Aggregate Labor Market Outcomes: The Role of Choice and Chance*

Per Krusell† Toshihiko Mukoyama‡ Richard Rogerson§ Ayşegül Şahin¶

May 2010

Abstract

Commonly used frictional models of the labor market imply that changes in frictions have large effects on steady state employment and unemployment. We use a model that features both frictions and an operative labor supply margin to examine the robustness of this feature to the inclusion of a empirically reasonable labor supply channel. The response of unemployment to changes in frictions is similar in both models. But the labor supply response present in our model greatly attenuates the effects of frictions on steady state employment relative to the simplest matching model, and two common extensions. We also find that the presence of empirically plausible frictions has virtually no impact on the response of aggregate employment to taxes.

Keywords: Labor Supply, Labor Market Frictions, Taxes
JEL Classifications: E24, J22, J64

*Some of the material in this paper was previously contained in our paper entitled "Labor Supply in a Frictional Labor Market". We thank Victor Rios-Rull (editor), Nicola Pavoni, Naoki Shintoyo and two anonyous referees for useful comments, as well as seminar participants at CEMFI, Columbia, Universitat Autonoma de Barcelona, USC, UCLA, the Atlanta Fed, Yale, UC Riverside, Queen's, Georgetown, Wharton, Toronto, Ryerson, Western Ontario, Stockholm School of Economics, IIES, University of Oslo, Concordia, Northern Illinois, Yonsei University, Korea University, Ohio State, Notre Dame, Penn State, Indiana, Maryland, George Washington, as well as conference participants at the Labor Markets Conference at the IFS (2008), the Winter Institute of Macroeconomics 2009 (Tokyo), the Bewley Conference at UT Austin, and the 2009 SED Conference. We thank Joe Song for excellent research assistance. Krusell thanks the NSF for financial support, Mukoyama thanks the Bankard Fund for Political Economy for financial support, and Rogerson thanks the NSF and the Korean Science Foundation (WCU-R33-10005) for financial support. The views expressed in this article are those of the authors and do not necessarily reflect those of the Federal Reserve Bank of New York or the Federal Reserve System. Corresponding author: Richard Rogerson. Address for correspondence: Department of Economics, Arizona State University, Tempe, AZ 85287. Phone: 480-727-6671. Fax: 480-965-0748. Email: Richard.Rogerson@asu.edu

†IIES, CAERP, CEPR, and NBER
‡University of Virginia and CIREQ
§Arizona State University and NBER
¶Federal Reserve Bank of New York

1 Introduction

Two frameworks dominate analyses of aggregate employment–frictionless models that follow in the tradition of Kydland and Prescott (1982), and frictional models in the tradition of Mortensen and Pissarides (1994). While frictionless models necessarily imply that changes in employment entirely reflect changes in desired labor supply (i.e., choice), the simplest specifications of frictional models imply that changes in employment entirely reflect changes in the probability of receiving an offer (i.e., chance). It seems clear that both choice and chance influence individual employment outcomes in reality; that is, at any point in time some individuals are not employed by choice, while others are not employed by chance. There is good reason to believe that these two features have interesting interactions, in that the presence of frictions may attenuate the labor supply responses in frictionless models, while the presence of an operative labor supply margin might similarly attenuate the effects of frictions. In this paper we assess the relative importance of these two forces in shaping aggregate steady state employment.

We carry out this analysis in the model of Krusell et al (2009). That paper built an empirically reasonable model includes frictions and an operative labor supply margin that exhibits empirically reasonable income and substitution effects. In considering the implications of the model for labor market flows we adopt a more general view of unemployment than adopted by official statistical agencies. Specifically, we assign an individual to this state, which we refer to as generalized unemployment, if they are not working but answer yes to

the question of whether they would like to work at the market wage rate. This concept of unemployment arises naturally in our model and can be connected to the data gathered by the Current Population Survey. Our emphasis on the desire to work as opposed to active search for work is motivated both by the work of Jones and Riddell (1999, 2006) regarding marginally attached workers, the fact that active search seems to imply relatively little time use, and the fact that many workers find jobs through friends and relatives.

We use this model to ask two simple questions about the forces that influence steady state employment and unemployment. The first question is how changes in frictions affect aggregate steady state outcomes. In the simplest matching model, the level of frictions (captured by both the offer arrival rate and the separation rate) critically affects the level of both aggregate employment and unemployment. We assess the extent to which this is altered when one embeds the frictional model in a context where individuals also solve an empirically reasonable lifetime labor supply problem. Intuitively, if employment opportunities are harder to come by (or jobs do not last very long), individuals can adjust lifetime labor supply by extending the length of employment spells when employed, or by accepting more employment opportunities when not employed. In our calibrated model we find that the increase in *unemployment* is very similar to that implied by a simple matching model. In contrast, we find that labor supply responses greatly attenuate the direct effect of frictions on *employment*. Specifically, we find that a decrease in the arrival rate of employment opportunities leads to a large increase in the unemployment rate but only a small decrease in the employment rate.

We conclude that while the role of frictions for steady state aggregate unemployment seems robust to adding a nondegenerate labor supply decision, the impact of frictions on steady state employment is significantly overstated in simple matching models. We show that this same result holds in versions of the matching model in which match formation and match termination decisions are introduced. While these extensions add an element of choice to the simplest matching model, we show that incorporating empirically reasonable income and substitution effects is of first order importance in assessing the quantitative effects of frictions on employment.

Second, we use our model to assess the effects of increases in labor taxes used to fund lump-sum transfers. This question, recently examined in a frictionless model by Prescott (2004), seems a simple and sharp example of how an operative labor supply margin influences steady state employment. We ask how these effects are altered by the presence of reasonable frictions. We find that the employment effects are effectively unchanged by the presence of frictions. This result holds not only for tax increases but also tax decreases, which is perhaps more interesting since it is more likely that frictions will interfere with the desire to increase the fraction of time spent in employment.[1] We conclude that frictions do not seem to be of first order importance in the determination of steady state employment. Interestingly, in our model with frictions, higher taxes lead to both higher unemployment and higher non-participation, even holding the level of frictions constant. So, although the aggregate

[1] A similar result was found in Krusell et al (2008), but the calibrated model in that paper was not consistent with worker flows.

effects on employment in our model are effectively those found in the frictionless version of the model, the analysis shows that there are also effects on both the level and nature of unemployment.

Our paper is related to many papers in the literature. Merz (1995) and Andolfatto (1996) were the first to introduce frictions into an otherwise standard version of the growth model. A key feature of these models is that employment is completely determined by frictions, just as in simple frictional models. The model in Alvarez and Veracierto (1999) is closer to ours, since it features both a standard labor-leisure choice and frictions, but it cannot be calibrated to match worker flows since worker flows are indeterminate in their equilibrium. Moreover, they do not ask the question of how changes in frictions affect steady state outcomes. Garibaldi and Wasmer (2005) develop a three state model of the labor market that matches flows between the three states, but their model assumes linear utility. Ljungqvist and Sargent (2006, 2008) consider models that feature indivisible labor and frictions, but do not consider the impact of frictions on aggregate employment. Low et al (2010) consider a model with frictions and a nondegenerate labor supply decision. They consider a richer model of frictions and income support programs, but their analysis is partial equilibrium and they address very different issues than we do.

An outline of the paper follows. Section 2 describes the model. Section 3 describes the calibration of the model and presents the implications of the calibrated model for labor market flows. Section 4 analyzes the effects of changes in frictions on steady state outcomes

in a simple matching model, while Section 5 considers the same issue in some extensions of this model. Section 6 presents the results for analyzing tax and transfer programs. Section 7 discusses robustness and Section 8 discusses some issues regarding the nature of idiosyncratic shocks. Section 9 concludes.

2 Model

The economy is basically that in Krusell et al (2009).[2] The model has two key features. First, abstracting from frictions it features a canonical dynamic model of labor supply, in a context that features idiosyncratic shocks and incomplete markets for both credit and risk-sharing.[3] As documented in Krusell et al (2009), idiosyncratic shocks are an essential element in allowing the model to match the key features of labor market flows. While we could carry out our analysis in the context of a model that assumed complete markets, we believe that the incomplete markets model has become a more useful benchmark for quantitative work in models that feature idiosyncratic shocks. The frictions that we focus on are the two key frictions that characterize steady state labor market outcomes in almost any search and matching model: a job separation rate for employed individuals, and an offer arrival rate for non-employed individuals. While our model is somewhat minimalist, it seems a natural benchmark for an initial quantitative assessment of how frictions interact with labor supply.

[2] The model is essentially that of Krusell et al (2009). One difference is that here we assume that a separated worker must spend at least one period out of employment. The earlier paper does not perform any analysis of how frictions or taxes affect steady state outcomes. We also explore some alternative calibrations here.

[3] Several papers have recently analyzed labor supply in models with idiosyncratic shocks and incomplete markets, including Floden and Linde (2001), Low (2005), Domeij and Floden (2006), Pijoan-Mas (2006), and Chang and Kim (2006, 2007). Relative to these papers the distinguishing feature of our model is the presence of frictions.

The economy is populated by a continuum of workers with total mass equal to one. All workers have identical preferences over streams of consumption and time devoted to work given by:

$$\sum_{t=0}^{\infty} \beta^t [\log(c_t) - \alpha e_t]$$

where $c_t \geq 0$ is consumption in period t, $e_t \in \{0, 1\}$ is time devoted to work in period t, $0 < \beta < 1$ is the discount factor and $\alpha > 0$ is the disutility of work. Our preference specification assumes offsetting income and substitution effects, which we think represents a natural benchmark.[4] Individuals are subject to idiosyncratic shocks that affect the static payoffs of work relative to not working. While many shocks may have this property, e.g., shocks to market opportunities, shocks to home production opportunities, health shocks, family shocks, preference shocks etc..., we represent the net effect of all of these shocks as a single shock, and model it as a shock to the return to market work. In particular, letting s_t denote the quantity of labor services that they contribute if working, we assume an AR(1) stochastic process in logs:

$$\log s_{t+1} = \rho \log s_t + \varepsilon_{t+1}$$

where the innovation ε_t is a mean zero normally distributed random variable with standard deviation σ_ε. This process is the same for all workers, but realizations are *iid* across workers.

We formulate equilibrium recursively and focus solely on the steady state equilibrium.

[4] The search and matching literature commonly assumes linear utility. Relative to the linear specification, the key feature of our specification is a much more substantial income effect. To the extent that the balanced growth specification is challenged by some micro studies, the issue is that the income effect is perhaps even larger (see, for example, Hall (2009)).

In each period there are markets for output, capital services and labor services, but there are no insurance markets, so individuals will (potentially) accumulate assets to self-insure. We normalize the price of output to equal one in all periods, and let r and w denote steady state rental rates for a unit of capital and a unit of labor services, respectively. If a worker with productivity s chooses to work then he or she would contribute s units of labor services and therefore earn ws in labor income. We assume that individual capital holdings must be nonnegative, or equivalently, that individuals are not allowed to borrow. There is a government that taxes labor income at constant rate τ and uses the proceeds to finance a lump-sum transfer payment T subject to a period-by-period balanced budget constraint. In a later section we also consider a stylized unemployment insurance system. In steady state, the period budget equation for an individual with k_t units of capital and productivity s_t is given by:

$$c_t + k_{t+1} = rk_t + (1-\tau)ws_te_t + (1-\delta)k_t + T.$$

The production technology is described by a Cobb-Douglas aggregate production function:

$$Y_t = K_t^{\theta} L_t^{1-\theta}.$$

K_t is aggregate input of capital services and L_t is aggregate input of labor services:

$$\begin{aligned} K_t &= \int k_{it} di \\ L_t &= \int e_{it} s_{it} di. \end{aligned}$$

Output can be used either as consumption or investment, and capital depreciates at rate δ.

Frictions in the labor market are captured by two parameters: λ_w and σ, where λ_w is the employment opportunity arrival rate and σ is the employment separation rate. Specifically, we assume there are two islands which we label as the production island and the leisure island. At the end of period $t-1$ an individual is either on the production island or the leisure island, depending upon whether they worked during the period. At the beginning of period t each individual will observe the realizations of several shocks. First, each worker receives a new realization for the value of their idiosyncratic productivity shock. Second, each individual on the production island observes the realization of an *iid* separation shock: with probability σ the individual is relocated to the leisure island. At the same time, each individual who began the period on the leisure island, observes the realization of an *iid* employment opportunity shock: with probability λ_w an individual is relocated to the production island. In terms of connecting our model with the literature it is intuitive to think of σ as the exogenous job separation rate, and λ_w as the exogenous job arrival rate. Note that given our timing assumption, an individual who suffers the σ shock will necessarily spend at least one period in nonemployment. Once the shocks have been realized, individuals make their labor supply and consumption decisions, though only workers with an employment opportunity can choose e equal to 1. An individual on the production island who chooses not to work will then be relocated to the leisure island at the end of period t and will therefore not have the opportunity to return to the production island until receiving a favorable employment opportunity shock.

An individual's state consists of his or her location at the time that the labor supply decision needs to be made, the level of asset holdings, and productivity. Let $W(k,s)$ be the maximum value for an individual who works and $N(k,s)$ be the maximum value for an individual who does not work given that he or she has productivity s and capital holdings k. Define $V(k,s)$ by:

$$V(k,s) = \max\{W(k,s), N(k,s)\}.$$

The Bellman equations for W and N are given by:

$$W(k,s) = \max_{c,k'}\{\log(c) - \alpha + \beta E_{s'}[(1-\sigma)V(k',s') + \sigma N(k',s')]\}$$

$$s.t.\ c + k' = rk + (1-\tau)ws + (1-\delta)k + T$$

$$c \geq 0,\ k' \geq 0$$

and

$$N(k,s) = \max_{c,k'}\{\log(c) + \beta E_{s'}[\lambda_w V(k',s') + (1-\lambda_w)N(k',s')]\}$$

$$s.t.\ c + k' = rk + (1-\delta)k + T$$

$$c \geq 0,\ k' \geq 0$$

3 Calibration

We calibrate the model as in Krusell et al (2009), and so refer the reader to that paper for more a more detailed analysis and discussion of the calibration. A key aspect of the calibration procedure is to choose parameters so that the distribution of workers across states and the flows of workers between states are similar to those in the US economy. Official statistics divide non-employed workers into the two categories of unemployed and out of the labor force based primarily on how they answer a question regarding active search in the previous four weeks. Krusell et al (2009) argue that a different criterion is more natural, and we use their criterion to assign the non-employed into two mutually exclusive groups. This assignment is based on how an individual responds to the question of whether they would like to work if work were available. The group who answers yes to this question is larger than the group who is unemployed based on the standard definition. We will refer to our categories as representing generalized notions of unemployment and nonparticipation, and to remind the reader of this difference we will use E to denote the employment state, U^G to denote the generalized unemployment state, and N^G to denote the generalized not in the labor force state. In order to have a consistent definition in the model and the data, we use this same criterion to define generalized unemployment in the data. The generalized unemployment rate is somewhat larger than the official unemployment rate (8.4% versus 5.1%). We also compute flows among labor market states based on our definitions of the three states. As a practical matter it turns out that this adjustment has very little effect on the transition

probabilities.

An additional issue to address in calibrating the model concerns the population that the model best captures. Our model has single agent households that live forever. In reality, people have finite lives and often live in multi-member households. In Krusell et al (2009) we present transition probabilities for different choices of the underlying population sample, and argue that the model's ability to account for the flows is not particularly affected by the choice of the underlying population, though the fit is somewhat better for males than females. We present results for calibrations based on two different population samples. For our benchmark calibration we take a broad interpretation of the model and use it to capture labor market flows of all individuals older than 16. In section 7 we consider a narrower interpretation, in which we calibrate the model to flows for males aged 25-54, and show that our key conclusions hold for this alternative calibration.

Having described how we will measure flows across states in the data and the model, we now consider how to calibrate the model's parameters. The model has nine parameters that need to be assigned: preference parameters β and α, production parameters θ and δ, idiosyncratic shock parameters ρ and σ_ε, frictional parameters σ and λ_w, and the tax rate τ. The length of a period is set to one month. Because our model is a variation of the standard growth model, we can choose some of these parameter values using the same procedure that is typically used to calibrate versions of the growth model. The features of incomplete markets and uncertainty implies that we cannot derive analytic expressions for the steady state, and

so cannot isolate the connection between certain parameters and target values. Nonetheless, it is still useful and intuitive to associate particular targets and parameter values. Specifically, given values for λ_w, σ, ρ, and σ_ε, we choose $\theta = .3$ to target a capital share of .3, δ to achieve an investment to output ratio equal to .2, the discount factor β to target an annual real rate of return on capital equal to 4%. The other preference parameter α, which captures the disutility of working, is set so that the steady state value of employment is equal to .633. This is the value of the employment to population ratio for the population aged 16 and older for the period $1994 - 2006$.[5]

The tax rate is set at $\tau = .30$. Following the work of Mendoza et al (1994) there are several papers which produce estimates of the average effective tax rate on labor income across countries. Examples include Prescott (2004) and McDaniel (2006). There are minor variations in methods across these studies, which do produce some small differences in the estimates, and the value .30 is chosen as representative of these estimates.[6]

It remains to choose values for the λ_w, σ, ρ and σ_ε. We choose λ_w so that the steady state generalized unemployment rate in our model (i.e., $U^G/(E + U^G)$) is equal to .084, which is the average value for the generalized unemployment rate in the US data for the period $1994 - 2006$. We choose σ to target the flow rate from employment to generalized unemployment.

[5] We calibrate to values for the period 1994-2006 because this is the period for which we have consistent measures of labor market flows.

[6] Note that Prescott (2004) makes an adjustment to the average labor tax rate to arrive at a marginal tax rate that is roughly 40%. For purposes of computing the effect of changes in taxes this adjustment plays no role.

Krusell et al (2009) showed that the ability of the model to account for the flows between states remains relatively constant for a wide range of values of ρ and σ_ε. What mattered most was that ρ was reasonably persistent (at least .5), but not too close to being a unit root (say less than .97), and that σ_ε was not too small. In their benchmark calibration they assumed $\rho = .92$ and $\sigma_\varepsilon = .21$ expressed on an annual basis. These values correspond to one set of estimates of idiosyncratic wage shocks for prime-aged working males, as reported in Floden and Linde (2001). A key issue for our quantitative exercises is the extent to which different specifications of the shock process influence our results, despite having little impact on worker flows. It turns out that the results are relatively unaffected by considering different calibrated values for ρ and σ_ε, given that in each case we recalibrate the remaining parameters to continue to hit the same targets. As a result, we will only present results for this one set of values for ρ and σ_ε. Table 1 shows our calibrated parameter values.

Table 1
Benchmark Calibration

Targets								
$\frac{I}{Y} = .20, \frac{rK}{Y} = .3, \frac{E}{P} = .633, \frac{U^G}{E+U^G} = .084, r - \delta = .04, E \to U^G = .021$								
Parameter Values								
θ	δ	β	α	ρ	σ_ε	λ_w	σ	τ
.30	.0067	.9967	.546	.9931	.1017	.428	.022	.30

The labor market flows in our calibrated model and the data are displayed in Table 2.

Table 2
Flows in the Model and Data

Adjusted US 1994-2006				Model			
FROM	TO			FROM	TO		
	E	U^G	N^G		E	U^G	N^G
E	0.961	0.021	0.018	E	0.947	0.021	0.032
U^G	0.251	0.507	0.242	U^G	0.400	0.535	0.065
N^G	0.034	0.047	0.919	N^G	0.033	0.044	0.923

A major discrepancy has to do with the flow of workers from U^G to N^G. As discussed in Krusell et al (2009), this discrepancy is much less if we consider male workers aged 21-65 or 25-54 instead of the whole population, as we will see in our alternative calibration presented later. Additionally, assuming some survey response error that causes spurious transitions between N^G and U^G also removes much of the discrepancy.[7] While there is room for additional improvements relative to this simple model, we feel that the match is sufficiently close to justify using this model to revisit some basic questions about the forces that shape steady state employment and unemployment.

Even accounting for survey response error as noted above, the flow rate from U^G to E is somewhat high relative to the data. If one is concerned about the calibrated level of frictions being reasonable, this might be viewed as an important target. Krusell et al (2009) also presents an alternative calibration in which the flow rate from U^G to E is targeted instead of the stock of U^G. While we do not report any results for this alternative calibration, we note here that all of the results presented below are effectively identical for this alternative

[7] Survey response error also lowers the measured flow rate from U^G to E since some of the people counted in U^G are actually in N^G and therefore transition to E with much lower probability,

calibration.[8]

Although our calibration targets flows for the entire population, we can still contrast outcomes across different subgroups of the population in our model. Of particular relevance is the distinction between individuals who vary in their degree of "attachment" to the labor force. One simple measure of this in the model is the individual's value of the idiosyncratic shock s. In a frictionless version of our model with complete markets, individuals would work when s is above some threshold. If we look at different parts of the productivity distribution we see very different behavior of individuals. In what follows we will contrast how behavior changes in the upper part of the productivity distribution with that of the overall population. Specifically, we will focus on the highest 42% of the distribution. In steady state, the breakdown of this group between the three states E, U^G, and N^G, is .920, .056, .024. The key feature of this group is that virtually everyone in this group wants to work. We will see later on that this group exhibits very different responses than the aggregate.

Because wealth accumulation is a key element in shaping labor supply responses of individuals in our model, it is important to assess the extent to which the wealth distribution in our model is similar to that in the data. Table 3 shows the share of wealth held by various groups in the population, both for our model and for the US, as well as the Gini coefficient. The values for the US are taken from Budria Rodriguez et al (2002).

[8] Alternatively, if we were to use a slightly smaller value of σ our calibration procedure would produce a much smaller value for the transition rate from U^G to E, since the stock of workers in E is almost an order of magnitude larger than the stock in U^G.

Table 3
Share of Wealth Owned by Various Groups

	Gini	Top 1%	Top 5%	Top 10%	Top 20%	Top 40%	Top 60%	Top 80%
Model	.61	.06	.23	.39	.61	.87	.97	1.00
Data	.80	.35	.58	.69	.82	.94	.99	1.00

The basic message from Table 3 is similar to that found in previous analyses of this type.[9] In particular, the model does a reasonable job of capturing the wealth distribution except for the concentration in the upper tail. Note that the presence of our transfer program improves the model's ability to fit the lower part of the wealth distribution relative to models without this feature. The Gini coefficient in the model is about three quarters as large as it is in the data. Although our model does not capture the existence of individuals like Bill Gates, given the very small size of this group we believe this failure is not particularly significant from the perspective of understanding aggregate labor supply.

4 Frictions and the Steady State I: A Benchmark Comparison

One of the defining features of the Pissarides matching model and its many variants is that the level of frictions play a key role in determining not only the level of aggregate unemployment but also in determining the level of aggregate employment.[10] Intuitively, labor supply considerations will attenuate the impact of changes in frictions on aggregate employment. The reason for this is that if it becomes harder to find employment opportunities, then workers will be more willing to continue with a job opportunity once they find it, or decide to accept

[9] See, for example, Krusell and Smith (1998), Budria Rodriguez et al (2002), and Castaneda et al (2003).
[10] See Pissarides (2000) for a variety of models that have this property.

employment at lower productivities. The goal of this section is to explore the quantitative importance of these effects in our model relative to standard frictional models.

We begin by exploring the impact of exogenous changes in the level of λ_w, that is, we evaluate the impact on the steady state of an exogenous change in the level of frictions. We are primarily interested in the extent to which the responses in our model are different than those that would emerge in a benchmark version of the Pissarides matching model. In the simplest Pissarides model, the match separation rate is exogenous, but the job offer arrival rate is endogenously determined by the volume of vacancy posting. In this model all job offers are accepted, so the job offer arrival rate is also the probability that an unemployed worker becomes employed. If the match separation rate is σ and the job offer arrival rate is λ_w, and we assume that individuals can begin to work in the same period as receiving a job offer, then the law of motion for the unemployment rate is:

$$u_{t+1} = (1 - \lambda_w)u_t + \sigma(1 - u_t).$$

It follows that the steady state employment rate is given by:

$$\bar{u} = \frac{\sigma}{\lambda_w + \sigma}.$$

We set $\sigma = .022$ as in our benchmark calibration, and then set λ_w so that the steady state unemployment rate is equal to .084, which was the same target that we matched in our calibration. The implied value of λ_w is .24. We will then consider equal proportional changes in the value of λ_w in the two models, i.e., we increase or decrease λ_w by the same

percentage in the two models. Although the value of λ_w is endogenously determined in the Pissarides model, we do not model the source of this change. Rather, we focus simply on the consequences of such a change for employment and generalized unemployment.

Table 3 shows the effects for the aggregate employment to population ratio (E/P) and the unemployment rate in the two models, for our benchmark calibration. We emphasize that the predictions of our model are very similar for different values of ρ and σ_ε, and for the alternative calibration procedure in which λ_w is targeted to match the E to U^G flow. In the interest of space we only report results for the benchmark calibration, as shown in Table 4.

Table 4
Effect of λ_w on Employment and Generalized Unemployment Rates

Our model			Pissarides model		
	E/P	$U^G/(U^G+E)$		E/P	$U^G/(U^G+E)$
$\lambda_w = 0.6$	63.5%	5.6%	$\lambda_w = 0.34$	93.9%	6.1%
$\lambda_w = .428$	63.3%	8.4%	$\lambda_w = 0.24$	91.6%	8.4%
$\lambda_w = 0.2$	62.2%	16.0%	$\lambda_w = 0.11$	83.6%	16.4%

In reading this table each row represents the same percentage change in λ_w relative to the two benchmark calibrations, which by construction each have the same unemployment rate. A striking result emerges. If one looks at the responses on generalized unemployment rates, one observes that the effects are very similar across the two different models, especially for the case of decreases in λ_w. Moreover, the effects are large–when λ_w is decreased from the benchmark setting to the lowest value in the table, the generalized unemployment rate roughly doubles in both cases. But when one looks at the employment to population ratio responses one sees dramatic differences. In the Pissarides model, changes in the generalized unemployment rate and changes in the employment to population ratio are necessarily mirror

images of each other since by construction all workers are in the labor force. Hence, the Pissarides model also predicts large employment responses as a result of changes in λ_w. In sharp contrast, our model predicts very small changes in employment to population ratios. The change in the employment to population ratio in our model is only about one-seventh as large as the change in the Pissarides model. For example, when moving from the benchmark specification to the lowest value of λ_w in the table, the employment to population ratio decreases by eight percentage points in the Pissarides model but only slightly more than 1 percentage point in our model.

To see why the two models give such different employment responses it is instructive to examine the durations of employment and generalized unemployment spells, shown in Table 5.

Table 5
Effect of λ_w on Spell Durations

Our model			Pissarides model		
	E	U^G		E	U^G
$\lambda_w = 0.6$	17.3	1.6	$\lambda_w = 0.34$	45.5	3.0
$\lambda_w = .428$	18.9	2.2	$\lambda_w = 0.24$	45.5	4.2
$\lambda_w = 0.2$	23.8	4.2	$\lambda_w = 0.11$	45.5	8.9

In both models a decrease in λ_w leads to an increase in the duration of generalized unemployment, and the proportional changes are very similar in the two models. But the changes in employment durations are very different in the two models. In the Pissarides model a decrease in λ_w has no effect on the duration of employment spells. In contrast, in our model the duration of employment spells increases significantly in response to decreases in λ_w. For example, in moving from the benchmark value of λ_w to the lowest value in the

table, the duration of employment in our model increases by more than one quarter.

Another way to present this information is to see how the transition matrix across the three states is affected. Table 6 shows the transition matrices for the original calibration ($\lambda_w = .428$) and the lower value of .2.

Table 6
Transition Rates for Different Levels of Frictions

$\lambda_w = .428$				$\lambda_w = .20$			
FROM	TO			FROM	TO		
	E	U^G	N^G		E	U^G	N^G
E	0.947	0.021	0.032	E	0.958	0.022	0.021
U^G	0.400	0.535	0.065	U^G	0.190	0.759	0.051
N^G	0.033	0.044	0.923	N^G	0.014	0.058	0.928

Most of the changes are relatively small, with the exception of the flow from U^G to E and U^G to U^G. But consistent with the previously described patterns, there is slight decrease in the flow from E to N^G with a corresponding increase in the transition rate from E to E.

It is also useful to see how frictions affect the decision rules in the benchmark model. In steady state, each productivity level is associated with a threshold level for assets, such that the worker desires to works if assets are below this level, and does not desire to work if assets are above this level. As productivity increases so does the threshold value. Figure 1 shows the contour of reservation values and how it shifts as frictions change.

As frictions become larger, i.e., as λ_w decreases, the asset threshold becomes smaller for any given level of productivity. Finally, it is instructive to examine how the distribution of employment across productivity states is influenced by changes in λ_w. Figure 2 plots employment to population ratio as a function at each productivity level for various values of

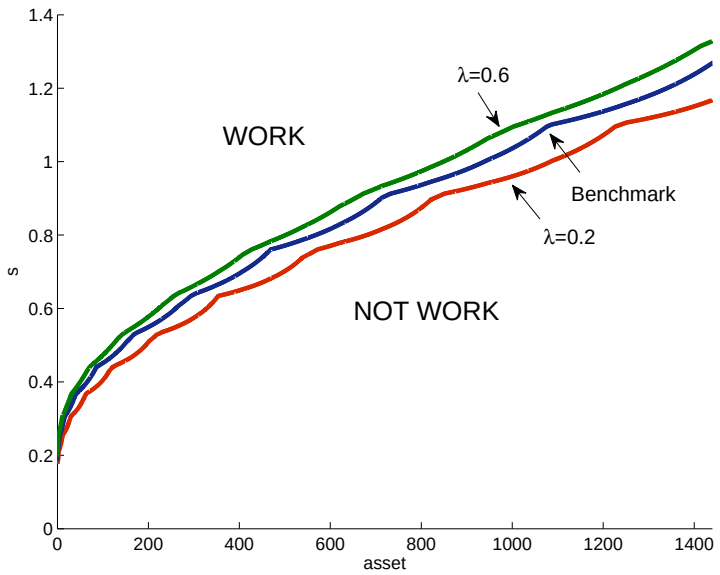

Figure 1: Effect of Frictions on Employment Decision Rule

λ_w.

As frictions increase, some employment is shifted from the right tail to the left tail. Intuitively, if there are no frictions, then all workers with sufficiently high productivity will work, but in the presence of frictions, some of these workers are not able to work because they do not have an employment opportunity. It is interesting to note that even for a very large change in frictions, the increase in mass at the bottom of the productivity distribution is quite small, and it remains true that the lowest productivity workers do not work at all.[11]

It is also of interest to contrast outcomes for the sample of high productivity individuals that we described earlier with those for the aggregates shown in Table 4. Table 7 shows the results for this group.

[11] It is important to keep in mind that our model includes a government transfer program, so that individuals do receive some income even when not working.

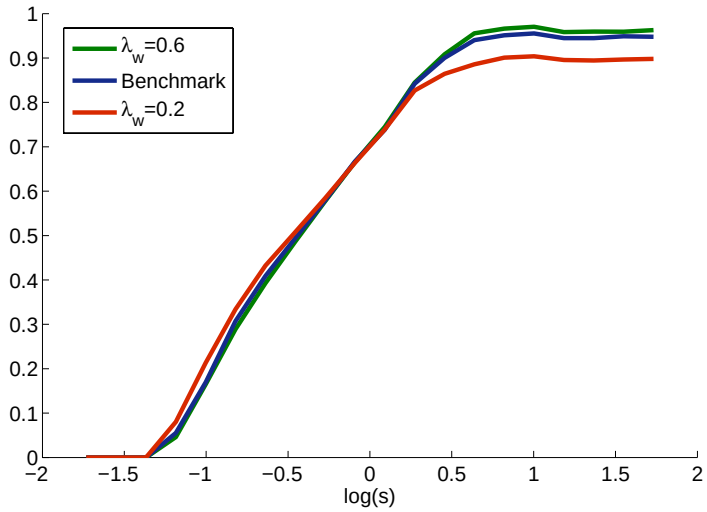

Figure 2: Frictions and Employment to Population Ratios

Table 7
Effect of λ_w

High Productivity		
	E/P	$U/(U+E)$
$\lambda_w = 0.6$	93.1%	3.9%
$\lambda_w = .428$	92.0%	5.6%
$\lambda_w = 0.2$	87.6%	11.3%

The interesting result that emerges is that this group responds very much like the aggregates from the Pissarides model. In particular, for this group the responses in E and U^G are close to mirror images of each other. This suggests that while the Pissarides model is an appropriate model for describing what happens to steady state outcomes for a particular subgroup of the population, it is not appropriate for understanding changes at a more aggregate level.

We can also repeat the above analysis to examine how the two different models respond to exogenous changes in σ, the separation shock. Proceeding as above, Table 8 presents the

effects on employment and generalized unemployment.[12]

Table 8
Effect of σ on Employment and Generalized Unemployment Rates

	Our model		Pissarides model	
	E/P	$U^G/(U^G+E)$	E/P	$U^G/(U^G+E)$
$\sigma = 0.01$	63.9%	6.2%	96.0%	4.0%
$\sigma = .022$	63.3%	8.4%	91.6%	8.4%
$\sigma = 0.03$	62.9%	9.9%	88.9%	11.1%

The results are very similar to those found for changes in λ_w. Changes in generalized unemployment rates in response to changes in σ are about one half as large in our model as in the Pissarides model. And the employment response is again only about one-seventh as large in our model as in the Pissarides model. Table 9 shows that the reason for the large differences in employment rate responses has to do with a labor supply effect that produces offsetting changes in employment durations.

Table 9
Effect of σ on Spell Durations

	Our model		Pissarides model	
	E	U^G	E	U^G
$\sigma = 0.01$	23.9	2.1	100.0	4.2
$\sigma = .022$	18.9	2.1	45.5	4.2
$\sigma = 0.03$	16.6	2.2	33.3	4.2

In the Pissarides model, changes in σ lead mechanically to changes in employment duration. The implication is that the large changes in σ are associated with large and proportional changes in employment duration. In contrast, in our model, decreases in σ lead to what in comparison are only very moderate increases in employment duration. This is due to a labor supply response. When σ is high, it is less likely that an individual has an employment

[12] Because the values of σ are the same in the two benchmark economies we now consider equal changes in the two economies.

opportunity in any given period, and as a result they respond by being willing to work at lower productivity levels. This in turn implies less "voluntary" separations. But when σ decreases, the reverse is true, and individuals become choosier about when to work, leading to more voluntary separations.

To close this section we think it is important to emphasize the important role of asset accumulation in generating the above results. In particular, adding curvature to the utility function is not sufficient to capture the effects that we are stressing. To see this, note that without asset accumulation the individual's desire to work would depend purely on the level of the idiosyncratic shock and, in particular, not on the level of frictions. Frictions would merely influence the probability of working conditional on wanting to work. Because of this, there is no labor supply response due to a change in frictions, and the key results we stress would disappear.

5 Frictions and the Steady State II: Extensions

One of the key findings in the previous section was that labor supply responses greatly attenuate the effect of frictions on steady state employment. Readers familiar with the matching literature might reasonably argue that this result is heavily influenced by our choice of the benchmark model. In particular, a key feature of the benchmark model is that given the level of frictions, there are no other margins of adjustment that work to at least partially offset the effect of frictions. But while this is a property of the benchmark model, simple and popular extensions of this model, including those in Pissarides (1985) and Mortensen and

Pissarides (1994), do include an additional choice margin that might play the same role as the labor supply channel in our model.

In Pissarides (1985), when a meeting between a worker and a firm occurs, the pair receives a random draw of a permanent match quality. The optimal decision about whether to form a match is characterized by a reservation rule, i.e., proceed with forming the match if the draw for match quality is above some threshold. In this setting, steady state employment will depend on both the level of frictions and the reservation value. Intuitively, if frictions become more severe, workers will become less choosy about which matches to form, thereby giving rise to a force that can at least partially offset the direct effect of more severe frictions.

Similarly, in Mortensen and Pissarides, all matches start at the same high level for match quality, but this quality subsequently evolves stochastically. In this setting a key decision is when to terminate a match, which under fairly standard conditions will again be characterized by a reservation rule. In this setting an increase in frictions can lead to a lower reservation value, implying that match terminations will decrease. Once again, this creates an opposing effect on steady state employment relative to the direct effect.

The question that we ask in this section is whether our finding about the quantitative importance of the labor supply channel for employment responses remains when we compare our model with either of these extensions. We note at the outset that although one naturally expects these extensions to lessen the difference between our model and the benchmark Pissarides model, there is good reason to think that a significant difference will remain. This

is due to the specification of linear utility in the matching literature. In a standard model of labor supply, including the model we are using in this paper, when a worker decreases the fraction of life spent in employment, average consumption decreases, which in turn increases the marginal utility of consumption and creates an incentive for the individual to increase the fraction of time spent in employment. In contrast, a decrease in average consumption in a model with linear utility does not increase the marginal utility of consumption, and therefore does not contain this force leading to higher employment.

In fact, we will find that our labor supply channel is a substantially more powerful offsetting force than the margins present in either of these extensions. We conclude that in order to assess the quantitative effects of frictions on steady state employment it is important to not only have the presence of labor supply margins but also that the labor supply decision exhibit reasonable income and substitution effects. We proceed to describe in more detail each of the two extensions described above.

5.1 Extension 1: Adding a Match Formation Decision

In this subsection we analyze an extension to incorporate the match. In the spirit of our earlier calculation, we consider a continuum of workers, each of whom solves the same decision theoretic problem with the following features. Preferences are given by:

$$\sum_{t=0}^{\infty} \beta^t [c_t - bh_t]$$

where c_t is consumption in period t, and $h_t \in \{0, 1\}$ is time devoted to work. If the individual begins period t not employed, then he or she will receive a job offer with probability λ_w.

Conditional on receiving a job offer, the wage associated with this offer is a random draw from the distribution with cdf $F(w)$. The wage associated with this job will remain fixed for the duration of the match. If the worker decides to accept the offer, he or she will begin the job in the same period as the offer was made. As in our earlier models, any match that existed in period $t-1$ ends with probability σ at the beginning of period t. In this case the individual is in the same situation as someone who began the period unemployed. Consumption in each period is equal to labor earnings. Letting $V(w)$ be the value of employment at wage w and U be the value of being unemployed, the Bellman equations are:

$$V(w) = w - b + \beta[(1-\sigma)V(w) + \sigma U]$$

and

$$U = \beta[(1-\lambda_w)U + \lambda_w \int \max(V(w), U) dF(w)],$$

It is easy to show that the optimal job acceptance decision for this worker is characterized by a reservation wage, which we denote by w^*. One can also show that decreases in λ_w or increases in σ lead to decreases in the reservation wage. The dynamics of the employment rate, e_t, is

$$e_{t+1} = (1-\sigma)e_t + \lambda_w(1 - F(w^*))(1 - e_t).$$

We focus on the steady state behavior of the unit mass of workers that each solve this problem, and in particular will ask how changes in the two frictional parameters λ_w and σ affect steady state employment. For our numerical calculations we consider a period to be

a month, and set the values of β, λ_w, and σ to be the same as in our calibrated model. An important consideration in comparing results across models is that one might expect the shape of the distribution characterizing the uncertainty, in particular in the vicinity of the reservation wage. With this in mind we calibrate this model so that the cdf $F(w)$ is the same as the cdf for the stationary distribution of the idiosyncratic shock process from our calibrated model. We then choose the value of b so that the steady state employment rate is the same as in our calibrated model, i.e., equal to .633.[13] These last two choices imply that the distribution of wages is the same in the two settings, and that at least in an average sense, the marginal decision is in the same place in the distribution.[14]

5.2 Extension 2: Adding a Match Termination Decision

The second extension is in the spirit of Mortensen and Pissarides (1994). Preferences are the same as in extension 1. As in extension 1, we continue to assume that if a worker receives an offer, the wage is drawn from a distribution with cdf $F(w)$. However, if the job is accepted, it will evolve stochastically in future periods, according to an AR(1) process:

$$\log w_{t+1} = \rho \log w_t + \varepsilon_{t+1}$$

where ε is an iid normally distributed random variable with mean zero and standard deviation σ_ε. The timing is as follows. For any worker who was employed in period $t-1$, at the

[13] We solve the model using value function iteration. We use a grid with 10000 points on w on the interval $[-2\sigma_w, 2\sigma_w]$, where σ_w is the standard deviation of the distribution described by $F(w)$, and applied Tauchen's (1986) method for the discrete approximation.

[14] This cannot hold exactly, since employment decisions in our model are determined by both productivity and assets.

beginning of $t-1$ they are subject to a separation probability that occurs with probability σ. If a separation does not occur, a new draw for ε is realized, at which point the worker decides whether to continue with the job. If not, they separate and are in the same position as a worker who started the period not employed, or who experienced a separation shock. Letting $G(w'|w)$ denote the cdf for next period's wage given this period's wage is equal to w implied by the stochastic process for wages on the job, the Bellman equations are

$$V(w) = w - b + \beta[(1-\sigma)\int \max(V(w'), U)dG(w'|w) + \sigma U]$$

and

$$U = \beta[(1-\lambda_w)U + \lambda_w \int \max(V(w), U)dF(w)].$$

The optimal search strategy for this individual will be described by a single reservation wage, which is relevant both for which new offers to accept, and which jobs to separate from. We again denote the reservation wage by w^*.

Denote the measure of employed workers over wages by $M_t(w)$. Then the law of motion for the employment rate in this model is described by:

$$\begin{aligned} e_{t+1} &= (1-\sigma)\textstyle\int(1-G(w^*|w))dM_t(w)) \\ &\quad +\lambda_w(1-F(w^*))(1-e_t) \end{aligned}$$

The evolution of $M_t(w)$ is described by:

$$\begin{aligned} M_{t+1}(w') &= \lambda_w(1-e_t)\max(F(w')-F(w^*),0) \\ &\quad +(1-\sigma)\textstyle\int \max(G(w'|w)-G(w^*|w),0)dM_t(w) \end{aligned}$$

We calibrate this model in a similar fashion. In particular, we set β, λ_w, and σ as before. We choose the parameters ρ and σ_ε that describe the stochastic evolution of wages on the job

to be the same as those in our original calibration, and choose the cdf $F(w)$ to correspond to that of the stationary distribution of the stochastic process on wages. We then choose b so that the steady state employment rate is equal to .633.[15]

5.3 Results

We now consider the effects of changes in frictions on steady state employment.[16] Table 10 contains results for changes in λ_w.

Table 10
Effect of λ_w on Steady State Employment

	Our Model	Extension 1	Extension 2	Pissarides
	E/P	E/P	E/P	E/P
$\lambda_w = 0.6$	63.5%	67.2%	66.4%	70.7%
$\lambda_w = .428$	63.3%	63.3%	63.3%	63.3%
$\lambda_w = 0.2$	62.2%	54.1%	54.3%	44.6%

The first column repeats the results for our model that also appeared in Table 4. The next two columns reports results for the two extensions just described. The final column shows results for the benchmark Pissarides model used in the previous section, except that we have now calibrated λ_w in this model so as to give a steady state employment rate of .633.[17]

We begin by comparing the employment effects associated with a small decrease in λ_w, from the benchmark value of .428 to the value of .2. In our model, the drop in steady

[15] Once again we solve the model using value function iteration. We use a grid with 240 values for w on the interval $[-2\sigma_w, 2\sigma_w]$ and applied Tauchen's (1986) method for the discrete approximation of $F(w)$ and $G(w'|w)$. The computation of the steady-state e is more involved—we iterated over the descretized measures $M_t(w)$ and e_t using their transition equations until they converged.

[16] The effects on generalized unemployment in our model are the same as those reported earlier, so we do repeat them. For the other models, all non-employed workers are unemployed by standard interpretations.

[17] As we move from row to row we adjust the value of λ_w for this specification proportionately. Moving from the first row to the third row the values of λ_w for the Pissarides model are .053, .038, and .018.

state employment is 1.1, while the corresponding numbers for extension 1, extension 2, and the Pissarides model are 9.2, 9.0 and 19.7. Two simple conclusions follow. First, both extensions serve to significantly dampen the steady state employment responses relative to the Pissarides model. Extensions 1 and 2 both have a response that is less than half as large. Second, however, the extent of this dampening is still very much less than what occurs in our model. While Extension 1 yielded the smallest drop in steady state employment, this drop is still more than seven times larger than the corresponding drop in our model.

While we will not discuss the other values in Table 10 in any detail, we note that this factor seven difference seems to apply equally well for both large decreases and increases in λ_w.

Table 11 repeats this exercise for changes in the separation rate σ.

Table 11
Effect of σ on Steady State Employment

	Our Model	Extension 1	Extension 2	Pissarides
	E/P	E/P	E/P	E/P
$\sigma = 0.01$	63.9%	73.4%	68.8%	79.1%
$\sigma = 0.022$	63.3%	63.3%	63.3%	63.3%
$\sigma = 0.03$	62.9%	59.3%	60.1%	55.9%

The basic result is the same here as in Table 10. Once again the two extensions do significantly dampen the responses relative to the benchmark Pissarides model. But these responses are still more than five times as large as the responses in our model.

We conclude that our key result about the role of frictions in determining steady state employment is robust to considering these extended versions of the benchmark Pissarides model. That is, in an empirically reasonable model that includes both frictions and an oper-

ative labor supply margin consistent with the neoclassical theory of labor supply, labor supply responses greatly attenuate the effect of changes in frictions on steady state employment. Put somewhat differently, the level of frictions does not seem to be a major determinant of steady state employment.

6 Taxes and the Steady State

In this section we analyze the predictions of our model for the labor market effects of increases in the size of the tax and transfer program.[18] Prescott (2004) argued that differences in the scale of tax and transfer programs could account for the bulk of the observed differences in hours worked between the US and several European countries. His analysis assumed no frictions and abstracted from the issue of how workers are distributed across labor market states. In a steady state setting, these tax calculations are one of the sharpest examples of how labor supply (i.e., choice) influences aggregate employment. It therefore is an interesting calculation to revisit in our model that features both choice and chance.

We assess the importance of frictions for this exercise by comparing the results in our benchmark calibrated economy with the results that emerge from the case in which λ_w is set equal to 1, and the model is calibrated without targeting the generalized unemployment rate. In the results that we report below we consider a change in τ holding all other parameters constant, including the two frictional parameters σ and λ_w. Models of the sort considered

[18] Krusell et al (2008) carry out this analysis in a model without idiosyncratic shocks. Krusell et al (2009) show that such a model does not do a good job of accounting for worker flows. Moreover, that paper did not distinguish between unemployment and nonparticipation and so could not be used to assess the consequences for these variables and statistics such as the duration of unemployment.

by Mortensen and Pissarides (1994) imply that the levels of these frictions will also respond to changes in such things as tax rates. However, in view of the results from the previous section, we know that from the perspective of the effects on steady state employment, the effects associated with changes in frictions will be of second order importance.

Table 12 shows the results for the case of $\lambda_w = 1$ and our benchmark calibration. To also show how the results are influenced by having even higher levels of frictions, we also report results for the case of $\lambda_w = .2$.[19]

Table 12
Taxes and the Employment/Population Ratio

	$\tau = 0.00$	$\tau = 0.15$	$\tau = 0.30$	$\tau = 0.45$
$\lambda_w = 1.0$	.868	.791	.633	.484
$\lambda_w = .428$	.854	.779	.633	.488
$\lambda_w = .2$	.829	.764	.633	.493

The striking result from this table is that the presence of frictions has virtually no effect on the impact of tax increases on employment. For the case of tax decreases, the presence of frictions does have some effect, but even when $\lambda_w = .2$ the effect of frictions is relatively small compared to the overall change. For example, when taxes are reduced to zero, the employment rate increases by roughly 24 percentage points when there are no frictions, and by roughly 20 percentage points when $\lambda_w = .2$. It follows that for evaluating the steady state effects of tax changes, the presence of reasonable frictions has little impact on the aggregate response of employment.

Table 13 shows the implications of tax changes for the unemployment rate for the same

[19] Once again, in this case all parameters of the model are recalibrated to match the same targets, but we are not requiring that the model match the level of unemployment.

three cases considered in Table 12. Once again, we emphasize that we are holding the levels of frictions constant in this experiment. If changes in taxes do lead to associated changes in frictions, there would potentially be additional important effects on unemployment.

Table 13
Taxes and the Unemployment Rate

	$\tau = 0.00$	$\tau = 0.15$	$\tau = 0.30$	$\tau = 0.45$
$\lambda_w = 1.0$	.021	.021	.021	.020
$\lambda_w = .428$	.057	.066	.084	.097
$\lambda_w = 0.2$	.111	.125	.155	.178

An interesting result emerges. Given that the results with frictions are virtually identical to results without frictions (especially for the case of tax increases), one might expect that the changes in the employment rate will be reflected mostly in changes in the participation rate rather than the generalized unemployment rate. But the table shows that changes in taxes do affect the generalized unemployment rate in the models with frictions. In particular, when taxes are increased from .30 to .45, and the employment to population ratio drops from .63 to .49, we see that the generalized unemployment rate increases from .08 to .10 and from .16 to .18 for the cases of $\lambda_w = .428$ and .20 respectively. To see the intuition behind this result, note that when taxes increase, employment durations decrease, implying that individuals will have more transitions from E to N^G, and consequently more unemployment spells when transitioning back to E from N^G.

This is further illustrated by looking at spell durations, shown in Table 14.

Table 14
Spell Durations (E, U^G, N) and Taxes

	$\tau = 0.00$	$\tau = 0.15$	$\tau = 0.30$	$\tau = 0.45$
$\lambda_w = 1.0$	31.7/1.0/13.1	21.7/1.0/9.7	15.0/1.0/12.2	13.0/1.0/18.3
$\lambda_w = .428$	34.5/2.3/12.7	27.0/2.2/11.8	18.9/2.2/13.0	15.4/2.1/17.9
$\lambda_w = 0.2$	38.5/4.7/11.9	33.0/4.5/12.7	24.7/4.2/13.8	20.4/4.0/19.1

Some interesting patterns emerge. Specifically, an increase in taxes leads to shorter durations of employment and generalized unemployment spells, and longer durations of nonparticipation. The reason for the small decrease in generalized unemployment spell durations is that when taxes are high individuals have a higher reservation productivity level for a given value of assets, and this means that workers in the U^G state are more likely to experience a negative productivity shock and transition to N^G.

To summarize, the main finding of this section is that for reasonably calibrated frictions, the aggregate employment effects of the model with frictions is essentially identical to that of the model without frictions. However, in the model with frictions, changes in taxes do impact on statistics such as the generalized unemployment rate and the duration of E and U^G spells. In this sense the model with frictions has a richer set of predictions for the effect of tax changes than the model without frictions. Some researchers argue against the importance of the labor supply channel emphasized in the frictionless model in some contexts by suggesting that it is inconsistent with responses in the generalized unemployment rate. This analysis shows that such a general critique is not compelling in the context of a model with both a nondegenerate labor supply decision and frictions. More generally, if changes in taxes were accompanied by changes in the level of frictions, as implied by standard matching models, then our model implies that one could generate different changes in the generalized unemployment rate without having any significant effect on the employment effects that we found.

7 Sensitivity: Results for Alternative Calibrations

In this section we present results for two alternatives to our benchmark model and calibration. In the first alternative, the model is unchanged, but instead of calibrating the model to match flows for the entire population aged 16 and older, we instead calibrate to data for males aged 25-54. In the second alternative we change the specification of policy to allow for a stylized form of unemployment insurance. For both specifications we revisit the two experiments examined in the context of the benchmark model: changes in frictions and changes in the scale of tax and transfer programs. While the exact magnitudes of the effects are different in these alternatives, the two main conclusions from our analysis of the benchmark model remains; first, that labor supply effects greatly attenuate the effect of frictions on steady state employment, and second, that the presence of frictions is not of first order importance in understanding how tax increases influence steady state employment.

7.1 Calibrating to Males Aged 25-54

In this section we present results for an alternative calibration of the model in which we target labor market flows for males aged 25-54 instead of the entire population. We use the same calibration procedure as before, with the only difference being the targets for some of the labor market statistics. In particular, we now target a value of $E/P = 87.6\%$, a generalized unemployment rate of 5.5% and an E to U^G flow rate of 0.017. Table 15 shows the calibrated parameter values.

Table 15
Calibration Based on Males 25-54

Targets								
$\frac{I}{Y} = .20, \frac{rK}{Y} = .3, \frac{E}{P} = .876, \frac{U^G}{E+U^G} = .055, r - \delta = .04, E \rightarrow U^G = .017$								
Parameter Values								
θ	δ	β	α	ρ	σ_e	λ_w	σ	τ
.30	.0067	.9967	.26	.9931	.1017	.356	.017	.30

The labor market flows in our calibrated model are displayed in Table 16.

Table 16
Flows in the Model and Data

Adjusted US 1994-2006				Model			
FROM	TO			FROM	TO		
	E	U^G	N^G		E	U^G	N^G
E	0.977	0.017	0.006	E	0.977	0.017	0.006
U^G	0.296	0.583	0.121	U^G	0.348	0.628	0.024
N^G	0.068	0.080	0.852	N^G	0.030	0.055	0.915

As noted earlier, the model's ability to match the flows for this group is broadly similar to its ability to match the flows for the entire population, though the absolute discrepancy between the U^G to N^G flow in the model and the data is now much smaller. Notably, the value of the U^G to N^G flow in the data is only about half as large. The smaller discrepancy in this flow implicitly leads to a smaller discrepancy in the U^G to E flow.

Next we carry out the key experiment of contrasting how changes in frictions affect the distribution of workers across states. Tables 17 and 18 report the results for changes in λ_w and σ respectively.

Table 17

Effect of λ_w on Employment and Unemployment Rates

	Our model			Pissarides model	
	E/P	$U^G/(U^G+E)$		E/P	$U^G/(U^G+E)$
$\lambda_w = 0.6$	88.6%	3.3%	$\lambda_w = 0.49$	96.7%	3.3%
$\lambda_w = 0.4$	88.0%	4.9%	$\lambda_w = 0.33$	95.1%	4.9%
$\lambda_w = .356$	87.6%	5.5%	$\lambda_w = 0.29$	94.5%	5.5%
$\lambda_w = 0.2$	85.4%	9.2%	$\lambda_w = 0.16$	90.6%	9.4%

Table 18

Effect of σ on Employment and Unemployment Rates

	Our model		Pissarides model	
	E/P	$U^G/(U^G+E)$	E/P	$U^G/(U^G+E)$
$\sigma = 0.01$	89.1%	3.7%	96.7%	3.3%
$\sigma = .017$	87.6%	5.5%	94.5%	5.5%
$\sigma = 0.02$	87.1%	6.2%	93.6%	6.4%
$\sigma = 0.03$	85.2%	8.6%	90.7%	9.3%

Relative to the benchmark case considered earlier, these tables show that the extent to which the labor supply response offsets the effects of frictions is lessened. Intuitively, the larger the fraction of time spent in employment, the less scope there is for labor supply responses to offset these effects. Nonetheless, while the magnitudes of the differences are affected, the basic message is the same: the employment effects in the Pissarides model are substantially larger than they are in our model, in this case by about a factor of two.

Table 19 reports results for the tax experiments.

Table 19

Taxes and the Employment/Population Ratio

	$\tau = 0.00$	$\tau = 0.15$	$\tau = 0.30$	$\tau = 0.45$
$\lambda_w = 1.0$	.962	.934	.876	.749
$\lambda_w = .356$	.941	.919	.876	.764

Relative to the earlier results, the effect of tax increases is significantly lower, even in the absence of frictions. The absolute effect of frictions is similar to what we found earlier, though these effects are now more important in percentage terms given the smaller magnitude of the

overall effects. Nonetheless, the results for the calibrated value of λ_w still suggests that the effect of frictions is of second order importance. In the case of tax decreases, the result is somewhat different due to the fact that with the higher calibrated value of E/P, frictions more quickly influence outcomes as we approach the maximum possible employment level.

7.2 Adding Unemployment Insurance

In our benchmark model we assumed that the only transfer program was a lump-sum transfer to all individuals, independently of whether they work or not. In this section we examine how our results are affected by allowing for a stylized UI system that provides a constant transfer payment that is only received by non-workers. In particular, we assume that a portion of the tax revenues are used to finance a payment to individuals who are not working. In our first calculation we fix the UI benefit, denoted by b, to be equal to .73, which in the steady state equilibrium corresponds to 18% of after tax average wages for employed people.[20] We carry out this extension in the context of the benchmark calibration, which means that the targets are the same as in the benchmark model. Table 20 presents the calibrated parameter values and Table 21 presents the flows in the model and the data.

[20] Many studies match a 50% replacement rate. We choose a lower value to reflect two factors about the UI system in the US: benefits are capped and are of finite duration. In present value terms, our system yields the same potential maximum benefit as a 50% replacement rate with duration of six months. If we focus on the bottom half of the wage distribution, our replacement rate is 32%.

Table 20

Calibration with UI System

Targets									
$\frac{I}{Y} = .20, \frac{rK}{Y} = .3, \frac{E}{P} = .633, \frac{U^G}{E+U^G} = .0839, r - \delta = .04, E \rightarrow U^G = .021, \frac{b}{\bar{w}} = .18$									
Parameter Values									
θ	δ	β	α	ρ	σ_e	λ_w	σ	τ	b
.30	.0067	.9967	.26	.9931	.1017	.367	.021	.30	.73

Table 21

Flows in the Model and Data With UI

Adjusted US 1994-2006				Model			
FROM	TO			FROM	TO		
	E	U^G	N^G		E	U^G	N^G
E	0.961	0.021	0.018	E	0.959	0.021	0.020
U^G	0.251	0.507	0.242	U^G	0.344	0.594	0.062
N^G	0.034	0.047	0.919	N^G	0.020	0.034	0.946

The ability of the model to account for the flows is very similar to that of the benchmark model without UI. The major discrepancy is again the flow of workers from U^G to N^G. Tables 22-24 show results when we conduct the three experiments in this model.

Table 22

Effect of λ_w on Employment and Unemployment Rates With UI

Our model			Pissarides model		
	E/P	$U^G/(U^G+E)$		E/P	$U^G/(U^G+E)$
$\lambda_w = 0.6$	63.8%	5.0%	$\lambda_w = 0.37$	94.7%	5.3%
$\lambda_w = .367$	63.3%	8.4%	$\lambda_w = 0.23$	91.6%	8.4%
$\lambda_w = 0.2$	61.6%	14.2%	$\lambda_w = 0.13$	85.6%	14.4%

Table 23

Effect of σ on Employment and Unemployment Rates With UI

	Our model		Pissarides model	
	E/P	$U^G/(U^G+E)$	E/P	$U^G/(U^G+E)$
$\sigma = 0.01$	64.6%	6.0%	95.8%	4.2%
$\sigma = .021$	63.3%	8.4%	91.6%	8.4%
$\sigma = 0.03$	62.3%	10.3%	88.4%	11.6%

Table 24
Taxes and the Employment/Population Ratio With UI

	$\tau = 0.00$	$\tau = 0.15$	$\tau = 0.30$	$\tau = 0.45$
$\lambda_w = 1.0$	.839	.746	.633	.512
$\lambda_w = .367$	.819	.733	.633	.514

Rather than going through the results in any detail, we simply note that they are very similar to those in the benchmark calibration. We conclude that adding a simple form of UI benefits has no effect on our conclusions.

We have also repeated the above exercise with a larger value of the UI benefit. In particular, we repeat the above procedure with a value of b equal to 1.46.[21] This implies a replacement rate of .36 relative to the average wage and of .67 relative to the wages of the bottom half of the wage distribution. This also implies that the replacement rate exceeds 1.00 for those individuals employed at the bottom of the wage distribution.[22] Having permanent UI benefits to all nonworkers of this magnitude presents a challenge in terms of matching the model to the US data. In particular, the disutility of working is now very close to zero and the closest we can get to matching the target value for E/P of .633 is .644. If the disutility of work gets very close to zero, one would expect the labor supply channel that we have emphasized to be less important. An important issue for future research is to explicitly model the specific details of transfer programs and assess the implications for the implied value of the disutility of work. While the implied value of α raises issues regarding the reasonableness of this specification, we think it is still of interest to explore this case. In the

[21] The parameter values for this calibration that differ from those in Table 20 are $\alpha = .003$, $\lambda_w = .345$, and $\sigma = .214$. The value of E/P in this calibration is .644 instead of .633.

[22] In the absence of frictions an individual who faces a replacement rate greater than one would never work, but frictions imply some option value to remaining in employment.

interests of space we focus on the effects of changes in λ_w and σ, with the results shown in Tables 25 and 26.

Table 25
Effect of λ_w on Employment and Unemployment Rates With UI

	Our model			Pissarides model	
	E/P	$U^G/(U^G+E)$		E/P	$U^G/(U^G+E)$
$\lambda_w = 0.6$	62.6%	4.6%	$\lambda_w = 0.41$	95.0%	5.0%
$\lambda_w = .367$	64.4%	8.4%	$\lambda_w = 0.23$	91.6%	8.4%
$\lambda_w = 0.2$	62.8%	13.6%	$\lambda_w = 0.14$	86.3%	13.7%

Table 26
Effect of σ on Employment and Unemployment Rates With UI

	Our model		Pissarides model	
	E/P	$U^G/(U^G+E)$	E/P	$U^G/(U^G+E)$
$\sigma = 0.01$	67.7%	5.5%	95.9%	4.1%
$\sigma = .0214$	64.4%	8.4%	91.6%	8.4%
$\sigma = 0.03$	60.4%	10.5%	88.5%	11.5%

The effect of a decrease in λ_w on E/P is similar to what we have found previously. However, somewhat surprisingly, we now find that an increase in λ_w leads to a decrease in E/P. This somewhat perverse result can potentially be explained by the fact that when frictions are high, individuals may continue to work even when productivity is very low because of the option value of remaining on the employment island. With α being so close to zero it seems that this effect is quite strong. Moving to the case of changes in σ, we now find that increases in σ lead to larger decreases in employment in our model than in the Pissarides model. The reason for this is intuitive. In our original model, a higher separation rate holding all else constant will decrease the amount of time spent in employment, thereby decreasing lifetime income and hence consumption. This decrease in consumption increases the desire of the individual to work, and so they respond by expanding the region of the

state space in which they prefer to work. However, in a world with sufficiently generous UI benefits, although an increase in σ holding all else constant will lead to less time spent in employment, this need not imply a decrease in lifetime income. As the UI benefit becomes sufficiently large, the income effect associated with the receipt of UI benefits can decrease the individual's desire to work. We leave it to future work to assess the extent to which this effect would occur in a model that entails a UI system that more closely matches the one found in the US.

8 A Contrasting View

The results of the previous sections suggest a very simple characterization of how our hybrid model compares with the standard frictionless and frictional models used in the literature. From the perspective of predicting changes in steady state employment, our hybrid model behaves very closely to frictionless models, whereas from the perspective of making predictions about changes in steady state unemployment, our model behaves very closely to the standard frictional models. The striking and important finding is that the one-to-one inverse mapping between employment and unemployment that is implicit in standard frictional models does not at all hold in terms of steady state outcomes in our model.

One might be tempted to summarize these findings as saying that the extension of the simple two-state model of the labor market with linear utility to a three state model that includes reasonable income and substitution effects behaves has very important implications for some key quantitative predictions regarding steady-state outcomes. However, in this sec-

tion we discuss one implicit assumption of our specification that is of particular relevance in producing these differences. In particular, by assuming an AR(1) process for the idiosyncratic shock process with normal innovations we have implicitly assumed that the invariant distribution describing the idiosyncratic productivities is continuous. As an extreme but simple alternative, we could have specified the idiosyncratic shock process so that it has support on only two points, one of which corresponds to zero productivity and the other which has some positive level of productivity. In this setting individuals will never want to work if they have zero productivity. There is one further assumption of interest: the probability of the high productivity state could be sufficiently low that individuals always want to work if they have high productivity, or it could be sufficiently high that individuals do not necessarily always want to work when productivity is high. If one were to adopt the former specification, then the model ceases to have an operative labor supply margin. And not surprisingly, this model will not have any of the labor supply effects that we have emphasized earlier. It would follow that taxes have very little effect on employment and that frictions have large effects on employment.[23] In contrast, if one adopts the latter specification then the model will behave very much like a model in which all workers are identical, and the labor supply responses will be even somewhat more powerful than in our earlier analysis.[24]

[23] These results hold for changes that are not too large. If taxes increase sufficiently, for example, then individuals might not want to work all of the time even in the high productivity state.

[24] In our benchmark model, an individual who suffers an involuntary spell of nonemployment during a high productivity period can only make up for the lost income by working in the future in some less productive states. The lower productivity of these states reduces somewhat the ability of the individual to substitute between voluntary and involuntary nonemployment spells.

An important issue is whether our criterion of asking the model to match observed labor market flows documented in Table 2 allows us to distinguish between these two different specifications. The answer is basically no, though there are some subtle issues. In particular, one can specify the two-state Markov model so as to generate each of the above properties and still have the resulting flows be similar to those that we found for our benchmark calibration. In particular, it can do an equally good job in matching the E to E, N^G to N^G, U^G to E, E to N^G and N^G to E flows as our benchmark calibration. The one subtle issue has to do with matching the U^G to N^G flow. As was also the case for our benchmark specification, this two state model cannot match the U^G to N^G flow from the data. However, the extent of mismatch is in some sense worse in the two state specification. If individuals always want to work when in the productive state, then the E to N^G flow is identical to the U^G to N^G flow. In our benchmark model the U^G to N^G flow does not match its value in the data, but at the same time the U^G to N^G flow is still roughly twice as large as the E to N^G flow. For the case in which individuals do not always want to work in the high productivity state, then the flow from E to N^G is necessarily larger than the flow from U^G to N^G, making the issue even more severe.

We conclude from this that our results are not robust to very different specifications of the innovations to the shock process, in the sense that there are specifications that could match the flows reasonably well and give very different implications for the effects of changes in frictions and changes in taxes. One reason for not considering the two state specification

in which individuals always work in the good state is that this specification has no operative labor supply margin, and one of the motivations for the development of our hybrid model is that one can easily see situations in which the labor supply decision is operative. What the above result implies however, is that one cannot dismiss the model that does not feature an operative labor supply margin purely on the basis of matching the labor market flows.

However, we believe there is alternative evidence that one can bring to bear on the issue which gives us reason to prefer the continuous distribution specification over the (two-state) discrete distribution case in which individuals always want to work if the productivity is high. If the distribution has all of its mass on two points and optimal behavior dictates wanting to always work whenever the idiosyncratic productivity is high, there is no scope for any aggregate changes to influence participation except via the idiosyncratic shock process. Such a specification seems hard to square with the fact that participation rates vary significantly across countries, and that participation rates have changed smoothly for various groups in the US over time, and often in different directions. These observations suggest to us that it is preferable to adopt a specification in which at each point in time there are some individuals for whom the participation decision has a continuous component that is affected at the margin by aggregate changes.

Perhaps a more interesting case would be one in which the idiosyncratic shocks allow for a positive mass at the zero productivity state. This would reflect the possibility that for many individuals their idiosyncratic shocks are such that working is not a possibility. This might

be relevant in thinking about certain types of health shocks, for example. An examination of Figure 1 suggests that our results are likely to be quite robust to introducing this feature. Figure 1 shows that in our benchmark specification there is no work done by those in roughly the bottom decile of the productivity distribution. Even in the case of a dramatic increase in frictions (from the benchmark value of .436 to the value of .2, resulting in an increase in the unemployment rate of roughly 19 percentage points), there is still virtually no work being done by those in the bottom decile of the distribution. It follows that adding even a sizeable mass point at the bottom of the distribution would not have any impact on the extent to which labor supply responses are able to compensate for increases in frictions.

9 Conclusion

We use an empirically reasonable three state model of the labor market to address two questions regarding the determination of steady state employment and unemployment at the aggregate level. The first concerns the effect of changes in frictions on aggregate employment. We find that changes in either the job loss rate of the job finding rate do not have large effects on aggregate employment, though they do have sizable effects on unemployment. In particular, the labor supply response present in our model greatly attenuates the employment response relative to the simplest matching model as well as common extensions. We conclude that choice plays a much larger role than chance in the determination of aggregate steady state employment. In contrast, chance plays a dominant role in the determination of aggregate steady state unemployment. The second issue is the effect of tax and transfer programs on

aggregate employment. We find that the presence of frictions has virtually no impact on the response of aggregate employment, but the model also predicts that higher taxes lead to higher unemployment and lower participation.

A key message for quantitative analysis of steady state labor market outcomes is that including an operative extensive labor supply margin consistent with neoclassical models of labor supply is important. Although frictions by themselves can exert a large direct effect on steady state employment, these effects are largely offset by labor supply responses.

While our analysis in this paper has focused solely on the determination of steady state labor market outcomes, it is obviously of interest to examine how the forces of choice and chance interact in contexts where transition dynamics are critical, such as when the economy is subjected to shocks. In particular, what are the responses of employment and unemployment when there are shocks to the level of frictions, either to the offer arrival rate or the separation rate? How does the presence of a labor supply channel affect the propagation of these shocks? While the framework that we have used in this paper is well suited to the analysis of this question, we think it is important to emphasize that there is no reason to conjecture that our results about the dampening effect of labor supply on the effects of frictions will continue to hold in the case of shocks to frictions.

References

[1] Alvarez, F., and M. Veracierto, "Labor-Market Policies in an Equilibrium Search Model," NBER Macro Annual 1999, edited by Ben Bernanke and Julio Rotemberg, 265-304.

[2] Andolfatto, D., P. Gomme, and P. Storer, "US Labour Market Policy and the Canada-US Unemployment Rate Gap," Canadian Public Policy-Analyse de Politiques 24 (1998), 210-232.

[3] Budria Rodriguez, S., J. Diaz-Gimenez, V. Quadrini and J. Rios-Rull,"Updated facts on the U.S. distributions of earnings, income, and wealth," Quarterly Review, Federal Reserve Bank of Minneapolis 2002, 2-35.

[4] Castaneda, A., J. Diaz-Jimenez, and J. Rios-Rull, "Accounting for U.S. Earnings and Wealth Inequality," Journal of Political Economy 111 (2003), 818-857.

[5] Chang, Y., and S. Kim., "From Individual to Aggregate Labor Supply: A Quantitative Analysis Based on a Heterogeneous Agent Macroeconomy," International Economic Review 47 (2006), 1-27.

[6] _____, "Heterogeneity and Aggregation: Implications for Labor Market Fluctuations," American Economic Review 97 (2007), 1939-1956.

[7] Domeij, D., and M. Floden, "The Labor Supply Elasticity and Borrowing Constraints: Why Estimates Are Biased," Review of Economic Dynamics 9 (2006), 242-262.

[8] Floden, M., and J. Linde, "Idiosyncratic Risk in the United States and Sweden: Is There a Role for Government Insurance?," Review of Economic Dynamics 4 (2001), 406-437.

[9] Garibaldi, P. and E. Wasmer, “Equilibrium Search Unemployment, Endogenous Participation, and Labor Market Flows,” Journal of European Economic Association 3 (2005), 851-882.

[10] Hall, R., “Reconciling Cyclical Movements in the Marginal Value of Time and the Marginal Product of Labor, ” Journal of Political Economy 117 (2009), 282-323.

[11] Jones, S., and C. Riddell, “The Measurement of Unemployment: An Empirical Approach,” Econometrica 67 (1999), 147-161.

[12] _____, "Unemployment and Non-Employment: Heterogeneities in Labour Market States," Review of Economics and Statistics 88 (2006), 314-323.

[13] Krusell, P., T. Mukoyama, R. Rogerson, and A. Sahin, “Aggregate Implications of Indivisible Labor, Incomplete Markets, and Labor Market Frictions," Journal of Monetary Economics 55 (2008), 961-979.

[14] _____, “A Three State Model of Worker Flows in General Equilibrium,” mimeo, 2009.

[15] Kydland, Finn, and E. Prescott,“Time to Build and Aggregate Fluctuations,” Econometrica 50 (1982), 1345-70.

[16] Krusell, P., and A. Smith Jr., “Income and Wealth Heterogeneity in the Macroeconomy,” Journal of Political Economy 106 (1998), 867-896.

[17] Ljungqvist, L., and T. Sargent, "Do Taxes Explain European Employment?: Indivisible Labour, Human Capital, Lotteries and Savings," NBER Macroeconomics Annual, 2006, 181-224.

[18] _____,"Taxes, Benefits, and Careers: Complete Versus Incomplete Markets," Journal of Monetary Economics 55 (2008), 98-125.

[19] Low, H., "Self Insurance in a Life Cycle Model of Labor Supply and Saving," Review of Economic Dynamics 8 (2005), 945-975.

[20] Low, H., C. Meghir, and L. Pistaferri, "Employment Risk and Wage Risk over the Life Cycle," forthcoming, American Economic Review, 2010.

[21] McDaniel, C., "Effective Tax Rates for 15 OECD Countries: 1950-2003," mimeo Arizona State University, 2006.

[22] Mendoza, E., A. Razin, and L. Tesar, "Effective Tax Rates in Macroeconomics: Cross-Country Estimates of Tax Rates on Factor Incomes and Consumption," Journal of Monetary Economics 34 (1994), 297-323.

[23] Merz, M.,"Search in the Labor Market and the Real Business Cycle," Journal of Monetary Economics 36 (1995), pp. 269–300.

[24] Mortensen, D. and C. Pissarides,"Job Creation and Job Destruction in the Theory of Unemployment," Review of Economic Studies 61 (1994), pp. 397–415.

[25] Pijoan-Mas, J., "Precautionary Savings or Working Longer Hours," Review of Economic Dynamics 9 (2006), 326-352.

[26] Pissarides, C., "Short-run Equilibrium Dynamics of Unemployment, Vacancies, and Real Wages," American Economic Review, 75 (1985), pp. 676–90.

[27] _____, Equilibrium Unemployment Theory (2nd edition), MIT Press, Cambridge, MA, 2000.

[28] Prescott, E., "Why Do Americans Work So Much More than Europeans?," Quarterly Review of the Federal Reserve Bank of Minneapolis, July 2004, 2-13.

[29] Tauchen, G., "Finite State Markov-chain Approximations to Univariate and Vector Autoregressions," Economics Letters 20 (1986), pp. 177–181.