Eligibility, Experience Rating, and Unemployment Insurance Take-up*

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Abstract

In this paper we investigate the causes and consequences of "unclaimed" unemployment insurance (UI) benefits. A search model is developed where the costs to collecting UI benefits include both a traditional "fixed" administrative cost and an endogenous cost arising from worker and firm interactions. Experience rated taxes give firms an incentive to challenge a worker's UI claim, and these challenges are costly for the worker. Exploiting data on improper denials of UI benefits across states in the U.S. system, a two-way fixed effects analysis shows a statistically significant negative relationship between the improper denials and the UI take-up rate, providing empirical support for our model. We calibrate the model to elasticities implied by the two-way fixed effects regression to quantify the relative size of these UI collection costs. The results imply that on average the costs associated with firm challenges of UI claims account for 41% of the total costs of collecting, with improper denials accounting for 8% of the total cost. The endogenous collection costs imply the unemployment rate responds much slower to changes in UI benefits relative to a model with fixed collection costs. Finally, removing all eligibility requirements and allowing workers to collect UI benefits without cost shows these costs to be 4.5% of expected output net of vacancy costs. Moreover, this change has minimal impact on the unemployment rate.

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1 Introduction

The U.S. unemployment insurance (UI) system is characterized by sizable "unclaimed" benefits. These are UI benefits that eligible unemployed do not collect, and they amount to around 27% of total UI expenditures, on average. Since UI benefits provide around 50% of a worker's previous wage, the presence of unclaimed benefits suggests there exist non-trivial costs to participating in the system. Unfortunately, little is understood about such costs or how they may interact with other parameters of the UI system. Characterizing these links is essential to understanding the effects of UI benefits on equilibrium outcomes. This paper provides a micro-foundation for the UI collection costs and explores their implications.

We develop a search model with matching frictions (in the class of Pissarides (2000)) where worker-firm interactions introduce an endogenous UI collection cost. There exist both UI eligible and ineligible workers in the model, with eligibility achieved by accumulating sufficient work history. Eligibility status is known by the firm, but unknown to the UI agency. Given this, there exists the possibility of UI fraud, as an ineligible worker can apply for UI benefits and potentially receive them. In the current U.S. system, firms have the opportunity to contest the worker's claim. That is, the firm contests the worker's eligibility for UI benefits. We model this feature and allow firms to potentially challenge a worker's eligibility. Firms optimally choose how often to do so, and when they do, workers can exert costly effort contesting the firm's challenge. These costs associated with firm eligibility challenges represent one cost of collecting UI benefits. In the model, we also include more traditional fixed utility costs. These may be thought of as administrative filing costs, stigma costs, or other similar costs a worker would pay when filing, regardless of whether or not the application is accepted and/or challenged. Determining what role each type of cost plays in the UI take-up decision represents a key contribution of our analysis.

The endogeneity of collection costs arises from firm behavior, which is related to the financing of UI benefits. Specifically we model the experience rating feature of UI finance in the U.S. system where firms pay a tax rate based on their history, or experience, sending workers to unemployment who then collect UI benefits. Thus, firms face a marginal tax cost of separating from a worker who decides to collect UI. Given this, firms have an incentive to challenge UI claims of separated workers. This occurs for both UI eligible and ineligible workers. Thus, verifying eligibility provides a deterrent to ineligible workers committing UI fraud.

The verification technology is imperfect, however, and only reveals the true eligibility status with some probability. The probability of being denied depends on eligibility status, as well as the effort exerted by the worker contesting the challenge. As a result, some UI fraud occurs in equilibrium. More importantly, in some instances eligible workers who apply are denied UI benefits. These cases are referred to as improper denials. In our model, workers are heterogenous in the fixed utility costs of applying and the costs of verifications, giving rise to unclaimed UI benefits; some workers find the expected benefits of collecting UI insufficient to cover the expected utility costs.

Our focus on the costs of improper denials is supported by our empirical analysis. To determine what factors are correlated with the UI take-up rate, we exploit the variation across U.S. states in unclaimed benefits and examine a two-way fixed effects regression of the UI take-up rate on several independent variables. The take-up rate is estimated with the methodology of Auray, Fuller, and Lkhagvasuren (2019) (who build on the methodology of Blank and Card (1991)), using the March supplement of the CPS and detailed state-level eligibility criteria. Focusing on the period from $2002-2015$, we find an average take-up rate of 73.4%. Improper denials are significantly negatively related to the UI take-up rate, after controlling for state and year fixed effects, the UI replacement rate, average duration of unemployment, measures of administrative filing costs, and the UI fraud rate in each state. That is, a state with a relatively high improper denial rate has a relatively low take-up rate, all else equal. While evidence exists that an increase in experience rating affects firm use of claim challenges, see Anderson and Meyer (2000) for example, our paper is the first (to the best of our knowledge) to link improper denials with the UI take-up rate.

Of course, there does exist the possibility that certain states had some general changes affecting the take-up of all "welfare" programs in the state. In this case, improper denials may have increased and the take-up rate decreased, but the cause was something general to all welfare programs. To account for this possibility, we also examine whether improper denials have an impact on the take-up rate of SNAP WIC (Supplemental Nutritional Assistance Program, Women, Infants, and Children) benefits. We find that improper denials have a positive but statistically and economically insignificant relationship with SNAP WIC take-up. This is especially interesting given the work of Brien and Swann (1997) and Bitler, Currie, and Scholz (2003) who examine take-up of SNAP WIC, both finding that the transaction costs and state-level program administration differences play a significant role in understanding low take-up rates in this program. If transactions costs matter but not improper denials, it appears that improper denials may have an effect unique to the issue of UI take-up. Thus, the results of this falsification test show there is no evidence that the link between UI take-up and improper denials is spurious correlation related to a general social program trend.

More generally, the link with take-up of social welfare programs and its associated literature is also worth discussing. Indeed, there exists a large literature examining the take-up of social welfare programs such as Medicaid, Welfare, SNAP (Food Stamps), Disability, and many others. Currie (2006) provides an excellent summary of this literature that seeks to characterize and understand low take-up in these programs. As Currie (2006) highlights, understanding the causes of low take-up in these programs represents the primary focus of this literature. Towards this end, there is some work examining the role of stigma costs, see for example Moffitt (1983), relative to transaction type costs. Currie (2006) writes that the majority of the literature finds a stronger role for transaction costs relative to stigma costs. The author further discusses the potential role played by hyperbolic discounting, although pointing out that the policy implications of low take-up driven by hyperbolic discounting are similar to if it is driven by transaction costs. While we include some fixed transaction costs in the UI application process in our model, we remain agnostic whether this is stigma or more traditional administrative costs. Our paper is unique to this literature in that we use a combination of a traditional empirical analysis with the development of an equilibrium model to identify the role of different types of UI collection costs. To the best of our knowledge, our paper is the first to examine the role of worker-firm interactions to understand low program take-up. Our contribution is thus two-fold: (i) we characterize a novel empirical relationship between improper denials and UI take-up and then (ii) use this empirical analysis along with an equilibrium search model to identify the various costs of collecting and to understand their implications.

In addition, there is an important distinction between UI benefits and the aforementioned social welfare programs that further distinguishes our paper from this literature. The UI program is an *insurance* program. All workers pay premiums via the experience rated taxes remitted by their employers. If the worker should become unemployed, they are "insured" and assuming they have a qualifying spell of employment and separation cause, they can claim the insurance payout. This makes UI benefits similar to employer provided health benefits. In contrast, a program such as SNAP is a more traditional social welfare program. All workers pay taxes to finance this benefit, but those who collect need not have paid in; that is, these are income transfers while UI benefits are insurance. In this sense, the study of UI take-up likely requires empirical analyses and theoretical frameworks distinct to these features of the UI system. Indeed, our analysis does suggest that the financing of UI benefits may play an important role in this discussion.

The aforementioned empirical relationship between the improper denial rate and the UI take-up rate provides the foundation for calibrating the model and identifying the relative magnitudes of the fixed collection costs relative to the costs associated with firm challenges and denials. Our calibration implies that traditional fixed administrative/stigma costs account for 59% of the total costs of collecting UI benefits, while the costs of challenges account for the remaining 41%. The costs from improper denials are around 13% of the fixed costs of applying. The calibrated model also matches other non-targeted elasticities from the empirical analysis, including the elasticity of the take-up rate with respect to the UI replacement rate.

Allowing for endogenous costs of collecting UI benefits matters when considering the effects of different UI policies. Specifically we consider changes in the UI replacement rate under our endogenous UI collection cost model, and a model with costs fixed at the baseline level. The unemployment rate responds slower to increases in the UI replacement rate when the costs of collecting are endogenous. When the replacement rate increases, so does the tax paid by firms, as both the benefit and the take-up rate have increased. As a result, firms increase the probability of an eligibility verification, which has implications for the unemployment rate.

In this paper, we provide a micro-founded mechanism to generate unclaimed UI benefits and explore the general equilibrium implications of UI policies in this setting. The existing literature examining the equilibrium effects of UI benefits generally ignores the issue of UI take-up, or assumes the take-up rate to be exogenous. Exceptions include Blasco and Fontaine (2016), who examine take-up of UI benefits in the French system focusing on the effects of unemployment durations on UI take-up. Kroft (2008) represents an example with endogenous UI collection costs. Kroft (2008) incorporates endogenous costs based on a "social" effect; more unemployed collecting UI reduces the costs to collecting, further increasing the take-up rate. The focus of Kroft (2008) is on determining the optimal UI replacement rate using the method of Baily (1978).

In our model, UI policy experiments indicate that the costs of collecting UI benefits amount to 4.5% of expected output net of vacancy costs. These experiments compare the baseline economy to several alternatives: an economy with no UI costs, an economy with only costs associated with challenges and denials, and a full-commitment economy. The full-commitment equilibrium assumes that ineligible unemployed never apply for UI benefits, and firms commit to never verifying eligibility. We also examine the optimal level of experience rating and find it depends on the nature of the UI collection costs. The potential gains from these alternatives range from $2.55\% - 4.55\%$ of net expected output, depending on the comparison economy.

Finally, this paper is also related to the work of Auray, Fuller, and Lkhagvasuren (2019). While both papers use the same method to calculate the UI take-up rate, and both feature an endogenous take-up rate, there are several important differences between the two. First, Auray, Fuller, and Lkhagvasuren (2019) focuses on understanding how private information affects and wages and unemployment durations of non-collectors in a directed search framework, where UI collection costs are exogenous. The take-up rate estimates are used in Auray, Fuller, and Lkhagvasuren (2019) to provide a numerical illustration of these differences. In contrast, the current paper focuses on determining the micro-foundations for endogenous UI collection costs. Importantly, while the focus is theoretical in nature in Auray, Fuller, and Lkhagvasuren (2019), in this paper we focus on using a rigorous empirical analysis of state-level differences in UI take-up rates to allow our model to identify the role of different UI collection costs.

The remainder of the paper proceeds as follows. Section 2 presents the data and our empirical analysis of the UI take-up rate across U.S. states. Section 3 and develops the model and equilibrium. Section 4 parameterizes the model based on the data in Section 2. Section 5 then performs a number of counter-factual experiments and Section 6 conducts UI policy experiments. Section 7 concludes.

2 Empirical Analysis

This section presents the key facts regarding unemployment benefit receipt across U.S. states. Each state has control over its UI benefit system. Although there are certain federal-level rules and guidelines, the operation of UI benefit systems is autonomous across states. Indeed, there exists variation in the level of UI benefits offered, taxes levied, the specific eligibility requirements, and perhaps more significantly, in the administration of these requirements.

Two states with equivalent eligibility requirements may enforce them quite differently. We seek to exploit these differences across states to provide possible clues regarding what drives the variation in take-up rates. The results from this analysis motivate the micro-foundations for UI collection costs we develop in Section 3. Below we detail the data we utilize in the empirical analysis, and provide a brief description of UI finance in the U.S. system, an important feature in our model in Section 3. We then move on to the empirical analysis.

2.1 Data

We utilize two data sets. First, UI take-up rates are constructed using the Current Population Survey (CPS). More specifically, we use the March Supplement, as it contains earnings information for the previous year, in addition to current labor market status. The earnings information is essential to determine an unemployed individual's eligibility for UI benefits.

Second, we also use data from the Benefit Accuracy Measurement Program (BAM) run by the U.S. Department of Labor. The BAM program is designed to assess the accuracy of paid and unpaid UI claims. The data consists of a random sample of weekly UI claims from state administrative records. A BAM auditor then carefully examines the claim to determine if the individual's payment was accurate or not. It is important to note that the BAM program is intended to gather statistics on the accuracy of the UI system's payments. Thus, the BAM audits do not function as a substitute for the individual state's own programs such as fraud prevention. While BAM auditors notify state official's regarding the results of their audits, the state still ultimately has control over their claims and denials. In addition to auditing paid UI claims, the BAM program also audits those claims that were denied. That is, an individual applies for UI benefits but is denied. In such cases the BAM audit determines whether the denial was justified or not, based on that state's particular UI eligibility rules. We discuss these issues in more detail below.

2.2 Experience Rating

The U.S. UI system is unique relative to most developed countries' systems on one dimension: its financing. In the U.S., benefits are financed via a payroll tax levied on employers. Moreover, the specific tax rate a firm faces depends on their "experience" sending workers to insured unemployment. Insured unemployment refers to the number of unemployed individuals who are collecting UI benefits. A firm that has previously sent a relatively large fraction of its payroll to insured unemployment will in general pay a higher tax rate than a firm with less "experience." This feature represents an important component of the model described in Section 3. Given its use in modeling, in this section we describe the main aspects of experience rating and present the available data.

Each state has a particular formula for calculating a firm's tax rate. The actual extent of experience rating depends on how a firm's tax rate responds to changes in its experience with insured unemployment. That is, how much will the firm's taxes increase if they send a worker to insured unemployment, and how does the increase in taxes relate to the total amount of benefits collected by the worker. This increase in future payroll taxes represents the marginal cost to the firm (in terms of UI taxes) of separating from a worker who collects UI benefits.

The U.S. system is "partially" experience rated. That is, on average the marginal cost of separating from a worker is less than one; firms do not fully pay for the benefits their former employees collect. Partial experience rating stems primarily from minimum and maximum tax rates. A firm at the minimum tax rate generally has a marginal cost higher than one, while a firm at the maximum tax rate has a marginal cost below one. The minimum and maximum tax rate vary significantly across U.S. states, as do the wages subject to the tax (referred to as the "taxable wage base"). For example, in 2016, Minnesota had a minimum tax rate of 0.30%, a maximum tax rate of 9.10%, and a taxable wage base of \$31,000. This implies a potential difference of almost \$3,000 per employee in UI taxes for different firms in the state. In contrast, Louisiana had a minimum tax rate of 0.10%, a maximum rate of 6.20%, and a taxable wage base of \$7,700. This leaves a maximum per-worker tax difference of about \$500. Thus, the degree of experience rating may vary significantly across U.S. states.

To capture this, our model in Section 3 requires an estimate of the marginal tax cost of separating from a worker. That is, when a firm separates from a worker who decides to collect UI benefits, how does this increase the taxes of the firm? To provide an estimate of this cost, we use data from the Department of Labor who tabulates an index referred to as the "Experience Rating Index," or "ERI." The specific calculation is:

$$\text{ERI} = \left[\frac{\text{BEN-(IEC+IAC+NNC)}}{\text{BEN}}\right] X100$$

BEN refers to total benefits charged in a given state. IEC represents "ineffective charges." To compute these, employers are aggregated into 30 groups based on their experience factor. Within each group, the difference between benefits charged to the employers (i.e. benefits collected by former employees) and the benefits contributed by those employers. Summing over the 30 groups produces the IEC. It is a measure of how much of benefit expenditures are not completely financed by firm taxes. IAC represents benefits charged to employers who have gone out of business (and thus from whom no taxes may be collected). Finally, NNC represents benefits collected that were not charged to any particular employer.

Thus, the ERI is a measure of how "responsible" employers in a given state are for the benefits charged by their former employees, providing one estimate of the average marginal cost of separating from a worker (in terms of UI taxes). As expected, given the specificity of the tax rate calculations, there exists noticeable variation across states in the ERI. We utilize tabulations from 1989-2004. From 2005 – 2007, the ERI is not tabulated by the U.S. Department of Labor. The tabulations are available from 2008 and on, however, the calculation is now different. Since 2008, the preferred metric is now "The Average Increase in an Employer's Per employee Tax for Incurring Benefit Charges Equivalent to 1% of its Taxable Payroll." The idea of this index is to calculate the average additional cost an employer will incur if it sends an employee to insured unemployment.[1] In the 1989-2004 period, the standard deviation of these ERIs across states is 8.01 with an average of 60.02. The first row in Table 1 presents the summary statistics for the ERI from 1989-2004. Topel (1983) also calculates an estimate of the marginal cost using the details of each state's tax scheme, generally finding a higher marginal cost (around 80%), although for an earlier time period.

2.3 Take-up Rate Estimates

"Unclaimed benefits" result from unemployed individuals who do not collect UI benefits they are eligible for. In this paper we argue that the "take-up" rate of UI benefits represents a key variable to understanding the effect of UI benefits on labor market outcomes. Despite its relevance for policy considerations, there does not exist any readily available data on the UI take-up rate from the usual government sources (e.g. BLS). In this section we describe our estimates of the take-up rate and explore some of its features.

The "take-up" rate is the fraction of unemployed eligible for UI benefits who collect them. Eligibility for UI benefits in the U.S. is determined by three factors: monetary criteria, separation

[1]From the Significant Measures of State UI Tax Systems, published by the BLS (Bureau of Labor Statistics), it is calculated as: "The difference between the maximum per employee cost at the tax base and the minimum per employee cost, divided by the difference between the experience rating percent (either Reserve Ratio or Benefit Ratio) corresponding to the maximum statutory tax rate and the experience rating percent corresponding to the minimum statutory tax rate."

Table 1: Summary Statistics–Key Variables

	Mean	Standard Deviation	Min	Max
Experience Rating Index	60.02	(8.01)	8	94
Take-up Rate	.734	(.201)	.271	.998
Improper Denial Rate	.101	(.051)	0	.310
Replacement Rate	.469	(.049)	.305	.584
Avg. Unempl. Duration (weeks)	22.361	(8.038)	8.144	50.481
Unemployment Rate	.066	(.022)	.021	.152
Fraud Rate (Separations)	.005	(.007)	0	.044
% Internet Claims	.384	(.298)	0	1
% Phone Claims	.424	(.317)	0	1
% In Person Claims	.147	(.266)	0	.996

criteria, and duration criteria. The specifics of each criteria vary considerably across U.S. states, but the general notion of each is described below.

Monetary criteria specify that an individual must have accumulated sufficient work experience prior to becoming unemployed. In most U.S. states, the monetary criteria require a certain threshold for earnings. A worker must have earned more than a multiple of their Weekly Benefit Amount (WBA), which is the amount of UI benefits they receive each week. For example, a state may specify that in the previous year, the worker must have earned at least $40X$ WBA. Since the WBA is typically 50% of previous weekly earnings, this criteria is approximately equivalent to requiring at least 20 weeks worked in the previous year. Other states simply have a number of weeks of previous employment required, and some have a hybrid requirement.

The separation criteria attempt to prevent workers who do not fall under the category "unemployed through no fault of their own." Thus, workers who voluntarily quit their jobs, or are fired for cause (such as tardiness or poor performance) are not eligible to collect UI benefits. Finally, the duration criterion arises from the fact that benefits have a limited potential duration. In most states an individual may collect UI benefits for at most 26 weeks.[2] Once an individual has ex-

[2]In periods of high unemployment, benefits may be extended an additional 13 or 20 weeks depending on the state's unemployment rate. During the period from $2009-2013$, benefits had a potential duration of 99 weeks in states with

hausted their benefits, they are no longer eligible until they have a new employment spell satisfying the monetary criteria.

Calculating the take-up rate thus involves determining eligibility. To do so, we use the method of Auray, Fuller, and Lkhagvasuren (2019) (who build on the method of Blank and Card (1991)) using the data from the March CPS supplement. The take-up rate is calculated by first determining who among the unemployed would be eligible for UI benefits. Eligibility is determined based on the individual's state of residence and that particular state's eligibility criteria.[3]

Thus, for each year in each state, we calculate the fraction of unemployed eligible for benefits. Then, the number of unemployed collecting UI benefits is determined from the fraction of unemployed collecting UI.[4] This fraction is available from the BLS for each state, and represents the number of unemployed collecting UI divided by total unemployed. We refer to this fraction as the "IUR." Thus, dividing the IUR by the fraction of unemployed eligible gives the take-up rate.

Figure 1 plots the U.S. average take-up rate (solid line) in each year from 2002-2015. The dashed line in Figure 1 plots the Insured to Total Unemployed ratio over the same period of time. Since 2002, there appears to be a slight downward trend in both the overall U.S. take-up rate and the Insured to Total Unemployed ratio. Our empirical analysis below focuses on the differences between take-up rates across U.S. states and time. In Table 1, the row labeled "Take-up Rate" shows the average take-up rate, the standard deviation across U.S. states and time, as well as the maximum and minimum observed take-up rates in particular states. As these summary statistics show, there exists a lot of variation across states in UI take-up rates, variation we seek to exploit in our empirical analysis below.

2.4 UI Collection Costs

UI benefits provide unemployed individuals with insurance against lost income. Since on average (U.S. average) 27% of those eligible do not collect these benefits, however, it is clear there exist some costs to collecting the benefits. The exact nature of these costs has not been well documented in the

high unemployment rates.

[3]See Auray, Fuller, and Lkhagvasuren (2019) for the details on how each eligibility criteria is handled specifically in the CPS data.

[4]The fraction of unemployed collecting UI is taken from the BLS tabulations, and refers to the fraction of unemployed persons collecting *regular program* UI benefits. "Regular program" benefits are those benefits available for the typical 26 weeks; therefore, this does not include any individuals collecting extended benefits.

Figure 1: Take-up Rates Over Time

Notes: The figure displays the average take-up rate for the U.S. over the period from 2002 − 2015. Take-up rates are calculated following the method in Auray, Fuller, and Lkhagvasuren (2019). The dashed line plots the Insured to Total Unemployed Ratio. Both lines have the same numerator, but differ in the denominator.

existing literature examining UI take-up rates.[5] Indeed, an exploration of the micro-foundations for such a cost represents one contribution of this paper.

The eligibility requirements detailed above imply individuals need to apply for UI benefits if they become unemployed. This application provides the UI agency the opportunity to verify the individual's eligibility. Thus, the time associated with filing this application represents one possible cost that may prevent some eligible unemployed from deciding to collect the benefits. To gauge the extent of this potential cost we examine how individuals actually file their initial UI benefit claim. Data on the initial filing method is available from the Benefit Accuracy Measurement (BAM) data described above.

There exist several possible filing methods tabulated in the BAM data. An individual may file: in person, by mail, by phone, by internet, or the employer may file the claim. Over time, the preferred filing methods have changed significantly. In the 1980s and early 1990s, most claims were

[5] Anderson and Meyer (1997) examine the effect of changes in the tax treatment of UI benefits on the take-up rate in the 1980s. They provide some survey results regarding why workers do not file, but no clear reason emerges.

filed in person, while today almost all claims are filed by phone or internet. Internet claims began in some states starting in 2002. Table 1 displays some summary statistics for the % filing by phone, online, and in person over the 2002-2015 time period.

One may expect that the initial filing method has an impact on the overall administrative cost for the individual filing the UI claim. To explore this possibility, we tabulate two variables for the empirical analysis below: $PHONE$ and INT, which represent the fraction of all claims in a state filed by phone and by internet, respectively. Given almost all claims are filed by one of these two methods in our period of study (2002-2015), one expects a state where more claims are filed online (phone) has a higher (lower) take-up rate if indeed this lowers the cost of filing a claim.

Of course, the particular method may not signal well the full administrative cost associated with filing a UI claim. In the end, the same application information must be gathered, so whether this occurs in person, by phone, or online may not significantly alter the cost of filing to the individual. Thus, while we do explore the potential impact of these filing costs on a state's take-up rate below, this represents only an imperfect look into the role of administrative (or other "stigma" types of costs) costs. Indeed, fully accounting for and identifying the role of such administrative/stigma costs in the take-up decision represents a key motivation for the equilibrium search model we develop below.

2.5 Improper Denials

Given the experience rating of UI finance, a firm separating from a worker who collects UI benefits faces an increase in costs via a higher tax rate in the future. All else equal, a firm prefers that a separated worker does not collect UI benefits. Since a firm cannot control this decision directly, how can they reduce their UI tax bill (in the case of exogenous separations)? One possibility is for the firm to challenge the worker's UI claim.

When a worker files a claim for unemployment benefits, the UI authority in that U.S. state contacts the worker's previous employer(s) to verify the relevant information. For example, they verify the worker's wages to determine eligibility and calculate the proper benefit amount. They also have to verify that the nature of the separation is proper, since certain separations render the worker ineligible for benefits. If indeed the individual is eligible, then benefits are provided; however, if it is determined that the individual is not eligible, then no benefits are provided. When disagreements between the worker and the firm arise, the case may move to the legal system to resolve the dispute. Thus, the costs associated with these disputes and challenges may be substantial for both the worker and the firm.

In some instances, an individual is *improperly* denied UI benefits; that is, they were eligible but were incorrectly determined as ineligible. Improper denials obviously pose a cost to those applying for UI benefits. The process of verifying eligibility described above is costly, and the prospect of going through the process and being denied benefits lowers the net expected gain from collecting UI benefits.

Data on improper denials is available from the BAM program. This information is available beginning in 2002 for each state. The Improper Denial Rate is the fraction of all denied applications that are determined to be improper. Classification of improper denials is made by BAM. To do so, BAM auditors examine claim denials and determine the actual eligibility of the claimant. Improper denials are those cases where an application is denied, but the BAM auditor determined the applicant was actually eligible. As discussed above, the BAM program is separate from each State's normal procedures for determining and correcting improper payments. Thus, the data we use on improper denials refer to denials deemed improper *after* the claim was filed and denied, and this determination does not coincide or indicate any legal action in the dispute by either the firm or the claimant. Table 1 presents the summary statistics for the improper denial rate across states and time.

Given the potential costs associated with having a claim challenged by a firm, the improper denial rate in a state may signal to a worker the likelihood of a difficult firm challenge. If these costs remain significant enough, high improper denials may deter workers from applying for UI benefits, lower the take-up rate in a particular state. This potential cost represents our main modeling focus below in both the empirical analysis and the model of Section 3.

2.6 UI Fraud

On the other side of improper denials, it is possible for an ineligible unemployed worker to apply for and receive UI benefits. This is referred to as UI "fraud." For the analysis here only two types of UI fraud are relevant. The first is misreported base period earnings, weeks, days, or hours worked. In other words, a worker did not accumulate sufficient work history to be eligible, but committed fraud by collecting benefits anyway. Separation issues represent the second form of fraud we include. This includes workers who quit or were fired for cause but still collected benefits. These two types of UI fraud are the relevant forms with regards to the eligibility verification process we discuss above and model below in Section 3.

We characterize UI fraud using the aforementioned BAM data. The main goal of the BAM program is indeed to characterize *overpayments* in the UI system; that is, cases where individuals are paid too much. Whether or not fraud occurs is determined by the BAM audit. They examine the claim, determine eligibility based on their audit (which may include information they gather not presented or misrepresented on the original claim), and then decide if fraud occurred or not. Overall, UI fraud accounts for around 3.0% of total UI benefit expenditures. From 2002 – 2015, benefits collected under the two types of "separation" fraud discussed above amounted to around 0.5% of total UI benefit expenditures.[6] Table 1 provides summary statistics for the relevant forms of UI fraud across U.S. states and time.

2.7 Benefit Generosity Across U.S. States

The replacement rate represents the most common measure of UI generosity. It is calculated as the weekly benefit amount (WBA) divided by weekly earnings in the previous (i.e. pre-unemployment) job. Most generally, the U.S. system offers a fixed replacement rate of 50%; an individual can expect to receive half of their previous weekly earnings. As with other elements of state UI systems, the specific rules for calculating an individual's WBA vary across states. There are several important factors determining the observed or actual replacement rate an individual receives.

First is the specific formula the state uses. Most have a formula that corresponds to roughly a 50% replacement rate. The WBA, however, is adjusted based on factors such as number of dependents. Second, there also exists a maximum benefit amount that varies across states. Since the WBA cannot exceed this amount, individuals with relatively high previous earnings will have

[6] Fuller, Ravikumar, and Zhang (2015) provide further discussion regarding other types of UI fraud. They show that "concealed earnings" fraud is the dominant form of UI fraud. This occurs when an unemployed worker finds a job but continues to simultaneously collect UI benefits. Fuller, Ravikumar, and Zhang (2015) focus on determining the optimal UI scheme with monitoring when concealed earnings fraud is present, and also present some general facts regarding UI fraud in the U.S. system.

a lower replacement rate.

We calculate replacement rates in each state and year using the BAM data. Specifically, we calculate an estimate of weekly wages using the previous earnings information on an individual's UI claim, along with the individual's WBA from the claim. The replacement rate is simply the WBA divided by the weekly wage. Table 1 presents the summary statistics for this variable.

2.8 Empirical Results

This section provides a statistical analysis of the relationship between the aforementioned variables. Specifically we examine how these variables impact the Take-up Rate in a particular state. Towards this end, we examine a two-way fixed effects model, with fixed effects at both the state and year levels. The goal of this analysis is to explore to what extent improper denials in a state affect the take-up rate. As discussed above, there exist costs to both the worker and firm if the firm decides to challenge the worker's UI claim. Moreover, with some probability, the worker pays the costs of contesting the claim, but is still improperly denied benefits. If these expected costs remain sufficiently high, they may exceed the expected benefits of collecting, causing the take-up rate to decrease. Thus, these costs imply a negative relationship between the improper denial rate in a state and its UI take-up rate.

The analysis in this section exploits the variation across states and time in improper denials rates to identify the effects on the take-up rate. Specifically, we estimate the model,

$$TUR_{i,t} = \alpha + \beta IPDR_{i,t} + \eta \mathbf{X_{i,t}} + \varepsilon_{i,t} \tag{1}$$

where $TUR_{i,t}$ is the UI take-up rate in state i in year t, $IPDR_{i,t}$ is the improper denial rate in state i in year t, and $\mathbf{X}_{i,t}$ represents a vector of other covariates for state i in year t.[7]

There is a natural relationship between the Take-up Rate and Improper Denial Rate that may affect the results. Specifically, a state with a higher rate of improper denials will (all else equal) have a lower take-up rate. The take-up rate is calculated as the total number collecting UI divided by the total number of unemployed eligible to collect UI. If an eligible individual is improperly denied, they would in theory appear in the denominator but not in the numerator, decreasing the take-up rate.

[7] See Appendix B and Table 10 for a summary of each variable for each U.S. state.

Table 2: Two-way fixed Effects Regression with Adjusted Take-up Rate Dependent Variable

	(1) Model 1	(2) Model 2	(3) Model 3	(4) Model 4	(5) Model 5
Improper Denial Rate	-0.421^{**}	-0.418^{**}	-0.419^{**}	-0.418^{**}	-0.429^{**}
	(0.158)	(0.163)	(0.164)	(0.164)	(0.162)
Replacement Rate		0.668^{***}	0.669^{***}	0.670^{***}	0.633^{***}
		(0.235)	(0.235)	(0.237)	(0.230)
Duration		0.00449^{***}	0.00449^{***}	0.00448^{***}	0.00455^{***}
		(0.00113)	(0.00114)	(0.00114)	(0.00114)
Internet Claims			0.00666	0.00690	
			(0.0421)	(0.0423)	
Fraud Rate				0.231	
				(0.919)	
Phone Claims					-0.0488
					(0.0435)
State Fixed Effects	YES	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES	YES
N	714	714	714	714	714
R^2	0.621	0.639	0.640	0.640	0.641

Standard errors in parentheses

* $p < 0.1$, $^{**}p < 0.05$, *** $p < 0.01$

This table presents the results of the two-way fixed effects regression with the adjusted take-up rate as the dependent variable. Standard errors are clustered at the State level.

To account for this, we make the following adjustment. We first compute the total number (in the population of denials) of those improperly denied. This is accomplished using the population numbers provided by the U.S. Department of Labor in the BAM reports on Denials. Next, we add these to the total number collecting UI benefits. This is the adjusted numerator, and the adjusted take-up rate is thus divided by the total number of eligible unemployed. We perform the state fixed-effects regression using the adjusted take-up rate as the dependent variable. As a robustness check, we present the results with the unadjusted take-up rate for both specifications in

Appendix C.

In additional to Improper Denials, there exist several other factors that may affect the UI take-up rate in a particular state. Of course, the generosity of benefits represents a key aspect of the UI take-up decision. More generous benefits, all else equal, should imply a higher take-up rate. Given this, we include the average Replacement Rate in the state in $\mathbf{X_{i,t}}$. The expected length of the unemployment spell also potentially affects the UI take-up decision. Those with longer expected durations, have a higher expected gain from collecting UI benefits. To account for this effect, we include the average duration of unemployment in each State as a control.

There may also be administrative costs associated with the UI benefit filing process. As discussed above, to proxy for the administrative costs of filing, we include the % of initial applications filed by internet. In some specifications, we use the % of initial applications filed by phone.

Finally, our specification also includes both state-level and year fixed effects. The state fixed effects are intended to capture any unobserved heterogeneity in the determination of a state's UI take-up rate not accounted for by the other control variables. For example, there may exist unobservable differences in the attitudes of a state's population towards UI benefits, or in the state's administration of these benefits. Such unobservable differences may cause a certain state to have a persistently higher take-up rate relative to other states. The state-level fixed effects account for such unobserved heterogeneity. Similarly, the take-up rate may be relatively high or low in a particular year for reasons not explained by only the duration or replacement rate, for example. The year fixed affects control for these differences.

Table 2 presents the results from several different specifications of the model in Equation (1). In all specifications, the coefficient on Improper Denials was negative and significant at the 5% level. States that more strictly enforce and challenge eligibility have higher improper denials. This implies higher expected initial cost of applying for benefits, reducing the net gain of collecting UI benefits, and thus reducing the take-up rate. Indeed we adopt this interpretation. Our finding here is also consistent with the findings of Anderson and Meyer (2000), who find that the increase in experience rating in Washington state negatively correlated with UI claims and positively correlated with claim denials.[8]

In Table 2, we also see the take-up rate is significantly positively related to the Replacement

[8] Anderson and Meyer (2000) examine only UI claims and thus do not consider the take-up rate as we do.

Rate and the Average Duration of Unemployment in the State. This is consistent with our theory and previous results in the literature (e.g. Anderson and Meyer (1997)). States with more generous benefits (higher Replacement Rate) have a higher UI take-up rate. In addition, States with longer average durations of unemployment also have higher take-up rates. Given an upfront cost of collecting, workers expecting a longer duration of unemployment have a higher expected benefit from collecting UI benefits.

Interestingly, the measures of the filing cost generally have little impact. The % filing by internet (phone) in a state is positively (negatively) correlated with the take-up rate, but insignificant. Although this suggests the traditional administrative costs of filing do not have a significant effect on the UI take-up rate, these variables likely do not capture the full extent of variation across states and time in UI administrative costs. Moreover, it may simply be that these administrative costs are essentially constant across states and time in the period we examine. Thus, despite the results suggesting fixed administrative (or potentially stigma) costs do not affect UI take-up, we still include a potential role for such costs in the model in Section 3.

Since the process of verifying eligibility goes through the worker's previous firm, the firm decides whether or not to challenge the information presented by the worker on their initial application. Given experience rated taxes, a firm prefers that a separated worker not collect UI benefits. Thus, the firm has an incentive to challenge the eligibility of a worker's UI claim. Indeed, firms in states with higher improper denials see a higher probability of successfully denying a worker's claim. Thus, they may respond by more frequently challenging claims, increasing the costs of applying for workers, reducing the take-up rate. This mechanism is detailed in Section 3.

Although we include both State and Year fixed effects, there still exists a possibility that the effect of improper denials is being confounded with other factors in states. It could be that certain states have experienced a trend of declining take-up in social insurance programs, in general, that happens to spuriously correlate with an increase in improper denials among UI claimants. For example, a certain state may decide to "crack-down" on social insurance programs. In this case we would observe a decrease in all social insurance program take-up rates, UI included, and an increase in improper denials. The decrease in UI take-up, however, may not be the result of an increase in improper denials but rather the state-wide shift in all social insurance programs.

To investigate such a possibility, we consider the following placebo/falsification test. We examine

Table 3: Two-way fixed Effects Regression with SNAP WIC Take-up as Dependent Variable

	(1) Model 1	(2) Model 2	(3) Model 3
Improper Denial Rate	0.0437	0.0270	0.0176
	(0.0565)	(0.0548)	(0.0524)
Replacement Rate		-0.211^{*}	-0.209^{*}
		(0.116)	(0.114)
Duration		0.000964^{*}	
		(0.000539)	
Unemployment Rate			0.466^{*}
			(0.242)
State Fixed Effects	YES	YES	YES
Year Fixed Effects	YES	YES	YES
N	714	714	714
R^2	0.783	0.788	0.789

Standard errors in parentheses

* $p < 0.1$, $^{**}p < 0.05$, *** $p < 0.01$

This table presents the results of the two-way fixed effects regression with the SNAP WIC take-up rate as the dependent variable. Standard errors are clustered at the State level. The Improper Denial Rate and Replacement Rate refer to the rates in the UI system.

the impact of improper denials of UI benefits on the take-up of another social program. In this case, we examine the take-up of SNAP (Supplemental Nutrition Assistance Program) WIC (Women, Infants, and Children) benefits. If improper denials are shown to statistically impact SNAP WIC take-up, then it would strongly suggest that the results presented in Table 2 (that improper denials of UI affect UI take up) are confounded by unaccounted for trends

Table 3 displays the results from this placebo test. In all the specifications, improper denials had a small positive but insignificant coefficient. Furthermore, the coefficients on the replacement rate, duration, and unemployment rate are all significant at the 10% level. Indeed, these variables should have an effect on the take-up of SNAP benefits. A higher UI replacement rate in a state implies that the unemployed may be more likely to rely on UI benefits to smooth income instead of SNAP benefits, implying the negative coefficient.[9] Similarly, an increase in the state's average unemployment duration (or unemployment rate) should increase take-up of SNAP, as workers face longer unemployment spells and have higher need for other assistance programs.

The results presented above suggest that improper denials have a negative impact on a state's UI take-up rate, implying that there exists some costs associated with these that lowers the net benefit of collecting for some workers. Certainly these costs do not represent the only cost of collecting UI benefits. In order to determine what role the costs associated with improper denials play relative to more traditional fixed utility costs of applying, we develop an equilibrium search model and explore its implications quantitatively benchmarking to the empirical results presented in Table 2.

3 Model

Given the empirical results of Section 2.1, the process surrounding improper denials appears to be an important determinant of the UI take-up rate. In this section, we develop a search-matching model with endogenous UI costs based on this process.

Time is continuous and lasts forever. There exists a unit mass of risk-neutral workers and a large number of risk-neutral firms. Both discount the future at rate r. All firms are ex-ante homogeneous. Workers may be either employed or unemployed. Each worker has the same productivity level, denoted by y. Firms are composed of one job, either filled or vacant.

Employed workers enjoy flow utility from the wage w. They are separated from the job exogenously at Poisson rate λ. We also incorporate UI eligibility as follows. For employed workers, there exist two possible employment states: *Benefit* eligible, denoted $i = B$, and *Not* Benefit eligible, $i = N$. Upon forming a match, all workers begin employment as UI ineligible; this is regardless of whether or not they previously collected UI or not. At Poisson rate σ, the worker becomes UI eligible. This represents a stylized version of the monetary criteria described in Section 2.3. Since separations remain exogenous and UI benefits last forever, the other two eligibility criteria discussed in Section 2.3 are not relevant.

[9] Keane and Moffitt (1998) examine the issue of multiple welfare program take-up and its effect on labor supply decisions. They find the joint program participation/take-up decision is an important factor, although they do not examine the trade-off between SNAP (food stamps in Keane and Moffitt (1998)) and UI benefits.

Assuming random eligibility maintains the stationarity of equilibrium in the model. An alternative is to allow for deterministic eligibility, where the worker gains UI eligibility after a fixed length of employment. This may more closely match the monetary requirements in most U.S. States. While monetary eligibility rules ultimately set a minimum requirement for earnings in order to become eligible, this does not always imply deterministic eligibility. If the worker's income is random, for example, then the exact date when eligibility accrues still remains uncertain. The key aspect of our assumption of random eligibility is the feature that neither the worker nor the firm know the exact date eligibility accrues. This prevents the firm from strategically using layoffs to prevent the worker from collecting UI benefits. We focus only on exogenous separations so this issue does not arise, but it is worth noting that while the assumption of random eligibility allows for a tractable model and solution, it rules out other strategic actions firms may take.

If separated, a worker decides whether or not to collect UI benefits. A non-collector receives flow utility from leisure (or home production) of d, while a worker collecting UI benefits receives flow utility from UI benefits B. The unemployment benefit is a function of the worker's previous wage, $w(\chi)$. Specifically, it is given by $B(\chi) = bw(\chi)$, where b is interpreted as the *replacement rate*. At separation, a UI collector also pays an upfront utility cost, denoted by $\phi\chi$, to collect UI benefits. This cost represents the fixed costs associated with applying for UI benefits, whether due to the time costs of the application process, some "stigma" cost, or other such similar costs. The "fixed" cost of applying is composed of two components: ϕ and χ, where $\phi > 0$ is a constant common across all workers. The cost χ is permanent for the worker (does not change over time), and is distributed across the population according to the distribution $F(\chi)$. Both UI eligible and ineligible workers may decide to apply for and collect UI benefits. This feature captures the UI fraud (where UI ineligible workers collect benefits) described above in Section 2.6. Eligibility is monitored, however, which may deter some UI ineligibles from collecting. Below we describe the eligibility monitoring process in more detail.

Firms are free to enter and pay a flow cost to open a vacancy, denoted by γ. In the event of a separation (at Poisson rate λ), the firm faces some workers who decide to collect UI benefits and some that do not. If the worker does collect benefits, the firm pays an upfront cost of τ. This "tax" captures the experience rating feature in the U.S. economy discussed in Section 2.2. From Section 2.2, the U.S. system involves only partial experience rating. Firms are subject to minimum and maximum tax rates. Thus, on average τ does not fully finance UI benefits. To capture this partial experience rating feature, and to allow for a fully balanced UI budget, we also assume that all firms pay a fixed flow tax $\underline{t}$. This represents the minimum tax rate for all firms, and τ then represents the increase in firm taxes when a separated worker decides to collect UI benefits. If the worker does not collect, the firm does not pay this tax. As stated above, we assume that upon forming a match, all workers are UI ineligible. Eligibility is perfectly observable by the firm, so that the firm knows if a worker moves to the UI eligible state.

In addition, if a worker decides to apply for UI benefits (recall the process described in Section 2.5), the firm can decide whether or not to challenge the worker's UI eligibility. The firm chooses the probability of such challenges optimally. Let $p_j, j \in \{B, N\}$ denote this probability. Notice, the firm chooses monitoring probabilities for eligible and ineligible workers separately. If the firm challenges the claim, we assume that initially the worker's claim is rejected by the UI agency. At this point, the worker decides whether or not to appeal the decision. Specifically, the worker decides how much effort to exert in the appeal process. Let a denote the worker's choice of effort. Further, let $s_j(a)$ denote the probability that the firm's challenge is successful; that is, the worker's claim is denied. We assume that $s_j(a)$ is strictly decreasing and strictly convex: $s_j'(a) < 0$ and $s_j''(a) > 0$. Thus, with probability $p_N s_N(a)$, an ineligible worker attempting to collect UI benefits is found to be ineligible and denied benefits. For a UI eligible worker, a successful eligibility challenge by the firm occurs with probability $p_B s_B(a)$ and results in an *improper denial.*

Challenges are costly for the firm. Specifically, they pay a flow cost $c(p)$ that depends on p. We assume that $c(p) \in \mathbf{C}^2$, and is strictly increasing and strictly convex: $c'(p) > 0$ and $c''(p) > 0$. If eligibility is denied, the firm is credited back the tax, τ.

Having an eligibility verification is also costly for the worker. In the event of a verification, the worker pays a cost $\chi(a)$ that depends on the effort they exert in the appeals process. This effort choice is made from the continuous interval of possible effort values given by $\left[\underline{a}, \bar{a}\right]$ We assume that this cost is linear in effort for the worker, given by $\chi(a) = \chi a$, where $\chi > 0$ is the idiosyncratic cost parameter. For each worker, this constant is permanent (i.e. does not change for the worker over time), but varies across the population. Recall, workers also face a fixed upfront cost of applying for UI benefits; as a result, the total cost of applying is $\phi\chi + p_j\chi a, j = B, N$. Thus, the parameter ϕ controls the proportion of the total UI filing cost attributable to improper denials relative to fixed costs associated with the application (or other stigma costs). Firms know the distribution of χ, and learn the worker's value upon forming a match (this is described further when discussing wage determination). Below we describe the worker and firm decisions regarding these eligibility verifications.

3.1 Timing

The timing of the model is as follows.

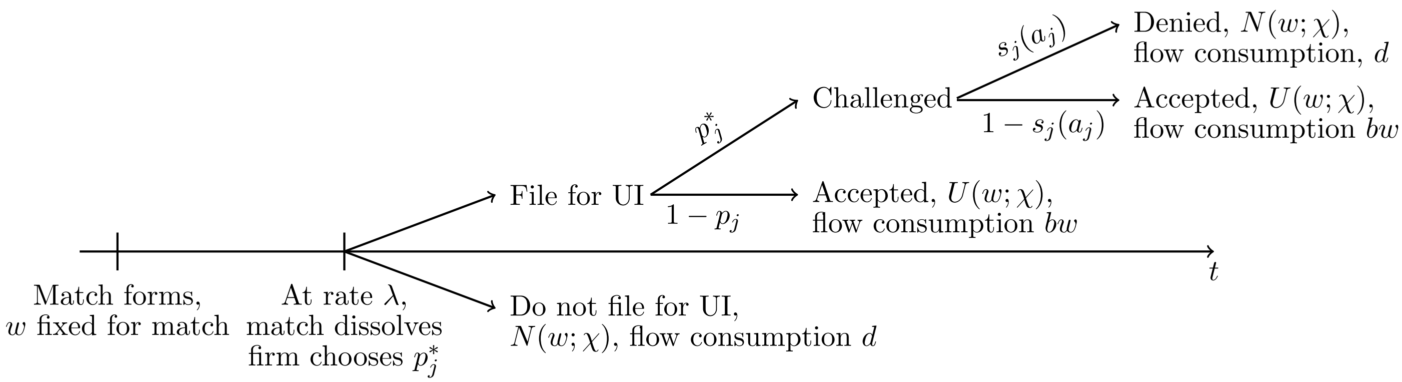


Figure 2: Timing following match formation

The graph shows the timing of events immediately before a given match forms, and then immediately after separation. Events proceed as: 1) A worker and firm meet and negotiate the wage and production takes place, 2) (Not shown in timing diagram) At rate σ the worker becomes eligible for UI benefits, 3) At rate λ, the match dissolves and the worker becomes unemployed, 4) The worker decides whether or not to file a UI claim, 5) If filing, they face two lotteries: A) they may have eligibility challenged (probability p_j), and B) if challenged, they may be denied (probability $s_j(a_j)$); if challenged, the worker decides how much effort to exert, a_j contesting the firm.

3.2 Matching Technology

There exists a matching function that describes the relationship between the number of unemployed workers, vacancies, and the resulting number of matches formed. Let u denote the number of unemployed workers, and v denote the number of vacancies. The number of matches formed is given by $m = m(u, \mathrm{v})$. The matching function, m, is continuous, strictly increasing, strictly concave (with respect to each of its arguments), and exhibits constant returns to scale with $m(0, \cdot) = m(\cdot, 0) = 0$. Following Pissarides (2000) terminology, define $\theta \equiv \mathrm{v}/u$, referred to as labor market "tightness."

Each vacancy is filled according to a Poisson process. Define $q(\theta) \equiv \frac{m(u, \mathrm{v})}{\mathrm{v}} = m(\frac{1}{\theta}, 1)$. Given this, a vacancy is filled with Poisson arrival rate $\frac{m(u, \mathrm{v})}{\mathrm{v}} = q(\theta)$. Similarly, each unemployed worker finds a job according to a Poisson process with arrival rate $\frac{m(u, \mathrm{v})}{u} = \theta q(\theta)$. Since matching is random, when the firm meets an unemployed worker, that worker is randomly drawn from the population according to the distribution $F(\chi)$.

3.3 Value Functions

This section describes the value functions for both workers and firms. We begin with workers and then describe value functions for firms.

3.3.1 Workers

The value functions for workers are given by the following. For the unemployed UI benefit collector and non-collector, respectively,

$$rU(w;\chi) = B(w;\chi) + \theta q(\theta)\left[E_N(w;\chi) - U(w;\chi)\right] \tag{2}$$

$$rN(w;\chi) = d + \theta q(\theta)\left[E_N(w;\chi) - N(w;\chi)\right] \tag{3}$$

In Equation (2), unemployed UI collectors receive flow utility $B(\chi) = b * w(\chi)$ and transition to employment at rate $\theta q(\theta)$. Equation (3) has a similar interpretation for an unemployed non-collector. Notice, since all workers start new employment ineligible for UI benefits, the relevant employed value function for both collectors and non-collectors is $E_N(\chi)$.

Employed workers are either in the $j = B$, benefit eligible, or $j = N$, not benefit eligible state. Denote the value functions as $E_B(w;\chi)$ and $E_N(w;\chi)$ for UI eligible and ineligible, respectively. For the UI eligible:

$$\begin{aligned} rE_B(w;\chi) = w(\chi) + \lambda \max\Big\{ &-\phi\chi + p_B(w;\chi)\Big(-\chi a_B^*(w;\chi) + s_B(a_B^*(w;\chi))\left[N(w;\chi) - E_B(w;\chi)\right] + \\ &(1 - s_B(a_B^*(w;\chi))\left[U(w;\chi) - E_B(w;\chi)\right]\Big) + (1 - p_B(w;\chi))\left[U(w;\chi) - E_B(w;\chi)\right], N(w;\chi) - E_B(w;\chi)\Big\} \end{aligned} \tag{4}$$

$$\text{s.t.} \quad a_B^*(w;\chi) \in \arg\max_{a_B} \Big\{ s_B(a_B)\left[N(w;\chi) - E_B(w;\chi)\right] + (1 - s_B(a_B)\left[U(w;\chi) - E_B(w;\chi)\right] - \chi a_B \Big\} \tag{5}$$

For the UI ineligible:

$$\begin{aligned} rE_N(w;\chi) = w(\chi) + \sigma\left[E_B(w;\chi) - E_N(w;\chi)\right] + \lambda \max\Big\{ &-\phi\chi + p_N(w;\chi)\Big(-\chi a_N^*(w;\chi) + s_N(a_N^*(\chi))\left[N(\chi) - E_N(\chi)\right] + \\ &(1 - s_N(a_N^*(w;\chi)))\left[U(w;\chi) - E_N(w;\chi)\right]\Big) + (1 - p_N(w;\chi))\left[U(w;\chi) - E_N(w;\chi)\right], N(w;\chi) - E_N(w;\chi)\Big\} \end{aligned} \tag{6}$$

$$\text{s.t.} \quad a_N^*(w;\chi) \in \arg\max_{a_N} \Big\{ s_N(a_N)\left[N(w;\chi) - E_N(w;\chi)\right] + (1 - s_N(a_N)\left[U(w;\chi) - E_N(w;\chi)\right] - \chi a_N \Big\} \tag{7}$$

In Equation (4), the employed UI eligible worker receives flow utility from the wage, $w(\chi)$, and at rate λ the job is dissolved. If this occurs, the worker must decide whether or not to apply for UI benefits. If the worker applies, they pay the fixed upfront cost $\phi\chi$, and one of two events occur: (i) they are subject to an eligibility verification and initially denied benefits (occurs with probability $p_B(\chi)$) or (ii) they are not (occurs with probability $(1 - p_B(w;\chi))$). If the eligibility verification does occur, the worker decides how much effort to exert appealing the eligibility challenge by the firm. Equation (5) shows the determination of this optimal appeal effort, denoted by $a^*_B(w;\chi)$. Then, whether or not the worker enters unemployment state U and collects UI, or state N (does not collect) depends on the outcome of the eligibility verification. Since monitoring is imperfect, with probability $s_B(a^*_B(w;\chi))$ the worker is improperly denied UI benefits and enters state N. If the worker decides not to apply for UI benefits, the change in expected lifetime utility is given by $N(w;\chi) - E_B(w;\chi)$.

Equation (6) has a similar interpretation to Equation (4), with different a eligibility verification probability, $p_N(w;\chi)$, and success rate, $s_N(a^*_N(w;\chi))$. The term after the wage in Equation (6) reflects the transition to UI eligible, occurring at Poisson rate σ.

The worker's optimal choice of $a^*_i(w;\chi)$ is characterized by the F.O.C. for Equations (5) and (7). These are (for $i \in \{B, N\}$):

$$s'_i(a_i)\big[N(w;\chi) - U(w;\chi)\big] = \chi \tag{8}$$

In the analysis below, we parameterize $s_j(a)$ as $s_j(a) = \exp(-\nu_j a)$, where $\nu_j > 0$ is a constant parameterizing the efficacy of appeal effort. In this case, $s_j(a)$ satisfies the aforementioned assumptions (strictly decreasing and strictly convex in a). Moreover, the optimal choice of effort then satisfies:

$$a^*_j(w;\chi) = \max\left\{\underline{a}, \frac{1}{\nu_j}\ln\left[\frac{\nu_j\big(U(w;\chi) - N(w;\chi)\big)}{\chi}\right]\right\} \tag{9}$$

Notice here that we allow for a lower bound on effort greater than zero, $\underline{a} > 0$. This additional restriction acts as an important identifying assumption in the calibration exercise detailed in Section 4.1. Economically, a lower bound on worker effort in fighting a firm challenge implies there exists some portion of these costs that are unavoidable. As an analogy, imagine that the worker must make a mandatory court appearance. The costs associated with this are given by $\chi\underline{a}$. Of course, some workers may choose to put more effort into the court appearance trying to argue their case, while others may simply "plead guilty" (i.e. put in no effort above the minimum). As discussed further below, this restriction allows the model to match elasticities implied by Table 2.

3.3.2 Firms

Next, consider the value functions for a firm. Let V denote the value of a vacancy, given by:

$$rV = -\gamma + q(\theta) \int_0^\infty [J_N(w;\chi) - V]\, dF(\chi) \tag{10}$$

In Equation (10), the firm pays the flow cost of opening a vacancy, γ, and matches with a worker at Poisson rate $q(\theta)$. The worker is drawn randomly from the population according to the distribution $F(\chi)$, and starts as *Not* Benefit eligible ($i = N$).

Let $J_i(w;\chi), i = N, B$ denote the value of a filled vacancy for a worker of "type" i with collection cost values χ. For a filled job with a currently UI ineligible worker ($i = N$):

$$\begin{aligned} rJ_N(\chi) = \max_{p_N(w;\chi)} \; & y - w(\chi) - \underline{\tau} \\ & + \lambda \left\{ \Omega_N(\chi) \left[-\tau(w;\chi) + p_N(w;\chi) s_N(a_N^*(w;\chi)\tau(w;\chi) - c(p_N(w;\chi)) \right] + V - J_N(w;\chi) \right\} \\ & + \sigma \left[J_B(\chi) - J_N(\chi) \right] \end{aligned} \tag{11}$$

In this case, the firm earns flow profits equal to $y - w(\chi) - \underline{\tau}$, where $\underline{\tau}$ is the minimum UI tax all firms pay. At arrival rate λ the job is dissolved; in this event, some workers decide to apply for UI benefits, while others do not. Here $\Omega_i(\chi), i \in \{B, N\}$ is an indicator variable for the worker's choice. It is equal to 1 if the worker applies for UI and 0 if not. Thus, if the worker applies for benefits, the firm must pay the upfront tax, $\tau(\chi)$. Notice, the firm's tax depends on χ. This obtains because, in equilibrium, the amount of taxes paid depends on the benefits collected by workers, which are dependent on χ via the wage: $bw(\chi)$. The firm optimally chooses $p_N(w;\chi)$, the probability of initiating an eligibility verification. Notice, the firm's choice of p_N depends on both w and χ. This is true because the worker's choice of appeal effort depends on w and χ. Thus, with probability $s_N(a_N^*(w;\chi))$ benefits are denied. In this case, the worker does not collect and the firm is credited back the tax τ. The firm also pays the cost of verifications, $c(p_N(w;\chi))$. Finally, at Poisson rate σ the worker gains UI eligibility and moves to state $i = B$ (*Benefit* eligible).

Notice, we are assuming that the firm is unable to commit itself to $p_i(w;\chi) = 0$. That is, the firm cannot commit to never challenging UI claims. This would be beneficial to workers and the firms since the costs associated with UI claims challenges reduce the joint surplus of a match, which the worker and firm split; therefore, there could exist a Pareto improvement via firm commitment to $p_i = 0$, for either or both $i = B, N$. For example, the firm commits to $p_i = 0$, but then pays the worker a lump-sum "severance payment," $\omega(\chi)$. If the lump-sum severance payment is negotiated as part of the bargaining process, this could move the joint surplus to its pair-wise efficient level. Engelhardt, Rocheteau, and Rupert (2008) provide an example of such wage contracts in a search-matching model with crime. The literature on wage contracts with on-the-job search, for example Shimer (2006), may also be relevant, as firm and worker interactions regarding separations represents the key issue, similar to a negotiation over UI collection.

The existence of such severance payments is difficult to determine in the data.[10] Importantly, the existence of improper denials and UI fraud suggest that such a wage setting mechanism does not obtain universally. This makes our setting distinct from the cases cited above for crime (Engelhardt, Rocheteau, and Rupert (2008)) and on-the-job-search (Shimer (2006)); in those cases efficient contracts can obtain along with crime (on-the-job-search) occurring in equilibrium. While it is impossible to determine what forces drive the lack of commitment and/or other wage contracts from obtaining more universally in our setting, there certainly exist other alternative explanations beyond the one we develop in this paper. A reputation mechanism for firms, for example, may represent on alternative. Therefore, it is worth noting our assumptions on this dimension.

For a UI eligible worker ($i = B$), the value of a filled vacancy is,

$$
\begin{aligned}
rJ_B(\chi) = \max_{p_B(\chi)} y - w(\chi) - \underline{\tau} + \lambda \Big\{ & \Omega_B(\chi) \left[-\tau(w;\chi) + p_B(w;\chi) s_B(a_B^*(w;\chi)) \tau(w;\chi) - c(p_B(w;\chi)) \right] \\
& + V - J_B(w;\chi) \Big\}
\end{aligned} \tag{12}
$$

which has a similar interpretation to Equation (11). In the discussion of wage determination below, it is helpful to have closed form solutions for the firm's value functions. Towards this end, define

$$
C_i(w;\chi) = -\Big\{ \tau \big[1 - p_i^*(w;\chi) s_j(a_i^*(w;\chi)) \big] + c(p_i^*(w;\chi)) \Big\} \tag{13}
$$

This represents the expected per-period costs for the firm when a worker of collection type $i = N, B$ is separated and decides to apply for UI benefits. We also define three "versions" of the firm's value function $J_N(w;\chi)$, each of which represents a different take-up decision by the worker. When

[10] Auray, Danthine, and Poschke (2019) provide some data about the determination of mandated and bargained severance pay in Continental European countries.

employing a worker who always collects UI benefits (both when eligible and ineligible) the firm has the value function denoted $J_N^1(w;\chi)$, and has $J_N^2(w;\chi)$ when employing a worker who only collects while eligible. Finally, $J_N^3(w;\chi)$ denotes the case for a worker who never collects. Given this, Equations (11) and (12) imply,

$$J_N^1(w;\chi) = \frac{1}{r+\lambda}\left\{y - w - \underline{\tau} + \lambda C_N(w;\chi) + \frac{\sigma\lambda\big[C_B(w;\chi) - C_N(w;\chi)\big]}{r+\lambda+\sigma}\right\} \tag{14}$$

$$J_N^2(w;\chi) = \frac{1}{r+\lambda}\left\{y - w - \underline{\tau} + \frac{\sigma\lambda C_B(w;\chi)}{r+\lambda+\sigma}\right\} \tag{15}$$

$$J_N^3(w;\chi) = \frac{1}{r+\lambda}\left\{y - w - \underline{\tau}\right\} \tag{16}$$

The firm chooses $p_i(w;\chi)$ optimally to maximize the value of a filled vacancy. Verifying eligibility more frequently reduces UI tax costs, but the firm also incurs a higher flow cost of verification, $c(p)$. Thus, $p_i(w;\chi)$ is chosen to maximize the expected value of challenging eligibility:

$$p_i^*(w;\chi) = \arg\max_{p_i} p_i s_i(a_i^*(w;\chi))\tau(w;\chi) - c(p_i) \tag{17}$$

Solving Equation (17) yields the following F.O.C:

$$s_i(a_i^*(w;\chi))\tau(w;\chi) = c'(p_i^*(w;\chi)) \tag{18}$$

Given the assumptions on $s_i(a_i^*(w;\chi))$ and $c(p)$, it is straight forward to show there is a well-defined and unique choice of $p_i^*(w;\chi) > 0$ for the firm. In the quantitative analysis below, we specify the following functional form for $c(p)$: $c(p) = (cp)^\zeta$, $\zeta > 0, c > 0$. In this case, the unique value of p_i^* is given by:

$$p_i^*(w;\chi) = \left[\frac{s_i(w;\chi)\tau(w;\chi)}{c\zeta}\right]^{\frac{1}{\zeta-1}} \tag{19}$$

Recall, the firm's UI challenge probability is a function of w and χ. This obtains because the probability of a successful challenge (for the firm) depends on the effort exerted by the worker, which depends on w and χ, $a_i^*(w;\chi)$, and because the firm's experience rated tax, $\tau(w;\chi)$, depends on χ via its dependence on w. While the firm takes the tax rate as given when making vacancy creation, it does affect eligibility challenge decisions and wage negotiations. This obtains because in equilibrium, firms pay some fraction, τ, of the expected (average) UI benefits collected by the separated worker. Thus, the firm's tax liability at separation is given by $\tau\dfrac{b * w(\chi)}{\theta q(\theta)}$. We discuss the dependence of $p_i^*(w;\chi)$ on w and χ in more details below in Section 4.2 and Figure 7.

3.4 Equilibrium

Determining equilibrium involves finding the following objects: $\{\theta, w(\chi), \Omega_i(\chi), p_i^*(w;\chi), \tau(w;\chi), \underline{\tau}\}$ for $i \in \{B, N\}$. That is, given the model and value functions described above, determining equilibrium requires finding market tightness, θ, the wage function $w(\chi)$, a UI take-up decision rule, $\Omega_i(\chi), i \in \{B, N\}$, optimal eligibility challenge decision by firms, $p_i^*(w;\chi), i \in \{B, N\}$, experience rated taxes $\tau(w;\chi)$, and the budget balancing tax $\underline{\tau}$. In addition, equilibrium determines the stock of workers in each employment state: $\{n_B^E, n_N^E, n_B^U(\chi), n_N^U\}$, where $n_i^E, i \in \{B, N\}$ denotes the number of workers employed by UI eligibility, and $n_i^U, i = B, N$ the number of unemployed UI collectors ($i = B$) and non-collectors ($i = N$), respectively. Notice, we solve for the number of UI collectors at each value of $\chi \leq \chi_B^*$. We do so because the transition rates to unemployed state $i = B$ depend on $p_i^*(\chi)$ and $s_i(a_i^*(\chi))$ and thus on χ; therefore, the distribution of UI collectors across χ does not necessarily match the population distribution $F(\chi)$. This is especially important for determining the budget balancing tax $\underline{\tau}$, since UI benefits also depend on χ.

3.4.1 Equilibrium Decision Rules

The first step in characterizing equilibrium is to examine worker decisions regarding UI benefit applications. These decision are characterized by cutoff values for χ, denoted by $\chi_i^*, i \in \{B, N\}$. That is, there exists a critical threshold for χ, denoted by χ_i^*, where the worker with eligibility status $i \in \{B, N\}$ collects if $\chi \leq \chi_i^*$ and does not if $\chi > \chi_i^*$. To find these cut-offs, define the function $\Gamma_i(\chi)$ as:

$$\begin{aligned}\Gamma_i(\chi) = & -\phi\chi + p_i(w;\chi)\Big[-\chi a_i^*(w;\chi) + s_i(a_i^*(w;\chi))(N(w;\chi) - U(w;\chi))\Big] + \\ & \Big[U(w;\chi) - E_i(w;\chi)\Big] - \Big[N(w;\chi) - E_i(w;\chi)\Big] \end{aligned} \tag{20}$$

where a_i^* is given by Equation (9). The worker prefers to apply for UI benefits when $\Gamma_i(\chi) \geq 0$. Simplifying this, we have $\Gamma_i(\chi) \geq 0$ when

$$\big[U(w;\chi) - N(w;\chi)\big]\big[1 - p_i^*(w;\chi)s_i\big(a_i^*(w;\chi)\big)\big] \geq \chi\big[\phi + p_i^*(w;\chi)a_i^*(\chi)\big] \tag{21}$$

Thus, the worker collects when the expected gain from collecting on the LHS exceeds the expected cost in the RHS.

Characterizing the cut-offs χ_i^* analytically is difficult. From Equation (21), the difference $U(w;\chi) - N(w;\chi)$ represents a key object. Since the UI benefit depends on the wage, which depends on χ and $U(w;\chi) - N(w;\chi)$, and the worker challenge effort decision, $a_i^*(w;\chi)$, depends on χ and $U(w;\chi) - N(w;\chi)$, there does not exist a closed form solution for χ_i^*. Some insight into the determination of χ_i^* is obtained however by examining the difference $U(w;\chi) - N(w;\chi)$. Using Equations (2) and (3) we can write:

$$U(w;\chi) - N(w;\chi) = \frac{b * w(\chi) - d}{r + \lambda + \theta q(\theta)} \tag{22}$$

From Equation (22), as $\theta q(\theta)$ increases, χ_i^* should decrease. This implies that the take-up rate is decreasing in the job-arrival rate; an economy with a shorter expected unemployment duration has a lower take-up rate relative to an economy with a longer expected unemployment duration. Moreover, as the replacement rate increases, χ_i^* should increase, increasing the take-up rate. The effects of a decrease in improper denials on the UI take-up rate represents another important moment in our analysis. Here the effects are more nuanced, as they do not affect $U(w;\chi) - N(w;\chi)$ directly, but rather $p_i^*(w;\chi)$ and $s_i\big(a_i^*(w;\chi)\big)$. If we decrease improper denials by decreasing ν_B, the parameter governing the eligibility verification technology (see Equation (9)), all else equal Equation (19) implies that $p_i^*(w;\chi)$ decreases. While there are many other indirect effects, generally this increases the expected gain from collecting, increasing χ_B^* and increasing the UI take-up rate. We explore the aforementioned relationships in more detail in the quantitative analysis of Sections 4 and 5.

3.4.2 Wage Determination

This section discusses the determination of wages in equilibrium, which occurs via Nash Bargaining. With the different levels of eligibility and UI collection status, the wage setting process is relatively complicated. To simplify, we assume that upon meeting a firm, the disagreement value of a worker is $N(\chi)$, the value for a non-collector. This is assumed to be true regardless of whether or not the unemployed worker is currently collecting benefits or not. This assumption actually reflects current UI laws in the U.S. system; if a worker rejects a suitable job offer, they are no longer eligible to collect UI benefits. Although no offers are rejected in equilibrium, walking away from the bargaining table renders the worker UI ineligible, implying this represents the relevant threat option.

One may argue, however, that while current law prevents a worker from rejecting the firm's offer and still collecting UI, it may be possible for the worker to commit fraud. That is, the worker could conceal the job offer rejection from the authorities and continue collecting UI benefits. This may seem particularly relevant, since we allow ineligible workers to potentially collect UI after a separation. While potentially feasible, data on UI fraud imply a low incidence of such behavior. Specifically, according to the BAM data discussed in Section 2.6, fraud from rejecting suitable job offers represents a negligible fraction of total UI fraud.[11] Thus, we maintain the assumption that all workers have disagreement value $N(w;\chi)$, and that the option to commit fraud via job rejections is unavailable. Overall, this assumption does not affect any of the main results of the paper, but simply provides valuable tractability.

Futhermore, notice that if a worker gains UI eligibility (happens with arrival rate σ), their surplus changes from $E_N(w;\chi) - N(w;\chi)$ to $E_B(w;\chi) - N(w;\chi)$. If the worker re-bargains, the wage changes once UI eligibility is obtained. We assume that there is no such re-bargaining, so the wage is constant for the duration of the match. Thus, there is just one wage function, which we denote by $w(\chi)$. Similar to the assumption of a common threat value, this assumption provides tractability but does not affect the main results of the paper. Given these assumptions we now describe the Nash Bargaining solution.

Letting β denote the bargaining parameter, the Nash Bargaining problem is given by:

$$w^*(\chi) = \arg\max \left[E_N(w;\chi) - N\right]^{\beta} \left[J_N(w;\chi) - V\right]^{1-\beta} \tag{23}$$
$$\text{s.t.} \quad \text{Equations} \quad (4), (6), (9), (11), (12), \text{ and } (19)$$

That is, the Nash Bargained wage maximizes the joint worker-firm surplus, subject to the constraint that when bargaining, both the worker and the firm explicitly consider how different wages alter the optimal choices of a_j^* and p_j^* for $j = N, B$.

In general, the problem described in Equation (23) does not have a convex set of feasible payoffs, which implies the wage solving Equation (23) may not represent the solution to the underlying bargaining problem. Convexity breaks down because 1) the firm's payoff has discontinuities at the worker's take-up decision cut-offs, χ_N^* and χ_B^*, and because 2) the negotiated wage affects the worker's take-up decision.

With these two conditions present, the firm has a discrete positive gain from a wage that changes the worker's decision from collecting to not-collecting, while the change in the worker's surplus is continuous (and thus smaller). This implies that the firm (or the worker) can credibly use the

[11] See Table 1 in Fuller, Ravikumar, and Zhang (2015) for more details.

threat of a breakdown in negotiations to counter-offer the current wage $w^*(\chi)$, with a wage that changes the worker's take-up decision. This occurs as long as the firm's expected gain from the change in wages and take-up decision are less than the worker's surplus from collecting.

This becomes an issue near the cut-offs $\chi_j^*, j = N, B$. Here, the worker is marginal with regards to the UI take-up decision. Since the UI benefit is a function of the worker's wage, the wage impacts the take-up decision. Recall, the UI take-up decision is characterized by Equation (21). Substituting Equation (22) and Equation (21) into Equation (20), we can write Γ as a function of w:

$$\Gamma(w;\chi) = \Big[\frac{b * w(\chi) - d}{r + \lambda + \theta q(\theta)}\Big]\Big[1 - p_i^*(w;\chi)s_i\big(a_i^*(w;\chi)\big)\Big] - \chi\big[\phi + p_i^*(w;\chi)a_i^*(w;\chi)\big] \tag{24}$$

Thus, near the cut-offs $\chi_j^*, j = N, B$, $\Gamma_j(w;\chi)$ is close to zero. The firm, however, strictly prefers the worker not collect, as in this case the firm obtains a discrete positive jump in their surplus. Specifically, examining Equations (14) to (16), the firm gains $\lambda C_N(w;\chi)\Big(1 - \dfrac{\lambda\sigma}{r + \lambda + \sigma}\Big)$ for $j = N$ and $\dfrac{\lambda\sigma C_B(w;\chi)}{r + \lambda + \sigma}$ for $j = B$. These represent the firm's expected per-period costs of dealing with the UI system.

Whether it is the firm or the worker initiating the negotiations deviating from $w^*(\chi)$ depends on how the take-up decision responds to a change in the wage; i.e. $\dfrac{\partial\Gamma_j(w;\chi)}{\partial w(\chi)}$. If $\dfrac{\partial\Gamma_j(w;\chi)}{\partial w(\chi)} > 0$, then a decrease in the wage decreases $\Gamma_j(w;\chi)$, moving the worker from collecting to not collecting. Here the firm initiates the counter-offer, lowering $w^*(\chi)$. If $\dfrac{\partial\Gamma_j(w;\chi)}{\partial w(\chi)} < 0$, then the wage must increase to change the worker's take-up decision. In this case, the worker initiates the counter-offer, realizing they can negotiate over the take-up decision and the firms potential gain of $\lambda\big[\tau(1 - p_j^*(w;\chi)s_j(a_j^*(w;\chi)))\big]$.

The sign of $\dfrac{\partial\Gamma(w;\chi)}{\partial w(\chi)}$ is ambiguous given the effects of w on a_j and p_j. While a decrease in the wage clearly decreases $U(w;\chi) - N$, it thus also causes a decrease in a_j. This in turn decreases $s_j(a_j)$, changing p_j. Furthermore, a decrease in w also decreases the firm's tax, τ, further decreasing p_j. The sign of $\dfrac{\partial\Gamma(w;\chi)}{\partial w(\chi)}$ thus depends on which of the aforementioned effects dominates. We find both cases obtain in our quantitative analysis.

In Appendix A we provide details on this process and show analytically how our solution indeed satisfies the requirements of a Nash solution to the bargaining problem. Here we present the implications of this feature for the equilibrium described to this point. These issues require two adjustments to the equilibrium determination described above. First, clearly the equilibrium wage must be adjusted from $w^*(\chi)$ for some values of χ. Second, the determination of $\chi_j^*, j = N, B$ also requires adjustment from Equation (21). We begin with the latter. Denote by $\tilde{\chi}_j^*$ the adjusted equilibrium cut-off for $j = N, B$. This cut-off must be that where (i) the worker prefers to collect for all $\chi \le \tilde{\chi}_j^*$, and (ii) there do not exist any possible wage "re-negotiations." The second of these requirements implies that we must add the discrete gain for the firm, $\lambda C_N(w;\chi)$ for $j = N$ and $\frac{\sigma\lambda}{r+\lambda+\sigma} C_B(w;\chi)$ for $j = B$, to the function $\Gamma_j(w;\chi)$. Thus, $\tilde{\chi}_j^*$ is determined by

$$\Big[\frac{b * w^*(\chi) - d}{r + \lambda + \theta q(\theta)}\Big]\Big[1 - p_i^*(w^*;\chi)s_i\big(a_i^*(w^*;\chi)\big)\Big] - \chi\big[\phi + p_i^*(w^*;\chi)a_i^*(w^*;\chi)\big] = \Upsilon\lambda C_N(w^*;\chi) + (1-\Upsilon)\frac{\sigma\lambda}{r+\lambda+\sigma}C_B(w^*;\chi) \tag{25}$$

where Υ is an indicator variable with $\Upsilon = 1$ for $j = N$ and $\Upsilon = 0$ for $j = B$. Equation (25) says that $\tilde{\chi}_j^*$ is such that the worker's expected "gain" from collecting UI is just equal to the firm's "gain" from the worker not collecting. Notice that this implies $\tilde{\chi}_j^* < \chi_j^*$. Then, for $\chi < \tilde{\chi}_j^*$ and $\chi > \chi_j^*$, wages are given by $w^*(\chi)$. For $\chi \in [\tilde{\chi}_j^*, \chi_j^*]$, the wage is determined according to the following problem:

$$\tilde{w}(\chi) = \arg\max_{w} \left[E_N(w;\chi) - N\right]^{\beta} \left[J_N(w;\chi) - V\right]^{1-\beta} \tag{26}$$

$$\text{s.t.} \quad \text{Equations} \quad (4), (6), (9), (11), (12), (19) \text{ and}$$

$$\Gamma(\tilde{w};\chi) \le 0 \tag{27}$$

This alternative wage maximizes the joint worker-firm surplus, subject to the worker does not collect UI benefits. Given this constraint, the relevant value functions correspond to this take-up decision. Notice that the constraint in Equation (27) must bind. If it did not, then $w^*(\chi)$ would represent the equilibrium wage. Thus, the wage for $\chi \in [\tilde{\chi}_j, \chi_j^*]$ is such that $\Gamma(\tilde{w};\chi) = 0$.[12] With these two wage functions, $w^*(\chi)$ and $\tilde{w}(\chi)$, at any χ neither the worker or the firm has a credible counter-offer to the prevailing wage.

[12] This is somewhat similar to the solution proposed in Conley and Wilkie (1996) to bargaining with non-convex sets. Conley and Wilkie (1996) propose a solution where the problem is convexified, and the final solution determined as the point on this convex hull maximizing the joint surplus. Our solution is similar in that we choose the maximal element on the edge of the set, but we do not formally convexify the set via say lotteries.

3.4.3 Equilibrium Characterization

Equilibrium is characterized by the following set of equations. Given the parameters, the worker's value functions in Equations (2) to (6) and optimal effort choices in Equation (9), the firm knows the probabilities $s_i(a_i^*(w;\chi))$ and then Equation (19) determines $p_i^*(w;\chi), i = B, N$. Equations (23) and (26) then determine the wage function $w(\chi)$. Then, we use Equation (25) to determine the values of $\tilde{\chi}_i^*$. Given these, market tightness is determined by the free-entry condition, or $V = 0$. From Equation (10),

$$\frac{\gamma}{q(\theta)} = \int_0^\infty J_N(w;\chi)dF(\chi) \tag{28}$$

With $\{\theta, w(\chi), \tilde{\chi}_i^*, p_i^*(w;\chi)\}$ determined, we now turn to the equilibrium stocks of workers across the different employment and unemployment states. Define the following stocks, $\{n_B^E, n_N^E, n_B^U(\chi), n_N^U\}$, which refer to the number of workers employed and eligible, employed and ineligible, unemployed and collecting UI benefits, and unemployed not collecting, respectively. Notice, the number of unemployed UI collectors is denoted as a function of χ. This arises from the fact that the flows from employment (either eligible or ineligible) depend on χ via the probabilities $p_i^*(\chi)$ and $s_i\big(a_i^*(\chi)\big)$; as a result, the number of UI collectors is not distributed randomly by $F(\chi)$ as are the other states. The stocks are determined by the following four equations.

$$\lambda n_B^E = \sigma n_N^E \tag{29}$$

$$(\sigma + \lambda) n_N^E = \theta q(\theta) \left[N_B^U + n_N^U\right] \tag{30}$$

$$\begin{aligned}&\lambda f(\chi) \left[(1 - p_B(w;\chi)s_B(a_B^*(w;\chi)))n_B^E + (1 - p_B(w;\chi)s_B(a_B^*(w;\chi)))n_N^E\right] = \\ &\theta q(\theta) n_B^U(w;\chi), \text{for all} \chi \leq \tilde{\chi}_B^*\end{aligned} \tag{31}$$

$$n_B^E + n_N^E + N_B^U + n_N^U = 1 \tag{32}$$

where $N_B^U = \displaystyle\int_0^{x_B^*} n_B^U(\chi)dF(\chi)$ is the total number of workers filing for and granted UI benefits. Equation (29) states that the flows into and out of UI-eligible employment must be equal. Equation (30) equates the flows into and out of UI-*ineligible* employment, and Equation (31) equates the flows into and out of insured unemployment for each χ below the threshold $\tilde{\chi}_B^*$. Equation (32) normalizes the measure of workers to 1. Solving these equations for n_B^E, n_N^E, and $n_B^U(\chi)$ yields:

$$n_B^E = \frac{\sigma\theta q(\theta)}{[\lambda+\sigma][\lambda+\theta q(\theta)]} \tag{33}$$

$$n_N^E = \frac{\lambda\theta q(\theta)}{[\lambda+\sigma][\lambda+\theta q(\theta)]} \tag{34}$$

$$n_B^U(\chi) = \frac{\lambda f(\chi)\left[\lambda\big(1-p_N^*(w;\chi)s_N(a_N^*(w;\chi))\big)+\sigma\big(1-p_B^*(w;\chi)s_B(a_i^*(w;\chi))\big)\right]}{[\lambda+\sigma][\lambda+\theta q(\theta)]} \tag{35}$$

The unemployment rate, denoted by u, is given by $N_B^U + n_N^U$. From Equation (32) this implies $u = 1 - n_B^E - n_N^E$. Equations (33) and (34) imply:

$$u = \frac{\lambda}{\lambda+\theta q(\theta)} \tag{36}$$

which is the same expression one obtains in the standard Pissarides framework. The take-up rate represents another key moment. It is given as the ratio of the number collecting UI benefits, N_B^U, to the number of unemployed eligible for benefits. The number of unemployed eligible for benefits is simply the total number unemployed multiplied by the fraction of employment that is UI-eligible. Denoting the take-up rate by TUR we have,

$$TUR = \frac{N_B^U}{u\frac{n_B^E}{1-u}} \tag{37}$$

It is important to note that this is the model equivalent to the take-up rate calculated in Section 2.3. Specifically, this is not corrected for those improperly denied or those committing UI fraud (ineligibles that collect). This is appropriate since the model is calibrated to data on the un-adjusted take-up rate.

Next, consider the improper denial and UI fraud rates. As discussed in Section 2.5, the improper denial rate is calculated as the fraction of denied claims that are improperly denied. The corresponding moment in the model is given by:

$$\text{Improper Denial Rate} = \frac{n_B^E D_B}{n_B^E D_B + n_N^E D_N} \tag{38}$$

where $D_i = \displaystyle\int_0^{x_i^*} p_i^*(w;\chi)s_i^*(\chi)dF(\chi)$ denotes the fraction of workers in eligibility state $i \in \{B, N\}$ applying for benefits but being denied. The numerator is the number of eligible employed, n_B^E, multiplied by the fraction filing an application and having it denied, D_B; this represents the number of improper denials. The denominator is the total number of UI applications denied, both proper and improper. Similarly, the UI fraud rate is defined as:

$$\text{Fraud Rate} = \frac{n_N^E P_N}{N_B^U} \tag{39}$$

where $P_N = \int_0^{\chi_N^*} \Big[1 - p_N^*(w;\chi) s_N(a_i^*(w;\chi))\Big] dF(\chi)$. Equation (39) thus gives the total number of ineligible workers who have an application accepted, divided by the total number or workers collecting UI benefits.

4 Calibration

The model is calibrated to U.S. data for the time period from $2002 - 2015$. Given the model in Section 3, the following parameters must be specified: $\{r, \beta, \eta, \lambda, F(\chi), \tau(\chi), \underline{\tau}, \gamma, b, d, \nu_B, \nu_N, \underline{a}, c(p)\}$. Several of the parameters are determined directly from the data. The time period is taken to be one month and the discount factor is set to capture a 4% per-annum interest rate; i.e. $r = (1 + 0.04)^{1/12} - 1$. Similarly, following Fredriksson and Holmund (2001), the bargaining parameter, β, and matching function elasticity, η, are set to $\beta = \eta = 0.5$.

This leaves $\lambda, F(\chi), \tau(\chi), \underline{\tau}, \gamma, b, d, \nu_B, \nu_N, \underline{a}$ and $c(p)$ to be determined. These parameters are calibrated targeting the appropriate moments in the data. The arrival rate of job separations is set to hit a target unemployment rate of 6.62%, which implies $\lambda = 0.0127$, or an average employment duration of around 6.5 years. Related, the value of γ is set to match the average unemployment duration during the $2002 - 2015$ time period. The average duration was 22.36 weeks (or 5.59 months), which implies $\gamma = 173.83$.

The distribution of UI application costs, $F(\chi)$, is parameterized as follows. First, we assume that it follows an exponential distribution with rate parameter μ_χ. That is, $f(\chi) = \dfrac{1}{\mu_\chi}\exp(-\dfrac{1}{\mu_\chi}\chi)$ and $F(\chi) = 1 - \exp(-\frac{1}{\mu_\chi}\chi)$. The value of μ_χ is set to 1. This has no effects on the results, as the remaining parameters adjust accordingly to hit the key moments. We provide robustness results with respect to changing μ_χ in Appendix C.2.

Next we pin down the parameters governing the likelihood the firm challenges a worker's UI claim. Here we parameterize $c(p)$ by setting $\zeta = 2$ in Equation (19). Similarly to the case of μ_χ, this particular parameter did not have any noticeable effects on the key moments, as the other calibration targets adjust accordingly. In addition, we set the value of c in Equation (19) to 0.45.

Table 4: Parameters

r	0.033	Discount rate
β	0.5	Bargaining parameter
η	0.5	Elasticity of matching function
λ	0.0127	Job separation rate
τ	0.6	Experience rating parameter
μ_χ	1	Rate parameter for $F(\chi)$
γ	173.83	Vacancy creation costs parameter
b	0.469	UI benefit replacement rate
d	0	Non-collector flow utility
ϕ	0.977	Fixed cost of applying for UI
ν_B	0.5893	Effectiveness of worker effort, eligible
ν_N	0.0148	Effectiveness of worker effort, ineligible
c	0.45	Effectiveness of firm eligibility verifications
$\underline{a}$	6.39	Minimum worker challenge effort
$\tilde{\chi}_N^*$	0.0615	Endogenous cut-off, ineligible
χ_N^*	0.0623	Second cut-off, ineligible
$\tilde{\chi}_B^*$	1.1534	Endogenous cut-off, eligible
χ_B^*	1.1535	Second cut-off, eligible

Higher values of c ($c = 1$ for example) required very low values of ν_N in order to hit the targeted fraud rate. While this works, it tended to make the overall simulation of equilibrium somewhat unstable for some of the comparative statics performed below.

Given this parametrization, ν_B and ν_N in Equation (9) are set to match the UI improper denial and fraud rates from $2002 - 2015$, respectively. Data on both are discussed in Section 2 and summarized in Table 1. While Table 1 describes a particular type of fraud, from separations, in the calibration we target total UI fraud. Using the same BAM data described in Section 2.1, the total UI fraud rate averaged 3.3% from 2002-2015, as measured by the % of UI collectors who

Table 5: Calibration Results

Moment	Model	Data
Unemployment rate	6.62%	6.62%
Unemployment duration	5.59	5.59
Take-up rate	73.3%	73.4%
Improper Denial Rate	9.99%	10%
Fraud Rate	3.35%	3.30%
Elasticity of TUR to IMP. DEN.	−0.0575	−0.0575

The first column lists the moment, the second column the model's predictions, and the third column the value of the moment in the data.

commit fraud. We targeted the higher total UI fraud rate as this made equilibrium computation significantly more stable relative to the much smaller fraud from separations of 0.5%.[13]

For the UI replacement rate, b, and non-collector flow utility, d, we begin by noting that for our analysis, the consumption value of UI benefits represents the key parameter. In a business cycle model of the labor market, the flow utility of unemployment, B, represents both consumption while unemployed and some leisure value of unemployment. As others have noted (Shimer (2005) and Hagedorn and Manovskii (2008) and the large associated literature), this value relative to the wage has important implications for matching business cycle moments. In our setting, however, assuming the leisure value of unemployment is the same for UI collectors and non-collectors, then only the consumption value of UI benefits matters with respect to the take-up rate. Given this, we set $d = 0$ and b equal to the observed UI replacement rate (averaged across all States) from $2002 - 2015$, which is 0.469.

The value of τ is set to match existing data on experience rating. Recall from Section 3.3.2 the firm's experience rated tax liability at separation is a percentage of the expected UI benefits

[13]The primary issue relates to the worker's ability to contest the firm's eligibility challenges. For very low values of χ, workers will exert high effort, even if the effort is very ineffective (i.e. ν_j is low). Thus, generating a very low fraud rate requires a value of ν_N essentially equal to 0.

collected by the separated worker, $\tau \frac{b * w(\chi)}{\theta q(\theta)}$. We set $\tau = 0.6$ to match the ERI data presented in Section 2.2.

4.1 Identification of UI collection costs

Identifying the relative size of the two "types" of UI collection costs represents the key aspect of our calibration. These relative costs are determined by the size of ϕ compared to the costs associated with UI claim challenges by firms. The latter depend on the probability of firm challenges, $p_j^*(w;\chi)$, which ultimately depend on the worker's choice of effort in the challenge, a_j^*, as this controls the likelihood of success for the firm in the challenge. In this regard, the minimum level of effort a worker can exert in the challenge, $\underline{a}$, represents a key parameter.

To pin down these two key parameters, ϕ and $\underline{a}$, we choose ϕ to hit the target UI take-up rate and $\underline{a}$ to hit the target elasticity of the take-up rate with respect to the improper denial rate. In the $2002-2015$ period, the average take-up rate in the U.S. was 73.4%, implying $\phi = 0.977$. The target elasticity of the take-up rate with respect to the improper denial rate is taken from the two-way fixed effects regression results in Table 2. Here we use the specification in Model 3, with a coefficient on Improper Denials of -0.419, implying an elasticity of -0.0575.

With the parameters ϕ and $\underline{a}$ determined, we can then characterize the relative contribution of the different types of UI collection costs to the take-up decision. To begin, consider the initial calibrated steady state. The fixed costs, which could be administrative costs, stigma, or other similar utility costs that remain fixed (i.e. should not change in equilibrium), are simply represented by ϕ. The endogenous costs are those associated with firm eligibility challenges. Recall Equation (21) that characterizes the decision to take-up UI benefits or not.

From Equation (21) we can see that the total cost of collecting UI benefits is given by the term $\chi\left[\phi + p_i^*(\chi)a_i^*\right]$. To characterize the average contribution of the firm challenges, we calculate $\int_0^{\chi_i^*} p_i^*(\chi)a_i^* dF(\chi)$. For both eligibles ($i = B$) and ineligibles ($i = N$) this gives the total costs paid by workers associated with firm challenges. We then compare these costs to ϕ. Table 6 provides a breakdown of the cost of collecting UI benefits in the calibrated economy. From this table, we see that fixed costs account for 59% of the total UI collection costs, while costs associated with firm challenges account for 41%.

Table 6 shows how large the costs associated with firm challenges are relative to the fixed

Table 6: Relative Contribution of Different UI Collection Costs

Cost	% of Total Costs	% of Fixed Costs, ϕ
ϕ	59%	100%
$E\left[p_j^*(w;\chi)a_j^*(w;\chi)\right]$	41%	57%
$E\left[p_B^*(w;\chi)a_B^*(w;\chi)\right]$	8%	13%

upfront cost of applying for UI benefits. Table 7 displays the distribution of these costs across the population. Specifically we show the percentage of total UI costs associated with firm challenges by percentiles of the population via the distribution of χ. For example, the first row labeled the 20% Percentile corresponds to the bottom 20% of χ values according to the distribution $F(\chi)$, *conditional* on collecting UI benefits. According to Table 7, for the bottom 20% of χ values, the costs associated with firm challenges are 99% of total UI collection costs, and the costs associated with improper denials are just under 4% of total costs for this group. It is important to note that these figures refer to the relative size of the different UI collection costs, not the overall size of these costs. Indeed, for those in the bottom 20% of the χ distribution, the overall costs of collecting are small since they are proportional to χ.

Table 7: Distribution of Relative Contribution of UI Collection Costs

Percentile	$E\left[p_j a_j\right]$	$E\left[p_B a_B\right]$
20%	99.06	3.81
40%	41.68	41.68
60%	27.96	27.96
80%	19.28	19.28
100%	16.56	16.56

This also explains the pattern displayed in Table 7 that the relative contribution of firm challenge costs is decreasing the higher the values of χ become. This obtains because as χ increases, worker effort in the challenge is decreasing, implying the fixed costs of applying tend to dominate. Further notice that the costs from $E\left[p_N^*(w;\chi)a_N^*(w;\chi)\right]$ are only relevant for the bottom 20% of UI collectors (i.e. the second and third columns are identical after the 20% row). This is simply the result of a relatively small fraction of collectors engaging in UI fraud, who also coincide with the lowest values of χ. This also underscores the important role the costs of improper denials play.

To gain another perspective on the size of $\underline{a}$ relative to other moments in the model, we calculate $\frac{\lambda p_j^*(\tilde{\chi}_j^*)\underline{a}\tilde{\chi}_j^*}{w(\tilde{\chi}_j^*)}$. That is, how large are the expected costs associated with effort relative to the worker's wage. For $j = N$ this implies 0.6% of the wage, and 0.3% for $j = B$.

Table 8: Un-Targeted Elasticities

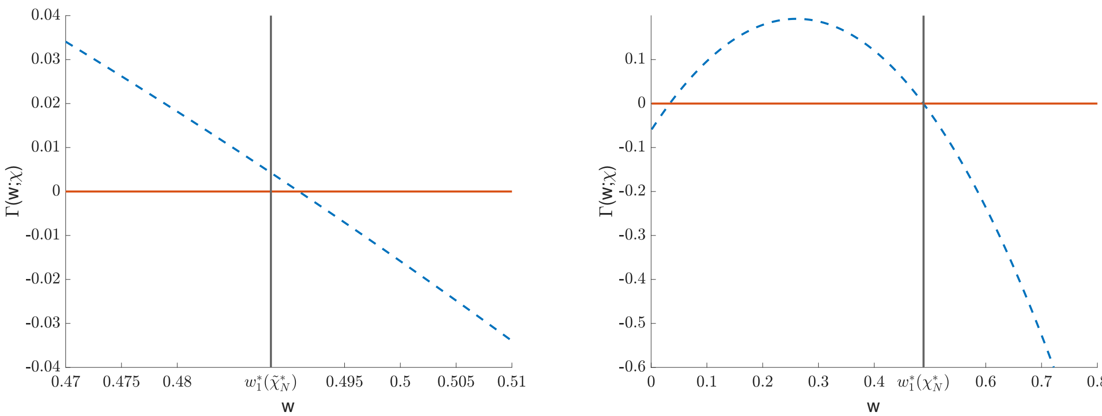
Elasticity	Model	Data
Replacement Rate	0.448	0.412
Duration	0.442	0.137
Fixed costs, ϕ	0.489	–

To further evaluate how well the model captures the relevant data, consider Table 8. Here we examine several un-targeted elasticities in the model and compare them to their data-counterparts where available. The first row of Table 8 examines the model-predicted elasticity of the take-up rate with respect to a change in the UI replacement rate. From Table 2, empirically we find an elasticity of 0.412, while the model predicts an elasticity of 0.448. The model has a higher over-prediction for the elasticity of the take-up rate with respect to the average duration of unemployment. Empirically Table 2 predicts the elasticity at 0.137, while the model predicts 0.442. The last row in Table 8 shows the model's predicted elasticity of the take-up rate with respect to the fixed cost of applying, ϕ. While there is no data counterpart available for this moment, the relatively large elasticity underscores the importance of these fixed costs in the UI application process. These fixed costs have a stronger effect on the take-up rate than a change in the improper denial rate. Indeed, the difference is roughly commensurate with the relative size of improper denial costs compared to ϕ.

4.2 Properties of Equilibrium Allocations

In this section we illustrate some important features of equilibrium outcomes. Since improper denials represent a key portion of the analysis, it is useful to understand how certain equilibrium objects relate. To begin, consider how the wage function changes with the value of χ. Note, the cut-offs $\tilde{\chi}_i$ effectively make the wage function piecewise. Thus, we denote the wage as $w_1(\chi)$ for a worker always collecting, $w_2(\chi)$ for a worker only collecting while eligible, and $w_3(\chi)$ for a worker who never collects. Figure 6 displays the equilibrium wage under the baseline parametrization described above. There exists several features to discuss.

First, recall from Section 3.4.2 that wage determination is different for the regions of $\chi \in [\tilde{\chi}_j^*, \chi_j^*]$. Specifically, the wage is set at $\tilde{w}_j(\chi)$ solving $\Gamma_j(\tilde{w};\chi) = 0$. Whether this involves a wage higher or lower than the original Nash wage, $w^*(\chi)$, depends on how $\Gamma_j(w;\chi)$ changes with w. We find in our parametrization that $\tilde{w}_1(\chi) > w_1^*(\chi)$ while $\tilde{w}_2(\chi) < w_2^*(\chi)$.



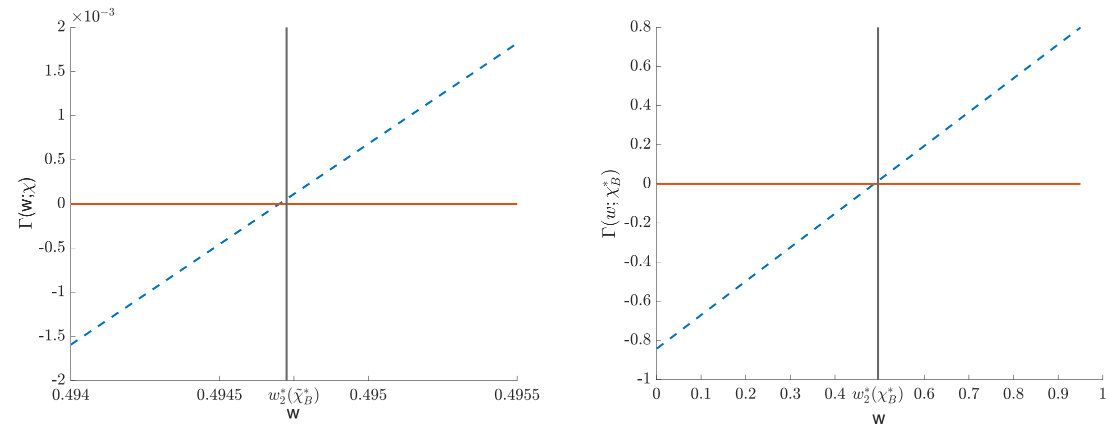
(a) Take-up Decision at $\tilde{\chi}_N^*$, as function of wage

(b) Take-up Decision at $\tilde{\chi}_N^*$, as function of wage

Figure 3: The effect of wages on the take-up decision at χ_N^*

Notes: The figures displays $\Gamma(w;\chi)$. The dotted line plots $\Gamma(w;\chi)$ and the vertical line is placed at the wage $w_1^*(\chi)$. Where positive, the worker prefers to collect benefits when ineligible, while where negative the worker does not collect. Figure 3(b) shows the non-monotonicity of $\Gamma(w;\chi)$, which implies that the worker can counter-offer a higher wage, leveraging their take-up decision.

This is illustrated in Figure 3, which plots the function $\Gamma(w;\chi)$, evaluated at $\chi = \tilde{\chi}_N^*$. Where $\Gamma_N(w;\tilde{\chi}_N^*)$ is positive, the worker prefers to always collect UI benefits, and when negative the worker only collects while eligible. The vertical line labeled $w_1^*(\tilde{\chi}_N^*)$ denotes the wage determined by the solution to Equation (23). First notice that at $w_1^*(\tilde{\chi}_N^*)$, $\Gamma_N(w;\tilde{\chi}_N^*) > 0$; this is straight-forward given the definition of $\tilde{\chi}_N^*$ in Equation (25). Second, in order to move the worker to non-collection, the wage must increase. In this case, the worker knows the firm benefits from a change in the take-up decision, and thus is able to negotiate over this decision to achieve a higher wage. The actual wage for this worker is $\tilde{w}_1(\tilde{\chi}_N^*)$, and is the wage solving $\Gamma_N(\tilde{w}_1(\tilde{\chi}_N^*); \tilde{\chi}_N^*) = 0$.



(a) Take-up Decision at $\tilde{\chi}_B^*$

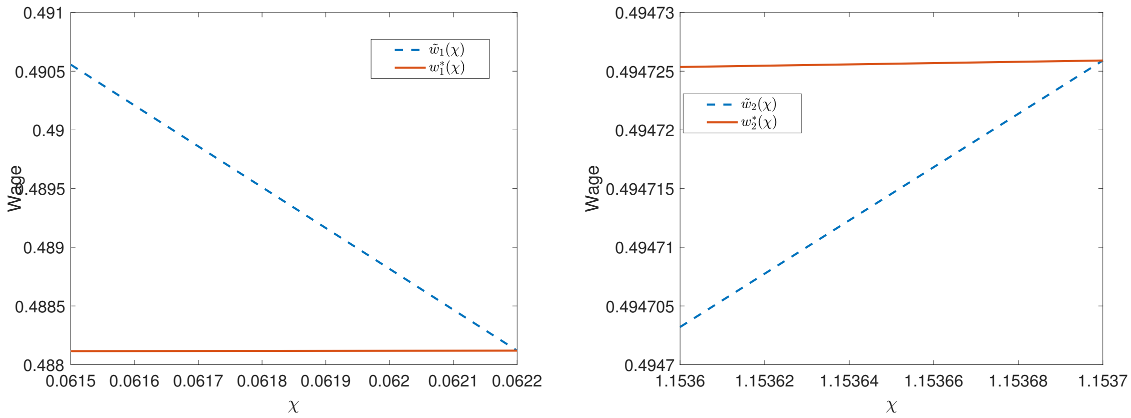
(b) Take-up Decision at χ_B^*

Figure 4: The effect of wages on the take-up decision near χ_B^*

Notes: The figure displays $\Gamma(w;\chi)$ for a $\chi \in (\tilde{\chi}_B^*, \chi_B^*)$. Where positive, the worker prefers to collect benefits when ineligible, while where negative the worker does not collect. In this case, the firm may have a credible counter-offer of a lower wage changing the worker's take-up decision.

Next consider the case of wages for $\chi \in [\tilde{\chi}_B^*, \chi_B^*]$. Figures 4(a) and 4(b) show the determination of $\tilde{w}_2(\chi)$ in this range and its effect on the take-up decision (represented by $\Gamma_B(w;\chi)$). Figure 4(a) shows the case of $\chi = \tilde{\chi}_B^*$. At this χ and the original wage w_2^*, the worker strictly prefers to collect UI. Here the firm counters with a lower wage making the worker just indifferent between collecting and not. Similarly, in Figure 4(b), we show the case of $\chi = \chi_B^*$. Consistent with the definition of χ_B^*, $\Gamma_B(w_2^*(\chi_B^*); \chi_B^*) = 0$. Here, the wage changes only infinitesimally to move the worker from a collector to non-collector.

Overall, the wage setting in the regions of $\chi \in [\tilde{\chi}_j^*, \chi_j^*]$ implies higher wages for $j = N$ and lower wages for $j = B$, relative to $w_1^*(\chi)$ and $w_2^*(\chi)$, respectively. This feature is summarized in Figures 5(a) and 5(b). Here we plot the "re-negotiated" wage $\tilde{w}_i(\chi)$ along with the original "Nash" wage w_i^*, for $i = 1, 2$. Indeed, near the cut-off $\tilde{\chi}_N^*$, $\tilde{w}_1(\chi)$ is higher than $w_1^*(\chi)$, and decreases until being essentially equal to $w_1^*(\chi)$ at $\chi = \chi_N^*$. Near $\tilde{\chi}_B^*$, $\tilde{w}_2(\chi)$ begins lower than $w_2^*(\chi)$, increasing until $\chi = \chi_B^*$. Overall, these changes to wages are relatively small and affect only a small group of workers.



(a) Wage setting near χ_N^*

(b) Wage setting near χ_B^*

Figure 5: Wage setting in the regions $[\tilde{\chi}_j^*, \chi_j^*]$

Notes: The figure displays $\tilde{w}_1(\chi)$ and $\tilde{w}_2(\chi)$ for $\chi \in [\tilde{\chi}_j^*, \chi_j^*]$. The dashed lines represent $\tilde{w}$, while the solid lines represent w^*.

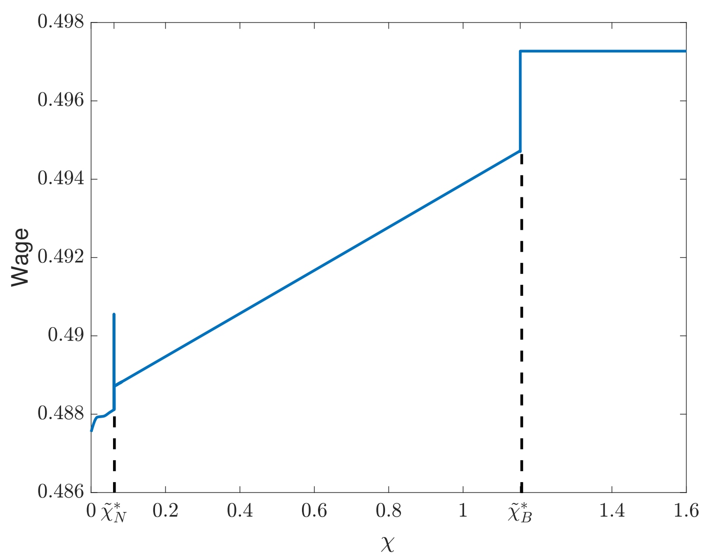


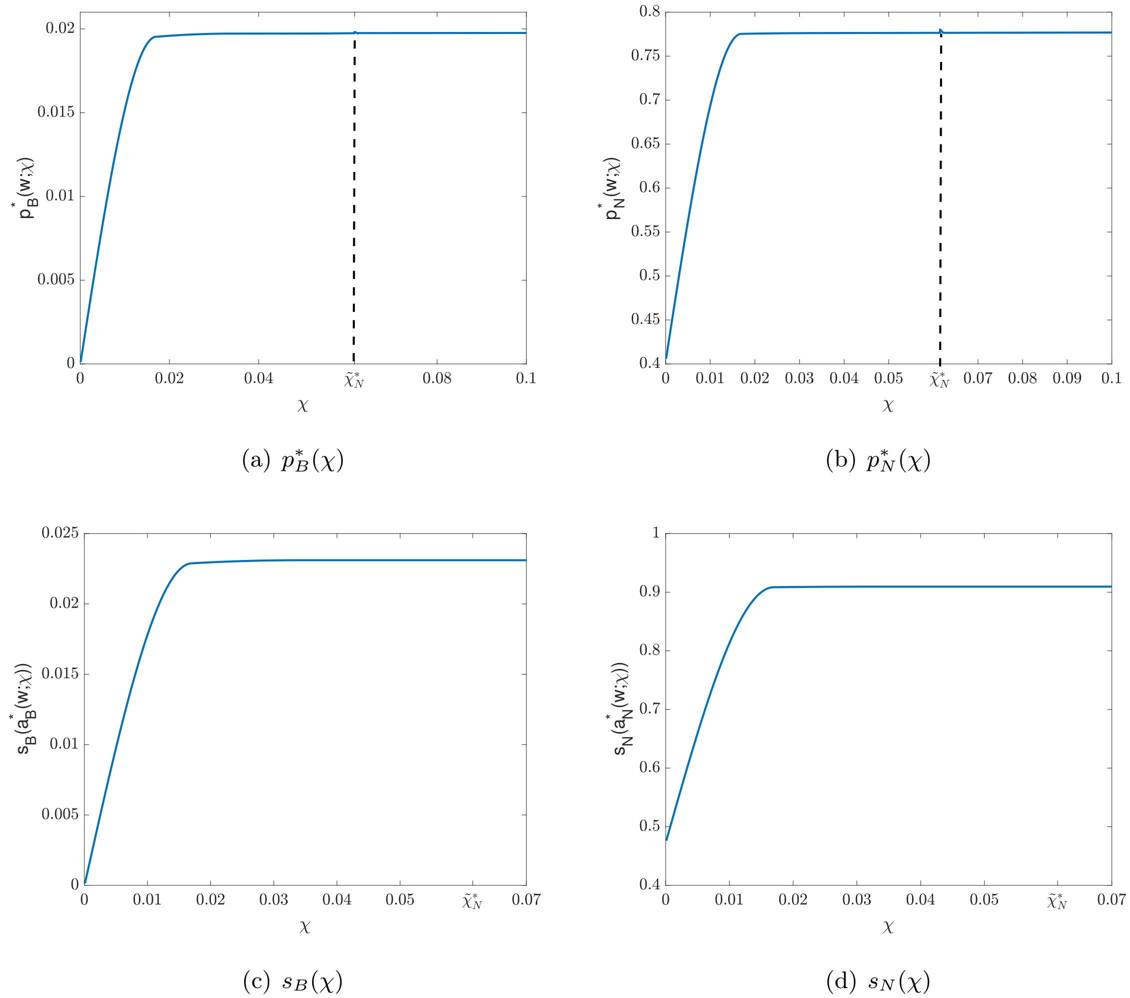
Figure 6: This figure plots the piecewise wage as a function of χ. The two cut-offs, $\tilde{\chi}_j^*, j = N, B$ are shown with dashed vertical lines. At these points, there is a wage adjustment for an interval from $[\tilde{\chi}_j^*, \chi_j^*, j = N, B$. This jump is most evident at $\tilde{\chi}_N^*$.

Figure 6 displays the entire piecewise wage function. First, it is clear that the wage changes in $[\tilde{\chi}_N^*, \chi_N^*]$ are much larger than the changes in $[\tilde{\chi}_B^*, \chi_B^*]$, with the latter unnoticeable when viewed in context. This is true because the costs associated with challenges for firms are much larger when dealing with ineligible workers relative to eligible workers (see Figure 7 below). This gives the firm/worker more to bargain over in the wage "re-negotiation." Second, notice that wages jump up as each threshold, χ_N^* and χ_B^*, is crossed. Intuitively, workers with $\chi \in (\chi_N^*, \chi_B^*]$ are cheaper for the firm. These workers only apply for UI benefits when eligible. Since eligibility challenges are much less likely when the firm separates from a UI eligible worker, this saves the firm significant costs relative to a UI ineligible worker. These cost savings are partially passed on to the worker in the form of higher wages, hence the jump in wages as χ crosses each χ_j^* threshold. Once the threshold χ_B^* is crossed, workers no longer collect UI benefits, and the wage jumps up to a higher level where it remains constant with respect to χ.

Next, consider Figure 7. Here we plot the functions $p_i^*(w;\chi)$ and associated functions $s_i[a_i^*(w;\chi)]$ for the calibrated economy. As expected, the occurrence of firm verifications is much less frequent for eligible workers (Figure 7(a)) relative to ineligible workers (Figure 7(b)), since the probability of a successful challenge is much lower for the former, as displayed in Figures 7(c) and 7(d) which plot the probability of success for the firm. The probability of a successful verification for the firm increases with χ, as worker effort decreases, eventually becoming constant when the lower bound on effort is binding.

In Figures 7(a) and 7(b), firm verification probabilities are increasing with χ for two reasons, both of which are evident from Equation (19). First, as discussed above, the probability of a successful challenge is increasing in χ. Second, the firm's tax, τ is a function of the wage via the UI benefit: $\tau = \dfrac{bw(\chi)}{\theta q(\theta)}$. Recall from Figure 6 that wages are increasing in χ, and thus so is the firm's tax. In response, the firm is willing to challenge eligibility more frequently. Also notice, there are small jumps in $p_j^*(w;\chi)$ that occur at the cut-offs $\tilde{\chi}_j^*$, resulting from the change in wages at this point, which in turn affects the firm's experience rated tax.

It is also useful to note that the firm still chooses $p_j^*(w;\chi)$ in the interval $(\tilde{\chi}_B^*, \infty)$, even though these workers do not collect UI benefits. This simply represents an off-equilibrium path for p_j^*. Workers must know this value in order to make their UI take-up decision. In other words, the firm chooses a function $p_j^*(w;\chi)$, and in equilibrium the endogenous cut-offs $\tilde{\chi}_j^*$ and χ_j^* make the



(a) $p_B^*(\chi)$ (b) $p_N^*(\chi)$

(c) $s_B(\chi)$ (d) $s_N(\chi)$

Figure 7: The top two figures plot the firm's optimal choice for eligibility challenge probabilities, with the top left graph corresponding to challenges of UI eligible workers and the top right challenges of UI ineligibles. The bottom two figures plot the probability of a successful challenge for the firm.

equilibrium $p_j^*(w;\chi)$ a piecewise function.

5 Comparative Statics

This section presents the results of several comparative static policy experiments. In particular we focus on changes in the level of experience rating and the UI replacement rate. The results offer insight into the key relationships in the model, and they also highlight the importance of incorporating endogenous UI collection costs.

5.1 Experience Rating

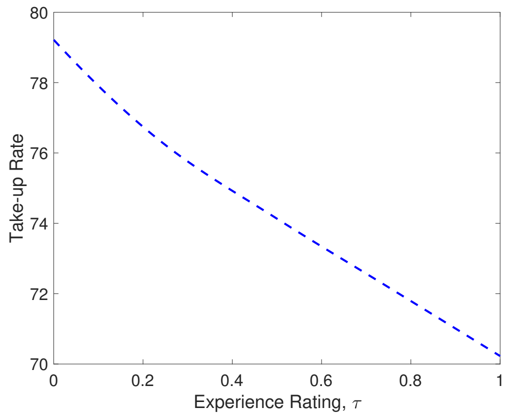
The first experiment is to change the level of experience rating, τ. Recall, experience rating is a key mechanism in the model; it creates the incentives for firms to challenge the UI claims of both eligible and ineligible workers. As the level of experience rating varies, so will firm actions to reduce their UI bill via proper and improper denials, which in turn impacts several moments in the model.

Figure 8 displays the results. Note, in each graph, τ is the fraction of the expected UI benefits, $\tau \dfrac{b}{\theta q(\theta)}$. When the fraction τ changes, the lump-sum tax $\underline{\tau}$ must change in response to maintain a balanced UI budget. In the model economy, an increase in experience rating decreases the take-up rate (Figure 8(a)) and the unemployment rate (Figure 8(b)), increases the improper denial rate (Figure 8(c)), and decreases the fraud rate (Figure 8(d)).

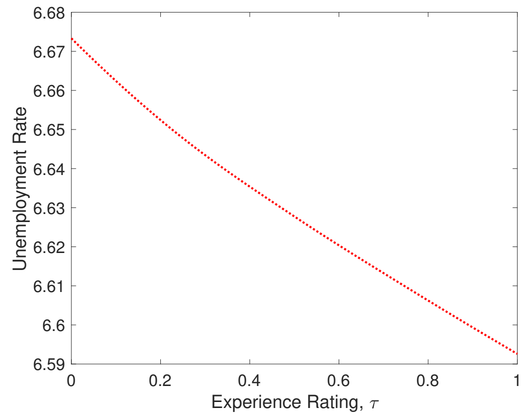
First consider the decrease in the take-up rate. As τ increases, recall from Equation (19) that $p_j^*(w(\chi);\chi)$ is increasing in τ for any given χ. As the costs to the firm of a separated worker collecting UI increase, the firm increases the probability of challenging a claim. As $p_j^*(w(\chi);\chi), j = B, N$ increases, the take-up rate decreases as workers are more reluctant to file a claim.

Next consider the effect of experience rating on the unemployment rate in Figure 8(b). The unemployment rate decreases from a high of around 6.67% when $\tau = 0$ to a low just above 6.59% when $\tau = 1$. From Equation (36), the unemployment rate changes when θ changes, and θ changes when firm profits change in Equation (28). When τ changes, there are several competing effects on firm profits. First, for low τ, the higher take-up rate tends to increase the total UI tax bill firms pay, but since there is no experience rating, this is an equally distributed lump-sum tax. Second, the composition of UI collectors changes with τ, as improper denials and fraud also change (see Figures 8(c) and 8(d)). Shifting the distribution of UI collectors has implications for firm profits as these workers have different wages, as shown in Figure 6. Overall, the effects of a lower UI bill dominate, which underscores how the firm is able to utilize the verification technologies optimally to minimize the impact of UI take-up on their profits.

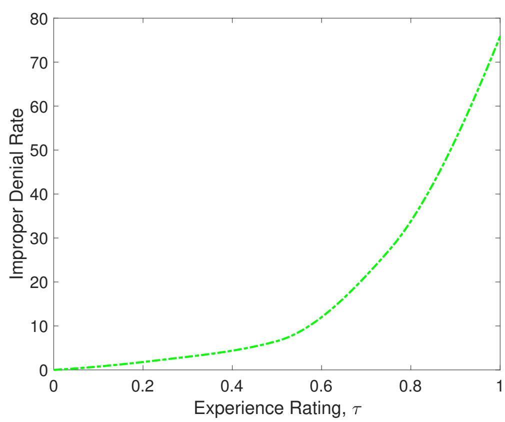
Figures 8(c) to 8(d) show the responses of the improper denial and UI fraud rates, respectively. These movements follow from the changes in $p_j^*(w(\chi);\chi)$ and $\tilde{\chi}_j^*, j = B, N$ to changes in τ. As discussed above, when τ increases, firms respond by increasing $p_j^*(w(\chi);\chi)$ for all χ. This in turn causes $\tilde{\chi}_j^*, j = B, N$ to decrease, making workers less likely to file for UI benefits if separated from



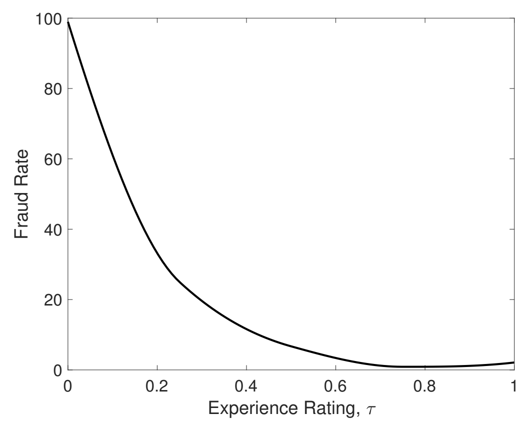
(a) Take-up Rate



(b) Unemployment Rate



(c) Improper Denial Rate



(d) Fraud Rate

Figure 8: Each graph plots the response of a particular moment in response to a change in the level of experience rating, τ. The upper left figure plots the response of the Take-up Rate and the upper right figure the response of the Unemployment Rate. The lower left figure plots the Improper Denial Rate and the lower right figure the Fraud Rate. On the horizontal axis, τ is the fixed fraction of the expected UI benefits a firm pays, $\tau\frac{bw(\chi)}{\theta q(\theta)}$; i.e. τ is the fraction of expected UI benefits the firm is responsible for.

their job. The decrease in the fraud rate in Figure 8(d) is thus straightforward: fewer ineligible workers apply for benefits, as firms are increasingly challenging their claims. The rapidly increasing improper denial rate in Figure 8(c) is the result of two forces. First is the increasing $p_B^*(w(\chi);\chi)$. Second is the fact that the decreasing fraud rate implies that a much larger percentage of denials are among UI eligible workers ($j = B$); as a result, the percent of denied applications that are improper must increase.

It is interesting to compare the results here to the existing literature examining the effects of experience rating on labor market outcomes. With respect to the effect of experience rating on the unemployment rate, the literature is inconclusive. Most find that experience rating reduces unemployment. The work of Feldstein (1976) and Topel (1983) focuses on the separation element, showing that a move from partial to full-experience rating reduces separations and the unemployment rate. Others, such as Burdett and Wright (1989) and Marceau (1993) find that experience rating may increase the unemployment rate when vacancies or the size of the firm are endogenous. The work of Albrecht and Vroman (1999), Wang and Williamson (2002), and Cahuc and Malherbet (2004), among others, also allow for endogenous vacancy creation and all find experience rating decreases unemployment. We find a monotonically decreasing relationship between experience rating and the unemployment rate; however, the mechanisms in our model are quite different from the existing literature. Typically higher experience rating lowers the unemployment rate because it reduces the number of separations. In contrast, we keep separations fixed and show that experience rating affects the job finding rate as firms influence overall UI taxes by lowering the UI take-up rate. Firm challenges and denials play a key role in these effects.

5.2 Replacement Rate

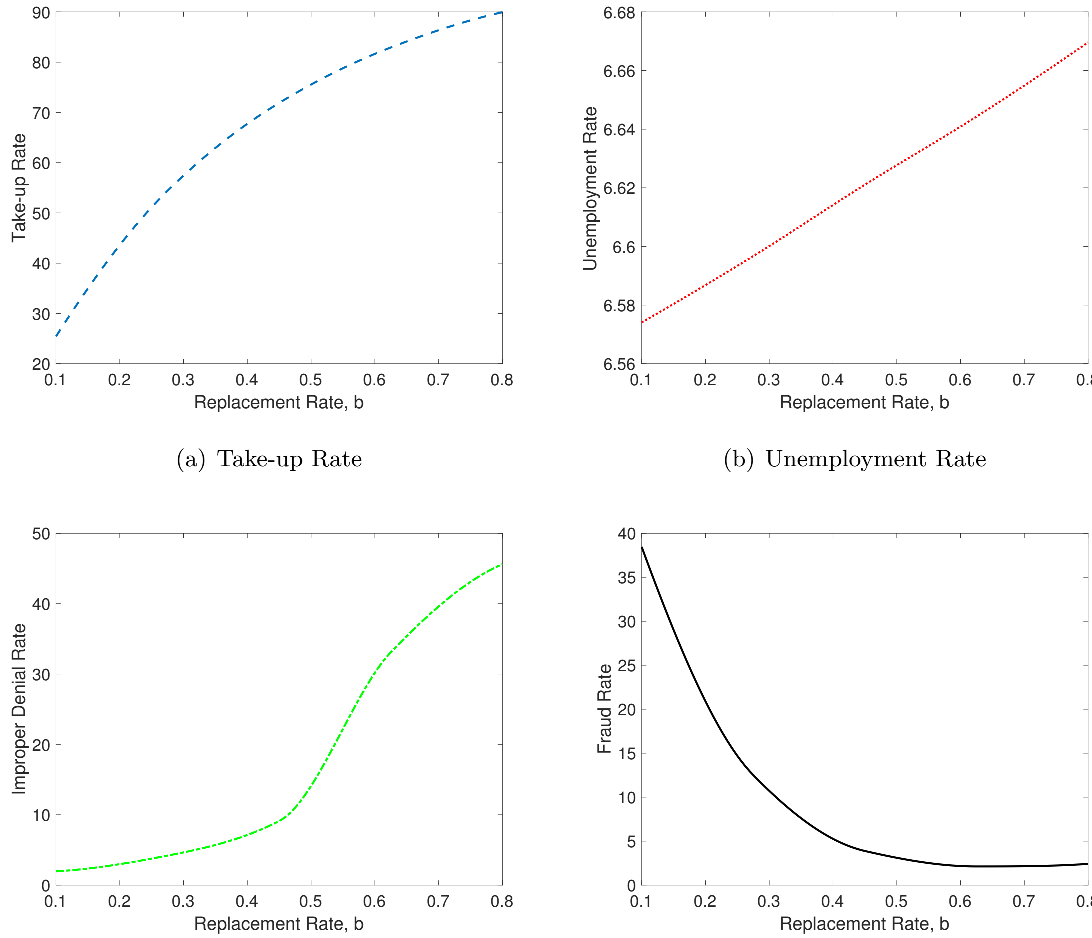
We now consider the effects of changes in the UI replacement rate on equilibrium outcomes. In this experiment we change the replacement rate, b, while maintaining the baseline level of experience rating $\tau = 0.6$. Figure 9 presents the results.

As the replacement rate increases from the baseline level of $b = 0.469$, the UI take-up rate is increasing, as seen in Figure 9(a) . While this represents an intuitive result, there are several competing effects worth discussing. Clearly the increase in b increases the benefit to collecting UI, all else equal. At the same time, in Figures 9(c) and 9(d) we see that the improper denial rate increases while the UI fraud rate decreases. These effects are the result of firms responding to the higher UI benefits by increasing $p_j^*(w(\chi);\chi), j = B, N$. When the replacement rate increases, so does the firm's tax burden from a separated worker who collects UI benefits; in response, firm's challenge worker's applications more frequently. Interestingly, the increase in $p_j^*(w(\chi);\chi)$ has competing effects on the decision of eligible and ineligible workers.

Understanding the changes in the cut-offs $\tilde{\chi}_j^*, j = B, N$, which are the key determinants of the UI take-up rate, is very important to understanding these competing effects. When the UI replacement rate increases, $\tilde{\chi}_N^*$ decreases so that ineligible workers are less likely to apply for UI benefits. The firm's increases in $p_N^*(w(\chi);\chi)$ are strong enough to dissuade ineligible workers from applying. The decrease in $\tilde{\chi}_N^*$ and increase in $p_N^*(w(\chi);\chi)$ implies a non-monotonic effect on the probability of being denied benefits for this group. As b initially increases, ineligible workers are becoming more likely to be denied. Eventually, however, this reverses and the probability of an ineligible worker being denied benefits starts to decrease, owing to the rapid decrease in the number of ineligibles who apply. Thus, the decreasing fraud rate in Figure 9(d) is the result of firm's increasing challenges and dissuading ineligible workers from applying for UI.

For eligible workers, the effects are more straightforward. As b increases, both $p_B^*(w(\chi);\chi)$ and $\tilde{\chi}_B^*$ increase. Thus, more eligible workers apply for UI benefits, and more of them are improperly denied. Indeed, the improper denial rate is increasing convexly with b in Figure 9(c). Overall, however, the take-up rate is increasing as the result of more eligible workers collecting. The aforementioned competing effects show that the increase in the UI take-up rate is far from straightforward. The take-up rate increases in a concave fashion, the result of changing worker and firm actions. These interesting dynamics highlight the importance of incorporating the endogenous UI collection costs.

The increase in b also increases the unemployment rate, which is displayed in Figure 9(b). This obtains for the same reasons it increases in Pissarides (2000), namely by increasing the subsidy to search. In our model, there also exists a tax rate effect. Higher benefits and a higher take-up rate increase total UI taxes levied on firms, lowering firm profits and decreasing vacancy creation.



(a) Take-up Rate

(b) Unemployment Rate

(c) Improper Denial Rate

(d) Fraud Rate

Figure 9: Each graph plots the response of a particular moment in response to a change in the UI replacement rate, b. The upper left figure plots the response of the Take-up Rate and the upper right figure the response of the Unemployment Rate. The lower left figure plots the Improper Denial Rate and the lower right figure the Fraud Rate.

5.3 Fixed vs. Endogenous UI Collection Costs

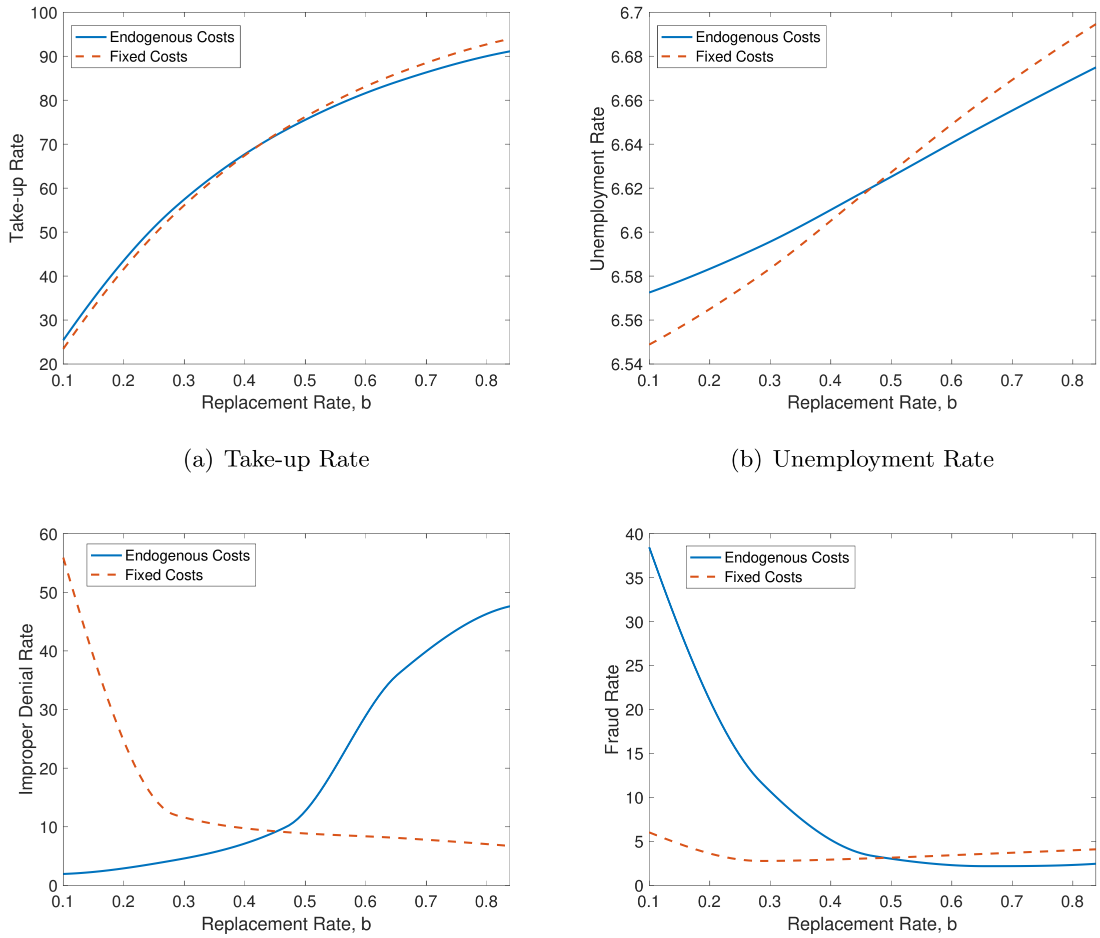
Understanding the effects of increasing the UI replacement rate on equilibrium outcomes has been the goal of a large literature. In our paper, we have two key additional elements: an endogenous take-up rate, as well as endogenous UI collection costs. To help further understand the role played by these firm challenges and denials, we compare the effect of changing the UI replacement rate in two different economies. The first is simply the baseline economy, where the costs to collecting UI benefits are endogenously determined by worker and firm actions on $p_j^*(w(\chi);\chi)$ and $a_j^*(w(\chi);\chi)$.

The comparison economy is one where the costs of collecting remain fixed at baseline levels. That is, we change the replacement rate, b, but hold $p_j^*(w(\chi);\chi)$ and $a_j^*(w(\chi);\chi)$ fixed at their respective baseline levels.

To ensure comparability, we also re-calibrate γ so that both economies produce the same unemployment rate at the baseline level of $b = 0.469$. Although the two economies have the same p_j^*'s and a_j^*'s, they produce different unemployment rates at the baseline b because of different wages. Specifically, in the fixed costs economy, $p_j^*(w(\chi);\chi)$ and $a_j^*(w(\chi);\chi)$ must also be held fixed during the wage negotiation. In the baseline economy, however, the wage negotiation considers the impact of different wages on the UI benefit and thus on $p_j^*(w(\chi);\chi)$ and $a_j^*(w(\chi);\chi)$. Thus, the maximization problem in Equation (23) produces a different result in each case. For the fixed cost economy, we set $\gamma = 173.1$. This implies identical unemployment rates (6.62%) at $b = 0.469$, although the other moments, fraud rates and improper denial rates differ slightly. Figure 10 displays the results.

Consider the response of the take-up to an increase in the UI replacement rate in the aforementioned two economies. Figure 10(a) plots the responses in each economy. For low replacement rates the take-up rate in the fixed cost economy is lower than in the endogenous cost one, but grows faster and is higher at higher replacement rates. This pattern is explained by the different responses of improper denial and fraud rates in Figures 10(c) and 10(d). In the fixed cost economy, the improper denial rate is decreasing, while the fraud rate is generally increasing slightly, the opposite pattern compared to the endogenous cost economy. This is the direct result of firms being unable to change p_j^* in the fixed cost economy. As a result, at low replacement rates improper denials are too high and fraud too low relative to what the firm finds optimal, decreasing the take-up rate (relative to endogenous costs), and vice versa at higher replacement rates.

The firm's inability to optimally manage their UI tax costs via eligibility verifications has important implications for the response of the unemployment rate, plotted in Figure 10(b). Similarly to the differences in UI take-up rates, the unemployment rate in the fixed cost economy is lower for low replacement rates, but is eventually higher at higher replacement rates. Thus, the unemployment rate responds "slower" to changes in UI benefits when UI collection costs are endogenous, relative to the case of fixed UI collection costs. In the fixed cost economy, firms are unable to control their UI costs as b increases; as a result, the unemployment rate increases relatively quickly as vacancy creation slows. In contrast, firms in the baseline endogenous cost economy are able to control the



(a) Take-up Rate

(b) Unemployment Rate

(c) Improper Denial Rate

(d) Fraud Rate

Figure 10: Each graph plots the response of a particular moment in response to a change in the UI replacement rate, b, for the model with endogenous UI collections costs (solid lines) relative to model with fixed collection costs (dashed lines). The upper-left figure compares the response of the Take-up Rate and the upper-right figure the response of the Unemployment Rate. The lower-left and lower-right graphs display the different responses of the Improper Denial and UI Fraud Rates, respectively.

increase in their UI costs by increasing improper denials and decreasing the fraud rate.

Overall, this comparative statics exercise highlights the importance of allowing for an endogenous UI take-up rate *and* of incorporating endogenous costs of collecting UI benefits. In the next section we explore some policy implications of the model and equilibrium.

6 UI Policy Experiments

The relationships between experience rating, UI collection costs, improper denials, and the take-up rate have important implications for UI policy. Several questions arise when considering this link. If the take-up rate is driven by the utility costs associated with collecting benefits, how significant are these costs? Given the implied costs of collecting, what are the optimal take-up, improper denial, and UI fraud rates?

We conduct several experiments to answer these questions. Outcomes are compared using a standard "welfare" function, adjusted for the costs associated with the UI system. Specifically we use the welfare function:

$$\begin{aligned} W =& (1-u)y - \theta u \gamma + \\ & \sum_{i=B,N} \left\{ \frac{n_i^E}{1-u} \Big[\int_0^{\chi_i^*} \big(-c(p_i) - \chi(\phi + p_i(\chi)) \big) n_B^U(\chi) d\chi \Big] \right\} \end{aligned} \tag{40}$$

Equation (40) represents a standard welfare function of output net of vacancy costs, adjusted for the costs associated with UI collection.Specifically, for each group of workers, benefit eligible or ineligible ($i = B, N$), the welfare function includes the cost of utilizing the eligibility verification technology for the firm, minus the expected utility cost to those workers actually verified. It also includes the upfront fixed cost workers pay when applying for UI benefits, ϕ. These costs are integrated according to the following weights. The costs are accumulated for anyone who is collecting UI benefits, $n_B^U(\chi)$. We then weight the costs for eligible ($i = B$) and ineligible ($i = N$) according to their respective proportions of employment, $\frac{n_i^E}{1-u}$, and integrate over χ. Thus, when we refer to "net expected output," this is expected output net of vacancy and UI collection costs.

Finally, notice, the UI benefits and taxes are not included in the welfare function. This arises simply from risk neutrality (unemployed utility is linear in the benefit) combined with the balanced budget assumption. That is, any benefit flows are canceled by equivalent taxes deducted from output. The results of our UI policy experiments are summarized in Table 9.

The size of UI collection costs relative to the rest of the economy represents the first important question to answer. That is, how large are UI collection costs relative to expected output net of vacancy costs? To answer this question, we calculate equilibrium in an economy where workers are able to collect UI without any costs, $\phi = 0$, and we force $p_j^*(w(\chi); \chi) = 0, j = B, N$, for all χ.

The column labeled "No Costs" in Table 9 presents the results of this case. This yields a gain of 4.50% relative to the baseline economy. The unemployment rate and duration are indeed higher, while the improper denial rate goes to 0% and the fraud rate is 100%.[14] Given there are no fixed costs to collecting, and the firm never challenges applications, all separated workers prefer to collect UI benefits. Since the take-up rate is defined in Equation (37) as the fraction of eligible unemployed collecting UI benefits, this can exceed 100% if all eligible collect and some (or all) ineligible workers collect. In our parametrization, the maximum take-up rate is 107.69%, which is achieved in this hypothetical economy.

One could consider the economy with no UI collection costs as an economy with no eligibility requirements and no application costs for UI benefits. Once a worker separates from an employer, the UI office is automatically notified and the worker begins receiving UI benefits. It is interesting to note that even with the fraud rate of 100% (all ineligible workers collect UI), there are significant gains in net expected output. Indeed, with this many workers collecting UI benefits, the tax burden increases, which does increase the unemployment rate and duration as seen in Table 9. However, this is far out-weighed by the reduction in utility costs imposed on workers and firms dealing with the UI system of showing and verifying eligibility. It is also worth noting that in our model, all employment is full-time and (on average) lasts for many years. In reality, there exist part-time and short-term jobs that may become more appealing to workers in a world with no UI eligibility conditions; this would clearly lower the gains from this hypothetical economy as expected output could drop significantly. Thus, our results suggest there exists interesting future work examining these types of scenarios.

It is also interesting to note that some of the total UI collection costs are paid by workers ineligible for UI, who try to collect but are denied or at least challenged (see also Table 6). Does preventing these workers from collecting via eligibility requirements, which must be enforced, in-

[14] Technically, from Equation (38), when $p_j(w(\chi); \chi) = 0$, for all χ, the improper denial rate is undefined as the denominator is also 0. Here when we refer to an improper denial rate of 0%, we simply mean there are no improper denials.

Table 9: UI Policy Experiments

	Comparison Economy					
	Baseline	No Costs	No Costs, No Fraud	$\phi = 0$	Opt E.R., $\phi > 0$	Opt. E.R. $\phi = 0$
% Gain	–	4.50%	4.50%	2.55%	0.03%	4.55%
Take-up Rate	73.3%	107.69%	100%	107.48%	76.2%	107.69%
Unemp. Rate	6.62%	6.67%	6.67%	6.62%	6.65%	6.68%
Duration (Months)	5.59	5.64	5.63	5.59	5.62	5.64
Imp. Den. Rate	10%	0%	0.00%	35.03%	2.41%	0%
Fraud Rate	3.37%	100%	0.00%	8.40%	24.7%	100%

This table breaks down the gains in net expected output of several comparison economies relative to the baseline calibrated economy. The column labeled "No Costs" refers to the case with $\phi = 0$ and $p_j(w(\chi); \chi) = 0$, while the column labeled "No Costs, No Fraud" refers to the same "No Costs" economy, but also assumes ineligible workers commit to never collecting UI benefits. The column labeled "$\phi = 0$" sets the fixed cost ϕ to zero, but allows firms to set $p_j^*(w(\chi); \chi)$ optimally. The last two columns examine the gains from setting experience rating, τ, at the optimal level in an economy with the baseline ϕ and an economy with $\phi = 0$, respectively. Note, in some economies, the take-up rate exceeds 100%. This obtains as both ineligibles and eligibles are collecting.

crease net expected output? The column labeled "No Costs, No Fraud" in Table 9 explores this issue. It refers to an economy with no collection costs, i.e. $\phi = 0$ and $p_j^*(w(\chi); \chi) = 0, j = B, N$, for all χ, and we assume that ineligible workers ($i = N$) commit to never applying for UI benefits. Thus, only eligible workers collect UI benefits, and they are never challenged by the firm when doing so. From Table 9, this economy achieves a gain of 4.50%, the same gain achieved by the "No Costs" economy. The only small difference with the "No Cost" economy is a slightly lower average unemployment duration. This is the result of lower UI expenditures as only eligibles collect, lowering the tax burden.

The relatively large gain in net expected output from removing all UI collection costs suggests these costs are significant. To gauge what role the firm challenges and denials play in these gains, we next consider a hypothetical economy with $\phi = 0$, but allow firms to set $p_j^*(w(\chi); \chi), j = B, N$ optimally, i.e. according to Equation (19). Then, we can compare the gains from this experiment to the "No Costs" case; the difference represents the effect of firm challenges on net expected output. The results are presented in Table 9 in the column labeled "$\phi = 0$."

When firms are still allowed to challenge claims, the gains decrease to 2.55%. Thus, the proportion of the gains in net expected output attributable to ϕ is 2.55/4.50 = 57% is commensurate with the proportion of all UI collection costs accounted for by ϕ, 59% in Table 6. With $\phi = 0$ the take-up rate still increases significantly from the baseline scenario, but remains below the maximum as not all workers prefer to file applications given the potential costs associated with the firm challenging the worker's claim. In this case, the improper denial rate is 35.03% and the fraud rate is 8.40%.

Throughout our analysis, experience rating plays an important role. The comparative statics exercises in Section 5.1 indicated interesting changes when the level of experience rating changes. To explore this, we examine the optimal level of experience rating. The last two columns in Table 9 examine the optimal level of experience rating under different scenarios. The column labeled "Opt. E.R., $\phi > 0$" examines the baseline calibrated economy with the baseline fixed collection costs, ϕ, but looks for the net expected output maximizing level of experience rating τ. To determine this, we set different levels of τ, determine equilibrium in each case (and thus the associated lump-sum tax $\underline{\tau}$), and compare the value of Equation (40). For the baseline ϕ, the optimal level of experience rating is $\tau = 0.2525$.

This result is the product of several forces. On the one hand, lower levels of experience rating tend to increase net expected output by reducing the costs of collecting UI benefits. On the other hand, however, lower experience rating also increases the take-up rate and thus the unemployment rate, which decreases net expected output. Even though risk neutral workers do not experience a traditional insurance benefit from collecting UI, the optimal level of τ still implies a higher take-up rate than occurs under the calibrated level of experience rating.

The last column, labeled "Opt. E.R., $\phi = 0$" further emphasizes this intuition. In this case we set $\phi = 0$ and then determine the optimal level of experience rating. Since firms can still challenge claims in this economy, the optimal level of experience rating is $\tau = 0$. It is optimal to finance the UI system entirely via the lump-sum tax $\underline{\tau}$. The same intuition applies here. The optimal allocation minimizes the costs of collecting UI benefits. When UI costs are only those associated with firm challenges, it is optimal to avoid those completely. Setting $\tau = 0$ accomplishes this. It is also interesting to note that this economy achieves a net expected output gain slightly higher than the "No Costs, No Fraud" economy.

From a policy perspective, what do we learn from these UI policy experiments? First, the utility costs associated with collecting UI benefits impose significant costs on both workers and firms. Second, it appears that both costs associated with firm challenges and denials as well as the fixed "administrative" costs are significant. Moreover, the additional taxes arising from letting all unemployed collect UI (the "No Cost" economy) are greatly outweighed by the reduced utility costs of filing. These results suggest that gains exist from revisiting eligibility criteria and their enforcement. Given that our results in Table 2 show no changes to the take-up rate from apparent advances in the application technology (i.e. from in person to phone/online), simplifying relying on technological advances is unlikely to reduce these collection costs significantly.

7 Conclusion

In this paper we explore the micro-foundations of the costs of collecting UI benefits. Using data across U.S. states, we characterize the relationship of the UI take-up rate with several key variables. We find evidence that the likelihood of having eligibility verified and benefits improperly denied has a significant negative impact on the take-up rate. Based on these results, we develop a search model with matching frictions that incorporates UI eligibility and endogenous UI collection costs. UI benefits are financed by an experience rated tax levied on firms. This tax gives firms incentives to challenge claims for both UI eligible and ineligible workers applying for UI benefits. In equilibrium there exist both improper denials and UI fraud. The costs of collecting UI benefits take two forms: a fixed upfront administrative cost, and those associated with an eligibility verification.

We use the model along with the results from the empirical analysis to identify the relative size of the two types of UI collection costs. Our calibration matches the model and data elasticities of the take-up rate with respect to the improper denial rate. The model also performs well matching untargeted elasticities. The results suggest an important role for the costs associated with challenges and denials, while the fixed administrative costs account for 59% of total UI collection costs. The elasticity of the UI take-up rate with respect to these fixed costs is relatively high, comparable to the elasticity of the take-up rate with respect to the UI benefit replacement rate.

Allowing for the endogenous UI collection costs has an important impact on comparative statics exercises. Most notably, in the baseline economy the unemployment rate (and unemployment duration) respond much slower to increases in the UI replacement rate relative to an economy where UI collection costs remain fixed at baseline levels. The difference arises because in the economy with endogenous costs, firms respond to increases in UI benefits by increasing their use of eligibility challenges. This changes the incentives workers face, which ultimately causes a change in the composition of UI collectors.

Finally, several UI policy experiments show that the costs of collecting UI benefits are significant. These costs range from $2.55\% - 4.55\%$ of net expected output, depending on the comparison economy. The largest gains obtain in an economy with no fixed costs to applying and where experience rating is set to zero. No experience rating implies there are no firm challenges. This hypothetical economy suggests that removing all eligibility criteria and allowing workers to automatically qualify for UI benefits may be welfare improving.

Overall our results show that considering both unclaimed benefits and endogenous costs of collecting UI have important implications for labor markets and UI policy. The link with experience rating represents an important dimension of our analysis. While we assumed exogenous separations, allowing for endogenous separations represents an interesting direction for future research. This would allow one to explore the joint determination of firm decisions about separation and whether or not to initiate a UI eligibility review, helping to illuminate the full extent to which experience rating affects labor market outcomes. Finally, allowing for quits provides a path to further exploring the benefits and costs of moving to a system where all workers automatically receive UI benefits.

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A Nash Bargaining Game

In this section we present the details of wage determination under the specified Nash Bargaining game. As many others have noted (see Binmore, Rubinstein, and Wolinsky (1986) and Shimer (2006) for example), the problem described in Equation (23) requires the set of feasible payoffs to be convex. In a standard version of the model (i.e. the baseline model from Pissarides (2000)), this is generally true. For the current model, a potential issue arises stemming from the assumption that flow income for unemployed UI collectors is a fraction of the previous wage. Recall, the worker decides at the instant of separation to apply for UI benefits or not. Since the negotiated wage affects the flow value of UI collection, $B(\chi) = bw(\chi)$, the negotiated wage may influence the decision to collect or not. If a worker switches from a UI collector to a non-collector (or vice versa) for feasible wages, the set of feasible payoffs is not convex.

Discontinuities in $J_N(w;\chi)$ represent the fundamental issue with the bargaining set. These arise as the firm's value function jumps when the worker's UI collection decision changes. For example, as χ changes we have,

$$J_N(w;\chi) = \begin{cases} \frac{y-w-\underline{\tau}}{r+\lambda} & : \chi > \chi_B^* \\ \frac{y-w-\underline{\tau}+\sigma J_B(w;\chi)}{r+\lambda+\sigma} & : \chi_N^* < \chi \leq \chi_B^* \\ \frac{y-w-\underline{\tau}-\lambda\left(\tau[1-p_N s_N]+c(p_N)\right)+\sigma J_B(w;\chi)}{r+\lambda+\sigma} & : \chi \leq \chi_N^* \end{cases} \tag{41}$$

Notice, $J_N(w;\chi)$ is discontinuous at the cut-offs $\chi_j^*, j = N, B$, jumping as the cost of working with the UI system has discrete jumps (the firm either pays the expected experience rated tax or does not). Now, this is potentially an issue when the wage affects the UI benefit and thus the UI take-up decision. If the expected value of UI take-up, which we denote by $\Gamma(w;\chi)$, is increasing in the wage, then an issue arises.

In addition, the worker's value function, $E_N(w;\chi)$, may have convex kinks at the points where the UI take-up decision changes. Specifically, consider the slope of $E_N(w;\chi)$ with respect to w. To do so, define the following for $j = N, B$:

$$CW_j(w;\chi) = -\chi\left[\phi + p_j a_j\right] + p_j a_j\left[N(w;\chi) - U(w;\chi)\right] \tag{42}$$

With this definition, we can write

$$rE_N(w;\chi) = w + \sigma\left[E_B(w;\chi) - E_N(w;\chi)\right] + \lambda\Big\{CW_N(w;\chi) + U(w;\chi) - E_N(w;\chi)\Big\} \tag{43}$$

for $\chi \in [0, \chi_N^*]$, and

$$rE_N(w;\chi) = w + \sigma\big[E_B(w;\chi) - E_N(w;\chi)\big] + \lambda\Big\{N(\chi) - E_N(w;\chi)\Big\} \tag{44}$$

for $\chi \in (\chi_N^*, \chi_B^*]$. Thus, for $\chi \in [0, \chi_N^*]$ the slope of $E_N(w;\chi)$ is $\frac{1}{r+\sigma+\lambda}\Big(1 + \sigma\frac{\partial E_B(w;\chi)}{\partial w} + \lambda\big[\frac{\partial C_N(w;\chi)}{\partial w} + \frac{\partial U(w;\chi)}{\partial w}\big]\Big)$. For $\chi \in (\chi_N^*, \chi_B^*]$, however, the slope of $E_N(w;\chi)$ is $\frac{1}{r+\sigma+\lambda}\Big(1 + \sigma\frac{\partial E_B(w;\chi)}{\partial w}\Big)$. Finally, for $\chi > \chi_B^*$, the slope of $E_N(w;\chi)$ is $\frac{1}{r+\lambda}$. Thus, as the worker goes from never collecting, to collecting only when eligible, to always collecting, the slope of $E_N(w;\chi)$ is larger if $\frac{\partial C_N(w;\chi)}{\partial w} + \frac{\partial U(w;\chi)}{\partial w} > 0$. With the discontinuties in the firm's value function, even if the aforementioned kinks are concave, the set of feasible payoffs remains non-convex.

Imagine a worker with a value of χ near one of the cut-offs (χ_N^* or χ_B^*). This worker marginally prefers to collect UI ($\Gamma(w;\chi)$ is close to zero). When $\Gamma(w;\chi)$ is increasing in w, the firm can counter-object to the current wage, $w^*(\chi)$ with a slightly lower wage and this changes the worker's UI collection decision from collect to not-collect. While the decrease in the wage makes the worker worse off, the jump in the firm's value function implies they can offer a high enough probability of breakdown in the negotiations that convinces the worker to accept this new lower wage instead risking a lottery over the original wage and nothing.

When, on the other hand, $\Gamma(w;\chi)$ is decreasing in w, then the worker has a credible counter-offer. Specifically, the worker can counter with a wage higher that $w^*(\chi)$, with the firm knowing at this higher wage, the worker will not collect UI benefits. In this case, the worker is using the UI take-up decision to bargain over the firm's discrete jump in surplus.

While the set of feasible payoffs is generally not convex, we now show that the solutions to Equations (23) and (26) do indeed represent the Nash solution in our applications. We begin with a formal definition of the Nash Equilibrium. This assumes two players, denoted i and j below, which could be either the worker or the firm.

Definition 1 *A wage, $w^* \in \mathcal{W}$, is a Nash solution to the bargaining problem in Equation (23) when w^* satisfies: if $z * w \succ_i w^*$ for some $z \in [0,1]$ and $w \in \mathcal{W}$, then $z * w^* \succeq_j w$ for $i \neq j$.*

This represents a standard definition of a Nash solution, which imposes Pareto optimality. That is, if one player benefits from proposing an alternative wage $w \neq w^*$ and a probability of walking away from the bargaining table, $1 - z$, then it must be the case that the other player still prefers

$z * w^*$. Using this definition, we characterize under what circumstances Equation (23) defines the Nash solution to the bargaining game.

Proposition 1 *Define $\chi_j^*, j = N, B$ by Equation (24) and $\tilde{\chi}_j^*, j = N, B$ by Equation (25). Then, for $\chi \in [0, \tilde{\chi}_N^*]$, $\chi \in (\chi_N^*, \tilde{\chi}_B^*]$, and $\chi > \chi_B^*$, the wage defined by Equation (23) is a solution to the Nash Bargaining game and an equilibrium wage. For $\chi \in (\tilde{\chi}_N^*, \chi_N^*]$ and $\chi \in (\tilde{\chi}_B^*, \chi_B^*]$, the wage defined by Equation (26) is a solution to the Nash Bargaining game and an equilibrium wage.*

Proof: The first step and key to the proof is to show that $\tilde{\chi}_j^*$ is the relevant cut-off for this problem. From the definition of a Nash wage in Definition 1, the wage determined by Equation (23) needs adjustment whenever the firm has a credible counter-offer against $w^*(\chi)$. For brevity, we show here the case of $\tilde{\chi}_N^*$, and use the case where the firm proposes a lower wage. The other cases follow similar logic. Working from the definition of a Nash wage, the firm has a credible counter-offer when for some $z > 0$, where $1 - z$ represents the probability negotiations break down, $zJ_N^2(\tilde{w}_1(\chi)) > J_N^1(w_1^*(\chi))$ and $E_N^2(\tilde{w}_1(\chi);\chi) - N > z\Big[E_N^1(w_1^*(\chi);\chi) - N\Big]$. Thus, in order for the firm to have credible counter offer to $w_1^*(\chi)$, their gain from the alternative wage must exceed the worker's loss. It is this feature that allows the firm to set z low enough to ensure the above relationships hold. Now, the difference in surplus for the worker is $E_N^2(\tilde{w}_1(\chi);\chi) - E_N^1(w_1^*(\chi);\chi)$, which is the difference in wages plus the change in $\Gamma(w_1^*(\chi);\chi)$. For the firm, the gain is the decrease in wages plus the jump/change in $\lambda C_N(w_1^*(\chi);\chi)\Big(1 - \dfrac{\lambda\sigma}{r+\lambda+\sigma}\Big)$. Thus, for the firm to counter-offer $\tilde{w}_1(\chi)$, their gain must exceed the worker's loss. This is only possible when $\lambda C_N(w_1^*(\chi);\chi)\Big(1 - \dfrac{\lambda\sigma}{r+\lambda+\sigma}\Big) + \Gamma(w_1^*(\chi);\chi) \geq 0$. For example, consider any $\chi < \tilde{\chi}_N^*$. Here $\lambda C_N(w_1^*(\chi);\chi)\Big(1 - \dfrac{\lambda\sigma}{r+\lambda+\sigma}\Big) + \Gamma(w_1^*(\chi);\chi) < 0$, implying the worker's loss from $\Gamma(w_1^*(\chi);\chi)$ is greater than the firm's gain. The decrease in the wage necessary to make $\Gamma(w;\chi) \leq 0$ for this worker is greater than the surplus the firm has to offer. Therefore, the cut-off for UI collection decisions is given by the χ solving $\lambda C_N(w_1^*(\chi);\chi)\Big(1 - \dfrac{\lambda\sigma}{r+\lambda+\sigma}\Big) + \Gamma(w_1^*(\chi);\chi) = 0$.

Now, to show the result, begin with the cases of $\chi \in [0, \tilde{\chi}_N^*]$, $\chi \in (\chi_N^*, \tilde{\chi}_B^*]$, and $\chi > \chi_B^*$. Importantly, by definition of χ_j^* and $\tilde{\chi}_j^*$ $(j = N, B)$ the wages determined here by Equation (23) ignore any jumps or convexities in the firm and worker value functions. Thus, for each set of value functions, $E_N^1(w;\chi), J_N^1(w;\chi)$, $E_N^2(w;\chi), J_N^2(w;\chi)$, the set of feasible payoffs is convex, and hence the solution to Equation (23) is well-defined in each case (Osborne and Rubinstein (1994) provides a proof). Denote these wages as $w_i^*(\chi), i = 1, 2, 3$. Now consider the case of $\chi \in (\tilde{\chi}_N^*, \chi_N^*]$ and $\chi \in (\tilde{\chi}_B^*, \chi_B^*]$. Again, by definition of $\tilde{\chi}_j^*, j = N, B$ and $\chi_j^*, j = N, B$, and the definition of $\tilde{w}_j^*$ in Equation (26), the same proof as the first case applies (see Osborne and Rubinstein (1994)). As a result, these wages are a Nash solution. Given the definitions of $\tilde{\chi}_j^*, j = N, B$ and $\chi_j^*, j = N, B$, worker decisions are consistent at these wages, and they thus also represent equilibrium wages. ■

A.1 Nash Algorithm and FOCs

For $\chi \in [0, \tilde{\chi}_N^*]$, $\chi \in (\chi_N^*, \tilde{\chi}_B^*]$, and $\chi > \chi_B^*$ the wage is determined as:

$$w(\chi) = \arg\max \left[E_N(\chi) - N\right]^{\beta} \left[J_N(\chi) - V\right]^{1-\beta} \tag{45}$$

The F.O.C. for this Nash problem is given by (using the equilibrium condition that $V = 0$),

$$(1-\beta)\left[E_N(\chi) - N\right]^{\beta-1} \left(J_N\right)^{\beta} \Big(\frac{\partial E_N(w;\chi)}{\partial w}\Big) + \beta \left[E_N - N\right]^{1-\beta} \left(J_N\right)^{-\beta} \Big(\frac{\partial J_N(w;\chi)}{\partial w}\Big) = 0 \tag{46}$$

Here, the partial derivatives of E_N and J_N with respect to w represent the key quantities. The dependence of future unemployment income for a UI collector on the current negotiated wage is an interesting feature of the current model. Indeed, it affects the above FOCs. The actual FOCs depend on the worker's value of χ, and are piecewise in χ. It is important to note that in the bargaining process, even off equilibrium, the worker and the firm both know the relevant cutoffs $\chi_j^*, j = N, B$ and $\tilde{\chi}_j^*, j = N, B$. Moreover, the firm observes the worker's value of χ. As a result, both the worker and the firm know the relevant range of χ they are bargaining in, and the relevant value functions are differentiable in the appropriate range of χ. The function is differentiable in any given range of χ, and wage negotiations do not jump out of any range by definition of the cut-offs $\chi_j^*, j = N, B$ and $\tilde{\chi}_j^*, j = N, B$.

To begin, consider the case of $\chi \leq \tilde{\chi}_N^*$; this worker always prefers to collect UI benefits, regardless of eligibility status. Differentiating Equation (43) with respect to w_i (where w_i represents the current wage in the negotiation, and w represents the wage offered in the market by all other firms) gives

$$\begin{aligned} E_N'(w_i) &= \frac{1}{r+\sigma+\lambda}\left[1 + \sigma E_B'(w_i;\chi) + \lambda C W_N'(w_i;\chi)\right] \\ &= \frac{1}{r+\sigma+\lambda}\left[1 + \frac{\sigma}{r+\lambda}\left[1 + A_B'(w_i;\chi)\right] + \lambda C W_N'(w_i;\chi)\right] \end{aligned} \tag{47}$$

Note, we have

$$CW_j'(w;\chi) = -\chi \frac{\partial(p_j a_j)}{\partial w} - \frac{\partial(p_j s_j)}{\partial w}\big[U(w;\chi) - N\big] + U'(w;\chi)\big[1 - p_j s_j\big] \tag{48}$$

Finally, we have the case where $\chi > \chi_B^*$; the worker never files for UI benefits. In this case, the value functions $E_N(w;\chi)$ and $E_B(w;\chi)$ are simplified to,

$$E_N(w;\chi) = \frac{1}{r+\lambda+\sigma}\Big[w + \sigma E_B(w;\chi) + \lambda N\Big] \tag{49}$$

$$E_B(w;\chi) = \frac{w+\lambda N}{r+\lambda} \tag{50}$$

Differentiating Equation (49) at the wage w_i gives

$$E_N'(w_i;\chi) = \frac{1+\frac{\sigma}{r+\lambda}}{r+\lambda+\sigma} = \frac{1}{r+\lambda} \tag{51}$$

In general, closed form solutions do not exist for the Nash wages via these F.O.C. (except in the case of non-collectors). Our process for wage determination is thus as follows. For a given parameterization, determine the values of $\tilde{\chi}_j^*$ and χ_j^* for $j = N, B$. Then, for $\chi \leq \tilde{\chi}_N^*$, numerically find the maximum to the objective function defined in Equation (45). This determines $w_1^*(\chi)$. Then, for $\chi \in (\tilde{\chi}_N^*, \chi_N^*]$, find $\tilde{w}_1(\chi)$ by finding the maximum of Equation (26). Repeat this for $w_2^*(\chi)$ and $\tilde{w}_2(\chi)$. The final section of the wage function $w_3^*(\chi)$ is found simply as the maximum of Equation (45).

B Summary Data

In Table 10 we show descriptive statistics for each state. For example, for the Take-up Rate, for each state we find the average Take-up Rate in the 2002-2015 time period. Table 10 is sorted by the Improper Denial Rate, from largest to smallest.

Table 10: Summary Statistics By State

State	Take-up Rate	Improper Denial Rate	Duration	Replacement Rate
MO	0.65	0.21	25.73	0.30
NV	0.65	0.19	23.80	0.35
TN	0.66	0.16	22.79	0.30
PA	0.99	0.16	23.38	0.38

OH	0.72	0.16	23.06	0.31
IA	0.69	0.15	18.23	0.38
IL	0.76	0.15	26.68	0.28
CA	0.80	0.14	25.38	0.33
LA	0.75	0.14	20.97	0.31
WI	0.97	0.14	21.45	0.34
MN	0.75	0.14	21.14	0.34
WA	0.57	0.13	22.60	0.35
NY	0.81	0.13	25.65	0.32
DC	0.53	0.13	29.36	0.31
MA	0.95	0.13	22.98	0.33
TX	0.59	0.12	20.82	0.35
MI	0.93	0.12	26.65	0.35
UT	0.54	0.11	15.39	0.35
OR	0.97	0.11	24.06	0.34
CO	0.62	0.11	24.22	0.35
IN	0.70	0.11	22.95	0.38
NH	0.61	0.11	21.90	0.30
AK	0.98	0.10	18.84	0.23
VA	0.54	0.10	21.09	0.34
MT	0.80	0.09	18.43	0.33
NM	0.71	0.09	23.05	0.36
NJ	0.98	0.09	27.52	0.37
NC	0.79	0.09	23.96	0.37
AR	0.99	0.09	22.78	0.37
GA	0.55	0.09	25.88	0.34
VT	0.95	0.08	18.60	0.36
NE	0.73	0.08	17.72	0.34
CT	0.97	0.08	25.49	0.30
HI	0.99	0.08	23.61	0.40

SD	0.42	0.08	17.20	0.34
ID	0.85	0.08	18.48	0.36
ME	0.62	0.08	20.51	0.36
AZ	0.64	0.07	20.77	0.30
MD	0.67	0.07	24.32	0.33
FL	0.61	0.07	26.31	0.29
OK	0.59	0.07	19.19	0.36
WY	0.53	0.07	14.84	0.36
SC	0.71	0.07	26.62	0.34
WV	0.84	0.07	23.21	0.32
ND	0.45	0.07	15.64	0.34
KY	0.49	0.07	19.15	0.38
AL	0.45	0.06	23.81	0.30
RI	0.87	0.05	25.77	0.39
DE	0.93	0.05	24.96	0.31
MS	0.76	0.04	25.06	0.32
KS	0.81	0.03	18.44	0.37

This table presents summary statistics for key variables by state. The data represent the average value of each variable in the state from 2002-2015, and are sorted by the average Improper Denial Rate from largest to smallest.

C Robustness Checks

In this section we provide some robustness checks for the main results presented in the paper.

C.1 Empirical Analysis Robustness

This section displays the same results presented in Table 2, with the exception that we use the "unadjusted" take-up rate as the dependent variable. That is, we do not adjust the number of insured unemployed to include those improperly denied. As we see in Table 11, we obtain very similar results for either the Adjusted or the Un-adjusted UI Take-up rate as the dependent variable.

In the original specifications, presented in Table 2, we used the average unemployment duration

Table 11: Two-way fixed Effects Regression with Un-Adjusted Take-up Rate Dependent Variable

	(1)	(2)	(3)	(4)	(5)
	Model 1A	Model 2A	Model 3A	Model 4A	Model 5A
Improper Denial Rate	-0.361^{**}	-0.369^{**}	-0.368^{**}	-0.367^{**}	-0.376^{**}
	(0.159)	(0.165)	(0.168)	(0.168)	(0.165)
Replacement Rate		0.888^{***}	0.887^{***}	0.890^{***}	0.867^{***}
		(0.306)	(0.308)	(0.309)	(0.310)
Duration		0.00783^{***}	0.00783^{***}	0.00782^{***}	0.00786^{***}
		(0.00117)	(0.00117)	(0.00117)	(0.00118)
Internet Claims			-0.00918	-0.00865	
			(0.0424)	(0.0424)	
Fraud Rate				0.513	
				(1.040)	
Phone Claims					-0.0289
					(0.0417)
State Fixed Effects	YES	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES	YES
N	714	714	714	714	714
R^2	0.705	0.739	0.739	0.739	0.740

Standard errors in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

This table presents the results of the two-way fixed effects regression with the *un-adjusted* take-up rate as the dependent variable. Standard errors are clustered at the State level.

(Duration) in the two-way fixed effects regressions as a dependent variable. Workers in states facing more unemployment risk may be more likely to collect UI benefits. The unemployment rate in a state represents an alternative to the Duration that may also capture this effect. Below in Table 12 we present the same specifications as Table 2, only we use the Unemployment Rate in a state instead of the Duration. As shown in Table 12, the coefficient on Improper Denials is still negative and significant at the 5% level, although they are slightly smaller relative to the cases with the Duration. Interestingly, the coefficient on the Unemployment Rate is negative and significant at the 5% level. This implies that states with lower unemployment rates have higher take-up rates. From Table 2, however, the coefficient on Duration is positive and significant at the 1% level.

Table 12: Two-way fixed Effects Regression with Adjusted Take-up Rate Dependent Variable

	(1)	(2)	(3)	(4)	(5)
	Model 1A	Model 2A	Model 3A	Model 4A	Model 5A
Improper Denial Rate	-0.421^{**}	-0.342^{**}	-0.343^{**}	-0.343^{**}	-0.351^{**}
	(0.158)	(0.149)	(0.150)	(0.150)	(0.148)
Replacement Rate		0.719^{***}	0.719^{***}	0.720^{***}	0.690^{***}
		(0.250)	(0.251)	(0.252)	(0.245)
Unemployment Rate		-1.287^{**}	-1.285^{**}	-1.282^{**}	-1.259^{**}
		(0.575)	(0.572)	(0.576)	(0.566)
Internet Claims			0.00536	0.00547	
			(0.0455)	(0.0457)	
Fraud Rate				0.101	
				(0.967)	
Phone Claims					-0.0398
					(0.0478)
State Fixed Effects	YES	YES	YES	YES	YES
Year Fixed Effects	YES	YES	YES	YES	YES
N	714	714	714	714	714
R^2	0.621	0.634	0.634	0.634	0.635

Standard errors in parentheses

* $p < 0.1$, $^{**}p < 0.05$, *** $p < 0.01$

This table presents the results of the two-way fixed effects regression with the adjusted take-up rate as the dependent variable. Standard errors are clustered at the State level. In these specifications we include the unemployment rate instead of the average duration of unemployment.

C.2 Robustness of Quantitative Analysis to μ

In this section we verify that changing the value of μ, the mean of the distribution of χ, $F(\chi)$, does not affect the main results. Since the model is calibrated to hit several moments, other parameters adjust as μ changes, ultimately leaving the key quantitative relationships relatively unchanged.

Table 13: Robustness of Relative Contribution of UI Collection Costs to μ

	% of Total Costs			% of Fixed Costs, ϕ		
Cost	$\mu = 0.5$	$\mu = 1$	$\mu = 3$	$\mu = 0.5$	$\mu = 1$	$\mu = 3$
ϕ	62%	59%	75%	100%	100%	100%
$E[p_i^*]$	38%	41%	25%	52%	57%	33%
$E[p_B^*]$	5.4%	8%	6.4%	8.7%	13%	8.5%

First consider the relative sizes of the different UI collection costs, originally presented in Table 6. Table 13 presents the results. Here we display the same information as Table 6 for three values of μ: $\mu = 0.5$, the baseline $\mu = 1$, and then $\mu = 3.0$. As Table 13 shows, changing μ has only a minor impact on the relative sizes of the different UI collection costs.

Next consider the effect of changing μ on the un-targeted elasticities presented for the baseline $\mu = 1$ in Table 8 which are presented in Table 14.

Table 14: Robustness of Un-Targeted Elasticities to μ

Elasticity	$\mu = 0.5$	$\mu = 1$	$\mu = 3$	Data
Replacement Rate	0.457	0.448	0.448	0.412
Duration	0.453	0.442	0.443	0.137
Fixed Cost, ϕ	0.490	0.489	0.490	–

Finally, consider the welfare results displayed in Table 9. In Table 15 we present these welfare results for different values of μ. While there are several comparison economies presented in Table 9, here we focus on only two: the “No Costs” economy where $\phi = 0$ and $p_i(\chi) = 0$ and the “$\phi = 0$” economy, where $\phi = 0$ but firms still set $p_i^*(\chi)$ optimally. As shown in Table 15, the welfare results do not change significantly with μ.

Table 15: Robustness of Welfare Results to μ

	% Welfare Gain	
Value of μ	No costs	$\phi = 0$
$\mu = 0.5$	4.47%	2.17%
$\mu = 1$	4.50%	2.55%
$\mu = 3$	4.49%	2.45%