]^a\right)}{a\mathcal{P}\left(\lambda_t\right)}\right\} = -\mathcal{P}\left(\lambda_t\right)\frac{\sum_{i=1}^{a}\left(a-i\right)\left[1-\mathcal{P}\left(\lambda_t\right)\right]^{a-i-1}}{a} < 0$$

Thus since both the first term in parentheses and the second term $\frac{\mathcal{P}'(\lambda_t)}{\mathcal{P}(\lambda_t)}$ in equation 27 are either negative or non-positive, this implies that $\Gamma_\lambda(a;\lambda_t)$ and consequently, $\Gamma_\lambda(\xi_t,\lambda_t)$ must be non-negative.

Differentiating equation 6 with respect to ξ_t, we get:

$$\Gamma_{\xi}\left(\xi_t, \lambda_t\right) = \sum_{a=0}^{\infty} p_{\xi}(a; \xi_t)\Gamma\left(a; \lambda_t\right) \tag{28}$$

where

$$p_{\xi}(a; \xi_t) = \left(\frac{a - \xi_t}{\xi_t}\right) p\left(a; \xi_t\right)$$

Clearly, $p_{\xi}(a; \xi_t)$ is negative for $a < \xi_t$ and non-negative for $a \geq \xi_t$. Since an increase in ξ_t shifts the distribution of applications towards higher a and since $\Gamma(a; \lambda_t)$ is generally declining for $a > 1$, we get that ξ tends to weigh negatively on acceptance probability $\Gamma(\xi, \lambda)$ at higher levels of search effort.

C.1 DMP calibration

To calibrate the DMP model, I target the same moments as the baseline model with the exception of the average number of applications, since in DMP, meetings are one-to-one and there is no concept of multiple applications. Instead, to discipline the scaling factor on the search cost function, I target the average percentage of the unemployed who applied to at least 1 vacancy in the last 4 weeks. Faberman et al. (2022) report that about 93 percent of the unemployed apply to at least 1 job. Thus, $g(s)u$ represents the measure of effective job-seekers where $g(s)$ takes into account that not all of the unemployed apply to a vacancy in every period. Further, I assume that $g(s)$ takes the functional form of $g(s) = 1 - exp(-s)$, and thus $g(0) = 0$ and $\lim_{s\to\infty} g(s) = 1$. Further, the matching function follows a Den-Haan matching function:

$$\text{Matches} = \frac{g(s)uv}{\left([g(s)u]^{\alpha} + v^{\alpha}\right)^{1/\alpha}}$$

The elasticity of the matching function, α, is set to 0.5, which is within the range of estimates as documented in Petrongolo and Pissarides (2001). Table 3 summarizes the calibrated parameters.

Table 3: Calibrated parameters for DMP

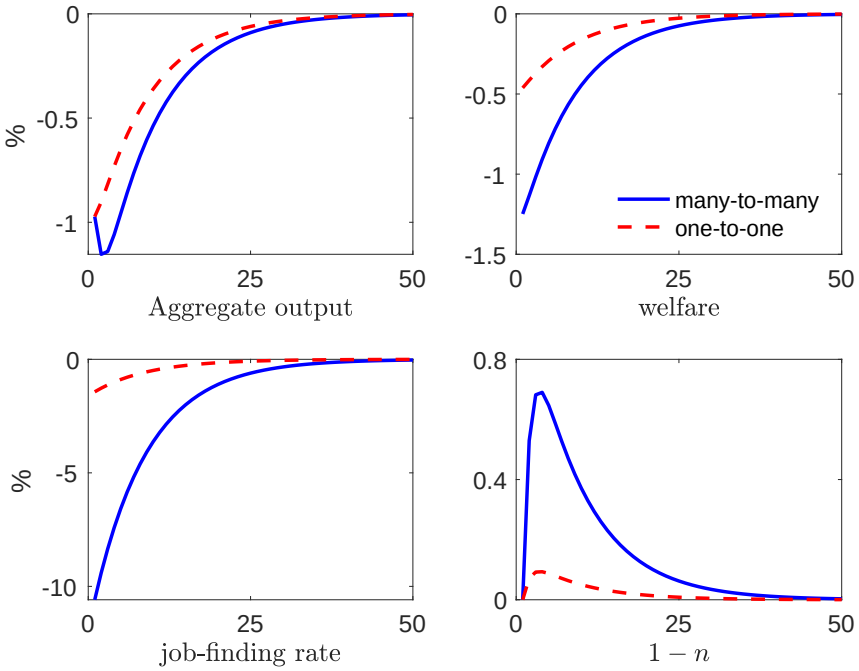
Calibrated Parameters				
Parameter	Value	Targets	Model	Data
κ^{dmp}	0.020	Unemployment rate	0.05	0.05
χ^{dmp}	0.0018	% of unemployed applied to at least 1 job in last month	0.93	0.93
z^{dmp}	0.452	Consumption drop	0.884	0.884

Note: This table provides the internally calibrated parameters for the DMP economy.

C.2 Comparison of decentralized economy outcomes

Figure 10 shows the impulse response in aggregate output and unemployment for the decentralized economies of the multiple applications model (blue solid line) and that of the DMP model (red dashed line). Similar to the Ramsey planner's outcomes, the economy with multiple applications features more volatile responses to a negative one percent productivity shock. This

Figure 10: IRF decentralized economy: multiple applications vs. DMP



Note: This figure plots the impulse response in aggregate output, welfare, job-finding rates and unemployment. Welfare is measured in terms of the average current utility in the economy. The blue solid line shows the decentralized economy outcomes when workers can submit multiple applications, while the red dashed line shows the decentralized economy outcomes for the DMP model.

occurs as greater search effort gives rise to more applications submitted, which adds to more congestion among workers. Unlike the DMP model, where $g(s)$ is bounded between 0 and 1, the number of applications a worker can send is only bounded below by 0 and unbounded above. Thus, greater search effort in the multiple applications model can have a more pronounced effect on worker job-finding rates and unemployment as the number of effective competitors at a job can increase significantly as search effort ξ increases.

C.3 Impulse responses under same parameterization

In this section, I impose that the DMP model follows the same parameters as in the baseline model. The bottom row of Figure 11 shows that in this case, the planner in the DMP model chooses benefits to be completely pro-cyclical. The planner cuts benefits at the beginning of the shock and keeps them persistently lower for the entire duration of the shock. The cut in benefits hastens the recovery in search effort with s recovering to its steady state level 30 months after the shock. This is unlike the Ramsey planner solution in the economy with multiple applications, where the persistent rise in benefits keeps search effort ξ below its steady state level until the shock completely dissipates, as depicted in the top row of Figure 11.

C.4 Calibration: alternative search cost functions

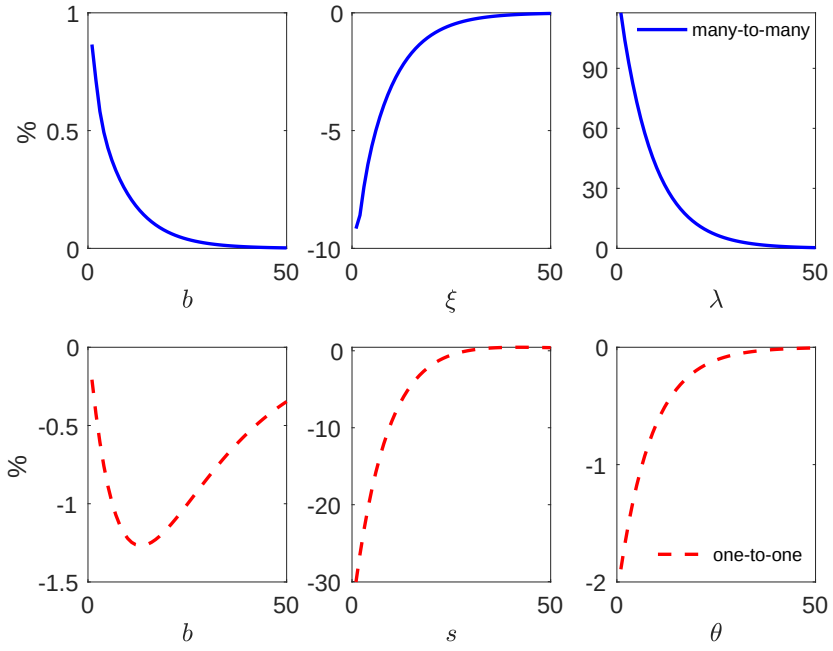
To consider how the planner's choices differ under different search cost functions, the model is recalibrated to match the same targeted moments. Since the unemployment rate and consumption drop upon unemployment pin down κ and z, only the scaling coefficient changes with the curvature of the search cost function to match the target pinning down search effort. Table 4 shows the results

Table 4: Calibrated parameters from models with alternative search cost functions

Calibrated Parameters for search cost function $\chi\xi$				
Parameter	Value	Targets	Model	Data
κ	0.310	Unemployment rate	0.05	0.05
χ	0.038	Average applications	0.93	0.93
z	0.452	Consumption drop	0.884	0.884
Calibrated Parameters for search cost function $\chi\xi^4$				
Parameter	Value	Targets	Model	Data
κ	0.310	Unemployment rate	0.05	0.05
χ	4.0e-5	Average applications	0.93	0.93
z	0.452	Consumption drop	0.884	0.884
Calibrated Parameters for search cost function χs				
Parameter	Value	Targets	Model	Data
κ	0.020	Unemployment rate	0.05	0.05
χ	0.011	Average applications	0.93	0.93
z	0.452	Consumption drop	0.884	0.884
Calibrated Parameters for search cost function χs^4				
Parameter	Value	Targets	Model	Data
κ	0.020	Unemployment rate	0.05	0.05
χ	1.2e-4	Average applications	0.93	0.93
z	0.452	Consumption drop	0.884	0.884

Note: This table shows the calibrated parameters for the models with alternative search cost functions.

Figure 11: IRF of key variables under same parameterization



Note: This figure plots the impulse response in the planner's main instrument b, and its impact on key equilibrium variables concerning search effort (ξ, s) and congestion (λ, θ). The same parameters are imposed on both the economy with multiple applications and the DMP search economy. The blue solid line shows the Ramsey planner solution in the economy where workers submit multiple applications, while the red dashed line shows the Ramsey planner solution for the DMP economy where meetings are one-to-one.