UI and DI: Macroeconomic Implications of Program Substitution*

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Abstract
We study the substitutability of two large income replacement programs in the United States: Unemployment Insurance (UI) and Social Security Disability Insurance (DI). We investigate empirically the effect of the duration of unemployment benefits on the applications for DI and the number of beneficiaries. Using variation in the timing and magnitude of UI extensions across states during the Great Recession, we find that benefit extensions are associated with declines in DI applications. To obtain causal inference, we use two identification strategies. First, using a synthetic cohort and exploiting the sharp and unexpected decline in benefit durations in Missouri in April 2011, we find a sizable increase in DI applications coming from the decline in the duration of unemployment benefits. Second, we use a border discontinuity design and find that the number of DI beneficiaries decreases in response to extensions of benefit durations. Motivated by these findings, and to understand the implications of the two programs for policy, we construct a search model of the labor market with worker heterogeneity in health and skills. In times of low job finding rates, marginal workers claim DI as opposed to UI. The relative generosity of UI and DI benefits affects who uses which program. In particular, extending the duration of UI benefits limits the number of nonemployed individuals that use DI to replace lost income. This effect keeps more workers attached to the labor force and leads to compositional changes by drawing in people with worse health conditions and lower productivity, thereby putting downward pressure on job finding rates. At the same time, by cutting the costs, UI extensions lead to a lower tax rate, which in turn boosts the labor market. We calibrate the model and use it to quantify these tradeoffs and to evaluate the implications of the program substitution for the labor market.

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1 Introduction

Unemployment insurance (UI) and Social Security Disability Insurance (DI) are two of the largest income replacement programs in the United States. On the one hand, between a half and two thirds of eligible unemployed workers claim weekly UI checks, which replace around 40% of their lost income for a temporary period of time. On the other hand, around 8 million people are currently receiving DI benefits, who are paid on average $1,300 per month in addition to providing some health benefits until they reach retirement age and leave the program.

Recent empirical evidence suggests that economic conditions play an important role for individuals’ decision to take up DI (Autor et al. (2013), Autor and Duggan (2003)). Preventing workers who are otherwise capable to work from seeking DI has potentially positive welfare effects. Relative to UI, DI is more costly to run per recipient because DI recipients rarely return to the labor force, whereas UI payments last for a relatively short period of time. Moreover, DI recipients have access to health care, whose costs have been increasing over time. Therefore, to the extent that access to unemployment benefits can keep workers attached to the labor force, there might be an economic rationale for using UI policies actively to keep unemployed workers attached to the labor force. Motivated by this premise, this paper studies the substitutability of these programs and its implications for policy design.

We start with an empirical investigation of the effects of UI benefit durations on DI applications and claims. Our focus on the duration rather than the amount of weekly UI checks is motivated by the fact that the former is already actively used in response to deteriorating labor market conditions. We use three different empirical strategies to investigate this relationship and find that increasing the maximum duration of unemployment benefits deter workers from applying to, and eventually receiving, DI. First, we use the variation in the timing and magnitude of UI extensions during the Great Recession induced by the Extended Benefits (EB) and Emergency Unemployment Compensation (EUC08) programs. The EB program allowed for 13 or 20 weeks of extra benefits in states with elevated unemployment rates based on a set of “triggers” related to the insured and total unemployment rates. The EUC08 program had 4 tiers, providing potentially up to 53 weeks of additional benefits. The availability of each tier was dependent on state unemployment rates. Coupled with the wide variation in the severity of the recession across states, the structure of these additional UI programs introduced large variation in both the timing and the magnitude of UI extensions. At the height of the Great Recession, some states had as high as 99 weeks of UI benefits available for their unemployed workers.
Using this variation across states and over time, we find a negative relationship between
the duration of unemployment benefits and DI applications with an elasticity around -0.08.

Given that the design of the EB and EUC08 programs tied UI durations directly to
state labor market conditions, the variation across states is potentially endogenous with
respect to DI applications, which also depend on labor market conditions, rendering the
interpretation of the cross-sectional relationship challenging. To overcome this potential
endogeneity problem and to measure the causal effect of UI extensions on DI outcomes,
our second approach exploits the sharp and unexpected decline in UI duration in Mis-
souri. In April 2011 Missouri, motivated by political considerations, cut the duration of
its regular benefits from 26 to 20 weeks. Because the EUC and EB benefits depended on
the regular weeks provided by the states, this 6 week cut implied further cuts, resulting
in a total decline of 16 weeks. Crucially, these changes happened within a week and
were unexpected. Following Johnston and Mas (2018), we implement the synthetic con-
trol method developed by Abadie and Gardeazabal (2003). We match U.S. states based on
their disability applications, unemployment rates and industry employment compositions
before April 2011 to construct an artificial state that serves as a control group for the treat-
ment in Missouri. We find that, compared to this control state, monthly DI applications in
Missouri rose by around 0.03 percentage points following the abrupt policy change, and
stayed high for around 2 years.

While the sharp decline in Missouri was unanticipated, large, and plausibly exogenous
to labor market conditions–making it ideal as a quasi-natural experiment–external validity
considerations remain when extrapolating these results to draw nationwide conclusions.
Furthermore, if rejections increase during an economic downturn, a change in applications
does not necessarily result in a change in the DI stock. Then, an important consideration,
especially for the fiscal implications of this interaction, is whether UI extensions eventually
lead to a decline in the DI stock, that is a reduction in the number of workers who
actually receive DI payments. To complement our analysis using DI applications, we use
a border county design that uses UI variation across all states. This identification strategy,
previously used in Card and Krueger (1994), Hagedorn et al. (2019), and Dube et al.
(2010), relies on the idea that the fundamental drivers of local economies are continuous
in space, whereas policies show sharp discontinuities along the state border. In this
empirical approach, our outcome variable is the county-level number of workers receiving
DI benefits. Our analysis here reaches a similar conclusion: Counties in states that
extend benefit durations see a noticeable decline in the number of DI beneficiaries with
an elasticity around -0.038. Considering that on average around one third of applications
are awarded, the estimated elasticity is broadly in line with the elasticity obtained from our panel of state-level DI applications.

Our empirical analysis reveals that UI benefits act in part as a substitute for DI benefits. These findings are important for several reasons. First, as alluded to before, workers are very likely to remain out of labor force once they start receiving DI benefits. The DI program is quite costly for this reason. Second, providing more generous benefits might help the government budget by preventing some unemployed workers going claiming DI. If this is the case, our findings suggest that the welfare benefits of the UI program might be higher than previously thought because of the substitution margin that we document in this paper. These important considerations motivate our quantitative analysis.

In the second part of the paper, we build a quantitative framework to rationalize and understand the empirical findings, and to understand the macroeconomic implications of the substitutability of the UI and DI programs. Specifically, we build a search model with workers that are heterogeneous in their health and skills. They face labor force participation and job search decisions. Nonemployed workers can apply for DI benefits, which requires them to withdraw from the labor force. Alternatively, they can look for a job, while collecting unemployment benefits as long as they are eligible. During an unemployment spell, unemployment benefits expire stochastically. DI awards depend on applicants’ health as well as aggregate labor market conditions. The latter allows us to account for the so called “vocational considerations”.

We test the calibrated model along several dimensions. First, we engineer a downturn with a completely unexpected and persistent decline in labor productivity, and compute the transition path of the economy following this shock. The persistent decline in job finding prospects pushes down the value of remaining in the labor force and makes disability insurance look more valuable than unemployment insurance for the unemployed, resulting in a higher DI application rate, and eventually a higher take up rate, consistent with the data.

Second, we reduce the duration of unemployment benefits unexpectedly and compute the transition of the economy to the new steady state. We find that a decline in UI results in more applications for (and recipients of) DI. The elasticity in the model of DI recipients with respect to a permanent cut in UI is roughly in line with its empirical counterpart, as measured by the Missouri event study.

Related literature. This paper is related to several strands of the literature on UI and DI. There is a recent and growing literature using variation in UI durations during the
Great Recession to study its individual level effects on search effort.\(^1\) Other related papers use similar variation to study the effects of UI extensions on aggregate employment and unemployment.\(^2\) Our paper uses similar sources of variation in the UI duration but studies UI’s impact on aggregate DI outcomes.

Many papers in the DI literature study the secular trend in number of DI beneficiaries and try to shed light on the underlying reasons for the significant increase in claimants as well as its consequences for labor force participation and unemployment.\(^3\) Another strand looks at how permanent economic shocks affect DI take-up.\(^4\) There is a also a growing literature studying labor supply effects of DI receipt using detailed administrative data.\(^5\) We take a different approach than these studies. We keep our focus on the interaction between UI and DI, and what this implies for labor market dynamics at the macro level.

An important and closely related paper to ours is by Mueller et al. (2016). They use UI extensions as a source of variation in UI exhaustions and ask whether workers who exhaust their UI apply for DI afterwards. They use similar aggregate data to ours, and exploit panel and event study methods to show that there is no statistically significant relationship between exhaustions and DI applications. Our paper differs from theirs in multiple ways. First, we use UI extensions as a direct source of variation rather than as a source of variation for expirations. Second, we use different empirical strategies. We exploit the discontinuity of UI at state borders and use county level DI data. In addition, we study a natural experiment to study effects of a UI cut on DI applications. Lastly, our focus is on the macroeconomic implications of this interaction rather than understanding the individual level effects. Our findings and the findings of Mueller et al. (2016) can be reconciled if workers make the DI application decision upon losing employment rather than waiting to use all available UI benefits.

The rest of the paper is organized as follows. Section 2 provides evidence for substitution between the UI and DI programs. Section 3 presents the model that features UI extensions and the decision to apply for DI. Section 4 discusses model calibration and Section 5 studies the macroeconomic implications of the substitution away from DI to UI when UI is extended. Section 6 concludes.

\(^1\)See Rothstein (2011) and Farber and Valletta (2013) for “micro” effects of UI.
\(^2\)See Hagedorn et al. (2019), Johnston and Mas (2018) for “macro” effects, and Di Maggio and Kermani (2017) for aggregate demand effects of UI.
\(^3\)For example see work by Autor and Duggan (2003), Duggan and Imberman (2009) and Liebman (2015).
\(^4\)Autor et al. (2013) study Chinese imports and show that local labor markets more exposed to Chinese trade have higher DI transfers. Black et al. (2002) study the coal industry and show that DI participation increased after the coal bust in the Appalachian regions.
2 An Empirical Investigation of UI–DI Program Substitution

We first document that DI outcomes are counter cyclical. This finding implies that DI is used as an insurance against labor market shocks. As documented by several studies, DI is a costly program and is not meant to be used as insurance against nonemployment. Therefore, we ask if other labor market policies such as unemployment benefit extensions have a material impact on the tendency of individuals to go on disability, and investigate the effect of UI policies on DI take up. To this end, we exploit three different strategies to establish that higher UI benefit durations reduce DI take-up. We first analyze state level data on DI applications. We exploit variation in UI durations across states during the Great Recession induced by discretionary programs to establish that extensions of UI durations are associated with a decrease in DI applications. To estimate the causal relationship, we exploit a quasi-natural experiment in Missouri in April 2011, when UI duration was cut abruptly over the course of a week. Finally, we exploit the discontinuity of UI at state borders to ascertain the effect of UI duration on DI take up. The institutional details relevant for our identification strategy and the various data sources used in the analysis are presented in Appendix Section B.

Unemployment and DI applications over the cycle. In Figure 1, we plot the time series of the cyclical components of the unemployment rate and number of DI applications. After 1984 DI applications are strongly countercyclical—they closely track the unemployment rate. The post-1984 correlation between the two is 0.8. SSA requires DI applicants to refrain from job search. Because being a DI recipient is a highly persistent state—recipients are typically outside the labor force for good—any other policy that keeps the worker attached to the labor force has potentially important implications.

Note the decoupling of the unemployment rate and DI applications in the early 1980s. This feature can be traced to the U.S. Congress, which passed a legislation in 1980 mandating the SSA to increase the frequency of disability reviews and tighten medical criteria for DI eligibility. Following the recession in 1981 the public backlash lead the Congress to pass another legislation in 1984, changing the disability determination system substantially. This change resulted in a broader definition of disability and provided applicants more influence over the decision process. See Autor and Duggan (2003) for more details on this episode.
A cohort study of DI take up. We now turn to the question of whether adverse labor market conditions result in more people claiming DI. Establishing the cyclicality of DI receipt—as opposed to applications—is more challenging due to the significant lag between the application date and the administrative decision on the case. To address this issue, we follow a strategy similar to Storesletten et al. (2004), where we use panel data from the SIPP and compare cohorts at similar ages that faced different macroeconomic histories. This allows us to measure how the labor market conditions that an individual faces affects its decision to claim DI.

To this end, first, we classify each year between 1929 and 2017 an expansion (contraction) if the real GNP per capita growth rate is larger (smaller) than its long-run average. Second, using information available in the SIPP, we identify workers who receive DI. Third, we calculate the share of DI recipients for each cohort between ages 25 and 60 for each year between 1995 and 2013.

In Figure 2 we plot the average DI share by cohort against the share of expansionary years that specific cohort lived through in their career, controlling for age effects.
Our analysis shows that cohorts who lived through more expansionary years in their working lives are less likely to be receiving DI benefits.

Taking stock. We showed that DI applications are strongly counter cyclical and that adverse labor market conditions translate into a higher DI take up rate. We now turn to whether counter cyclical UI extensions prevent workers from applying for and eventually receiving DI benefits.

Exploiting variation in UI durations induced by discretionary programs. The Extended Benefits (EB) and the Emergency Unemployment Compensation programs (EUC) gradually raised the potential maximum duration of unemployment benefits from its typical duration of 26 weeks in most states to a maximum of 99 weeks. Both of these programs were based on explicit triggers that depended on state-level labor market conditions, in particular the unemployment rate. Due to large variation in the severity of the Great Recession across states, there were large differences in the timing and magnitude of UI durations. We use a monthly panel of states to investigate the link between UI extensions and DI applications over the period 2006–2014.

Specifically, we estimate

$$\log(\text{DI applications}_{st}) = \alpha_s + \gamma_t + \beta \log(\text{UI duration}_{st}) + \eta U_{st} + \xi_{st},$$

where $\text{DI applications}_{st}$ is the seasonally adjusted number of DI applications in state $s$ at
Since DI applications are cyclical for reasons unrelated to unemployment benefit policies, we control for the state unemployment rate $U_{st}$. We include state and time fixed effects to control for permanent differences across states and aggregate time-varying factors that shift DI applications. We cluster standard errors by states to deal with serial correlation of residuals.

Table 1: Unemployment Benefit Extensions and Disability Insurance

### A. STATE LEVEL ANALYSIS

<table>
<thead>
<tr>
<th>Variables</th>
<th>log(DI Applications)</th>
</tr>
</thead>
<tbody>
<tr>
<td>log(UI Duration)</td>
<td>−0.082**</td>
</tr>
<tr>
<td></td>
<td>(0.035)</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>0.020***</td>
</tr>
<tr>
<td></td>
<td>(0.006)</td>
</tr>
<tr>
<td>$N$</td>
<td>4896</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.989</td>
</tr>
<tr>
<td>Time FE</td>
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</tr>
<tr>
<td>State FE</td>
<td>✓</td>
</tr>
</tbody>
</table>

### B. BORDER COUNTIES

<table>
<thead>
<tr>
<th>Variables</th>
<th>(1) log(DI Beneficiaries)</th>
<th>(2) log(DI Beneficiaries)</th>
<th>(3) log(DI Beneficiaries)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta_p$ log(UI Duration)</td>
<td>−0.039***</td>
<td>−0.038***</td>
<td>−0.040***</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.011)</td>
<td>(0.012)</td>
</tr>
<tr>
<td>$\Delta_p$ log(Pop\textsubscript{20–64})</td>
<td>0.391***</td>
<td>0.396***</td>
<td>0.468***</td>
</tr>
<tr>
<td></td>
<td>(0.095)</td>
<td>(0.099)</td>
<td>(0.100)</td>
</tr>
<tr>
<td>$\Delta_p$ log(Unemployed)</td>
<td>−0.007</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.014)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\Delta_p$ log(Employed)</td>
<td></td>
<td></td>
<td>−0.109**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.045)</td>
</tr>
<tr>
<td>$N$</td>
<td>10534</td>
<td>10534</td>
<td>10534</td>
</tr>
<tr>
<td>$R^2$</td>
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<td>0.997</td>
<td>0.997</td>
</tr>
<tr>
<td>County Pair FE</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

Notes: Panel A: Monthly state-level data on DI applications covering years between 2006–2014. Standard errors are clustered by state. Panel B: Estimates of the border county design. $\Delta_p$ denotes the pairwise difference operator between border county pairs. Data cover 2006–2014. Standard errors are clustered by border county pairs. *** p<0.01, ** p<0.05, * p<0.1.

Panel A of Table 1 shows that DI applications decline in states that extend unemployment benefit durations. The estimated elasticity of DI applications with respect to benefit duration is -0.08, meaning that an increase of benefit durations from 26 weeks to 52 weeks is associated with a 5.8% decrease in DI applications.

**Missouri case study.** While the state-level analysis is suggestive of program substitution between UI and DI, it suffers from a well-known identification problem. Namely, because
UI durations are mechanically a function of the state unemployment rate, and because DI applications may also respond to labor market conditions, the variation in benefit durations is not exogenous. To overcome this challenge and establish a causal link, we exploit the sharp unexpected decline of benefit durations in Missouri. Specifically, Missouri cut its regular benefits from 26 to 20 weeks in April 2011 as a result of a compromise reached to end a Republican filibuster of legislation that would have accepted federal money to extend benefits under the EB program. Since the EUC and EB benefit calculations depend on regular weeks provided by states, this 6 week cut resulted in further cuts that amounted to a 16 week overall decline in the maximum potential benefit duration. Importantly, the cut was unanticipated and happened very quickly (within a week), therefore arguably the measured outcome does not suffer from potential confounding factors such as anticipation effects.

Figure 3: Missouri UI Cut

Notes: DI applications in Missouri relative to a synthetic control of other US states following the unanticipated UI cut in April 2011.

Following Johnston and Mas (2018), we use the synthetic control method developed by Abadie and Gardeazabal (2003). Specifically, we compare Missouri to a synthetic control of other US states based on their disability applications, unemployment rates and employment shares by NAICS-1 sectors before the April 2011 cut. Figure 3 shows a noticeable jump in DI applications around the time of the sharp cut in unemployment benefit durations. Specifically, after the policy change, DI applications in Missouri rose

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7Johnston and Mas (2018) use this experiment to study the effects of the unexpected cut on unemployment and unemployment duration. See their discussion for more details on how the events leading to the sharp UI cut unfolded.
by around 0.02% on a monthly frequency and stayed high for around 2 years. Thus, over this period, the benefit cut is estimated to have led to an increase of more than 0.2% in DI applications. Quantitatively, total DI applications over a year increase by around 0.1%. Importantly, this increase in DI applications was not a result of higher unemployment rate. In fact, as shown by Johnston and Mas (2018), the cut in UI durations led to a sizable decline in the unemployment rate.

Discontinuity of UI durations at state borders. So far, we have established that UI extensions lead to a nonnegligible decline in DI applications. While this finding is indicative of substitution between the UI and DI programs, it does not necessarily imply that benefit extensions result in fewer DI beneficiaries, which is the main interest of our paper. A discrepancy might arise if, for example, benefit extensions also lead to a change in the award rate of new applications. We now investigate how the number of workers that are on DI changes when UI durations get extended. To this end, we use a border discontinuity design as in Card and Krueger (1994), Hagedorn et al. (2019), and Dube et al. (2010), among others, and compare counties that are geographically close—and thus share many common features—but are subject to different UI benefit durations as they belong to different states.

To implement this strategy, we estimate the following specification:

\[ \Delta_p y_t = \alpha_p + \beta \Delta_p \log(\text{UI Duration}_t) + \Delta_p X'_t \gamma + \varepsilon_{pt}. \]  

Here, \( p \) indexes a border county pair, \( \Delta_p \) denotes the pairwise difference operator between two counties in the same pair. \( X'_t \) is a set of controls that include county population, employment, and unemployment. \( y_t \) is the outcome of interest. The number of DI beneficiaries at the county level are reported at an annual frequency. Therefore, we take annual averages of monthly UI durations and estimate equation 1 on annual data. Our sample covers the period 2006–2014. We cluster standard errors by county pairs.

Panel B of Table 1 reports our estimates of the effects of benefit extensions on DI beneficiaries. Column 1 reports an elasticity around -0.04, which implies that an increase in UI duration from 26 weeks to 52 weeks leads to a 2.7% decline in the number of DI beneficiaries. This negative elasticity provides further evidence that UI acts to some extent as a substitute for DI. Furthermore, considering that on average around one third of applications are awarded, the estimated elasticity is broadly in line with the elasticity

\[ y_{cp(c)t} = \eta_c + \alpha_{p(c)t} + \beta \log(\text{UI Duration}_{c(c)t}) + X'_t \gamma + \varepsilon_{pt}, \]

where DI take up \( y_{cp(c)t} \) is regressed on county and pair-time fixed effects as well as state UI duration and county-level observables.
of applications estimated previously.

![Figure 4: Workers on Disability vs UI Duration](image)

Notes: Binned scatterplot of county level disabled workers against UI duration in the sample of border counties. Both variables are residualized against county and pair-time dummies as well as county population and unemployment.

To supplement the regression analysis and provide visual evidence, Figure 4 presents a binned scatterplot of log disabled workers against log UI duration, where both variables are residualized against county and pair-time dummies, population and unemployment levels. The figure also includes a quadratic fitted to the underlying data, revealing a linear relationship between (log) UI duration and DI beneficiaries.

3 A Model of Unemployment and Disability Insurance

We now develop a model of the labor market that embeds the two income replacement programs of interest and allows for a substitution between them. We later use this model to quantify the macroeconomic implications of the empirical findings for the design of social assistance programs.

3.1 Environment

Time $t$ is discrete and runs forever. There is a unit mass of workers, with risk neutral preferences and discount factor $\beta$. There is a larger mass of firms. Workers are either employed, unemployed and searching for a job, applying for DI or receiving DI benefits. Unemployed job seekers could be eligible or ineligible for UI benefits. Since our model
features a labor force participation margin, we refer to workers who are not employed as the non-employed and job seekers as the unemployed, who are a subset of the non-employed.

**Worker Skill and Health**  We assume that workers are heterogeneous along two dimensions: skill and health. A worker’s skill takes values on grid $s \in \{s_1, \ldots, s_S\}$. Each worker starts from the lowest skill, and she experiences stochastic appreciation and depreciation of skills based on her employment status. An employed worker’s current skill $s_i$ ($i \in \{1, \ldots, S\}$) evolves according to:

$$s' = \begin{cases} 
  s_{i+1} & \text{with probability } \pi^d \\
  s_i & \text{with probability } 1 - \pi^d 
\end{cases}$$

Similarly, a non-employed worker’s skill $s_i$ follows:

$$s' = \begin{cases} 
  s_{i-1} & \text{with probability } \pi^d \\
  s_i & \text{with probability } 1 - \pi^d 
\end{cases}$$

We further assume that a worker can be in three health levels $h \in \{0, 1, 2\}$ indicating no, some and severe work limitations. Workers incur disutility from work that depends on their health level, denoted by $c(h)$, where $c(h)$ increases in the severity of work limitation. We assume that workers start their lives with no work limitation ($h = 0$), and are subject to exogenous health shocks each period. A worker’s health can diminish with probability $\lambda^d(h)$, and improve with probability $\lambda^a(h)$. Unlike the skill process, here we allow the transition rates between health levels to depend on the current work limitation of the worker. We further assume that each period workers are hit with a mortality shock at rate $\nu$.

**Matching**  Meetings between vacancies and unemployed workers follow a constant returns to scale matching function $M(u, v) < \min\{u, v\}$. Labor market tightness $\theta = \frac{v}{u}$ is the ratio of vacancies to unemployed workers. The contact rate for an unemployed worker is $f(\theta) = \frac{M}{u} = M(1, \theta)$ and for a firm is $q(\theta) = \frac{M}{v} = M(1/\theta, 1)$. We assume that matches are ex-post heterogeneous; upon contact a random match specific productivity $x$ is drawn from distribution with c.d.f. $G(x)$ and is constant throughout the duration of the match. The worker-firm pair, depending on this match productivity and worker’s skill, decide whether to consummate the match or not.
Production  A worker-firm pair with match specific productivity $x$, worker health $h$ and skill $s$ produces output that potentially depends on all these factors. We keep the notation general and denote output from the match by $y(x, h, s)$.

Government Policy  The government levies a proportional tax $\tau$ on output to finance the UI and DI programs. We assume that the probability of admission to the DI program conditional application is a function of the aggregate labor market conditions summarized by market tightness, worker health and skill, denoted by $p(\theta, h, s)$.$^9$ We model UI eligibility as in Mitman and Rabinovich (2014). Workers can be eligible or ineligible for UI benefits, denoted by a superscript $i \in \{E, I\}$. An ineligible worker who is employed becomes re-entitled for UI at rate $r$, and UI expires at rate $e$ while a worker is unemployed and searching for a job. We assume that if a worker applies for DI, she gives up her UI eligibility and becomes ineligible.

Timing  The timing of events within period $t$ is as follows:

1. Productivity $x$ of new matches are realized.

2. Employed workers decide to quit or continue with their matches. Non-employed workers decide to search for a job or apply for disability benefits.

3. Production and consumption take place. Employed workers consume a bargained wage $w$, eligible unemployed workers receive benefit $b$, workers on disability receive $d$. All workers consume home production $\xi$.

4. Firms decide how many vacancies to post, and they pay a flow cost $\kappa$ per vacancy. This determines market tightness:

$$\theta = \frac{v_t}{u^E_t + u^I_t}$$

where $u^E_t$ and $u^I_t$ denote the mass of eligible and ineligible unemployed workers respectively.

5. $f(\theta)(u^E_t + u^I_t)$ of workers find jobs. Fraction $\delta$ of matches are exogenously destroyed.

$^9$This is to incorporate the so called “vocational considerations”, that is the DI examiner takes into account employability of the applicant. This leads to a higher probability of admission during recessions keeping health constant.
6. UI-eligible non-employed workers become ineligible with probability $e_t$ (benefit expiration). Ineligible employed workers become eligible with probability $r_t$ (benefit re-entitlement).

7. Health and skill shocks are realized.

3.2 Value Functions

We express decision problems of the worker and firm recursively. We drop time subscripts and use primes (‘) to denote the next period. To save on notation, we use operator $\mathbb{E}$ to take expectations, where it is understood to be taken with respect to the health and skill processes. Since the skill process depends on the employment status of the worker, we use subscripts $n$ for nonemployment and $e$ for employment to clarify which underlying skill process we refer to while taking expectations.

**Worker Problem** A non-employed worker with health and skill, given by tuple $(h, s)$, and eligibility status $i$ decides whether to search for a job or apply for DI. Her value at this stage is:

$$\hat{U}^i(h, s) = \max \{ U^i(h, s), D^A(h, s) \} \text{ for } i \in \{E, I\}.$$ 

Value of job search for an eligible worker is:

$$U^E(h, s) = \xi + b + \beta (1 - \nu) \left[ \left( 1 - f(\theta) \right) e \mathbb{E}_n [ \hat{U}^I(h', s')] + \left( 1 - f(\theta) \right) (1 - e) \mathbb{E}_n [ \hat{U}^E(h', s')] \right]$$

$$+ f(\theta) \int_{x'} \mathbb{E}_n \left[ \max \{ W^E(x', h', s'), \hat{U}^E(h', s') \} \right] dG(x')$$

The worker consumes home production $\xi$ and UI benefit $b$. With probability $\nu$ the worker dies, in which case her value is 0. Conditional on survival, if she does not contact a firm, she continues to the next period non-employed. If the worker contacts a firm, she decides whether to take the job or not depending on match productivity $x$. While the eligible worker is unemployed, with probability $e$, her UI benefits expire and she continues as an ineligible worker into the next period.

Value of job search for an ineligible worker is similar, except now the worker does not
receive UI benefits. This value is given by:

\[ U^I(h, s) = \xi + \beta(1 - \nu) \left[ (1 - f(\theta))\mathbb{E}_n[\tilde{U}^I(h', s')] \right] + f(\theta) \int_{x'} \mathbb{E}_n \left[ \max \left\{ W^I(x', h', s'), \tilde{U}^I(h', s') \right\} \right] dG(x') \]

Value of employment for an eligible worker is:

\[ W^E(x, h, s) = w - c(h) + \beta(1 - \nu) \left[ \delta \mathbb{E}_e[\tilde{U}^E(h', s')] + (1 - \delta) \mathbb{E}_e \left[ \max \left\{ W^E(x, h', s'), \tilde{U}^E(h', s') \right\} \right] \]

The employed worker consumes a bargained wage (discussed later) and incurs disutility from work, which increases with her work limitation. Conditional on survival, the worker separates into non-employment with exogenous probability \( \delta \). Otherwise, after the realization of her new skill and health status, the worker decides to continue with her current match or transition to non-employment next period.

Value of employment for an ineligible worker is:

\[ W^I(x, h, s) = w - c(h) + \beta(1 - \nu) \left[ \delta \mathbb{E}_e[\tilde{U}^I(h', s')] + (1 - \delta) \mathbb{E}_e \left[ \max \left\{ W^I(x, h', s'), \tilde{U}^I(h', s') \right\} \right] \]

which is similar to the problem of an eligible employed worker. While the worker is employed, with probability \( r \), she becomes re-entitled to UI benefits and continues as an eligible employed worker into the next period.

Value of applying for DI benefits is given by:

\[ D^A(h, s) = \xi + \beta(1 - \nu) \left[ p(\theta, h, s)\mathbb{E}_n[D^R(h', s')] + (1 - p(\theta, h, s))\mathbb{E}_n[\tilde{U}^I(h', s')] \right] \]

The worker consumes home production while applying for DI. She is admitted into the program with probability \( p(\theta, h, s) \). With the complementary probability she continues to the next period as non-employed. Importantly, whenever the worker applies for DI benefits, she automatically becomes ineligible for UI.
Finally, the value of receiving DI benefits is given by:

$$D^R(h, s) = \xi + d + \beta(1 - \nu)\mathbb{E}_\pi\left[ \max \left\{ D^R(h', s'), \tilde{U}^I(h', s') \right\} \right]$$

Note that, conditional on survival, we allow for the worker to leave the DI program and potentially search for a job next period.

**Firm Problem**  The firm problem largely mirrors the worker problem. There is free-entry of firms, therefore the value of posting a vacancy is zero. The firm Bellman Equations already reflect this equilibrium condition.

A firm with match productivity $x$, employing an eligible worker with health-skill tuple $(h, s)$ has value:

$$J^E(x, h, s) = (1 - \tau) \times y(x, h, s) - w$$

$$+ \beta(1 - \nu)(1 - \delta)\mathbb{E}_c\left[ \mathbb{I}\left\{ W^E(x, h', s') > \tilde{U}^E(h', s') \right\} J^E(x, h', s') \right]$$

Output is taxed proportionally at rate $\tau$ and the firm captures the after-tax revenue net of wage payments as flow profits. Conditional on worker survival and no exogenous separation, the worker-firm match continues to the next period if the worker does not quit into non-employment following her new skill and health status realizations.

Similarly, the value of firm employing an ineligible worker is given by:

$$J^I(x, h, s) = (1 - \tau) \times y(x, h, s) - w$$

$$+ \beta(1 - \nu)(1 - \delta)\mathbb{E}_c\left[ \mathbb{I}\left\{ W^E(x, h', s') > \tilde{U}^E(h', s') \right\} J^E(x, h', s') \right]$$

$$+ (1 - r)\mathbb{E}_c\left[ \mathbb{I}\left\{ W^I(x, h', s') > \tilde{U}^I(h', s') \right\} J^I(x, h', s') \right]$$

where the continuation value reflects the fact that worker can become re-entitled for UI benefits while employed.
**Free Entry**  As already mentioned, free entry drives down the value of posting a vacancy to zero, resulting in the following condition:

\[
\kappa = \beta q(\theta) \frac{1}{u} \left\{ \sum_h \sum_s u^E(h, s) \int_x I\{W^E(x, \mu, s) > \tilde{U}^E(\mu, s)\} f^E(x, h, s) dG(x) + \sum_h \sum_s u^I(h, s) \int_x I\{W^I(x, \mu, s) > \tilde{U}^I(\mu, s)\} f^I(x, h, s) dG(x) \right\}
\]

where \( u = \sum_h \sum_s \left( u^E(h, s) + u^I(h, s) \right) \) is the total mass of unemployed workers, and \( u^i(h, s) \) for \( i \in \{E, I\} \) is the mass of unemployed workers with health \( h \), skill \( s \) and UI-eligibility status \( i \).

### 3.3 Match Surplus and Wage Bargaining

Joint surplus from a match is defined as:

\[
S^i = J^i + W^i - \tilde{U}^i \quad \text{for } i \in \{E, I\}.
\]

Wages are determined according to generalized Nash Bargaining with worker share \( \phi \in (0, 1) \) to maximize:

\[
(W^i - \tilde{U}^i)^\phi (J^i)^{1-\phi}
\]

resulting in a linear surplus sharing rule; worker captures share \( \phi \) of joint surplus and firm captures the rest:

\[
W^i - \tilde{U}^i = \phi S^i \\
J^i = (1 - \phi) S^i
\]

### 3.4 Equilibrium Definition

The stationary equilibrium of the model is a set of value functions \( W^E(x, h, s), W^I(x, h, s), U^E(h, s), U^I(h, s), J^E(x, h, s), J^I(x, h, s), D^A(h, s), D^R(h, s) \), proportional output tax rate \( \tau \), market tightness \( \theta \), and wages \( w^E(x, h, s), w^I(x, h, s) \) such that:

- The value functions satisfy the worker and firm Bellman Equations.
- Market tightness satisfies the free-entry condition in Equation (2).
• \( w^E(x, h, s) \) and \( w^I(x, h, s) \) maximize Equation (3).

• Worker distribution evolves according to the laws of motion in Appendix Section C.1.

• Tax rate \( \tau \) balances the government budget constraint, i.e. \( \tau = \frac{b \sum h, s u^E(h, s) + d \sum h, s r(h, s)}{\sum x, h, s y(x, h, s)(e^E(x, h, s) + e^I(x, h, s))} \), where \( e^i(x, h, s) \) for \( i \in \{E, I\} \) is the mass of employed workers with match productivity \( x \), health \( h \), skill \( s \) and UI-eligibility status \( i \), and \( r(h, s) \) is the mass of DI recipients with health \( h \) and skill \( s \).

4 Calibration (Preliminary)

In this section we discuss the choice of functional forms, parameters and the calibration strategy. We set a model period to one month, consistent with the frequency of observations from the multiple data sources that we use.

Functional Forms To solve the model, we need to choose a functional form for \( M(U, V) \). We assume a constant elasticity of substitution matching function as proposed by Haan et al. (2000):

\[
M(U, V) = \frac{UV}{(U^\lambda + V^\lambda)^{1/\lambda}}
\]

which yields contact rates for unemployed job seekers and and firms given by:

\[
f(\theta) = \frac{\theta}{(1 + \theta^\lambda)^{1/\lambda}} \quad \text{and} \quad q(\theta) = \frac{1}{(1 + \theta^\lambda)^{1/\lambda}}
\]

where \( \lambda \) is an elasticity parameter.

For now, we assume that output from a match only depends on worker skill and there is no heterogeneity in match specific productivity, hence the production function is given by \( y(x, h, s) = s \).

Calibration Strategy There are 16 parameters in the model. We choose 10 parameters without solving the model and jointly estimate the remaining 6 to be consistent with a number of average labor market outcomes during the pre-recession peak period of December 2007. Table 3 summarizes model parameters and their values.
Parameters Set Outside of the Model  We set the monthly discount factor to $\beta = 0.9967$ yielding an annual interest rate of 4 percent. We fix the life of workers to 40 years, yielding $\nu = 1/480$.

We set the UI expiration and re-entitlement rates to $e = 1/5.98$ and $r = 1/5.52$ respectively. This follows from the weekly calibration of Mitman and Rabinovich (2014), who in turn target an expected regular UI benefit duration of 26 weeks and account for the fact that it takes 6 months of employment to gain eligibility for unemployment benefits.

To discipline the health evolution process, we follow an approach similar to Low and Pistaferri (2015). Specifically, we assume that there are three distinct health levels corresponding to no, limited and severe work limitations. To categorize workers into these health groups we first pool the 1996, 2001, 2004 SIPP panels. We assume a worker has no work limitation if she answers “no” to question: “Do you have a physical, mental, or other health condition that limits the kind or amount of work you can do at a job or business?”. In case she answers yes we further use the response to question: “Does ... health or condition prevent you from working at a job or business?”. If the answer is affirmative we assume the worker is severely disabled, otherwise we assume she has a moderate work limitation. After having identified the health status of workers for each survey month in the SIPP, we calculate the average transition rates between these three health levels, which gives us our exogenous health evolution process. Table 2 summarizes these transition probabilities.

<table>
<thead>
<tr>
<th></th>
<th>Severe</th>
<th>Moderate</th>
<th>Good</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe</td>
<td>.9712</td>
<td>.0106</td>
<td>.01812</td>
</tr>
<tr>
<td>Moderate</td>
<td>.0205</td>
<td>.9098</td>
<td>.0695</td>
</tr>
<tr>
<td>Good</td>
<td>.0017</td>
<td>.0035</td>
<td>.9946</td>
</tr>
</tbody>
</table>

Notes: Monthly health transition rates calculated from the SIPP.

To discipline the process for skill evolution, we proceed as follows. First, we compute residual wage dispersion in the PSID and find that the standard deviation of wages is 0.61. To calculate residual wages, we run a standard Mincer regression, i.e. we regress the log of hourly wages on a number of observable worker characteristics, including age and age squared but excluding variables related to worker skill (like education).
middle point of the grid. We then solve for the skill appreciation probability that yields an expected annual wage gain of 1%. This yields a skill appreciation rate of $\lambda^a = 0.0016$. For the probability of skill loss, we target a 10% wage loss in three months following job displacement. This yields a skill depreciation rate of $\lambda^d = 0.0656$.

We set the elasticity parameter $\lambda$ of the matching function to 0.4, as estimated in Hagedorn and Manovskii (2008) for the US. We assume a standard worker bargaining share $\phi = 0.5$. For now, we take a simplistic approach and fix the DI admission probability to $p(\theta, h, s) = 0.25$, consistent with the calibration in Kitao (2014), who targets an expected DI wait time of around 4 months. We also shut down home production and set $\xi = 0$.

**Parameters Set by Solving the Model** We calibrate the remaining parameters to minimize the sum of squared percent deviations of model moments from their empirical counterparts.

We target the average job finding rate by three health statuses, the unemployment rate, the share of working age population on DI benefits and the average employment-to-nonemployment separation rate to estimate the level of DI benefits $d$, UI benefits $b$, level of disutility from work $c(h_1)$ and $c(h_2)$ for workers with severe and moderate work limitations, vacancy posting cost $\kappa$ and exogenous match destruction rate $\delta$. Panel B of Table 3 summarizes these parameter values, and Table 4 summarizes the targeted moments and their model counterparts.
Table 3: Model Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>Value</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Predetermined</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\beta$</td>
<td>Discount Factor</td>
<td>0.9967</td>
<td>4% annual interest rate</td>
</tr>
<tr>
<td>$\nu$</td>
<td>Death probability</td>
<td>1/480</td>
<td>40 year work life</td>
</tr>
<tr>
<td>$e$</td>
<td>UI expiration rate</td>
<td>1/5.983</td>
<td>26 week regular UI benefits</td>
</tr>
<tr>
<td>$r$</td>
<td>UI re-entitlement rate</td>
<td>1/5.523</td>
<td>6 month employment</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Worker bargaining share</td>
<td>0.5</td>
<td>–</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>Matching function parameter</td>
<td>0.4</td>
<td>Hagedorn and Manovskii (2008)</td>
</tr>
<tr>
<td>$p(\theta, h, s)$</td>
<td>DI admission probability</td>
<td>0.25</td>
<td>Kitao (2014)</td>
</tr>
<tr>
<td>$\xi$</td>
<td>Home production</td>
<td>0</td>
<td>–</td>
</tr>
<tr>
<td>$\lambda^a$</td>
<td>Skill appreciation probability</td>
<td>0.0016</td>
<td>See main text.</td>
</tr>
<tr>
<td>$\lambda^d$</td>
<td>Skill depreciation probability</td>
<td>0.0656</td>
<td>See main text.</td>
</tr>
<tr>
<td>B. Estimated</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\kappa$</td>
<td>Vacancy posting cost</td>
<td>0.1067</td>
<td></td>
</tr>
<tr>
<td>$d$</td>
<td>DI benefit level</td>
<td>0.1345</td>
<td></td>
</tr>
<tr>
<td>$b$</td>
<td>UI benefit level</td>
<td>0.1732</td>
<td></td>
</tr>
<tr>
<td>$\delta$</td>
<td>Exogenous separation rate</td>
<td>0.0097</td>
<td></td>
</tr>
<tr>
<td>$c(h_1)$</td>
<td>Severe work limitation disutility</td>
<td>0.2411</td>
<td></td>
</tr>
<tr>
<td>$c(h_2)$</td>
<td>Moderate work limitation disutility</td>
<td>0.1073</td>
<td></td>
</tr>
</tbody>
</table>

Table 4: Model Fit

<table>
<thead>
<tr>
<th>Moment</th>
<th>Data</th>
<th>Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unemployment Rate</td>
<td>0.045</td>
<td>0.0628</td>
</tr>
<tr>
<td>DI share</td>
<td>0.045</td>
<td>0.0514</td>
</tr>
<tr>
<td>EN separation rate</td>
<td>0.015</td>
<td>0.0125</td>
</tr>
<tr>
<td>Severe Job Finding Rate</td>
<td>0.0860</td>
<td>0.0187</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.2260</td>
<td>0.2436</td>
</tr>
<tr>
<td>Good</td>
<td>0.2516</td>
<td>0.3003</td>
</tr>
</tbody>
</table>

5 Quantitative Exercises (Preliminary)

In this section, we study the business cycle implications of the interaction between UI and DI. First, we introduce an aggregate productivity process to our stationary setting, assuming that the production function becomes $z \times y(x, h, s)$ and that aggregate productivity $z$
evolves according to an AR(1) process in logs:

$$\log(z_{t+1}) = \rho \log(z_t) + \sigma \varepsilon_{t+1}$$ (4)

We parameterize the persistence parameter and the standard deviation as $\rho = 0.975$ and $\sigma = 0.0044$ following Fujita and Ramey (2007).

We are primarily interested in the transition dynamics of our model. In calculating the relevant impulse responses, we focus on perfect foresight transition dynamics following one-time, unanticipated shocks out of steady state, using a shooting algorithm that we explain in Appendix Section D.2.

In our first exercise, we trace out the equilibrium outcomes of our model following a negative productivity shock that hits the economy at period $t = 1$ and follows the dynamics of Equation (4) afterwards with $\varepsilon_t = 0$ for $t > 1$. Figure 5 presents the impulse responses from this experiment.

Figure 5: Negative Productivity Shock

Notes: Transition paths following a temporary negative productivity shock. Y-axis is percent deviation from steady state.

Upon the negative productivity shock, the returns to posting a vacancy decreases, and thereby unemployment increases. This increase in unemployment is attenuated by some of the nonemployed workers applying for DI benefits and eventually receiving them. Our model qualitatively generates the patterns that are observed during labor market downturns.

We now turn to the role of the substitutability between UI and DI. In our second exercise, we study the effects of an unexpected and persistent UI cut on our model economy. Specifically, we start from the stationary equilibrium of our model with a 73-week
expected UI duration, mirroring the prevailing UI duration in Missouri right before April 2011. We then cut the expected UI duration to 56 weeks and allowing it to return to its steady state level at a rate of 0.975, again following the episode in Missouri. Figure 6 presents the impulse responses from this experiment.

Figure 6: Temporary UI Cut

Following the cut in unemployment benefits, the unemployment rate decreases, partly due to the “macro” effect (diminishing worker outside option reducing the reservation wage and increasing vacancy creation) and partly due to some of the non-employed workers leaving the labor force to apply for DI. As the value of search decreases, the unhealthy and unskilled workers substitute away to DI. Again, our model qualitatively generates the patterns observed during the Great Recession, in particular following the large and unexpected UI duration cut in Missouri in April 2011.

6 Conclusion
References


Appendix of:

UI and DI:
Macroeconomic Implications of Program Substitution

Fatih Karahan   Yusuf Mercan

A  Additional Figures

Figure A7: Geography of UI Benefits in the US

(a) UI Duration during the Great Recession

(b) Map of Border Counties

(c) Variation in UI Duration

Notes: Panel (a): Maximum, minimum and mean UI durations across US states during the Great Recession. Panel (b): Map of counties that lie on a state border. Panel (c): Average difference in UI durations and number of border-county pairs with a UI difference.
B Institutional Details and Data Sources

Institutional Details US states provide regular benefits to workers who lose their jobs through “no fault of their own”. Typically regular benefits are available up to 26 weeks. A number of states cut these benefits during the Great Recession and some made durations variable dependent on state level unemployment rate.11

There are two UI programs that compliment regular benefits; Extended Benefits (EB) and Emergency Unemployment Compensation (EUC) programs. EB is a joint federal and state program and provides 13 or 20 weeks of extra benefits in states whose unemployment rates pass certain “trigger” thresholds.12 The program is optional and should the state decide to opt in there are different trigger options to choose from that differ in generosity. Since initially half the cost of EB was paid by states, states at the onset of the Great Recession either opted out or picked strict thresholds. However ARRA 2009 changed EB to a fully federally funded program and consequently many states switched to more generous thresholds.

The federal government has historically introduced laws to provide additional benefits at times of extraordinary labor market conditions. EUC enacted in 2008, was a fully federally funded program from the beginning. It started off as providing 13 additional weeks after workers exhausted their regular benefits. Over time the program was expanded to include 4 tiers, providing a maximum of 53 weeks of benefits.13

Combining all the programs, at the height of the recession a worker could potentially receive up to 99 weeks of UI; 26 weeks through regular benefits, 53 weeks through EUC and 20 weeks through EB.14

Two details of UI duration determination are important for our empirical analysis. First, since UI is a function of state unemployment rates, different time paths of unemployment induce variation in durations across states over time. Secondly, UI policy is discontinuous at state borders. This means that counties that are geographically close and share a common labor pool might face different UI durations just because they belong to states

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11Most states have 26 weeks of regular benefits. Massachusetts and Montana are exceptional in that they provide up to 30 and 28 weeks of regular benefits. Some states during the recession cut down regular weeks. For instance in January 2012 Florida reduced benefits from 26 weeks to a moving scale of 12 to 23 weeks.
12These thresholds are related to state level 13 week Insured Unemployment Rate (IUR) and 3 month seasonally adjusted Total Unemployment Rate (TUR). In the vast majority of episodes, benefits were triggered by thresholds based on TUR.
13Similar to EB, these tiers had trigger thresholds based on IUR and TUR. As EUC evolved from a single tier to a 4 tier program, the level of the thresholds occasionally changed. In 2012, in states that did not have EB, Tier IV of EUC provided up to 16 weeks of benefits.
14In Massachusetts and Montana, since regular benefits are longer than 26 weeks, EB benefits are shorter thus the total available benefits stay the same.
that have different aggregate unemployment rates.

In contrast to the UI program, Social Security Disability Insurance is a fully federally administered program that pays benefits to eligible workers who become disabled. It is the largest income replacement program in the US. In December 2014 there were close to 9 million workers claiming disability. Including disabled adult children and disabled widow(er) beneficiaries this amounts to 4.8% of age 18-64 US population. Strikingly in some counties share of workers on DI exceed 10% of population. A beneficiary receives on average $1200/month. In 2015 close to 2.4 million applied to receive DI and around 30% were awarded benefits.\footnote{https://www.ssa.gov/oact/STATS/dibStat.html}

An important aspect of DI is that it is a federal program and hence is uniformly administered across US states. Therefore one can use the state level variation in UI when studying its effects on DI outcomes.\footnote{French and Song (2014) use the systematic difference between judges’ admission rates and their random assignment to cases to identify the causal effect of DI receipt on labor supply. To the extent that these judges are systematically concentrated in states with more generous UI programs, this would act in the opposite direction of our results.} This detail will be particularly important in our border discontinuity design.

Data Sources To exploit the variation in UI, we construct a state level panel of maximum potential UI durations. To this end, we use weekly trigger reports published by the Department of Labor.\footnote{EB reports are available at http://ows.doleta.gov/unemploy/trigger/. EUC reports are available at http://ows.doleta.gov/unemploy/euc_trigger/.} We calculate available weeks through each program (regular, EUCI-IV, EB) and sum these to get total available weeks in a state.\footnote{Calculation of benefits available through EB and EUC depend on regular state benefits. A notable example is North Carolina. In violation of the “non-reduction” rule of regular benefits, the federal government cancelled its agreement with North Carolina and its EUC benefits permanently expired in June 2013. We incorporate all changes to regular benefits (and their interactions with EB and EUC) when creating the panel.} We smooth several episodes where EUC benefits expired temporarily but were paid back retroactively. To get monthly or annual durations we take a simple average of the underlying weekly panel. Figure A7 plots maximum, minimum and mean UI durations during the Great Recession based on our dataset.

Our main outcome variables are the number of applications and beneficiaries for DI. Applications are available at the state level on a monthly basis and number of beneficiaries is available at the county level on an annual basis. We obtain these data from the Social Security Administration.\footnote{State level monthly application measures are from: https://www.ssa.gov/disability/data/SSA-SA-MOWL.csv. As suggested by the SSA, we adjust monthly applications to account for the fact that

\footnote{https://www.ssa.gov/oact/STATS/dibStat.html}
We seasonally adjust monthly DI applications using an X11 procedure similar to the algorithm used by the Bureau of Labor Statistics (BLS).

Apart from sources we discussed above, we use a number of other databases. County level resident unemployment and employment data are from the Local Area Unemployment Statistics (LAUS) published by the BLS. County level population estimates are from the Census Bureau. For our border discontinuity design we use counties in the US that are neighbors but are in different states. This list of counties is available through data files provided by Dube et al. (2010).

## C Model

### C.1 Laws of Motion for Worker Distribution

For notational simplicity we omit the evolution of worker skill and health while writing down the worker laws of motion. However, while solving the model we fully account for the skill appreciation/depreciation process and the evolution of health.

The mass of workers at the decision stage is denoted by \( \tilde{u}^i(h,s) \), where \( i \in \{I,E\} \) denotes UI eligibility. They evolve according to

\[
\begin{align*}
\tilde{u}^E(h,s) &= (1 - \nu) \left[ \left( (1 - f)(1 - e) + f \mathbb{I}\{\text{reject}\}\right) \mathbb{I}\{\text{search}\} \tilde{u}^E(h,s) \\
& \quad + \int \left( \delta + (1 - \delta)\mathbb{I}\{\text{quit}\} \right) e^E(x,h,s) dx + \int (1 - \delta) r \mathbb{I}\{\text{quit}\} e^I(x,h,s) dx \right] \\
\tilde{u}^I(h,s) &= (1 - \nu) \left[ (1 - f) e \mathbb{I}\{\text{search}\} \tilde{u}^E(h,s) \\
& \quad + \left( (1 - f) + f \mathbb{I}\{\text{reject}\} \right) \mathbb{I}\{\text{search}\} \tilde{u}^I(h,s) + (1 - p) \mathbb{I}\{\text{apply}\} \tilde{u}^I(h,s) \\
& \quad + \int \left( \delta + (1 - \delta)(1 - r) \mathbb{I}\{\text{quit}\} \right) e^I(x,h,s) dx + \mathbb{I}\{\text{search}\} r(h,s) \right]
\end{align*}
\]

months have different number of weeks over time.

\(^{20}\)https://www.ssa.gov/policy/docs/statcomps/oasdi_sc/
The mass of employed workers is denoted by \( e^i(x, h, s) \) and follows

\[
e^E(x, h, s) = (1 - \nu) \left[ fp(x) \{\text{accept}\} \{\text{search}\} \tilde{u}^E(h, s) + (1 - \delta) \{\text{continue}\} e^E(x, h, s) \right. \\
\left. + (1 - \delta) r \{\text{continue}\} e^I(x, h, s) \right]
\]

\[
e^I(x, h, s) = (1 - \nu) \left[ fp(x) \{\text{accept}\} \{\text{search}\} \tilde{u}^I(h, s) + (1 - \delta)(1 - r) \{\text{continue}\} e^I(x, h, s) \right]
\]

The stock of workers who are out of the labor force and receiving disability insurance evolves according to

\[
r(h, s) = (1 - \nu) \left[ p \{\text{apply}\} \tilde{u}^E(h, s) + p \{\text{apply}\} \tilde{u}^I(h, s) + \{\text{stay on DI}\} r(h, s) \right]
\]

### D Computational Details

#### D.1 Solution: Steady State

We use value function iteration with discretization to solve the model. Broadly, we bisect over a proportional tax rate to balance the government budget constraint. We outline the algorithm below.

1. For a given parameterization of the model, start with a guess of proportional tax rate \( \tau_0 \).

2. For \( \tau_n \) in iteration \( n \):
   - Start with an initial guess market tightness \( \theta_0 \) given tax \( \tau_n \). For each guess of \( \theta_k \) in iteration \( k \):
     - Iterate on the value functions until convergence.
     - Iterate on the worker laws of motion to compute the steady-state values of employment, unemployment and disability mass consistent with the decisions induced by the value functions.
     - Solve market tightness level \( \tilde{\theta}_{k+1} \) that satisfies the free-entry condition. Calculate its percent deviation from \( \theta_k \).
- If the percent deviation is less than tolerance level $\epsilon$, stop. Otherwise update the guess for market tightness to $\theta_{k+1} = \omega \theta_k + (1 - \omega) \tilde{\theta}_{k+1}$ with dampening parameter $\omega < 1$.

3. Calculate government expenditure $G = b \sum_{h,s} u^E(h,s) + d \sum_{h,s} r(h,s)$ and output $Y = \sum_{x,h,s} y(x,h,s)(e^E(x,h,s) + e^I(x,h,s))$.

4. Backout the implied tax rate $\tilde{\tau}_{k+1} = G/Y$ and calculate its percent deviation from $\tau_k$.

5. If the percent deviation is less than tolerance level $\epsilon$, stop. Otherwise update the guess for tax to $\tau_{k+1} = \omega \tau_k + (1 - \omega) \tilde{\tau}_{k+1}$ with dampening parameter $\omega < 1$.

**D.2 Solution: Transition Dynamics**

In this section we outline the algorithm used to solve for the transition path of the model to one-time unanticipated shocks.

1. Fix the number of time periods, $T$, it takes to reach the terminal steady starting from the initial steady state.

2. Compute the steady state equilibria under the initial and terminal conditions according to the algorithm in Section D.1.

3. Guess a sequence of proportional tax rates $\{\tau^0_{t}\}_{t=1}^{T-1}$.

4. For each path of tax in iteration $n$:
   (a) Guess a sequence of market tightness, $\{\theta^{0}_{t}\}_{t=1}^{T-1}$. In iteration $k$:
   (b) Solve for the value functions by iterating on the Bellman Equations backwards for $t \in \{T-1, \ldots, 1\}$.
   (c) Solve for the worker distribution forwards induced by the decisions implied by the value functions from the previous step.
   (d) Compute the path of market tightness, $\{\tilde{\theta}^{k+1}_{t}\}_{t=1}^{T-1}$, consistent with the path of worker distribution and vacancy creation found in the previous step.
   (e) Check if $\max_{1 \leq t \leq T} |\tilde{\theta}^{k+1}_{t} - \theta^k_{t}|$ is less than a predetermined tolerance level. If yes, continue; if no update $\{\theta^{k+1}_{t}\}_{t=1}^{T-1} = \omega \{\theta^{k}_{t}\}_{t=1}^{T-1} + (1 - \omega) \{\tilde{\theta}^{k+1}_{t}\}_{t=1}^{T-1}$ where $\omega \in (0, 1)$.

5. Calculate output $\{Y_{t}\}_{t=1}^{T-1}$ and government expenditure $\{G_{t}\}_{t=1}^{T-1}$. Calculate implied tax $\{\tilde{\tau}^{n+1}_{t}\}_{t=1}^{T-1}$.
6. Check if \( \max_{1 \leq t < T} |\bar{\tau}^{n+1}_t - \tau^n_t| \) is less than a predetermined tolerance level. If yes, continue; if no update \( \{\tau^n_{t+1}\}_{t=1}^{T-1} = \omega \{\tau^n_{t}\}_{t=1}^{T-1} + (1 - \omega) \{\bar{\tau}^{n+1}_t\}_{t=1}^{T-1} \) where \( \omega \in (0, 1) \).

7. Check if the worker distribution has converged to the distribution in the terminal steady state. If yes stop, if not increase \( T \) and repeat.