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The (Un)importance of Unemployment Fluctuations for Welfare *

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Abstract

This paper develops a real business cycle model with labor market search and matching frictions, which endogenously links both the cyclical fluctuations and the mean level of unemployment to the aggregate business cycle risk. The key result of the paper is that business cycles are costly for all consumers, regardless of their wealth, yet that unemployment fluctuations themselves are not the source of these costs. Rather fluctuations over the cycle induce higher average unemployment rates as employment is non-linear in job-finding rates and past unemployment. We first show this result analytically in special cases. We then calibrate a general equilibrium model with risk-averse asset-holding and liquidity-constrained workers to US data. Also under these more general circumstances, business cycles mean higher unemployment for all workers. The ensuing cost of cycles rise further for liquidity-constrained agents when replacement rates are lower or when workers' skills depend on the length of (un)employment spells.

JEL Classification System: E32,E24,J64

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The views expressed in this paper are those of the authors. They do not necessarily coincide with the views of the Federal Reserve Bank of Philadelphia or the Federal Reserve System. This paper is available free of charge at www.philadelphiafed.org/research-and-data/publications/working-papers/.

1 Introduction

Most often the costs of business cycles are computed abstracting from effects on mean employment. This typically leads to tiny estimates of the costs of cyclical fluctuations; see Lucas (2003). In contrast, the current paper points out that models with labor market search and matching frictions imply an endogenous link between the cycle and *both* mean unemployment risk and fluctuations of that risk. In the model unemployment is linked non-linearly to past unemployment and the job-finding rate. So when calibrating the Mortensen and Pissarides (1994) model to match business cycle fluctuations, we find notably higher average unemployment rates in the stochastic steady state than in the non-stochastic steady state. These effects on the means render economic volatility costly, while the mere fluctuation of unemployment about this mean is not,¹ rationalizing why economic volatility ranks so high on the public’s agenda.²

In this paper, we present a real business cycle model with Mortensen and Pissarides (1994) search and matching frictions in the labor market. Following influential papers by Shimer (2005) and Hall (2005), the implications of this model for unemployment fluctuations have recently received considerable interest. Yet the model also holds implications for mean unemployment rates and the costs of business cycles. Our model features two types of agents: a group that is liquidity-constrained and another group that can self-insure against unemployment fluctuations.³ The two-group setup serves as a robustness check, since many papers have found that the cycle affects differently workers who are liquidity-constrained and workers who have savings; see, e.g., Krusell and Smith (1999). We calibrate the model to US data and compute the costs of business cycles for different versions of the model with increasing degrees of complexity. We start with a version in which skills are homogeneous. We then allow for an interaction of skills with the lengths of unemployment and employment spells in order to accommodate the long-term earnings losses of displaced workers that have been well-documented, e.g., Jacobson, LaLonde, and Sullivan

¹ Following Krusell and Smith (1999), most papers apply the so-called “integration principle.” It states that eliminating business cycles means replacing all business cycle-dependent risk by its expected value conditional on idiosyncratic states; see, e.g., Krebs (2007). In our paper, instead, there are mean effects. So the integration principle typically does not hold.

² Seventy percent of the respondents in Shiller’s (1997) survey, economists and laymen alike, say that preventing recessions is important. More than 80% of these agree that smoothing out both recessions and booms is preferable to having a business cycle. Wolfers (2003) uses surveys on subjective well-being. He finds that eliminating unemployment volatility would raise well-being by an amount roughly equal to that from lowering the average level of unemployment by a quarter of a percentage point.

³ In the terminology of Mankiw (2000), these groups are modeled as “savers” and “spenders,” with no transition between the groups over time. The asset-holding workers live in large “families” following den Haan, Ramey, and Watson (2000). The liquidity-constrained live on their own.

(1993). In both cases, the mean effects are at the heart of the welfare costs that we find. The business cycle induces higher mean unemployment rates, and lower average skills.

The literature typically has taken a stand on whether stabilization merely reduces the correlation across workers in the unemployment and income risk that they face, or whether stabilization would also affect the average risks that workers face. In the former case gains from eliminating the business cycle can arise only through equilibrium effects on prices, while in the latter stabilization can directly reduce the risks that individuals in the economy face; see Atkeson and Phelan (1994). In the current paper, we take an agnostic view – and let the model decide. We find that it falls into the second category.

Key to the welfare costs of business cycles that we find in this paper is the second moment of job-finding rates. Job-finding rates need to be volatile enough to render unemployment as volatile as in the data. Different mechanisms by which unemployment fluctuations are induced imply a different degree of insurance provided to the worker. The setup in Hagedorn and Manovskii (2008), for example, relies on a generous replacement rate to achieve a small enough match surplus, which in turn allows the model to generate the right degree of unemployment volatility. The generous replacement rate, however, leaves a worker almost indifferent between unemployment and market work merely by assumption – with consequences for the ensuing costs of business cycles. Alternatively, Hall and Milgrom (2008) have proposed a sequential bargaining game that can be calibrated to generate the same unemployment fluctuations as in the data and that does not rely on such a small match surplus. Key is that the worker’s bargaining position is not directly related to income/consumption streams when unemployed. The welfare costs in this paper depend on the replacement rate. Relying on the latter two papers’ intuition and the calibration by Hagedorn and Manovskii (2008) allows us to trace out the costs of business cycles for alternative sizes of the outside option while still retaining the cyclical properties of the model.⁴ We view this as important since the implicit replacement income when a worker is unemployed is difficult to calibrate precisely.

We find that workers who have no means to save and self-insure and who obtain, say, only as little as 10% of their former wage income as replacement income when unemployed would be willing to give up around 1.2% of their steady-state consumption to avoid the business cycle. Most of these costs are due to an increase in average unemployment. For replacement rates

⁴ Mortensen and Nagypal (2007) provide a recent overview of the literature that followed Shimer’s (2005) observation that the standard Mortensen-Pissarides framework in its standard calibration would not match labor market fluctuations.

of 40%, welfare costs fall to about 0.35% of steady-state consumption for liquidity-constrained workers.⁵ This is slightly below the costs that the well-insured family has, confirming the result in Krusell and Smith (1999) that business cycles can be more costly for capital owners than for liquidity-constrained agents. Most important, however, the higher unemployment risk affects all workers. Workers with asset holdings are affected two-fold. On the one hand, they also have higher unemployment than in the steady state, and on the other hand, lower employment means lower returns to their capital.

We then extend the model to account for the fact that displacement can cause notable earnings losses for workers even several years after they have been displaced, and that these losses are higher in recessions; see, e.g., Jacobson, LaLonde, and Sullivan (1993). Krebs (2007), assuming an exogenous process for these earnings losses, shows that this observation can lead to considerable costs of business cycles. We take up this finding and allow for two types of skills: good and bad. In the model it takes work experience to acquire good skills, and these skills are more likely to be lost when workers become unemployed. Importantly, in our modeling this skill loss is more likely the longer the unemployment spell is, which means that there is an interaction of skill losses and the cycle. Skill transitions exacerbate the welfare costs of business cycles caused by higher mean unemployment.

Higher unemployment rates imply longer unemployment durations, which in turn mean that workers are more likely to lose their skills off-the-job (and less likely to gain skills through long employment spells). This means that besides employment the mean level of skills is also negatively affected: At a relatively low replacement rate of 10%, liquidity-constrained workers would be willing to pay 2.20% (relative to 1.2% without skill losses) of consumption to eliminate the cycle. And even with a 40% replacement income their cost of business cycles is 1.3% – more than three times as much as in the absence of skill transitions. Interestingly, our results indicate that the mean effects on the skill distribution (and welfare costs) are considerably larger when skills are worker-specific (so workers lose skills slowly when unemployed) rather than firm-specific (they lose the skills immediately).

⁵ As these results show, there is a negative relationship between the costs of business cycles for the liquidity-constrained workers and the replacement rate. In the model, higher benefits do not provide better insurance against *cyclical* fluctuations in idiosyncratic risk for the liquidity-constrained worker, however. Rather the association stems from the fact that higher benefits – if paid largely by capital-holders – insure liquidity-constrained workers against an increase in the *average* incidence of unemployment.

1.1 Relation to the literature

Krusell and Smith (1999) highlight that the costs of business cycles vary with employment and wealth status. Unemployed and liquidity-constrained workers face higher costs of business cycles. For log-utility, they find that these costs can run up to 3.6% of consumption. Mukoyama and Şahin (2006) extend this analysis, allowing for two skill groups. In their model, unskilled workers are not only subject to a higher mean level of unemployment than skilled workers, but they also hold less wealth to smooth consumption fluctuations. Welfare costs of business cycles are about eight times as high for the average unskilled worker as for skilled workers. The share of agents in the two skill groups does not vary with the cycle. In our paper, in contrast, the business cycle can affect the composition and the mean level of skills. Our papers also differ in that in our model there is no transition between the liquidity-constrained and unconstrained groups.⁶

Krebs (2003) assumes, and similarly Storesletten, Telmer, and Yaron (2001), that the cross-sectional variation of idiosyncratic human capital risk increases in recessions and shrinks in booms for all workers. Eliminating business cycles eliminates this pattern. Both papers find considerable costs of business cycles. Krebs (2007) in turn focuses on the welfare costs of business cycles when displacement causes long-term earnings losses, and when these losses are bigger in recessions than in booms, finding a cost of that component of 0.5% of consumption (for log-utility). In the current paper, we also allow for cyclical fluctuations in long-run earnings losses. Yet, unlike Krebs, we do not look at a mean-preserving spread of the risk. In our formulation earnings losses result from a loss of skills off-the-job. Yet while average earnings on the job are lower and earnings losses higher in a recession, part of the costs are offset in booms. The reason is that booms make it easier for lower-skilled workers to achieve sufficient consecutive work experience to move to a higher skill level. Eliminating the cycle eliminates both the losses and the gains. Thus, in our paper the mere fact that there is co-movement of earnings losses with the cycle does not generate costly business cycles. Rather the costs originate in a higher mean level of unemployment and a lower mean level of skills. Beaudry and Pages (2001) analyze the welfare costs of business cycles when workers have no incentive to save and when the contractual structure in the labor market insures existing workers against wage cuts, while workers who are

⁶ This has two countervailing effects on the size of the welfare costs that we measure. The liquidity-constrained agents in our model economy are much more severely constrained. While this should raise our estimates of the welfare costs, we also compare this to a non-stochastic steady state in which the same workers remain severely constrained and occasionally suffer from unemployment, which works in the opposite direction.

laid off in a recession enter the labor market at a lower wage level. When we interact the business cycle with skill transitions, in our paper, too, wages of re-entrants into the labor market are persistently lower in recessions than in booms. This, however, is due to a loss of skills off-the-job, and not merely to contractual reasons.⁷

In the aforementioned papers, the link between idiosyncratic unemployment and earnings risk and aggregate risk is imposed exogenously. In a paper closely related to ours, Costain and Reiter (2005) instead construct a heterogeneous agent economy with search and matching frictions in the labor market. They find that cycles impose an average cost of 0.27%, very similar to our results for the average worker when we abstract from an interaction of the the cycle with skills. Shifts in mean unemployment rates are important in their paper as well as in ours. We discuss these mean effects extensively and distinguish them from the effects coming from unemployment volatility. Also, we assess the interaction of the business cycle with the skill distribution, which amplifies the welfare costs of business cycles particularly for the constrained agents.⁸ Finally, in independent work, in a very recent paper Hairault, Langot, and Osotimehin (2008) also exploit the non-linearity of the job-flow equation in matching models. They focus on risk-neutral workers and constant wages, in which case – giving equal weight to vacancies and unemployment in the matching function – job-finding rates are linear in technology and unemployment rises unambiguously. This is a special case of our model, as we show in the appendix. More generally, however, mean job-finding rates will also be affected by the cycle, depending on the degree of risk-aversion and the degree of self-insurance against fluctuations. We therefore calibrate a model with risk-averse consumers, capital accumulation and different amounts of asset holdings. In this model, mean job-finding rates increase but nevertheless mean unemployment rises above steady state, rendering cycles costly. A further element that distinguishes our paper from Hairault, Langot, and Osotimehin (2008) is that we assess the interaction of higher mean unemployment with long-term earnings losses, which can exacerbate the costs of business cycles.

One of the few other papers in the literature that emphasizes that mean effects can generate costly business cycles is Barlevy (2004). In an economy with endogenous growth and decreasing

⁷ For log-utility, Beaudry and Pages (2001) find welfare costs of about 1.4% of consumption. They also assess the dependence of the welfare costs of business cycles on the replacement rate of unemployment insurance, finding that the welfare costs of business cycles are 25% (not pp.) higher in the absence of unemployment benefits.

⁸ An interesting result in Costain and Reiter (2005), which we do not assess here, is that fiscal policy in their model can reduce the costs of the cycle through cyclical taxation and counter-cyclical deficits.

returns to investment, he points out that eliminating cycles increases average growth rates. This growth effect renders cycles costly while consumption volatility per se is not. Mean effects of business cycles are also widespread, but less discussed, in New Keynesian business cycle models in which real and nominal frictions imply that fluctuations induce an inefficient utilization of resources; see, e.g., Levin, Onatski, Williams, and Williams (2005).⁹

Barlevy (2005) provides a broader overview of the literature on the welfare costs of business cycles, concluding that business cycles are likely costly – as we do. Lucas’ (2003) survey touches only marginally on mean effects and arrives at the opposite conclusion.

The remainder of the paper is organized as follows. In our model, mean effects are key for the welfare costs of business cycles. To prepare the ground, Section 2 dissects these in a simplified setup. Section 3 describes our real business cycle (RBC) model. Section 4 discusses the calibration of the model to US data. Section 5 presents estimates of the welfare costs of business cycles for different replacement rates and different scenarios for the co-movement of skills with (un)employment. A final section concludes. The Appendix presents further details on computation of the welfare costs, the calibration for the respective cases, and intuition for the mean effects in our RBC economy.

2 Mean effects on skills and employment in a simple framework

We start with a simplified framework, abstracting from capital accumulation and saving, from fluctuations in wages and hours worked on the intensive margin, and from wage bargaining. The simplified model illustrates that in standard labor market models stabilization can directly reduce the average risk a worker faces.¹⁰ The consumer’s utility is given by

$$E_t \left\{ \sum_{j=0}^{\infty} \beta^j u(c_{i,t+j}) \right\},$$

where $\beta \in (0, 1)$ is the time-discount factor, E_t marks expectations conditional on period t information, and

$$u(c_t) = \begin{cases} \log(c_t) & \text{if } \sigma = 1. \\ \frac{c_t^{1-\sigma}}{1-\sigma} & \text{if } \sigma \geq 0, \sigma \neq 1. \end{cases}$$

⁹ Our results carry over to a New Keynesian setting. An earlier working paper version of this paper assessed the welfare costs of business cycles in an estimated New Keynesian model for the US.

¹⁰ The full model in Section 3 provides an endogenous link between mean employment risk and the cycle.

The worker is liquidity-constrained and consumes his earnings when employed, w ,¹¹ and unemployment insurance benefits, I , when unemployed:

$$c_{i,t} = \begin{cases} w & \text{if employed with good skills,} \\ I & \text{if unemployed.} \end{cases}$$

Employment, e_t , evolves according to

$$e_t = (1 - \vartheta)e_{t-1} + s_{t-1}u_{t-1}. \quad (1)$$

At the end of period t , employed workers will be separated from their jobs with probability ϑ while unemployed workers, of which there is a mass $u_t = 1 - e_t$, are matched with a firm with probability s_t . New matches are effective from $t + 1$ onward. It is important to note that unemployment and the job-finding rate enter non-linearly in (1). As a result, we have

Proposition 1. *Average unemployment rates will exceed those in steady state¹² if (i) average job-finding rates do not exceed those in steady state, $E\{s_t\} \leq s$, and if (ii) job-finding rates and unemployment rates are non-positively correlated, $Cov(u_t, s_t) \leq 0$, with at least one of the inequalities holding strictly.¹³*

If above conditions are satisfied, the rise in average unemployment is the more pronounced, the more job-finding rates fluctuate with the cycle. The economics is simple. Let us focus on the case that $E\{s_t\} = s$. A negative correlation of job-finding rates and unemployment, which is at the heart of models of equilibrium unemployment, means that unemployed workers are more

¹¹ As remarked by Krusell and Smith (1999), among others, having wages co-move with the cycle would lead to slightly higher average earnings, since workers tend to be employed precisely when wages are high. Mean effects on employment associated with fluctuations would easily outweigh the gains, however. We do not report results here for brevity, but they are available upon request.

¹² Here as in the following we will refer to the non-stochastic steady state, i.e., the steady state in the absence of business cycle fluctuations, as the “steady state.”

¹³ Proof: using the stationarity of s_t and u_t , equation (1) implies

$$\vartheta E\{1 - u_t\} = E\{s_t u_t\} = COV(s_t, u_t) + E\{s_t\} E\{u_t\}.$$

Deducting the steady-state version of (1) on both sides of the above, we have that

$$-\vartheta [E\{u_t\} - u] = COV(s_t, u_t) + E\{s_t\} E\{u_t\} - su,$$

or equivalently

$$-\vartheta [E\{u_t\} - u] = COV(s_t, u_t) + [E\{s_t\} - s]E\{u_t\} + s[E\{u_t\} - u],$$

so

$$E\{u_t\} - u = -\frac{1}{\vartheta + s} (COV(s_t, u_t) + [E\{s_t\} - s]E\{u_t\}),$$

from which the proposition follows.

likely to find a job in a boom, when there are fewer unemployed workers to start with, than in a recession, when many workers are unemployed. As a result, average unemployment rises.¹⁴

Technology evolves according to

$$A_t - A = \rho_A(A_{t-1} - A) + \epsilon_t^A, \quad (2)$$

where $\rho \in [0, 1)$ and $\epsilon_t^A \stackrel{iid}{\sim} N(0, \sigma_A^2)$. Removing business cycles in this paper means reducing σ_A^2 to zero.¹⁵ Variables without a time index refer to values in steady state. In one of the specifications, we also allow for skill depreciation when unemployed, but abstract from introducing the notation here for brevity.

Assumptions about job-finding and unemployment

Unemployment will be endogenized in the model shown in Section 3. For now, we examine two different setups regarding the behavior of unemployment over the business cycle. In the first setup,

$$u_t = u - \xi_u(A_{t-1} - 1), \quad \xi_u \geq 0, \quad (3)$$

so $E\{u_t\} = u$. If $\xi_u > 0$, the job-finding rate, denoted s_t , adjusts endogenously to ensure that (1) holds. In the alternative setup, the separation rate follows a specified law of motion and unemployment responds endogenously according to (1).¹⁶

$$s_t = s + \xi_s(A_t - 1), \quad \xi_s \geq 0. \quad (4)$$

Note that the mean job-finding rate is as high as in the steady state, but that mean unemployment can be affected by the business cycle. Indeed, for the latter case up to second order the mean unemployment rate will be given by

$$E\{u_t\} - u = \frac{u}{\vartheta + s} \frac{\xi_s^2}{1 - (1 - \vartheta - s)\rho} \frac{\rho}{1 - \rho^2} \sigma_A^2. \quad (5)$$

¹⁴ While labor market models will generate the empirical fact that $Cov(u_t, s_t) < 0$, the condition $E\{s_t\} \leq 0$ holds less generally. $E\{s_t\} = 0$ if mean wages are unaffected by the business cycle and workers are risk-neutral, as is the case in special versions of the basic Mortensen-Pissarides model; see Appendix B.1.

¹⁵ We formulate technology as an AR(1) in levels rather than in logs, as is standard. This way, by eliminating the business cycle we do not change the mean of technology. Given the calibration of ρ and σ_A , technology becoming negative is almost a zero probability event. Results, quantitatively, are barely affected by this choice.

¹⁶ Hall (2005) regards variations in the separation rate of little importance for explaining unemployment fluctuations, a view that has been rejected recently by Fujita and Ramey (2007). We have conducted sensitivity analysis with counter-cyclical separation rates. If only separation rates fluctuate, they decrease average unemployment, due to the concavity of unemployment and separation rates in (1). When both separation and job-finding rates vary, however, the costs of cycles are slightly amplified relative to the case that we assess. The reason is that workers then would be laid off precisely when it is difficult to find a new job.

The first term on the right-hand side shows that the change in mean unemployment rates depends on the level of unemployment. The second term illustrates that the mean effect is the stronger the more job-finding rates co-move with the cycle, i.e., the larger ξ_s . The last term illustrates that the mean effects will be the stronger the more persistent and the more volatile technology is.¹⁷

More generally, however, the sign of $E\{s_t\} - s$ would be ambiguous; in particular, if the discount kernel is endogenous, workers are risk-averse, and/or the wage-bargaining process results in a non-linear dependence of wages on productivity. We therefore resort to a general equilibrium model with risk-averse workers in Section 3 and use numerical methods to analyze the welfare costs. Before doing so, however, we illustrate the welfare costs with the above simple examples.

2.1 Higher mean unemployment

The welfare costs of business cycles are the percentage share of steady-state consumption that consumers would be willing to forgo if business cycle fluctuations would be eliminated; see Appendix A for details.

Most of the literature assumes that business cycles do not affect mean unemployment risk.¹⁸ In line with this, a black solid line in Figure 1 reports the welfare costs of business cycles against the replacement rate when unemployment fluctuates according to (3).¹⁹ Even though workers are liquidity-constrained, regardless of the level of benefits there are no welfare costs of business cycles. Mere unemployment fluctuations shift states of unemployment over time with no effect on mean unemployment (by assumption) and the expected discounted stream of utility (as a result); see Atkeson and Phelan (1994) and Krusell and Smith (1999).²⁰ Even if workers had higher unemployment risk to start with, as assumed by Mukoyama and Şahin (2006), business cycles would not be costly.

In contrast, when the job-finding rate fluctuates according to (4) (see the black squares), mean

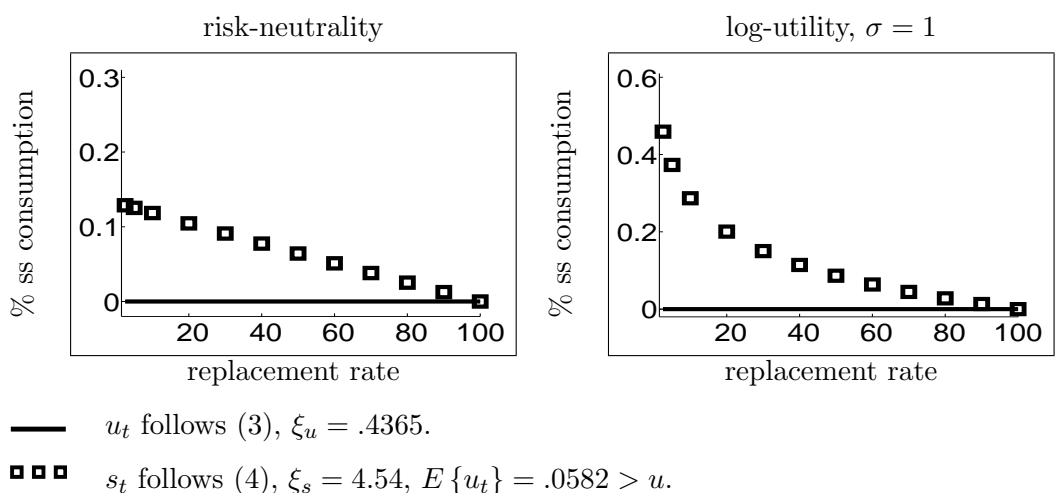
¹⁷ The proof is contained in Proposition 2, see Appendix B.2.

¹⁸ See, e.g., Atkeson and Phelan (1994), Krusell and Smith (1999) and Krebs (2007). Some counterexamples are listed in Barlevy (2005).

¹⁹ One period in the model is one month. The parameters we choose are in line with the more detailed calibration described in Section 4: $\beta = .997$, $\rho_A = .983$, $\sigma_A = .00257$. We normalize $A = 1$. The steady-state separation rate is set to $\vartheta = .024\%$ per month. The steady-state unemployment rate is $u = .057$, and the steady-state job-finding rate is $s = .4$ per month. When positive, we set $\xi_s = 4.54$ and $\xi_u = .4365$. These values replicate the standard deviation of either the job-finding rate or the unemployment rate, respectively.

²⁰ This is not to say that unemployment insurance would not affect welfare, but only that business cycles do not affect their role.

Figure 1: Welfare costs of business cycles – unemployment fluctuations



Notes: The panels show the welfare costs of business cycles (in percent of steady-state consumption) for alternative replacement rates of unemployment insurance (x-axis). From left to right: linear utility (risk-neutrality, $\sigma = 0$) and log-utility ($\sigma = 1$). A black solid line shows the case in which unemployment fluctuates over the cycle, following (3). Black squares show the case in which the job-finding rate follows (4). Average unemployment is 2.18% above steady state (corresponding to 0.12 percentage point).

unemployment exceeds the steady-state level by 0.12 percentage point, as a direct result of the non-linearity underlying the employment flow equation (1). The costs of business cycles exceed Lucas' (1987) estimates by an order of magnitude (see the black squares). In this context, higher unemployment benefits reduce the welfare costs of business cycles as they insure against the rise in *average* unemployment risk. When the replacement rate is 100%, average income when employed is the same as when unemployed and welfare costs of business cycles are nil again.²¹

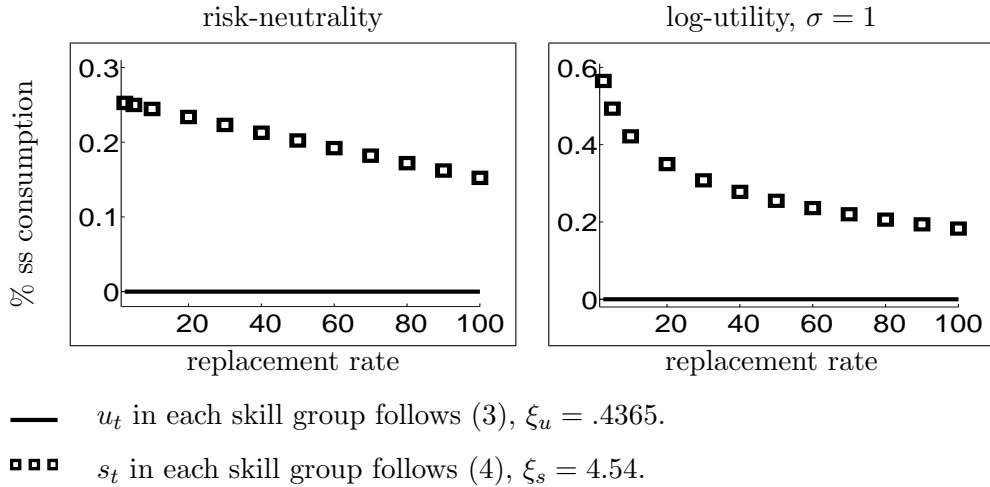
2.2 Higher mean unemployment and lower average skills

In addition to the framework described above, now we further assume that the workers' skills depend on their employment. For the sake of brevity, the details are postponed to Section 3. In brief, we assume that workers can have good skills (productivity 1.3) or bad skills (productivity 0.7). When employed, workers with bad skills on average need 48 months to acquire good skills. They never lose these skills if they remain employed. Unemployed workers with good skills lose these with a 10% probability in each month of unemployment. Unemployed workers cannot

²¹ We assume that replacement income is financed exogenously or composed of home production.

move from bad to good skills. This implies that unemployment spells are associated with longer-term earnings losses, and that on average losses are larger in recessions when the duration of unemployment tends to be longer. When unemployment rates in the two skill groups vary with

Figure 2: Costs of cycles – unemployment fluctuations and skill transition



Notes: As in Figure 1, but with skill transitions. The panels show the welfare costs of business cycles (in percent of steady-state consumption) for alternative replacement rates of unemployment insurance (x-axis). Left: linear utility (risk-neutrality), right: log-utility ($\sigma = 1$). The black solid line shows the case in which unemployment in each of the skill groups fluctuates over the cycle, following (3). Black squares mark the case in which the job-finding rate in each skill group follows (4). Mean unemployment rises by 1.8% above the non-stochastic steady state (so the mean unemployment rate rises by 0.1 percentage point). The share of workers with good skills on average falls by .38% (0.29 percentage point).

the business cycle, but mean unemployment in each of the skill groups is not affected, there are no welfare costs of business cycles; see the black solid line in Figure 2. This is the case even though recessions bring about higher longer-run earnings losses than booms, as in Krebs (2007) and even though – due to the possible skill losses – the average worker that suffered displacement will have a lower entry wage, as in Beaudry and Pages (2001).²² Eliminating the business cycle in this scenario would eliminate the correlation of unemployment across individuals but it would not affect the average risk of being caught in each of the four employment-skill states; see Atkeson and Phelan (1994).²³

²² In Krebs (2007) earnings losses upon displacement are larger in recessions than in booms. However, the displacement cost shock has mean zero. He increases the standard deviation of idiosyncratic risk in a recession. In our example, in contrast, the mean costs fluctuate. In Beaudry and Pages (2001), wages while employed are downward-rigid but upward-mobile. Wages ratchet up in booms to prevent workers from defecting to other employers. Costs of business cycles arise independent of any effects on skills, because entry-level wages are low in recessions, and lower than wages paid to workers in ongoing contracts, thereby increasing the earnings risk. In this paper, we do not allow for such contractual effects.

To the contrary, when job-finding rates in the two skill groups are on average as large as in steady state, but vary with the cycle, mean employment again is negatively affected (see the black squares). As can be seen, skill transitions further amplify the welfare effects shown previously in Figure 1. A higher level of average unemployment implies longer average unemployment durations. These in turn mean that more workers will lose their skills during an unemployment spell.²⁴ In the example shown, the share of lower-skilled workers in the population rises by about .25 percentage points above the non-stochastic steady state. Also the welfare costs do not fall to zero as benefits rise. Benefits can insure workers against the mean increase in overall unemployment, but not against the differential impact on the two skill groups.

3 The full model

Evidently, the precise interplay of job-finding, unemployment and aggregate cyclical risk is important for the costs of business cycles. This section extends the previous analysis to a real business cycle model with Mortensen and Pissarides (1994) search and matching frictions that generates this link endogenously. Workers fall into two categories, the liquidity-constrained workers analyzed above, and workers who can save into stocks and physical capital. For the latter we entertain a family structure as in den Haan, Ramey, and Watson (2000), which pools their assets and incomes. The two classes of workers are indexed by superscripts ^{liq} and ^{fam}, respectively. Workers do not transit between the groups.

3.1 Individual-specific productivity

There are two components to an individual's productivity: an aggregate component, A_t , and an idiosyncratic component. Workers can either have good or bad idiosyncratic productivity

²³ The average welfare costs mask heterogeneity across skill groups. Business cycles increase the probability that workers with good skills lose their skills (in a longer recession), but also raise the chances that workers with bad skills acquire good skills (in a prolonged boom). As a result, workers who already have good skills dislike business cycle fluctuations, while workers with bad skills like them (their skills cannot become worse than bad).

²⁴ Throughout this paper separation is exogenous. Nevertheless, in this example, inflow rates into lower-skilled unemployment rise in recessions since some unemployed workers with previously good skills lose them. As a result, when outflow rates are particularly low in recessions and are kept constant on average, once there are cyclical fluctuations, the incidence of being low-skilled rises by a disproportionate amount.

(skills), labeled by g and b . An individual i 's productivity is given by

$$A_{i,t} = \begin{cases} A_{g,t} := \epsilon_g A_t, & \text{if worker } i \text{ has good skills, } g, \\ A_{b,t} := \epsilon_b A_t, & \text{if worker } i \text{ has bad skills, } b, \end{cases}$$

where $\epsilon_g = 1 + \omega$ and $\epsilon_b = 1 - \omega$, $\omega \geq 0$. Individual productivity is determined at the end of each period. The aggregate component of productivity evolves according to (2). We denote the conditional probability that a worker will move from good to bad productivity when employed by $p^e(g, b)$ and when unemployed by $p^u(g, b)$. The transition matrix between individual productivity states is

$$P^e = \begin{bmatrix} p^e(g, g) & p^e(g, b) \\ p^e(b, g) & p^e(b, b) \end{bmatrix} \text{ when employed, and } P^u = \begin{bmatrix} p^u(g, g) & p^u(g, b) \\ p^u(b, g) & p^u(b, b) \end{bmatrix} \text{ when not.}$$

Through the different transition probabilities, the model can capture different assumptions about the appreciation or depreciation of skills across employment states; see Section 5.1.

3.2 Preferences and consumers' constraints

Preferences of individual workers are given by

$$E_t \left\{ \sum_{s=0}^{\infty} \beta^s u(c_{i,t+s}, h_{i,t+s}) \right\}.$$

Here, $c_{i,t}$ denotes consumption of consumer i , and $h_{i,t}$ denotes hours worked.²⁵ Period utility is given by

$$u(c_{i,t}, h_{i,t}) = \begin{cases} \frac{c_{i,t}^{1-\sigma}}{1-\sigma} - \kappa_h \frac{h_{i,t}^{1+\varphi}}{1+\varphi}, & \sigma > 0, \sigma \neq 1, \varphi > 0, \\ \log(c_{i,t}) - \kappa_h \frac{h_{i,t}^{1+\varphi}}{1+\varphi}, & \sigma = 1, \varphi > 0. \end{cases}$$

3.2.1 Families of asset-holding workers

There is a measure $\nu \in [0, 1]$ of identical families in the economy. Each family consists of a unit measure of members. In period t , a measure $e_{g,t}^{\text{fam}}$ of these are employed and have good skills and $e_{b,t}^{\text{fam}}$ are employed with bad skills. A measure $u_{g,t}^{\text{fam}}$ of family members have good skills but are unemployed. The remainder, $u_{b,t}^{\text{fam}} = 1 - e_{g,t}^{\text{fam}} - e_{b,t}^{\text{fam}} - u_{g,t}^{\text{fam}}$, are unemployed and have bad

²⁵ Hall (2007) finds that the variation in hours per employee accounts for 31.5% of the total cyclical fluctuation in labor input while the extensive margin accounts for 56.5%. A smaller remainder (11.6%), from which we abstract here, is explained by cyclical variation in the participation rate.

skills. The family collects and distributes all income, maximizing the sum of expected utilities of its individual members. As a result, the family's problem is

$$\max_{c_t^{\text{fam}}, i_t} E_t \left\{ \sum_{s=0}^{\infty} \beta^s U \left(c_{t+s}^{\text{fam}}, e_{g,t+s}^{\text{fam}}, e_{b,t+s}^{\text{fam}}, h_{g,t+s}^{\text{fam}}, h_{b,t+s}^{\text{fam}} \right) \right\},$$

where the period utility function is given by²⁶

$$U \left(c_t^{\text{fam}}, e_{g,t}^{\text{fam}}, e_{b,t}^{\text{fam}}, h_{g,t}^{\text{fam}}, h_{b,t}^{\text{fam}} \right) = \frac{(c_t^{\text{fam}})^{1-\sigma}}{1-\sigma} - e_{g,t}^{\text{fam}} \kappa_h \frac{(h_{g,t}^{\text{fam}})^{1+\varphi}}{1+\varphi} - e_{b,t}^{\text{fam}} \kappa_h \frac{(h_{b,t}^{\text{fam}})^{1+\varphi}}{1+\varphi}.$$

The family's budget constraint is given by

$$c_t^{\text{fam}} + \frac{i_t}{\nu} + t_t = e_{g,t}^{\text{fam}} w_{g,t}^{\text{fam}} h_{g,t}^{\text{fam}} + e_{b,t}^{\text{fam}} w_{b,t}^{\text{fam}} h_{b,t}^{\text{fam}} + u_{g,t}^{\text{fam}} I_g^{\text{fam}} + u_{b,t}^{\text{fam}} I_b^{\text{fam}} + \frac{r_t k_t}{\nu} + \Psi_t. \quad (6)$$

Here c_t^{fam} is per capita consumption by family members, and $\frac{i_t}{\nu}$ marks real investment per family member. t_t are lump-sum taxes per capita payable by the family. The terms $w_{g,t}^{\text{fam}} h_{g,t}^{\text{fam}}$ are the real earnings of employed household members of the respective idiosyncratic productivity. I_g^{fam} are real unemployment benefits. k_t is the amount of physical capital in the economy at the beginning of the period.²⁷ The real rental rate of capital is r_t . Ψ_t denotes income arising from the firms' profits, described below in equation (11). Capital evolves according to

$$k_{t+1} = k_t(1 - \delta) + i_t, \quad (7)$$

where $\delta \geq 0$ is the monthly rate of depreciation.

The family's first-order conditions

The family maximizes its objective by choosing investment, i_t , and consumption, c_t^{fam} , subject to (6) and (7). The investment first-order condition is

$$1 = E_t \{ \beta_{t,t+1} [(1 - \delta) + r_{t+1}] \},$$

where $\beta_{t,t+j} = \beta \frac{\lambda_{t+j}^{\text{fam}}}{\lambda_t^{\text{fam}}}$ is the stochastic discount factor, and $\lambda_t^{\text{fam}} = (c_t^{\text{fam}})^{-\sigma}$ is the family's marginal utility of consumption. The optimal consumption plan satisfies transversality condition

$$\lim_{j \rightarrow \infty} E_t \{ \beta_{t,t+j} k_{t+j} \} = 0, \quad \forall t.$$

²⁶ Due to additive separability of consumption and leisure the family optimally allocates the same consumption to all members. The notation also uses that we will later on focus on a symmetric equilibrium in which all employed family members of a respective type work exactly the same hours and earn the same wage.

²⁷ So $\frac{k_t}{\nu}$ is the capital holding per member of the family.

3.2.2 Liquidity-constrained consumers

The remaining measure $1 - \nu$ of consumers are liquidity-constrained. In period t , a share $e_{g,t}^{\text{liq}}$ of these are employed and have good skills while $e_{b,t}^{\text{liq}}$ are employed with bad skills. A share $u_{g,t}^{\text{liq}}$ of liquidity-constrained workers have good skills but are unemployed. The remaining share, $u_{b,t}^{\text{liq}} = 1 - e_{g,t}^{\text{liq}} - e_{b,t}^{\text{liq}} - u_{g,t}^{\text{liq}}$, are unemployed and have bad skills. Liquidity-constrained consumers consume their entire resources:²⁸

$$c_{i,t}^{\text{liq}} = \begin{cases} c_{e,g,t}^{\text{liq}} = w_{g,t}^{\text{liq}} h_{e,g,t}^{\text{liq}} & \text{if employed and of good productivity,} \\ c_{e,b,t}^{\text{liq}} = w_{b,t}^{\text{liq}} h_{e,b,t}^{\text{liq}} & \text{if employed and of bad productivity,} \\ c_{u,g,t}^{\text{liq}} = I_g^{\text{liq}} & \text{if unemployed and of good productivity,} \\ c_{u,b,t}^{\text{liq}} = I_b^{\text{liq}} & \text{if unemployed and of bad productivity.} \end{cases}$$

I_i^{liq} are real benefits paid to unemployed liquidity-constrained workers.

3.3 Firms

There are two sectors of production. One sector produces a homogeneous intermediate labor good. A final good sector uses the labor good and physical capital to produce a homogeneous consumption/investment good, y_t .

3.3.1 Final goods

The representative firm in the final good sector produces output according to

$$y_t = k_t^\alpha l_t^{1-\alpha}, \quad \alpha \in (0, 1).$$

The final good firm can rent capital and the labor good in competitive markets at rates r_t and x_t , respectively. The demand functions for capital and the labor good are, respectively,

$$k_t = \frac{\alpha}{r_t} y_t, \tag{8}$$

and

$$l_t = \frac{1 - \alpha}{x_t} y_t.$$

²⁸ We assume the absence of any opportunity to store wealth for this liquidity-constrained part of the population. This is a strong assumption. One might consider that these consumers could still save into cash or durable consumption goods. The first option, however, does not seem to be supported by micro data either; besides Gruber (2001) see Wolff (1998); and durable goods tend to be illiquid and thus cannot easily be used to smooth non-durable consumption over the business cycle.

3.3.2 Labor good firms

The one-worker labor firms produce a homogeneous labor good. Firm-worker matches inherit their productivity from the worker. Match i can produce amount $l_{i,t}$ of the labor good according to

$$l_{i,t} = A_t \epsilon_i h_{i,t},$$

where $\epsilon_i \in \{\epsilon_g, \epsilon_b\}$ depending on the type of the worker. In period t there is a mass $\nu e_{g,t}^{\text{fam}}$ of labor firms with workers who have good skills and live in a family, and a mass $\nu e_{b,t}^{\text{fam}}$ of workers who have bad skills and live in the family. There is the corresponding mass of $(1-\nu)e_{g,t}^{\text{liq}}$ and $(1-\nu)e_{b,t}^{\text{liq}}$ of workers of the two types who are liquidity-constrained. In equilibrium, labor good demand must match the labor good sector's supply. We focus on a symmetric equilibrium in which each firm-worker match with the same characteristics will have the same level of production, so

$$l_t = \nu \left(e_{g,t}^{\text{fam}} [A_t \epsilon_g h_{g,t}^{\text{fam}}] + e_{b,t}^{\text{fam}} [A_t \epsilon_b h_{b,t}^{\text{fam}}] \right) + (1-\nu) \left(e_{g,t}^{\text{liq}} [A_t \epsilon_g h_{g,t}^{\text{liq}}] + e_{b,t}^{\text{liq}} [A_t \epsilon_b h_{b,t}^{\text{liq}}] \right).$$

3.4 Labor market

The timing of the labor market is as follows. Workers who are already matched with firms bargain about wages and hours. Production takes place. Thereafter idiosyncratic transitions of productivity materialize and firms post vacancies. New matches are determined and separations occur. We work backwards and first describe separation and the bargaining. We then describe the matching process and vacancy posting decisions. In the model, there are four separate labor markets, one for each type of worker (the combinations of $(\text{fam}, \text{liq}) \times (g, b)$). For the sake of exposition, we describe all of the labor market activity for just one type of worker, a worker who has good skills and lives in the family. Unless noted otherwise, equations for the other types are entirely symmetric; i.e., they can be obtained by swapping g 's with b 's, when looking at a bad skill type, and by exchanging fam with liq , when looking at a worker who is liquidity-constrained.

3.4.1 Labor firm value and exogenous separations

Period profits from production of a labor firm are given by

$$\Psi_{g,t}^{\text{fam}} = x_t A_{g,t} h_{g,t}^{\text{fam}} - w_{g,t}^{\text{fam}} h_{g,t}^{\text{fam}}.$$

Toward the end of the period, after production has taken place and after the skill level of the match has been realized, each firm draws an exogenous separation shock, such that with

probability ϑ^{fam} the match is severed. If it survives, the match continues into the next period. Let $J_{g,t}^{\text{fam}}$ be the value of the firm in period t . This is given by:

$$\begin{aligned} J_{g,t}^{\text{fam}} &= \Psi_{g,t} \\ &\quad + p^e(g, g)(1 - \vartheta^{\text{fam}})E_t\{\beta_{t,t+1}J_{g,t+1}^{\text{fam}}\} \\ &\quad + p^e(g, b)(1 - \vartheta^{\text{fam}})E_t\{\beta_{t,t+1}J_{b,t+1}^{\text{fam}}\}. \end{aligned}$$

3.4.2 Bargaining

Firms and workers bargain about their share of the overall match surplus. In this paper, we adopt a simplified form of a bargaining mechanism analyzed by Hall and Milgrom (2008), who assume that the outside option in the bargaining process is to delay the bargaining by one period.²⁹ We assume that workers would face a constant stream of utility/income in the periods in which the bargain is delayed, labeled ‘strike’. In equilibrium, under complete information rational firms and workers would never delay the bargaining but instead they would agree on a wage immediately. A strike thus would never actually occur.

The surplus from working rather than delaying the bargaining is as follows.³⁰ When working, the worker earns wages but loses the strike payment. At the same time he suffers disutility of work. With the latter term being converted from utils to real values by dividing through the worker’s marginal utility of consumption, the worker’s surplus is

$$\Delta_{g,t}^{\text{fam}} = \left[w_{g,t}^{\text{fam}} h_{g,t}^{\text{fam}} - \text{strike}_g^{\text{fam}} - \kappa_h \frac{(h_{g,t}^{\text{fam}})^{1+\varphi}}{(1+\varphi)\lambda_{g,t}^{\text{fam}}} \right]. \quad (9)$$

For the family, $\lambda_{g,t}^{\text{fam}} = \lambda_{b,t}^{\text{fam}}$, and these in turn equal λ_t^{fam} due to perfect risk-sharing, while the two terms will generally not coincide for liquidity-constrained agents.³¹ Each period, wages and hours worked are determined by means of bargaining over the match surplus, where $\eta \in (0, 1)$ denotes the family’s bargaining power for the good skill type:

$$\max_{w_{g,t}^{\text{fam}}, h_{g,t}^{\text{fam}}} \left(\Delta_{g,t}^{\text{fam}} \right)^\eta \left(\Psi_{g,t}^{\text{fam}} \right)^{1-\eta}.$$

²⁹ They also allow for a small exogenous probability that the bargain breaks down, from which we abstract here for tractability. See Section 3.8 for further discussion.

³⁰ For workers belonging to the family, we follow den Haan, Ramey, and Watson (2000) in assuming that the family takes their labor supply decision. For these, the surplus reported is the gain of the family from having a marginal member employed rather than on strike.

³¹ $\lambda_{g,t}^{\text{liq}} = \left(c_{e,g,t}^{\text{liq}} \right)^{-\sigma}$ and $\lambda_{b,t}^{\text{liq}} = \left(c_{e,b,t}^{\text{liq}} \right)^{-\sigma}$.

The resulting first-order condition for hours worked equates the marginal rate of substitution of leisure and consumption and the marginal value product of labor,

$$\kappa_h \frac{(h_{g,t}^{\text{fam}})^\varphi}{\lambda_{g,t}^{\text{fam}}} = x_t A_{g,t}.$$

The first-order condition for wages yields the result that earnings are a convex combination of the firm's revenue and the terms determining the bargaining position (saved disutility of work plus remuneration when delaying the bargaining):

$$w_{g,t}^{\text{fam}} h_{g,t}^{\text{fam}} = \eta x_t A_{g,t} h_{g,t}^{\text{fam}} + (1 - \eta) \left[\kappa_h \frac{(h_{g,t}^{\text{fam}})^{1+\varphi}}{(1 + \varphi) \lambda_{g,t}^{\text{fam}}} + \text{strike}_g^{\text{fam}} \right]. \quad (10)$$

This wage equation resembles the standard wage equation with Nash bargaining, except for two differences. With Nash bargaining, the outside option of the worker is unemployment; therefore, typically unemployment benefits and market tightness enter the wage equation. Instead, in our wage equation, the term $\text{strike}_g^{\text{fam}}$ appears, which captures an exogenous shift in the bargaining position of the worker not related to consumption flows in equilibrium.³²

3.4.3 Matching firms with workers

The matching process takes the same form for all types. New matches arise according to

$$m_{g,t}^{\text{fam}} = \chi \left[\tilde{u}_{g,t}^{\text{fam}} \right]^\xi \left[v_{g,t}^{\text{fam}} \right]^{1-\xi}, \quad \chi > 0, \xi \in (0, 1).$$

Here $m_{g,t}^{\text{fam}}$ is the number of new matches. $\tilde{u}_{g,t}^{\text{fam}} = u_{g,t}^{\text{fam}} p^u(g, g) + u_{b,t}^{\text{fam}} p^u(b, g)$ is the share of unemployed workers in the family with good skills after new skills have been drawn. $v_{g,t}^{\text{fam}}$ is the number of vacancies corresponding to that type. With probability $q_{g,t}^{\text{fam}} = \frac{m_{g,t}^{\text{fam}}}{v_{g,t}^{\text{fam}}}$ a firm with a vacant good position finds a good worker in period t . Unemployed workers always search for a job. With probability $s_{g,t}^{\text{fam}} = \frac{m_{g,t}^{\text{fam}}}{\tilde{u}_{g,t}^{\text{fam}}}$ an unemployed worker of the respective type will find a job.

³² As before, all of the above equations hold analogously for workers with bad skills (replacing g indexes by b indexes). They also hold for liquidity-constrained workers (replacing $^{\text{fam}}$ labels by $^{\text{liq}}$), apart from the following. For the liquidity-constrained worker, instead of (9), the surplus is

$$\Delta_{g,t}^{\text{liq}} = \left[\frac{u(w_{g,t}^{\text{liq}} h_{g,t}^{\text{liq}}) - u(\text{strike}_g^{\text{liq}})}{\lambda_{g,t}^{\text{liq}}} - \kappa_h \frac{(h_{g,t}^{\text{liq}})^{1+\varphi}}{(1 + \varphi) \lambda_{g,t}^{\text{liq}}} \right].$$

The first-order condition for hours worked is unchanged, and instead of (10) the wage equation is given by

$$\eta \left[x_t A_{g,t}^{\text{liq}} h_{g,t}^{\text{liq}} - w_{g,t}^{\text{liq}} h_{g,t}^{\text{liq}} \right] = (1 - \eta) \left[\frac{u(w_{g,t}^{\text{liq}}) - u(\text{strike}_g^{\text{liq}})}{\lambda_{g,t}^{\text{liq}}} - \kappa_h \frac{(h_{g,t}^{\text{liq}})^\varphi}{(1 + \varphi) \lambda_{g,t}^{\text{liq}}} \right].$$

3.4.4 Vacancy posting

In order to stand a chance of finding a worker of a specific type, firms need to post a vacancy. As a result of free entry into the vacancy posting market, in equilibrium the cost of posting a vacancy for the respective type of worker, κ_g^{fam} , equals the discounted expected profits³³

$$\kappa_g^{\text{fam}} = q_{g,t}^{\text{fam}} E_t \left\{ \beta_{t,t+1} J_{g,t+1}^{\text{fam}} \right\},$$

where $q_{g,t}^{\text{fam}}$ is the probability of finding a worker once a vacancy has been posted.

3.4.5 Labor market flows

Employment of the good and bad skill types evolves according to

$$\begin{aligned} e_{g,t}^{\text{fam}} &= (1 - \vartheta) [e_{g,t-1}^{\text{fam}} p^e(g, g) + e_{b,t-1}^{\text{fam}} p^e(b, g)] \\ &\quad + s_{g,t-1}^{\text{fam}} [u_{g,t-1}^{\text{fam}} p^u(g, g) + u_{b,t-1}^{\text{fam}} p^u(b, g)], \\ e_{b,t}^{\text{fam}} &= (1 - \vartheta) [e_{b,t-1}^{\text{fam}} p^e(b, b) + e_{g,t-1}^{\text{fam}} p^e(g, b)] \\ &\quad + s_{b,t-1}^{\text{fam}} [u_{b,t-1}^{\text{fam}} p^u(b, b) + u_{g,t-1}^{\text{fam}} p^u(g, b)]. \end{aligned}$$

Note that current employment is equally non-linear in past unemployment and job-finding rates as in the simple model of Section 2, cp. equation (1). Unemployment evolves according to

$$\begin{aligned} u_{g,t}^{\text{fam}} &= \vartheta [e_{g,t-1}^{\text{fam}} p^e(g, g) + e_{b,t-1}^{\text{fam}} p^e(b, g)] \\ &\quad + (1 - s_{g,t-1}^{\text{fam}}) [u_{g,t-1}^{\text{fam}} p^u(g, g) + u_{b,t-1}^{\text{fam}} p^u(b, g)], \\ u_{b,t}^{\text{fam}} &= 1 - e_{g,t}^{\text{fam}} - e_{b,t}^{\text{fam}} - u_{b,t}^{\text{fam}}, \end{aligned}$$

and analogously for the liquidity-constrained workers.

3.4.6 Total profits

Total period profits (per capita of family members) that accrue to the family are given by

$$\begin{aligned} \Psi_t &= \frac{1}{\nu} \left\{ \nu \left(e_{g,t}^{\text{fam}} \Psi_{g,t}^{\text{fam}} + e_{b,t}^{\text{fam}} \Psi_{b,t}^{\text{fam}} \right) + (1 - \nu) \left(e_{g,t}^{\text{liq}} \Psi_{g,t}^{\text{liq}} + e_{b,t}^{\text{liq}} \Psi_{b,t}^{\text{liq}} \right) \right\} \\ &\quad - \frac{1}{\nu} \left\{ \nu \left(\kappa_g^{\text{fam}} v_{g,t}^{\text{fam}} + \kappa_b^{\text{fam}} v_{b,t}^{\text{fam}} \right) + (1 - \nu) \left(\kappa_g^{\text{liq}} v_{g,t}^{\text{liq}} + \kappa_b^{\text{liq}} v_{b,t}^{\text{liq}} \right) \right\}. \end{aligned} \tag{11}$$

The first row gives the period profits of all labor firms. The second row reports that the total costs for posting vacancies also need to be borne by the family.

³³ We continue to display the vacancy posting decisions only for the good type of workers who live in the family. The condition is analogous for the other types of workers.

3.5 Government

Government spending, g_t , is exogenous and follows the AR(1) process

$$g_t = \bar{g} + \rho(g_{t-1} - \bar{g}) + \epsilon_t^g, \quad \rho_g \in [0, 1].$$

\bar{g} is the long-run target for government spending, $\epsilon_t^g \stackrel{iid}{\sim} N(0, \sigma_g^2)$ is a Gaussian shock. The government's budget constraint is given by

$$\nu t_t = \nu \left(u_{g,t}^{\text{fam}} I_g^{\text{fam}} + u_{b,t}^{\text{fam}} I_b^{\text{fam}} \right) + (1 - \nu) \left(u_{g,t}^{\text{liq}} I_g^{\text{liq}} + u_{b,t}^{\text{liq}} I_b^{\text{liq}} \right) + g_t.$$

The government generates revenue from lump-sum taxes levied on the families (left), which it uses for unemployment benefits (the terms involving I) and government spending. In order to eliminate any dependence of the evolution of the economy on the precise nature of the tax rule only the (Ricardian) families/asset-holding households pay taxes. Lump-sum taxes, t_t , adjust to ensure government solvency in all states of the world.

3.6 Market clearing and equilibrium

In equilibrium, the final goods market and the labor and capital markets clear. The aggregate retail good is used for consumption by the two types of consumers, investment and government spending. Also vacancy posting activity requires resources, so output is used according to

$$y_t = c_t + \nu i_t + g_t + \nu \left(\kappa_g^{\text{fam}} v_{g,t}^{\text{fam}} + \kappa_b^{\text{fam}} v_{b,t}^{\text{fam}} \right) + (1 - \nu) \left(\kappa_g^{\text{liq}} v_{g,t}^{\text{liq}} + \kappa_b^{\text{liq}} v_{b,t}^{\text{liq}} \right),$$

where aggregate consumption demand, c_t , is given by

$$c_t := \nu c_t^{\text{fam}} + (1 - \nu) \left[e_{g,t}^{\text{liq}} c_{e,g,t}^{\text{liq}} + e_{b,t}^{\text{liq}} c_{b,g,t}^{\text{liq}} + u_{g,t}^{\text{liq}} c_{u,g,t}^{\text{liq}} + u_{b,t}^{\text{liq}} c_{u,b,t}^{\text{liq}} \right].$$

3.7 Welfare

The welfare of the family is given by

$$W_t^{\text{fam}} = \mathbf{u}(c_t^{\text{fam}}) - e_{g,t}^{\text{fam}} \kappa_h \frac{h_{g,t}^{1+\varphi}}{1+\varphi} - e_{b,t}^{\text{fam}} \kappa_h \frac{h_{b,t}^{1+\varphi}}{1+\varphi} + \beta E_t \{ W_{t+1}^{\text{fam}} \}.$$

The welfare of a liquidity-constrained worker with good skills who is employed, is

$$W_{e,g,t}^{\text{liq}} = \mathbf{u}(c_{e,g,t}^{\text{liq}}) - \kappa_h \frac{(h_{g,t}^{\text{liq}})^{1+\varphi}}{1+\varphi} + p^e(g, g) \left[\vartheta \beta E_t \{ W_{u,g,t}^{\text{liq}} \} + (1 - \vartheta) \beta E_t \{ W_{e,g,t}^{\text{liq}} \} \right] + p^e(g, b) \left[\vartheta \beta E_t \{ W_{u,b,t}^{\text{liq}} \} + (1 - \vartheta) \beta E_t \{ W_{e,b,t}^{\text{liq}} \} \right].$$

Swapping gs and bs yields the welfare of a liquidity-constrained worker with bad skills who is employed. The welfare of a liquidity-constrained worker with good skills who is unemployed is

$$\begin{aligned}
 W_{u,g,t}^{\text{liq}} = & \quad \mathbf{u}(c_{u,g,t}^{\text{liq}}) \\
 & + p^u(g, g) \left[s_{g,t}^{\text{liq}} \beta E_t \{ W_{e,g,t}^{\text{liq}} \} + (1 - s_{g,t}^{\text{liq}}) \beta E_t \{ W_{u,g,t}^{\text{liq}} \} \right] \\
 & + p^u(g, b) \left[s_{b,t}^{\text{liq}} \beta E_t \{ W_{e,b,t}^{\text{liq}} \} + (1 - s_{b,t}^{\text{liq}}) \beta E_t \{ W_{u,b,t}^{\text{liq}} \} \right].
 \end{aligned}$$

Welfare costs of business cycles are measured as discussed in Appendix A.

3.8 The bargaining position

For the calibration of the bargaining position of the worker, we follow Hagedorn and Manovskii (2008) with one important modification. For matching unemployment fluctuations, their calibration relies on a high replacement rate, $\frac{I}{w \cdot h}$. As a result, the worker would be almost indifferent between being employed and being unemployed almost by construction, with consequences for the welfare costs of business cycles. In our setup, instead, the bargaining position is determined by the value of parameter strike , which is independent of the replacement income. While we can nest the calibration of Hagedorn and Manovskii (2008) (we show results for different replacement rates in Section 5), we can also accommodate any other size of the replacement rate without affecting the positive implications of our model and, in particular, its cyclical properties.³⁴

4 Calibration of the baseline

The calibration is based on US data from 1984Q1 to 2007Q4. We use the Hodrick-Prescott filter with a conventional filter weight of 1,600 to extract the business cycle component from the quarterly data in logs. All variables are seasonally adjusted. Nominal variables are deflated by the GDP deflator. Output, consumption, investment and government spending are from the national accounts. Our measure for investment includes durable consumption. The measure for consumption is composed of consumption of non-durable goods and services. Total hours worked are average weekly hours in total private industries multiplied by employment (labor force minus

³⁴ Since business cycles in our model imply higher mean unemployment, the costs of financing benefits also increase. There are therefore some minor changes in the unemployment taxes levied on the family. To avoid this interaction, we also experimented with accounting for the replacement income as home production. Results were hardly affected. Parameter strike could be the true opportunity of a strike or could reflect the fact that the worker may be able to supplement a certain level of benefits by a positive amount of home production. Alternatively, there may also be insurance provided by the family for the liquidity-constrained worker, say, through spousal labor supply. Needless to say, neither of this is modeled here.

the number of unemployed). Our measure for total wages is compensation of employees from the national accounts. We use the civilian unemployment rate among those 16 years old and older. Vacancies are measured by the Conference Board’s index of Help-Wanted Advertising. The job-finding rate in our model is the hazard rate of transition from unemployment to employment in any given month. This time series is not readily available. We follow Shimer (2007), who proposes a measurement. These calculations also require the series of civilians unemployed for less than 5 weeks.

Table 1: Baseline calibration of the model

<u>Types and Preferences</u>			<u>Production</u>	
$1 - \nu$	.16	Gruber (2001).	A	.63 Normalize y to unity.
β	.997	Annual real rate of 4 percent.	α	.33 Conventional configuration.
φ	2.0	Domeij and Flodén (2006).	δ	.0087 Mean inv./GDP = 24%.
σ	1.0	Log utility	ω	0 No skill difference.
κ_h	36.37	Hours per worker, $h^{\text{fam}} = 1/3$.		
<u>Labor market - job finding</u>			<u>Labor market - separation</u>	
ξ	.5	Petrongolo and Pissarides (2001).	ϑ	.024 Job-finding rate of 40%.
κ^{fam}	.086	Unemployment rate, $u^{\text{fam}} = 5.7\%$.		
κ^{liq}	.161	Unemployment rate, $u^{\text{liq}} = 5.7\%$.		
χ	.34	$q^{\text{fam}} = .33$, den Haan et al. (2000).	<u>Labor market - bargaining</u>	
<u>Aggregate Shocks</u>			η	.5 Equal surplus sharing rule.
ρ_A	$.95^{1/3}$	autocorrelation tech shock	strike ^{fam}	.46 $\text{std}(\hat{u}_t)$, $\text{std}(\hat{u}_t^{\text{fam}}) = \text{std}(\hat{u}_t^{\text{liq}})$.
σ_A	.0026	targets $\text{std}(y_t)$	strike ^{liq}	.45 $\text{std}(\hat{u}_t)$, $\text{std}(\hat{u}_t^{\text{fam}}) = \text{std}(\hat{u}_t^{\text{liq}})$.
ρ_g	.922	as in data	<u>Government</u>	
σ_g	9.8e-4	as in data	\bar{g}	.19 Mean gov. spending/GDP.

Notes: This table presents the parameterization for the baseline version of the model and the corresponding targets. This version does not have any skill heterogeneity. This means, among other things, that the skill transition probabilities, such as $p^e(g, b)$, are irrelevant.

We seek to calibrate parameters for the workers in the family as much in line with those for the liquidity-constrained workers as possible. Table 1 summarizes our parameter choices and presents the targets that we match. Table 2 reports the resulting steady state. Table 3 compares second moments in the model to second moments in the data. Turning first to the parameters, the size of the liquidity-constrained group of workers is set to $1 - \nu = 0.16$. This follows Gruber (2001) who estimates that at least 16% of the US population cannot cover the consumption costs of an average unemployment spell.³⁵ Workers in the family and liquidity-constrained workers

³⁵ This number therefore represents a lower bound for the share of liquidity-constrained workers since it uses total wealth as the relevant pool of assets. When Gruber (2001) takes only liquid assets into account the share rises.

have the same preferences. The time discount factor targets a real rate of 4%, so $\beta = 1.04^{(-1/12)}$. The Frisch elasticity of labor supply is set to .5 as estimated by Domeij and Flodén (2006), which implies $\varphi = 2$. Workers have log utility for consumption, $\sigma = 1$.³⁶ In setting the scaling parameter for disutility of work, we target hours per worker in the family, $h^{\text{fam}} = 1/3$, which implies $\kappa_h = 36.37$.³⁷

Table 2: Implied steady state

<u>Per capita consumption</u> ⁽¹⁾		<u>Hours worked when employed and wages</u>	
c^{fam}	.55 family.		<u>fam</u> <u>liq</u>
c_e^{liq}	.65 constrained, employed.	$h^{\text{fam}}, h^{\text{liq}}$	.33 .30 hours per worker.
c_u^{liq}	.26 constrained, unemployed.	$w^{\text{fam}}, w^{\text{liq}}$	2.15 2.13 hourly wage.
<u>Income side of GDP</u>		<u>Labor market - stocks and flows</u>	
whn/y	.66 labor income to GDP.	$u^{\text{fam}}, u^{\text{liq}}$	.057 .057 unemployment rate.
$r^k k/y$	.33 capital share.	$v^{\text{fam}}, v^{\text{liq}}$	.075 .075 vacancies.
Ψ/y	.001 profit share.	$s^{\text{fam}}, s^{\text{liq}}$	.40 .40 probability of finding a job.
<u>Use of output</u>		<u>Labor market - profits of labor firms</u>	
i/y	.24 investment output ratio.	$\frac{\Psi^{\text{fam}}}{l^{\text{fam}}}, \frac{\Psi^{\text{liq}}}{l^{\text{liq}}}$	.037 .055 profit to output ratios.
c/y	.56 (non-dur. +services)/output.		
g/y	.19 government cons. /output.		
$\kappa v/y$	.0069 vacancy costs to output.		

Notes: Selected features of the steady state when the model is parameterized as described in Table 1. All values refer to a monthly frequency.

⁽¹⁾ The steady-state values for consumption depend on the values of the replacement rate (through income when unemployed for the constrained workers and through taxes for the family). The values reported here pertain to a 40% replacement rate ($\frac{l}{wh} = .40$).

In the baseline there are no skill differences within groups, $\omega = 0$. The steady-state level of technology, A , is set so as to normalize monthly steady-state output to unity. The depreciation rate of capital, δ , targets a steady-state investment to GDP ratio of 24%. The value of the separation rate in the economy is 2.4% per month, so as to ensure that the steady-state job-finding rate per month is 40%, the mean value in the data. We set the weight on unemployment in matching to $\xi = .5$ for all types of workers, following the evidence for the aggregate matching function in Petrongolo and Pissarides (2001). The vacancy posting costs for each type are

³⁶ Log-utility has the advantage that any non-cyclical component of idiosyncratic risk neglected in the current analysis would not affect the estimate of the cost of business cycles.

³⁷ Once the model is approximated to a second (or higher) order of accuracy, mean values and steady state values for endogenous variables cease to coincide. In principle one could either target steady-state values or mean values. We follow the common practice in the literature and target steady-state values; i.e., we associate those with the mean values observed in the data. This has the advantage of improving comparability with the literature and is a much simpler program. Qualitatively, none of our results depend on this procedure.

set so as to ensure that they have the same rate of steady-state unemployment, $u = 5.7\%$. The efficiency of matching, χ , is set such that firms with a vacancy find a worker with a 33% probability within a month's time, the value used in den Haan, Ramey, and Watson (2000) translated to a monthly frequency.

The bargaining power of workers is set to $\eta = .5$. Parameters strike³⁸, which determine the bargaining position of the respective type of worker, are set such that the model replicates the aggregate unemployment fluctuations in the data while restricting the unemployment fluctuations in the two subgroups to be of equal size.

Finally, the steady-state level of government spending is 19% of GDP, with its autocorrelation and standard deviation being chosen such that the model matches these moments in the HP-filtered data. The technology shock has an autocorrelation of $\rho_A = .95^{1/3}$, and its standard deviation is chosen to match the standard deviation of HP-filtered log quarterly output from simulations of the model to that in the data. Table 2 reports the resulting steady state, when assuming, in addition to the above parameters, that the replacement rate is 40%, which is about the average level for the US, see Engen and Gruber (2001).

Table 3 shows the standard deviations, auto- and cross-correlations of the economy-wide HP-filtered quarterly aggregates, and compares those moments to the data.³⁸ The model matches the serial correlations quite well. As is the case in the standard RBC model, however, the model predicts too much co-movement of some variables with the cycle, in particular of wages and earnings. It is somewhat more worrisome that the model accounts for only about two thirds of the volatility of consumption that we observe in the data and roughly half of the volatility of hours worked and wages.³⁹ Given that we attribute all unemployment fluctuations to the hiring margin, the job-finding probability is somewhat too volatile.

Table 4 illustrates what the above calibration implies for fluctuations of consumption in the respective groups. What was to be expected is that consumption of the average liquidity-constrained worker, c_t^{liq} , is somewhat more volatile than consumption in the family, and much more correlated with the business cycle. This is so since employment fluctuates considerably over the cycle, which induces larger swings in average per capita consumption of constrained workers than of workers who can save.

³⁸ In order to solve the model, we use second-order perturbation methods as in Schmitt-Grohé and Uribe (2004).

³⁹ In a previous version of this paper we estimated a New Keynesian version of the baseline model on US data, allowing for four additional shock processes, which are standard in the New Keynesian literature. We show that such a model indeed gives a very accurate description of the US business cycle.

Table 3: Second moments in the model compared to the quarterly data

Variable (quart.)	Std. deviation		Corr. with \hat{y}_t		AR(1) (qoq)	
	data	model	data	model	data	model
GDP and components						
\hat{y}_t	.89	.89	1.00	1.00	.87	.83
\hat{c}_t	.61	.43	.72	.92	.84	.83
\hat{i}_t	3.19	2.50	.86	.97	.89	.84
\hat{g}_t	1.06	1.06	-.11	.05	.77	.77
Labor market: wages and employment						
$\hat{h}_t + \hat{e}_t$	.97	.51	.76	.96	.82	.85
$\hat{w}_t + \hat{h}_t + \hat{e}_t$	1.36	.75	.74	1.00	.91	.84
\hat{w}_t	.96	.27	.27	.95	.75	.74
\hat{u}_t	8.25	8.25	-.79	-.92	.93	.85
Labor market: Job finding and separation						
\hat{v}_t	10.31	11.25	.80	.88	.90	.61
\hat{s}_t	6.15	8.92	.74	.97	.80	.78

Notes: The table compares second moments of variables as implied by the model to their counterparts in the data. The first two columns report unconditional standard deviations, the next two columns report the contemporaneous correlation with output and the final two columns report quarter-on-quarter autocorrelation coefficients. For the data moments, all values are computed from 1984:q1 to 2007:q4. All data are in logs, HP(1,600) filtered and multiplied by 100 in order to express them in percent deviation from steady state/trend. All data and model counterparts are in quarterly terms. From top to bottom: output per capita, consumption per capita, investment per capita, government spending, total hours worked, total wages, hourly wage rate, unemployment rate, vacancies, job-finding rate.

5 Results: the welfare costs of business cycles

For the baseline calibration discussed in the previous section, Figure 3 plots the welfare costs of business cycles for both groups of workers (asset-holding family members, and the average liquidity-constrained worker) as a function of the replacement rate.⁴⁰ As discussed in Appendix A, these costs are computed neglecting the transition path. Results are similar, however, when taking the transition into account. These numbers are reported at the end of this section. Three observations are apparent:

First, the costs of business cycles for liquidity-constrained workers fall with the replacement rate (see squares). As Section 2 highlighted, higher benefits insure the liquidity-constrained worker against a higher mean risk of unemployment. Since the cost of unemployment insurance is exclusively borne by the family, their welfare costs (thick solid line) rise with the unemployment

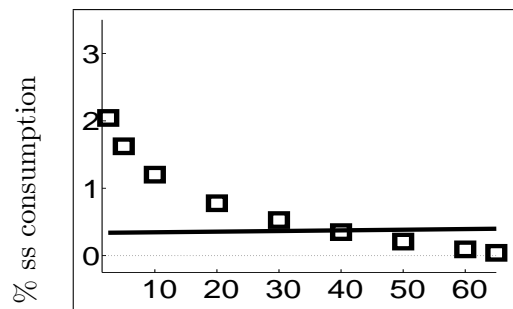
⁴⁰ The level of the replacement rate for the household does not play any role in the welfare costs of business cycles because on the one hand, we keep the bargaining position, strike, constant throughout our counterfactuals, and on the other hand, benefits are financed by lump-sum taxes levied on the family.

Table 4: Second moments in the model – break down by type

	Std.	Corr(x,y)	AR(1)		Std.	Corr(x,y)	AR(1)
<i>Consumption</i>				<i>Hours, wages and rental rates</i>			
$\widehat{c}_t^{\text{fam}}$	.42	.89	.82	$\widehat{h}_t^{\text{fam}}$	.10	.17	.76
$\widehat{c}_t^{\text{liq}}$	.52	.98	.83	$\widehat{h}_t^{\text{liq}}$	.07	.95	.72
$\widehat{c}_{e,t}^{\text{liq}}$	.29	.95	.72	$\widehat{w}_t^{\text{fam}}$	.28	.95	.75
<i>Unemployment, job-finding</i>				$\widehat{w}_t^{\text{liq}}$	.22	.95	.72
$\widehat{u}_t^{\text{fam}}$	8.29	-.93	.85	\widehat{r}_t^k	.89	.96	.82
$\widehat{u}_t^{\text{liq}}$	8.29	-.85	.86				
$\widehat{s}_t^{\text{fam}}$	9.06	.96	.78				
$\widehat{s}_t^{\text{liq}}$	8.22	.98	.79				

Notes: This table extends Table 3 by showing a breakdown of second moments by type of worker for selected variables, as implied by the model. All entries are in logs, HP(1,600) filtered and multiplied by 100 in order to express them in percent deviation from steady state. All data are in quarterly terms. Left: consumption of a family member, consumption of an average liquidity-constrained worker, of an employed liquidity-constrained worker (consumption of the unemployed counterpart does not fluctuate with the cycle); unemployment and the job-finding probability. Right: hours per worker, hourly wages, and the rental rate of capital. From left to right in each block: std deviation, correlation with output, quarterly autocorrelation.

Figure 3: Costs of business cycles in the baseline



replacement rate

- welfare costs for the family.
- welfare costs for avg. liq.-constrained.

Notes: Welfare costs of business cycles (in percent of steady-state consumption) for alternative replacement rates. The thick solid line shows the welfare costs for the family. Squares mark ex ante welfare costs for the liquidity-constrained workers.

benefits that the liquidity-constrained agents receive.⁴¹ Table 5 shows the means of endogenous

⁴¹ Results are very similar when attributing the replacement income to home production. The only visible difference is that there is no association between welfare costs for the family and the replacement rate. These

Table 5: Mean effects in the baseline (as percent change from steady state)

<u>Output and consumption</u>		<u>Unemployment</u>		<u>Hours per worker</u>	
y	-.15	u^{fam}	3.97	h_g^{fam}	.14
c^{fam}	-.24	u^{liq}	11.18	h_b^{fam}	-.0018
c^{liq}	-.36	<u>Unemployment rates</u>		<u>Wages and rental rates</u>	
c_e^{liq}	.005	$\text{urate}^{\text{fam}}$	3.97	w^{fam}	-.03
<u>Capital, and employment</u>		$\text{urate}^{\text{liq}}$	11.18	w^{liq}	.0036
k_t	-.11	<u>Job-finding rate</u>		w	-.03
e^{fam}	-.23	s^{fam}	4.18	x	.021
e^{liq}	-.67	s^{liq}	.19	r^k	-.012

Notes: The table shows percentage deviations of the mean of selected variables from the non-stochastic steady state. The values refer to a 40% replacement rate (corresponding to the left-most panel in Figure 3). Left column top to bottom: output, consumption of a family member, average consumption of a liquidity-constrained consumer, consumption of an employed liquidity-constrained consumer; capital and employment. Center column: unemployment; unemployment rate (coincides with percentage deviation in unemployment since the measure of workers in each family and liquidity-constrained group is normalized to unity); job-finding rates. Right column: hours per worker; wage per hour, w is the aggregate wage rate, price of labor, rental rate of capital.

variables for a 40% replacement rate as percent deviations from the steady state. Most notably, mean unemployment rates for both the family and the liquidity-constrained workers are higher than in the steady state. Intuitively, the business cycle drives the job-finding probability in a pro-cyclical manner. As Section 2 illustrated, for given mean job-finding rates, this can induce an increase in average unemployment rates, consistent with Table 5.⁴² For the liquidity-constrained workers unemployment rises by 11%, or by about 1.3 percentage points (to an unemployment rate of 7%). For the family the increase is smaller but still notable (4%, or 0.14 percentage point). Appendix B.1 provides further intuition for this effect in our model and also for the differential effect in the two groups of workers. The ensuing decline in employment reduces the return to capital and so has a negative effect on the capital stock. This effect is not present in Krusell and Smith (1999), who find that precautionary savings increase the level of capital. In our economy the negative effect on employment dominates the precautionary savings effect. In the presence of business cycles the average capital stock therefore is *lower* in our economy than in the steady state while the precautionary savings effect alone would have meant more savings (by the family) and thus more capital and higher wages (which would have been beneficial for wage earners).⁴³ Table 5 also shows in detail the mean effects in hours worked and wages.

results are available upon request.

⁴² In the above example, mean job-finding rates are also higher than in the steady state, thereby somewhat weakening this effect.

⁴³ If the cyclical volatility in unemployment rates is reduced by enough by setting a lower strike value, or the risk-

The family increases its labor supply along the intensive margin, while the liquidity-constrained worker hardly adjusts his hours worked. The differences can be explained by differences in the wealth effect associated with the drop in mean capital. In general, with log utility, and in the absence of non-labor income, the substitution and the income effect cancel out. The liquidity-constrained worker, having no capital-income by definition, does not face a decline in non-labor market income. Hence his labor supply along the intensive margin remains constant. The family, however, having lower capital income, is poorer. As a result, they counteract the drop in consumption by working more.⁴⁴

Second, for replacement rates of around 40% percent, which are in line with the average replacement rate in the US (see Engen and Gruber (2001)) the costs of business cycles are very similar for the family and the liquidity-constrained workers, 0.37% and 0.35%, respectively. On the one hand, the shifts in mean unemployment have a direct effect also on employment in the family. In addition, lower economy-wide employment means lower returns to capital for the family, plus the family also suffers from fluctuations in rental income over the cycle.

Third, in the baseline the costs of business cycles for the liquidity-constrained workers rise notably for lower replacement rates. For a replacement rate of 10%, for example, liquidity-constrained agents would be willing to pay about 1.2% of their steady-state consumption to eliminate all business cycle fluctuations.

The numbers reported above neglect the transition to the new steady state. However, similar patterns emerge when taking the transition path into account when computing the welfare costs. For example, for a 40% replacement rate, the welfare costs for the family are 0.24% of steady-state consumption, and for the liquidity-constrained workers they are 0.25% of steady-state

aversion of consumers is increased, the precautionary savings effect starts to dominate. Even abstracting from the movements in mean unemployment and capital, however, mean output in the economy would be affected. The reason is that output is convex in productivity and employment. Since productivity and employment co-move positively, the economy with business cycles will have higher output than the economy without business cycles, as mentioned by Krusell and Smith (1999), curbing the costs of business cycles. Similarly, even keeping the mean rates of employment and capital constant, the equilibrium rental rates and wages would be affected, since they are not linear in capital and employment. For example, the rental rate of capital is a concave function of the labor/capital ratio, cf. (8). Over the cycle this ratio mainly moves because of movements in labor input. The average rental rate of capital therefore is lower in the presence of the cycle than in its absence, and the opposite holds for the price of labor, x_t , and thus for wages.

⁴⁴ Also, unemployment of the low-skilled workers in our model and our calibration is more sensitive to the business cycle. Our calibration relies on small profits for firms in order to generate the cyclicity of unemployment for both types of workers. As a result, mean profits are sensitive to changes in wages and hours worked, which differ among the two groups of workers for the reasons explained above. Profits drive job-finding rates, which in turn drive mean unemployment. Consequently, with wages and hours being less sensitive to the business cycle for the liquidity-constrained, mean unemployment rates in this group are relatively more affected by the cycle.

consumption. For a 10% replacement rate the costs are 0.22% and 0.89% for the family and the liquidity-constrained workers, respectively.

The next section shows that these mean effects combine with skill transitions to also induce lower average skills in the economy.

5.1 Mean skills when there are persistent earnings losses upon separation

It is well-documented that workers can face severe and long-lasting earnings losses once they are displaced. For example, Jacobson, LaLonde, and Sullivan (1993) estimate the long-term earnings losses of high-tenured workers in Philadelphia who were displaced. They find that workers affected by mass layoffs lose on average 40-50% of their pre-displacement earnings in the first quarter of displacement. Even 6 years after this displacement, earnings for these workers are on average 25% lower than their pre-displacement earnings. In addition, these losses are counter-cyclical.⁴⁵ Farber (2005) uses the Displaced Workers Survey through 2004 and finds that the longer-term change in earnings between two full-time jobs for displaced workers is about 11% on average. These losses are counter-cyclical with a standard deviation of about 3 percentage points. Krebs (2007) uses these facts to specify an exogenous process for income after displacement and shows that cyclical variations in long-term earnings losses of displaced workers can generate sizable costs of business cycles.⁴⁶

In this section we also allow for such longer-term earnings losses. Toward this end, we allow for differences in skills and calibrate the transition matrices as follows: Workers who are employed are increasingly likely to have acquired better skills over time. They do not lose these skills if they remain employed. For a worker with bad productivity, it takes on average four years (48 months) to acquire good productivity:

$$P^e = \begin{bmatrix} 1 & 0 \\ 1/48 & 1 - 1/48 \end{bmatrix}.$$

⁴⁵ Costs emerge also for younger workers with less tenure. Fairlie and Kletzer (2003) look at the costs of displacement for young adult workers. They find that five years after the initial job loss, annual earnings are about as high as in the absence of the initial displacement, yet this level is about 10% lower than it would have been, absent any unemployment spells.

⁴⁶ Krebs (2007) mainly focuses on permanent earnings losses. However, he also discusses a model with tenure heterogeneity and earnings recovery after job displacement. His model is similar to the model entertained here, in that it features two tenure states. Similar to our results, he finds that costs of business cycles are higher for workers with longer tenure. The social cost of business cycles in his model is not much affected, however. Our paper differs from his in making clear that this depends very much on the degree of insurance available to the worker, and in highlighting that there can be important mean effects through changing the average composition of skills in the economy.

Upon unemployment, workers lose their good skills with a certain, positive probability. We look at two cases. In the first case, most of the gains in productivity over a worker’s employment spell are worker-specific. Once entering unemployment, the worker loses these skills only slowly, with a 10% probability in each month of unemployment:

$$P^u = \begin{bmatrix} .9 & .1 \\ 0 & 1 \end{bmatrix}.$$

In the above example, the cost of a job loss varies over the business cycle to the extent that the longer the unemployment spell is, the more likely is the worker to lose his skills. In order to match the sizable long-run costs of unemployment, we set $\omega = .3$. An average worker (averaged over good and bad types) who is displaced loses about 26% of his annual earnings when reemployed only after an unemployment spell of exactly a year, which is in line with Keane and Wolpin (1997).⁴⁷ Also, in the model, five years after any displacement, a worker with good productivity before displacement who finds himself in employment again, on average, has earnings that are 12.3% below his pre-displacement earnings. Krebs (2007) stresses that it is important that the earnings losses from unemployment are higher in recessions than they are in booms. Our model induces such fluctuations in the longer-term earnings losses. In the above calibration, long-run earnings losses have a standard deviation of 13% relative to their mean. The minimum and the maximum of the longer-run costs of displacement differ on average 20% from the mean. While sizable, this is only about half the fluctuation reported by Farber (2005)⁴⁸ and also falls short of the 40% fluctuation calibrated by Krebs (2007). Apart from the skill transition matrices, our calibration uses the same targets as in Table 1.⁴⁹ The left-most panel of Figure 4 reports the associated welfare costs of business cycles. For the liquidity-constrained workers, the costs of business cycles rise by about 1 percentage point above the baseline.⁵⁰ This is notably bigger

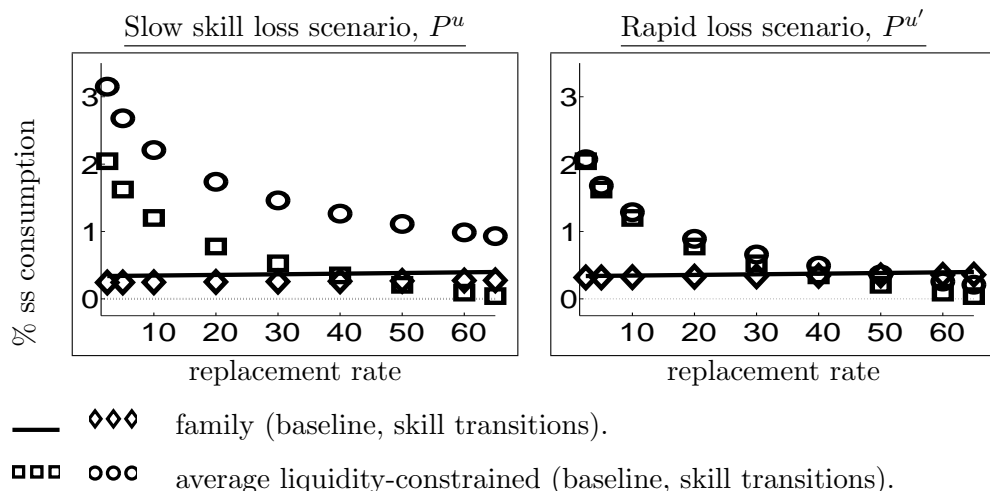
⁴⁷ Keane and Wolpin (1997) estimate that skills of white-collar workers depreciate by 30% for each year of unemployment (absence from white-collar work). For blue-collar workers the number is 9.6%.

⁴⁸ Figure 12 in Farber (2005) implies a mean of earnings losses of 11% and a standard deviation of 30%. The minimum and maximum costs differ 45% from the mean costs.

⁴⁹ Appendix C presents details about the steady state and about second moments.

⁵⁰ In our calibration, we set the strike value as the same share of earnings for the low- and high-skilled fractions (but different for the family and the liquidity-constrained workers). It turns out that as a result, the unemployment rates among workers with bad skills are more volatile (11.1%/11.8% for the savers/spenders) than the unemployment rates among workers with good skills (7.0%/6.5%). The job-finding probabilities behave very similarly in response to shocks in each of the two skill groups in the model. Nevertheless, *b* skill unemployment is more persistent, as there are also inflows from good skills to bad skills. As a result, while the unemployment hazard for the individual by and large is not affected by the skill group he is in, the volatility of the unemployment rates of the two skill groups is affected and so is the gap between the unemployment risk with or without business cycles.

Figure 4: Business cycle costs with skill losses



Notes: The panels show the welfare costs of business cycles (in percent of steady-state consumption) for log-utility ($\sigma = 1$) for alternative replacement rates of unemployment insurance for the liquidity-constrained (x-axis). The family has a replacement rate of 40%, the replacement rate $I^{liq}/(w^{liq}h^{liq})$ varies along the x-axis. Shown is the case of two different sizes of skill losses from unemployment. Left, unemployed workers who enter unemployment with good skills face a 90% chance of retaining them (transition matrix P^u). Right, the chance is just 5% (transition matrix $P^{u'}$). The black line and black diamonds show the welfare costs for the family in the baseline and under the skill loss scenario, respectively. The red squares and circles show the welfare costs for the average liquidity-constrained worker in the baseline and under the skill loss scenario.

than the number of 0.2% reported in Krebs (2007), in particular when bearing in mind that our calibration features lower long-run earnings losses. This rests on the fact that in our model the business cycle induces considerable shifts in means that fall mainly on the liquidity-constrained workers. Table 6 shows that unemployment rates for liquidity-constrained consumers increase by 8% (0.4 pp.) above the steady-state level for workers with good skills and by almost 15% (1.2pp) for workers with bad skills.

Importantly, the rise in unemployment and thus unemployment duration also works to reduce the share of workers with good skills. In the family, the share of workers with bad skills is on average 0.34% (0.07 pp.) larger than in the steady state. Among liquidity-constrained workers, who in the calibrated model suffer the biggest increase in unemployment induced by the cycle, there are almost 7% (1.4 pp.) more workers with lower skills than in the absence of business cycle fluctuations. As before, results are qualitatively not affected by accounting for the transition period. With a 40% replacement rate, the welfare costs of business cycles are 0.13% and 0.84% for the family and the liquidity-constrained worker; and .12% and 1.55% when replacement rates

Table 6: Mean effects with slow skill losses, P^u

<u>Output and consumption</u>		<u>Share of skills among</u>		<u>Hours per worker</u>	
y	-.15	<u>savers/spenders</u>		h_g^{fam}	.10
c^{fam}	-.10	$\text{skill}_g^{\text{fam}}$	-.089	h_b^{fam}	.10
c^{liq}	-1.02	$\text{skill}_b^{\text{fam}}$	.33	h_g^{liq}	-.0012
$c_{e,g}^{\text{liq}}$	.008	$\text{skill}_g^{\text{fam}}$	-1.80	h_b^{liq}	-.0012
$c_{e,b}^{\text{liq}}$	.008	$\text{skill}_b^{\text{liq}}$	6.87		
<u>Capital, and employment</u>		<u>Unemployment rates</u>		<u>Wages and rental rates</u>	
k_t	-.089	<u>by skill group</u>		w_g^{fam}	-.014
e_g^{fam}	-.092	$\text{urate}_g^{\text{fam}}$	.57	w_b^{fam}	-.014
e_b^{fam}	-.040	$\text{urate}_b^{\text{fam}}$	1.41	w_g^{liq}	.0062
e_g^{liq}	-2.14	$\text{urate}_g^{\text{liq}}$	8.10	w_b^{liq}	.0062
e_b^{liq}	4.70	$\text{urate}_b^{\text{liq}}$	14.93	w_t	-.10
<u>Unemployment</u>		<u>Job-finding rates</u>		x	.028
u_g^{fam}	-.04	s_g^{fam}	3.83	r^k	-.018
u_b^{fam}	4.52	s_b^{fam}	3.76		
u_g^{liq}	4.70	s_g^{liq}	.25		
u_b^{liq}	30.80	s_b^{liq}	.21		

Notes: The table shows percentage deviations of the means of selected variables from the non-stochastic steady state when skills evolve according to P^u and P^e . The values refer to a 40% replacement rate (corresponding to the left-most panel in Figure 4). Left from top to bottom: output, consumption of a family member, average consumption of a liquidity-constrained consumer, and consumption of an employed liquidity-constrained worker (good and bad skills); capital, no. of employed workers (each for good and bad skills); no. of unemployed (each for good and bad skills). Center column: share of good and bad skills in the family and among liquidity-constrained workers; unemployment rates by skill group (family and liquidity-constrained), job-finding rates by skill group. Right column: hours per employed worker for the family and for liquidity-constrained workers of each type, hourly wages for the groups, w_t denotes the aggregate average hourly wage rate, rental rate of capital.

are only 10%.

The right-hand panel instead focuses on a second case, in which much of a worker's gained productivity is firm-specific, and so workers have a very high (95%) probability of losing these skills once they are separated from firms:

$$P^{u'} = \begin{bmatrix} .05 & .95 \\ 0 & 1 \end{bmatrix}.$$

In this example, workers lose their skills with a 95% probability in every month of unemployment. Though becoming unemployed is more costly in this scenario, it barely implies higher costs of business cycles than the baseline. Intuitively, when skills depreciate faster, there is not

much interaction of this skill loss with the business cycle. Instead one compares an economy with fluctuations to a steady state in which workers also become unemployed from time to time, and in which they therefore also occasionally lose their skills to about the same degree in the cyclical economy. In sum, variation of human capital with the business cycle by itself does not generate costs of business cycles.

6 Conclusions

This paper developed an otherwise standard real business cycle model with Mortensen and Pissarides (1994) search and matching frictions and asset-holding as well as liquidity-constrained consumers. We calibrated the model to US data and used it to compute the cost of business cycles. We computed the cost for different degrees of the effectiveness of governmental unemployment benefit schemes and also allowed for interactions of the skills of workers with their employment state to cause longer-term earnings losses upon separation. Importantly, we let the model govern how both the fluctuations and the levels of idiosyncratic labor market risk change when the business cycle risk is eliminated.

General equilibrium effects apart, in the model unemployment fluctuations by themselves do not have any implications for the cost of business cycles. Nevertheless, even our lowest estimates for the costs of business cycles are an order of magnitude larger than the estimates provided by Lucas (1987). This is due to the fact that besides fluctuations in unemployment and consumption, which have been the focus of the previous literature, the model also implies significantly higher mean unemployment rates in the presence of a business cycle. These mean effects arise as a direct consequence of the non-linearity between unemployment and the job-finding probability in the employment-flow equation. Costs of business cycles therefore arise even for workers who are well-insured against idiosyncratic fluctuations in income and unemployment risk. Reducing business cycle fluctuations reduces average unemployment risk and increases welfare. For a 40% replacement rate of unemployment insurance, for instance, we find that both liquidity-constrained consumers and consumers with asset holdings, who are well insured against shortfalls of consumption when unemployed, would be willing to forgo about 0.35% of their steady-state consumption in order to avoid the cycle. These costs rise above 1 percent for liquidity-constrained workers with only a 10% replacement rate.

We then assessed the costs of business cycles when unemployment spells increase the risk of losing

skills acquired through previous work experience. In our calibrated model, the interaction of skills and business cycle shocks is quantitatively important when skills are worker-specific rather than job-specific. In the former case the business cycle increases not only average unemployment risk, but the ensuing longer average duration of unemployment also implies that workers are lower-skilled on average. For the liquidity-constrained workers, and for a 40% replacement rate, the welfare costs more than triple to 1.3 percent of steady-state consumption.

Our estimates of the costs of cycles focused on the cycle's effect on average employment and skills while we clearly have omitted further sources for costly business cycles. Most important to us, a number of authors have pointed out that the risk of infrequent disasters linked to cyclical phenomena significantly raises the costs of business cycles. These authors typically appeal to a (once in a lifetime) Great Depression scenario; see Chatterjee and Corbae (2007) and Salyer (2007). In the current paper, we not only abstract from such aggregate disasters, but in the same vein we limit the damage that unemployment can do to skills. In particular, regardless of the length of the unemployment spell, in the paper, skills never fall below a certain level. Business cycles would be more costly if very long-term unemployment – which is much more likely to occur when there are lasting deep recessions – were associated with a very deep (disastrous) loss of skills, or with the absence of any unemployment insurance. Needless to say that this would point to even higher costs of business cycles.

In sum, we found that a standard model with labor market frictions implies that business cycles increase mean unemployment risk and that they reduce the skill level of the workforce. According to this, business cycles are considerably more costly than the mere degree of aggregate fluctuations suggests, and these costs affect a wide range of consumers (in the model, all consumers). For future work, it would be interesting to investigate to what extent specific economic policies could achieve some of the potential stabilization gains. We currently investigate the implications in an estimated New Keynesian model for the US economy. In that economy both demand and supply shocks are prevalent, so monetary and fiscal stabilization policy become meaningful.

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A Measuring the welfare costs of business cycles

We compute the welfare costs of business cycles in terms of the consumption that consumers would be willing to forgo if business cycle fluctuations would be eliminated. We report these costs as a percentage share of steady-state consumption. This section illustrates the measurement for the simple model of Section 2. The worker’s value when employed, $W_{e,t}$, is given by

$$W_{e,t} = u(w_t) + \beta(1 - \vartheta)E_t \{W_{e,t+1}\} + \beta\vartheta E_t \{W_{u,t+1}\},$$

where $W_{u,t}$ is the worker’s value when unemployed in t . This value is

$$W_{u,t} = u(I) + \beta s_t E_t \{W_{e,t+1}\} + \beta(1 - s_t)E_t \{W_{u,t+1}\}.$$

Let $\bar{W}_u(\gamma)$ be the welfare of an unemployed worker when there are no business cycles and when a share, γ , is deducted from actual consumption in that economy in all periods. Similarly, let $\bar{W}_e(\gamma)$ be the counterfactual welfare for an employed worker when the same share, γ , of steady-state consumption has been deducted. The corresponding expressions for the log-utility case, $\sigma = 1$, are given by⁵¹

$$\begin{bmatrix} \bar{W}_u(\gamma) \\ \bar{W}_e(\gamma) \end{bmatrix} = \frac{1}{[1-\beta(1-s)][1-\beta(1-\vartheta)]-\beta^2\vartheta s} \begin{bmatrix} 1 - \beta(1 - \vartheta) & \beta s \\ \beta\vartheta & 1 - \beta(1 - s) \end{bmatrix} \cdot \begin{bmatrix} \log(b(1 - \gamma)) \\ \log(w(1 - \gamma)) \end{bmatrix}.$$

The welfare costs of business cycles are computed *ex ante*, not knowing the state of the economy or the individual state of employment. More precisely, we average over individual employment states and over all states of the economy by equating⁵²

$$E \{e_t W_{e,t} + u_t W_{u,t}\} \equiv e \bar{W}_e(\gamma) + u \bar{W}_u(\gamma) \Rightarrow \gamma. \quad (12)$$

⁵¹ The expressions for $\sigma \neq 1$ are

$$\begin{bmatrix} \bar{W}_u(\gamma) \\ \bar{W}_e(\gamma) \end{bmatrix} = \frac{1}{[1-\beta(1-s)][1-\beta(1-\vartheta)]-\beta^2\vartheta s} \begin{bmatrix} 1 - \beta(1 - \vartheta) & \beta s \\ \beta\vartheta & 1 - \beta(1 - s) \end{bmatrix} (1 - \gamma)^{1-\sigma} \begin{bmatrix} \frac{1-\sigma}{1-\sigma} \\ \frac{w^{1-\sigma}}{1-\sigma} \end{bmatrix}.$$

⁵² Most of the results presented in the paper rely on (12). This abstracts from the welfare costs/gains on the transition path to the non-stochastic steady state. Results that include these transition dynamics are computationally more demanding. We therefore report these results only occasionally. If we do, we draw

B Intuition for the effects on mean unemployment

This Appendix provides intuition for the mean effects on unemployment that we observe in the paper. The first subsection motivates in a simplified framework without capital, liquidity-constrained consumers and the intensive margin, why – general equilibrium effects aside – mean job-finding rates roughly move in sync with productivity. The second subsection shows that in that framework, this is exactly the case for risk-neutral consumers. Combining this with the job flow equation generates mean unemployment that is higher than in the non-stochastic steady state; see the intuition surrounding employment flow equation (1). For the special case, a closed-form formula for mean unemployment is presented. Starting from this, the third subsection explains why mean unemployment rates of the liquidity-constrained workers are more strongly affected by the cycle than for workers in the family; wealth effects play the main role. The fourth subsection explains why, in our calibration, wages of liquidity-constrained workers react less to the cycle, and links this to the former points.

B.1 Mean effects in the search and matching model

Section 2 highlighted the idea that having higher mean unemployment rates is natural whenever mean job-finding rates are not affected by the cycle. This section argues that – general equilibrium mean effects aside – mean job-finding rates are not much affected by the cycle, indeed.

To make this point, we abstract from the intensive margin, liquidity constraints and skill transitions and assume that labor is the only factor of production, so $x_t = 1$, and productivity is the only shock. Wages then are given by the convex combination of productivity and the bargaining outside option, strike,

$$w_t = \eta A_t + (1 - \eta)\text{strike},$$

where η is the worker's bargaining power, and A_t is productivity. The equilibrium value of a firm is given by

$$\begin{aligned} J_t &= A_t - w_t + (1 - \vartheta)E_t \{ \beta_{t,t+1} J_{t+1} \} \\ &= (1 - \eta)(A_t - \text{strike}) + (1 - \vartheta)E_t \{ \beta_{t,t+1} J_{t+1} \}. \end{aligned}$$

Abstracting from fluctuations in the stochastic discount factor $\beta_{t,t+1}$, the value of a firm is linear in the exogenous productivity shock. The free entry condition

$$\frac{\kappa}{q_t} = E_t \{ \beta_{t,t+1} J_{t+1} \},$$

$S = 1000$ states out of the non-stochastic steady state and use these as initial conditions to compute the welfare in the non-stochastic economy, withdrawing a share γ from consumption in each contingency. We then compute the value of γ which solves

$$E \{ e_t W_{e,t} + u_t W_{u,t} \} \equiv \frac{1}{S} \sum_{s=1}^S e_s \left[\tilde{W}_{e,s}(\gamma) + u_s \tilde{W}_{u,s}(\gamma) \right],$$

where $\tilde{W}_{e,s}$ is the counterfactual value of an employed worker when the initial state is s , and the economy is non-stochastic. Similarly, $\tilde{W}_{u,s}$, e_s , and u_s are evaluated at state s .

together with the matching function, $m_t = \chi u_t^\xi v_t^{1-\xi}$, and the definitions of the probabilities to find a worker and to find a job, $q_t = \frac{m_t}{v_t} = \chi \left(\frac{v_t}{u_t}\right)^{-\xi}$, $s_t = \frac{m_t}{u_t} = \chi \left(\frac{v_t}{u_t}\right)^{1-\xi}$, yields that

$$\begin{aligned} s_t &= \chi \left(\frac{\chi}{\kappa}\right)^{\frac{1-\xi}{\xi}} [E_t \{\beta_{t,t+1} J_{t+1}\}]^{\frac{1-\xi}{\xi}} \\ &:= \Upsilon [E_t \{\beta_{t,t+1} J_{t+1}\}]^{\frac{1-\xi}{\xi}}, \end{aligned} \quad (13)$$

where Υ is constant. In our calibration, $\xi = .5$, so that – abstracting from fluctuations of the pricing kernel and other general equilibrium effects – the job-finding rate is proportional to expected profits. To the extent that profits are linear in productivity, A_t , job-finding rates are also a linear function of productivity. Business cycle fluctuations that do not alter the mean of productivity therefore approximately will not alter the mean of the job-finding rate. In turn, by the job-flow equation, this means that mean unemployment rises; see Section 2.

B.2 A special case: linear utility

The above results can be made more precise for the special case of linear utility, $\sigma = 0$:

Proposition 2. *In a simplified version of our model, in which labor is the only factor of production, productivity is the only shock, there is no intensive margin, all workers live in the family and there are no skill differences, and in which utility is linear in consumption, the following holds if $\xi = 0.5$: (i) the job-finding rate is linear in productivity, $s_t = s + \phi_s(A_t - A)$, $\phi_s = \Upsilon \beta \rho \frac{1-\eta}{1-(1-\vartheta)\beta\rho}$, (ii) the unemployment rate, up to a second-order approximation, has a mean of*

$$E\{u_t\} = u + \frac{\phi_s^2}{1 - (1 - \vartheta - s)\rho} \frac{u}{\vartheta + s} \frac{\rho}{1 - \rho^2} \sigma_A^2. \quad (14)$$

In words: whenever there is persistence in productivity shocks $\rho > 0$, mean unemployment rates in the cyclical economy exceed the steady-state level, and increasingly so the more volatile innovations to productivity are (the higher σ_A).

Proof. With linear utility, $\beta_{t,t+1} = \beta$. Guess and verify yields that the value of the firm is

$$J_t = \frac{1 - \eta}{1 - (1 - \vartheta)\beta} (A - \text{strike}) + \frac{1 - \eta}{1 - (1 - \vartheta)\beta\rho} (A_t - A).$$

Using this, and $\xi = 0.5$, (13) yields that

$$s_t = s + \phi_s (A_t - A), \quad (15)$$

where s collects the constant terms and $\phi_s = \Upsilon \beta \rho \frac{1-\eta}{1-(1-\vartheta)\beta\rho}$, so the job-finding rate is exactly linear in productivity, and its mean is not affected by cyclical fluctuations if the mean of A_t is not affected. This proves part (i).

Regarding (ii), since $u_t = 1 - e_t$, the employment-flow equation (1) yields

$$u_{t+1} = (1 - \vartheta)u_t + \vartheta - s_t u_t.$$

Rewriting this, and using (15), we have that

$$\tilde{u}_{t+1} = (1 - \vartheta - s)\tilde{u}_t - \phi_s \tilde{A}_t \tilde{u}_t - \phi_s u \tilde{A}_t, \quad (16)$$

where a tilde marks deviations from steady state, e.g., $\tilde{u}_t = u_t - u$. Taking unconditional expectations, using the stationarity of the model and that for technology $E\{\tilde{A}_t\} = 0$, we have that

$$E\{\tilde{u}_t\} = -\frac{1}{\vartheta + s} \phi_s E\{\tilde{u}_t \tilde{A}_t\}. \quad (17)$$

In order to obtain an expression for $E\{\tilde{u}_t \tilde{A}_t\}$, multiply (16) by \tilde{A}_{t+1} , and expand the right-hand side by using $\tilde{A}_{t+1} = \rho \tilde{A}_t + \epsilon_{t+1}^A$. A second-order approximation of the resulting terms yields

$$\tilde{u}_{t+1} \tilde{A}_{t+1} \approx (1 - \vartheta - s) \left[\rho \tilde{u}_t \tilde{A}_t + \tilde{u}_t \epsilon_{t+1}^A \right] - \phi_s u \rho \tilde{A}_t^2 - \phi_s \tilde{A}_t u \epsilon_{t+1}^A.$$

Taking unconditional expectations and using stationarity again, we have that up to second order

$$E\{\tilde{u}_t \tilde{A}_t\} \approx -\frac{1}{1 - (1 - \vartheta - s)\rho} \phi_s u \frac{\rho}{1 - \rho^2} \sigma_A^2.$$

Using this with (17) yields the expression (14), which proves (ii). \square

B.3 The calibration, and the cyclicity of wages and profits

In our calibration, steady-state profits are higher for firms with liquidity-constrained workers than they are for firms with workers who live in the family. Nevertheless, profits – and thus job-finding rates – of the two groups are about equally volatile. This has to do with the flexibility of wages over the cycle, which in turn depends on the bargaining setup, as this section explains. Again ignoring the intensive margin and fluctuations in the price of labor, the family's wage first-order condition is given by

$$\eta(A_t - w_t^{\text{fam}}) = (1 - \eta)(w_t^{\text{fam}} - \text{strike}^{\text{fam}}).$$

The first-order condition for the liquidity-constrained worker (assuming log-utility) is

$$\eta(A_t - w_t^{\text{liq}}) = (1 - \eta) \frac{\log\left(\frac{w_t^{\text{liq}}}{\text{strike}^{\text{liq}}}\right)}{\lambda_t^{\text{liq}}},$$

where $\lambda_t^{\text{liq}} = \frac{1}{w_t^{\text{liq}}}.$

What happens when productivity changes? For the family we have:

$$\frac{dw_t^{\text{fam}}}{dA_t} = \eta.$$

For the liquidity-constrained we obtain, applying the implicit function theorem, that

$$\frac{dw_t^{\text{liq}}}{dA_t} = \frac{\eta}{(1 - \eta) \log\left(\frac{w_t^{\text{liq}}}{\text{strike}^{\text{liq}}}\right) + 1} < \eta \text{ because } \frac{w_t^{\text{liq}}}{\text{strike}^{\text{liq}}} > 1.$$

So, everything else equal, two observations are in order. First, the wage rate for liquidity-constrained workers will react less to technology and will thus be less volatile over the cycle. Note that this is actually borne out by Tables 4, 8 and 10. Notice also that, all else equal, liquidity-constrained workers will accept lower earnings. As a result of the effect described above, in a recession, wages of liquidity-constrained workers will not fall by as much as for workers in the family. This reduces the incentives to create jobs for liquidity-constrained workers more strongly than for the family. The opposite holds in booms. This leads to larger fluctuations in job-finding rates for the liquidity-constrained workers for any given level of steady-state profits of the labor firms. It thereby explains why profits of firms that employ liquidity-constrained workers can be larger in the steady state in our calibration (cp. Tables 2, 7, and 9), while nevertheless the fluctuations in job-finding rates and thus unemployment are similar for the two groups.

C Steady state and second moments for skill loss calibrations

C.1 Long-term earnings losses upon separation, slow skill loss P^u

Table 7: Implied Steady State, skill loss P^u

<u>Per capita consumption⁽¹⁾</u>		<u>Hours worked when employed and wages</u>					
			fam <u>g</u>	fam <u>b</u>	liq <u>g</u>	liq <u>b</u>	
c^{fam}	.55 family.	h	.33	.24	.29	.29	hours per worker.
$c_{e,g}^{\text{liq}}$	.70 constr., empl., good skill.	w	2.46	1.32	2.43	1.31	hourly wage.
$c_{e,b}^{\text{liq}}$	.38 constr., empl., bad skill.	<u>Labor market - stocks and flows</u>					
$c_{u,g}^{\text{liq}}$	.28 constr., unempl., good skill.	e	.75	.19	.75	.19	employment.
$c_{u,b}^{\text{liq}}$	.15 constr., unempl., bad skill.	u	.039	.017	.039	.017	unemployment.
<u>Income side of GDP</u>		urate	.050	.083	.050	.083	unempl. rate (avg: .057).
whn/y	.66 labor income to GDP.	v	.047	.028	.047	.028	vacancies.
$r^k k/y$	.33 capital share.	s	.40	.40	.40	.40	probability of finding a job.
Ψ/y	.001 profit share.	<u>Share of skills in family/liq.-constrained group</u>					
<u>Use of output</u>		skills	.79	.21	.79	.21	share of skills.
i/y	.24 investment output ratio.	<u>Labor market - profits of labor firms, strike values</u>					
c/y	.56 (non-dur. +services)/output.	$\frac{\Psi}{l}$	.025	.025	.071	.071	profit to output ratio
g/y	.19 government cons. /output.	strike	.53	.21	.49	.26	strike values
$\kappa v/y$	.0055 vacancy costs to output.						

Notes: Selected features of the steady state for the model with slow skill loss when unemployed, which underlies the left panel of Figure 4. All values refer to a monthly frequency.

⁽¹⁾ The steady-state values for consumption depend on the values of the replacement rate (through the income when unemployed for the constrained workers, and through taxes for the family). The values reported here pertain to a 40% replacement rate ($\frac{l}{wh} = .40$).

Table 8: Standard deviations, skill loss P^u

<u>Per capita consumption⁽¹⁾</u>			<u>Hours worked when employed and wages</u>					
c^{fam}	.49	family.						
$c_{e,g}^{\text{liq}}$	.30	constr., empl., good.	h	$\frac{\text{fam}}{g}$	$\frac{\text{fam}}{b}$	$\frac{\text{liq}}{g}$	$\frac{\text{liq}}{b}$	hours per worker.
$c_{e,b}^{\text{liq}}$	.30	constr., empl., bad.	w	.11	.11	.07	.07	hourly wage.
<u>Aggregate GDP components</u>			<u>Labor market - stocks and flows</u>					
y	.89	output.	e	.30	.30	.23	.23	employment.
c	.50	consumption.	u	6.9	11.9	6.2	13.6	unemployment.
i	2.4	investment.	urate	7.0	11.1	6.4	11.8	unempl. rate.
<u>Aggr. hours, wages, labor mkt</u>			v	13.7	9.6	11.4	9.4	vacancies.
$h_t e_t$	.49	total hours	s	9.8	8.5	8.2	8.0	job-finding prob.
$w_t h_t e_t$	.75	total wages	<u>Share of skills in family/liq.-constrained group</u>					
w_t	.31	wage rate	skills	.41	1.5	.41	1.5	share of skills.
u_t	8.2	unemployment						
v_t	11.7	vacancies						
s_t	9.1	job-find rate						

Notes: Percent standard deviations for the model with slow skill loss when unemployed, which underlies the left panel of Figure 4.

C.2 Long-term earnings losses upon separation, rapid skill loss P^u

Table 9: Implied Steady State, skill loss P^u

<u>Per capita consumption⁽¹⁾</u>		<u>Hours worked when employed and wages</u>				
			fam	fam	liq	liq
			<u>g</u>	<u>b</u>	<u>g</u>	<u>b</u>
c^{fam}	.55 family.					
$c_{e,g}^{\text{liq}}$	.84 constr., empl., good skill.	h	.33	.24	.27	.27
$c_{e,b}^{\text{liq}}$	.45 constr., empl., bad skill.	w	3.19	1.72	3.15	1.69
$c_{u,g}^{\text{liq}}$	.33 constr., unempl., good skill.	<u>Labor market - stocks and flows</u>				
$c_{u,b}^{\text{liq}}$	.18 constr., unempl., bad skill.	e	.44	.50	.44	.50
<u>Income side of GDP</u>		u	.011	.046	.011	.046
whn/y	.66 labor income to GDP.	urate	.024	.083	.024	.083
$r^k k/y$	.33 capital share.	v	.0007	.074	.0007	.074
Ψ/y	.001 profit share.	s	.40	.40	.40	.40
<u>Use of output</u>		<u>Share of skills in family/liq.-constrained group</u>				
i/y	.24 investment output ratio.	skills	.45	.55	.45	.55
c/y	.56 (non-dur. +services)/output.	<u>Labor market - profits of labor firms, strike values</u>				
g/y	.19 government cons. /output.	$\frac{\Psi}{t}$	.013	.005	.021	.011
$\kappa v/y$	.0083 vacancy costs to output.	strike	.68	.27	.58	.31

Notes: Selected features of the steady state for the model with rapid skill loss when unemployed, which underlies the right panel of Figure 4. All values refer to a monthly frequency.

⁽¹⁾ The steady-state values for consumption depend on the values of the replacement rate (through income when unemployed for the constrained workers and through taxes for the family). The values reported here pertain to a 40% replacement rate ($\frac{t}{wh} = .40$).

Table 10: Standard deviations, skill loss P^u

<u>Per capita consumption⁽¹⁾</u>			<u>Hours worked when employed and wages</u>					
				fam <u>g</u>	fam <u>b</u>	liq <u>g</u>	liq <u>b</u>	
c^{fam}	.49	family.						
$c_{e,g}^{\text{liq}}$	.36	constr., empl., good.	h	.13	.13	.09	.09	hours per worker.
$c_{e,b}^{\text{liq}}$	.36	constr., empl., bad.	w	.34	.34	.27	.27	hourly wage.
<u>Aggregate GDP components</u>			<u>Labor market - stocks and flows</u>					
y	.89	output.	e	.25	.87	.25	.87	employment.
c	.44	consumption.	u	.20	10.2	.27	10.3	unemployment.
i	2.4	investment.	urate	7.0	10.1	.18	10.1	unempl. rate.
<u>Aggr. hours, wages, labor mkt</u>			v	20.7	11.2	18.0	10.4	vacancies.
$h_t e_t$	.50	total hours	s	9.8	8.9	8.6	8.3	job-finding prob.
$w_t h_t e_t$	.69	total wages	<u>Share of skills in family/liq.-constrained group</u>					
w_t	.31	wage rate	skills	.3	.2	.3	.2	share of skills.
u_t	8.2	unemployment						
v_t	11.2	vacancies						
s_t	8.8	job-find rate						

Notes: Percent standard deviations for the model with rapid skill loss when unemployed, which underlies the right panel of Figure 4.

Table 11: Mean effects with rapid skill losses, $P^{u'}$

<u>Output and consumption</u>		<u>Share of skills among</u>		<u>Hours per worker</u>	
y	-.14	<u>savers/spenders</u>		h_g^{fam}	.13
c^{fam}	-.22	$\text{skill}_g^{\text{fam}}$	-.21	h_b^{fam}	.13
c^{liq}	-.40	$\text{skill}_b^{\text{fam}}$	.17	h_g^{liq}	-.0029
$c_{e,g}^{\text{liq}}$	.004	$\text{skill}_g^{\text{fam}}$	-.62	h_b^{liq}	-.0029
$c_{e,b}^{\text{liq}}$	.004	$\text{skill}_b^{\text{liq}}$	.50		
<u>Capital, and employment</u>		<u>Unemployment rates</u>		<u>Wages and rental rates</u>	
k_t	-.097	<u>by skill group</u>		w_g^{fam}	-.035
e_g^{fam}	-.20	$\text{urate}_g^{\text{fam}}$	-.059	w_b^{fam}	-.035
e_b^{fam}	-.28	$\text{urate}_b^{\text{fam}}$	4.50	w_g^{liq}	.0030
e_g^{liq}	-.62	$\text{urate}_g^{\text{liq}}$	.0024	w_b^{liq}	.0030
e_b^{liq}	-.63	$\text{urate}_b^{\text{liq}}$	11.82	w_t	-.017
<u>Unemployment</u>		<u>Job-finding rates</u>		x	.023
u_g^{fam}	-.28	s_g^{fam}	3.10	r^k	-.013
u_b^{fam}	5.07	s_b^{fam}	3.03		
u_g^{liq}	-.63	s_g^{liq}	.15		
u_b^{liq}	12.96	s_b^{liq}	.11		

Notes: The table shows percentage deviations of the means of selected variables from the non-stochastic steady state when skills evolve according to $P^{u'}$ and P^e . The values refer to a 40% replacement rate (corresponding to the right-most panel in Figure 4. Left from top to bottom: output, consumption of a family member, average consumption of a liquidity-constrained consumer, and consumption of an employed liquidity-constrained worker (good and bad skills); capital, no. of employed workers (each for good and bad skills); no. of unemployed (each for good and bad skills). Center column: share of good and bad skills in the family and among liquidity-constrained workers; unemployment rates by skill group (family and liquidity-constrained), job-finding rates by skill group. Right column: hours per employed worker for the family and for liquidity-constrained workers of each type, hourly wages for the groups, w_t denotes the aggregate average hourly wage rate, rental rate of capital.