Stabilization versus insurance: welfare effects of procyclical taxation under incomplete markets[1]

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Abstract

We construct and calibrate a general equilibrium business cycle model with unemployment and precautionary saving. We compute the costs of business cycles and locate the optimum in a set of simple government policies.

Our economy exhibits productivity shocks, giving firms an incentive to hire more when productivity is high. Nonetheless, the government can achieve a nontrivial welfare improvement by using fiscal policy to offset the business cycle. By making the tax rate procyclical to smooth hiring, the government reduces the unconditional probability of unusually long unemployment spells, and also smoothes wages, thus transferring risk away from workers. In our baseline calibration, the welfare loss from business cycles is around one-fourth of one percent of average consumption. By running a deficit of roughly 4% of GDP in recessions, the government eliminates half the variation in the unemployment rate, most of the variation in workers' aggregate consumption, and most of the welfare cost of business cycles.

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In so far as the absence of income-risk pooling reflects "imperfections" in capital markets, and I think it does, the cost of *individual* income variability measures the potential or actual gain from social insurance, not from stabilization policy.

Robert Lucas (1987), p. 29.

The real promise of the Krusell-Smith model and related formulations, I think, will be in the study of the relation of policies that reduce the impact of risk by reducing the variance of shocks (like aggregate stabilization policies) to those that act by reallocating risks (like social insurance policies).

Robert Lucas (2003), p. 10.

1 Introduction

Lucas (1987) derived a simple formula for the value of eliminating variation in aggregate consumption, and used it to argue that more aggressive macroeconomic stabilization policy would be unlikely to result in large welfare gains.[1,2] He also pointed out, though, that his formula ignored the much greater variation in individual consumption— and that the cost of business cycles might prove to be larger if idiosyncratic risk were taken into account. But then again, individual consumption risk might be seen as a separate issue, possibly calling for social insurance policies, but not central to understanding the benefits from macroeconomic stabilization.

However, we argue that macroeconomic stabilization and social insurance are interacting policies which are better analyzed jointly. Each alters the effects of the other, and in fact we will argue that they are partial substitutes. If insuring idiosyncratic risk is distortionary, then optimal policy is likely to leave some residual individual risk uninsured, which could potentially increase the

[1]By considering a change in variance without changing means, Lucas rules out the possibility that recessions represent a one-sided "gap" below "potential output". This paper likewise restricts attention to eliminating variance.

[2]A recent study following Lucas' representative agent approach is Alvarez and Jermann (2004).

benefits of stabilization policy. Likewise, business cycles change the distribution of idiosyncratic risk, so that the welfare impact of insurance also depends on the degree of macroeconomic stabilization.

This paper constructs a framework for analyzing the stabilization versus insurance tradeoff. Our model is a real business cycle economy in which productivity shocks cause variations in employment. In the model, labor is indivisible, jobs are formed through a matching technology, and wages are determined by bargaining, so individual labor income is affected both by wage variation and unemployment risk. We assume that workers are risk averse, and that there are no private markets in which to insure their labor income, so that they have an incentive to smooth their consumption through precautionary saving. The government has the option of providing insurance payments to the unemployed, which it finances over time by taxing employment. However, it need not balance its budget in every period, so it can vary the unemployment benefit and the tax rate with the cycle. In particular, by raising taxes in booms and lowering them in recessions, the government can stabilize output and employment over the cycle.

In this framework, aggregate and idiosyncratic risks are intimately related: when firms hire more in response to productivity shocks, they decrease workers' individual risk of unemployment. Variation in the unemployment rate affects workers' outside options, leading to variation in the wage. Moreover, even if the unconditional mean of unemployment is unchanged, variation in hiring will also increase the riskiness of labor income by changing the *persistence* of unemployment spells. The probability of remaining unemployed for many periods depends *exponentially* on the probability of not finding a job between one period and the next, so that variation in transition rates spreads out the unconditional distribution of unemployment spell lengths. Precautionary saving is quite effective in insuring individuals against short unemployment spells. But if the economy sometimes enters into recession, then the unconditional probability of occasionally suffering an exceptionally long unemployment spell is substantially increased.

Many papers have attempted to extend Lucas' calculation to allow for idiosyncratic risk. Imrohoroglu (1989) compared the welfare levels achieved through precautionary saving in economies with and without an aggregate risk component. She simplified her calculation by holding all prices constant; including general equilibrium effects is much harder, since prices and all other equilibrium quantities can depend on the entire distribution of asset holdings, a very high dimensional object. The numerical methods for calculating distributional dynamics developed by Krusell and Smith (1998) finally permitted Krusell and Smith (1999) to study a model like that of Imrohoroglu in general equilibrium. Gomes, Greenwood, and Rebelo (2001) used similar methods in a model of search from an exogenous wage distribution. Storesletten, Telmer, and Yaron (2001) used the same methods with a detailed calibration of the individual labor income process based on PSID data. An alternative that avoids calculating the dynamics of the asset distribution is to focus on a model in which agents prefer not to save, as Krebs (2003, 2004) has done in two papers highlighting the importance of multiple forms of capital and multiple risk factors for the costs of business cycles.

However, all the papers mentioned above share a common weakness: the source of the idiosyncratic component of risk is not modelled. Therefore, it is impossible to calculate the value of eliminating aggregate fluctuation without making further assumptions about how this affects idiosyncratic risk, which is far from obvious. Different authors have made different assumptions: for example, Atkeson and Phelan (1994) and Krusell and Smith (1999) propose ways of holding idiosyncratic risk fixed when aggregate output is stabilized. Imrohoroglu (1989) and Storesletten et. al. (2001) instead assumed that transition probabilities between different idiosyncratic labor market states vary with the business cycle, and that by smoothing aggregate fluctuations, these transition probabilities are also stabilized towards their means. This implies a substantial reduction of idiosyncratic risk when business cycles are eliminated, especially in the case of Storesletten et. al. (2001), who found strongly countercyclical labor income variance in the PSID.

Our paper avoids arbitrary assumptions about the relation between aggregate and idiosyncratic risk by endogenizing individual labor income risk in a natural way. Our solution method (Reiter 2002) is related to that of Krusell and Smith (1998, 1999), but in contrast to their papers, we solve a model with job matching and Nash wage bargaining. We find that switching off aggregate shocks stabilizes idiosyncratic transition probabilities, thus lowering the unconditional probability of the longest unemployment spells, and also stabilizes wages. In other words, we show that business cycles increase idiosyncratic risk, as Imrohoroglu (1989) and Storesletten et. al. (2001) assumed— and therefore they are several times more costly than Lucas found. The only other paper that has endogenized the effects of business cycles on idiosyncratic risk is Beaudry and Pages (2001). In their implicit contract model, eliminating cycles causes all wage variation to disappear. Thus they find much larger costs of business cycles than we do.

Another advantage of using an equilibrium model of the relation between aggregate and idiosyncratic risk is that we can move beyond the "magical" experiment (as Lucas (2003) called it) of simply switching off all fluctuation. In our model, both unemployment benefits and taxation distort the economy, and can be used to smooth (or amplify) aggregate fluctuations. Our calibration is chosen, following Costain and Reiter (2003), to ensure that both cyclical fluctuations in unemployment and policy-induced changes in unemployment are consistent with the data. With this calibration, we find that the government can eliminate most of the welfare loss from cycles by using countercyclical taxation to stabilize hiring. It can also increase welfare by lowering average unemployment benefits.

Since we compute optimal policy, our results are also comparable to those of the literature on optimal taxation in business cycle models. The environments most similar to ours are those where the government can insure itself through some state-contingent instrument (Lucas and Stokey 1983; Chari, Christiano, and Kehoe 1994); these papers find that the labor tax rate should be roughly constant. In papers where the government lacks instruments like state-contingent capital taxes, approximate labor tax smoothing is still a common result, but shocks induce a random walk in labor tax rates (Barro 1979; Aiyagari, Marcet, Sargent, and Seppala 2000). However, Greenwood and Huffman (1991) find that nonzero taxation amplifies real business cycles, and therefore obtain welfare gains from countercyclical tax rates. This is similar to our conclusions about excessive wage variation, in spite of the differences in the models.

The next section describes our economy. Section 3 discusses the set of fiscal policies we allow. Section 4 describes the algorithm we use to calculate our equilibrium distributional dynamics. Section 5 discusses how we evaluate social welfare, and Section 6 defines parameters. Section 7 analyzes the results: our steady state equilibrium, an equilibrium with business cycles, and the effects of various fiscal policies. Section 8 concludes.

2 The economic environment

2.1 State space

Time is discrete. We study fluctuations driven by an aggregate technology process Z_t following a two-state Markov process. The two technology states are called Z^1, which we will interpret as a "recession", and Z^2, which represents a "boom". The probability of transition from the bad state Z^1 to the good state Z^2 is π_{12}, and π_{21} is the probability of the opposite transition. Thus, if $\mathbf{1}(x)$ is an indicator function taking the value 1 when statement x is true, and 0 otherwise, the Markov process can be summarized as follows:

$$\begin{pmatrix} prob(Z_{t+1} = Z^1|Z_t) \\ prob(Z_{t+1} = Z^2|Z_t) \end{pmatrix} = \begin{pmatrix} 1-\pi_{12} & \pi_{21} \\ \pi_{12} & 1-\pi_{21} \end{pmatrix} \begin{pmatrix} \mathbf{1}(Z_t = Z^1) \\ \mathbf{1}(Z_t = Z^2) \end{pmatrix} \tag{1}$$

There are three types of agents in the economy. There is a continuum of risk-averse workers of measure 1. There is also a continuum of risk-neutral capitalists, whose measure need not be specified. The third agent is the government.

Workers can be in one of three labor market states $s \in \{0, 1, 2\}$. State 0 represents unemployment, while states 1 and 2 are employment in bad and good jobs, respectively. The mass of workers employed in bad jobs at time t is N_t^b, and the mass employed in good jobs is N_t^g; total employment is $N_t \equiv N_t^b + N_t^g \equiv 1 - U_t$.

The other relevant state variable for a worker is her asset holdings a. To rule out Ponzi schemes, we assume that assets must satisfy a liquidity constraint $a \geq -\overline{a}$. We will write the time-t joint cumulative distribution function over labor market status and asset holdings as $\Phi_t(s, a) : \{0, 1, 2\} \times [-\overline{a}, \infty) \to [0, 1]$. Note that we can back out the fraction of agents in each labor market state from Φ; for example, the number of unemployed is

$$U_t = \int_{-\overline{a}}^{\infty} \Phi_t(0, da) \qquad (2)$$

The pair $\Omega_t \equiv (Z_t, \Phi_t)$ is the minimum aggregate state variable for this model, and the minimum idiosyncratic state variable is (s_t, a_t). We conjecture that there exists an equilibrium in which the aggregate variables determined at t depend only on Ω_t, while individual decisions at t depend only on (s_t, a_t, Ω_t). In such an equilibrium, the time $t + 1$ distribution of idiosyncratic states will depend on the previous distribution, and on the technology shocks at t and $t + 1$.[3] We call this relation T:

$$\Phi_{t+1} = T(\Phi_t, Z_t, Z_{t+1}) \qquad (3)$$

To determine T, we must now discuss individual behavior.

2.2 The worker's problem

Workers search for jobs, work, and choose between consumption and saving. Their instantaneous utility function is $u(c, l)$, where c is consumption and l is leisure; the discount factor from one period to the next is β. However, for the

[3]The distribution Φ_{t+1} depends on the shock Z_{t+1} because Z_{t+1} affects the probabilities that the new jobs formed at $t + 1$ are bad or good.

purposes of this paper we will fix search effort and work effort, while making the consumption/saving decision endogenous. Thus, moral hazard effects are beyond the scope of the paper.

We will assume that time spent working or searching is $h(s) = 1 - l(s)$; in other words, it depends only on the individual labor market state. We will also make assumptions below to ensure that labor income is $w(s, \Omega)$, depending only on the labor market state and on the aggregate state. In particular, this means that wages do not depend on asset holdings. Labor income $w(s, \Omega)$ is defined after taxes and transfers, so this notation is used for state $s = 0$ to represent unemployment benefits (which we will assume are the only form of income received by the unemployed). Savings yield a fixed interest rate $R - 1$.

We will consider several types of labor market transitions. Job separation from bad jobs and good jobs occurs with probabilities δ^b and δ^g, respectively, where $\delta^b \geq \delta^g$. Unemployed workers who search when the current technology shock is Z find bad jobs with probability $p^b(Z', Z, \Phi)$, or good jobs with probability $p^g(Z', Z, \Phi)$. We assume that good jobs are more plentiful in good times: that is, $p^g(Z^1, Z, \Phi) \leq p^g(Z^2, Z, \Phi)$. Furthermore, workers in bad jobs may be promoted to good jobs, which occurs with probability p^{prom}, which we treat for simplicity as an exogenous constant. The focus of our analysis is on the hiring rates p^b and p^g, which depend endogenously on labor market tightness and thus on the hiring choices of capitalists.

Suppose the aggregate state at t is (Z, Φ), and the technology shock at $t + 1$ is Z'. Then we can write the transition from the unemployment and employment rates (U, N^b, N^g) at time t to the next period's rates $(U', N^{b\prime}, N^{g\prime})$ conditional on Z,Φ, and Z', as follows:

$$\begin{pmatrix} U' \\ N^{b\prime} \\ N^{g\prime} \end{pmatrix} = \begin{pmatrix} 1 - p^b(Z', Z, \Phi) - p^g(Z', Z, \Phi) & \delta^b & \delta^g \\ p^b(Z', Z, \Phi) & 1 - \delta^b - p^{prom} & 0 \\ p^g(Z', Z, \Phi) & p^{prom} & 1 - \delta^g \end{pmatrix} \begin{pmatrix} U \\ N^b \\ N^g \end{pmatrix} \tag{4}$$

Equivalently, we could state this equation as a relation between an individual's probabilities of being in the various labor market states s at t, and the probabilities of being in those states at $t + 1$.

We now have enough information to define the worker's problem in recursive form, in terms of the value function $W(s, a; Z, \Phi)$.

Worker's Bellman equation:

$$W(s, a; Z, \Phi) \;=\; \max_{c} \; u(c, 1 - h(s)) \;+\; \beta E\{W(s', a'; Z', \Phi')|s, Z, \Phi\} \tag{5}$$

$$\text{s.t.} \quad (1),\ (3),\ (4), \quad a' = Ra + w(s, Z, \Phi) - c, \quad \text{and} \quad a' \geq -\overline{a}$$

In this equation, the expectation operator is understood to refer to the exogenous Markov process (1) for the aggregate shock Z, and also to the transition laws (3) and (4) for the distribution Φ and the idiosyncratic labor state s conditional on the realization of Z'.[4]

2.3 The capitalists' hiring problem

Capitalists are risk neutral; their discount factor $1/R$ determines the interest rate $R - 1$ mentioned above.

Capitalists may open job vacancies; these vacancies, together with the total job search of workers, determine the rate of job matching. As is common in matching models, we make constant returns to scale assumptions in production and in matching, which permits us, without loss of generality, to consider the opening of vacancies one by one. Job vacancies may be in one of three states $z \in \{0, 1, 2\}$, where $z = 0$ means that the vacancy is empty, $z = 1$ means that the vacancy has been filled with a bad job, and $z = 2$ means that the vacancy has been filled with a good job. We assume no adjustment costs in vacancy creation; therefore vacancies are opened or closed until the value of an empty vacancy is zero.

Let the cost of holding open a vacancy be κ per period. Suppose that paying this cost results in probability $q^b(Z', Z, \Phi)$ of forming a bad job, and probability $q^g(Z', Z, \Phi)$ of forming a good job, per period. Then if we know

[4] This Bellman equation is based on the assumption that workers never quit. This can be ensured by making workers sufficiently impatient compared with the interest rate, so that those who start with low assets will never accumulate enough to prefer quitting into unemployment. We check this after solving our Bellman equations.

the value of a filled job $J(z, Z, \Phi)$ for $z \in \{1, 2\}$, the zero profit condition on unfilled vacancies ($z = 0$) must be

$$J(0, Z, \Phi) \;=\; 0 \;=\; -\kappa + \frac{1}{R}E\{q^b(Z', Z, \Phi)J(1, Z', \Phi')|\Omega\} + \frac{1}{R}E\{q^g(Z', Z, \Phi)J(2, Z', \Phi')|\Omega\} \tag{6}$$

where the expectation is taken with respect to the dynamics (1) and (3) of the aggregate state variables Z and Φ.

The value J of a filled job will depend on the quality of the match, $z \in \{1, 2\}$, and on the aggregate state Ω. In general, it would also depend on the asset holdings of the worker in the match. However, we will see that in our framework, the wage does not depend on asset holdings; and we will choose parameters such that workers never accumulate sufficient assets to make quitting into unemployment desirable. These two aspects of our specification suffice to make the value of a filled job independent of the worker's assets.

The marginal product of a filled job is $y(z, Z)$, net of capital costs. The firm must pay the worker the equilibrium wage associated with the quality of the job, $w(z, Z, \Phi)$, and it must also pay a tax $\tau(Z, \Phi)$ to the government. As we saw earlier in the case of the worker, bad and good jobs separate at rates $\delta^b(Z)$ and $\delta^g(Z)$, respectively, and bad jobs are promoted to good jobs with constant probability p^{prom}. Thus filled jobs ($z \in \{1, 2\}$) expect the following transitions:

$$\begin{pmatrix} prob(z' = 0|z) \\ prob(z' = 1|z) \\ prob(z' = 2|z) \end{pmatrix} = \begin{pmatrix} \delta^b & \delta^g \\ 1 - \delta^b - p^{prom} & 0 \\ p^{prom} & 1 - \delta^g \end{pmatrix} \begin{pmatrix} \mathbf{1}(z = 1) \\ \mathbf{1}(z = 2) \end{pmatrix} \tag{7}$$

This information now allows us to recursively define the value $J(z; Z, \Phi)$ of a filled job ($z \in \{1, 2\}$).

Bellman equation for a filled job:

$$J(z; Z, \Phi) \;=\; y(z; Z) - \tau(Z, \Phi) \;-\; w(z, Z, \Phi) + \frac{1}{R}E\{J(z'; Z', \Phi')|z, Z, \Phi\} \tag{8}$$

$$\text{s.t.} \quad (1),\ (3),\ \text{and}\ (7)$$

2.4 The labor market

We assume that total matches at $t+1$ are given by

$$M_{t+1} = \mu V_t^{1-\lambda} U_t^{\lambda} \tag{9}$$

where V_t is total vacancies. Now suppose that in equilibrium, total vacancies are $V(Z,\Phi)$. We also define labor market tightness as $\theta(Z,\Phi) = V(Z,\Phi)/U$. Let $\pi^g(Z)$ be the fraction of new jobs which turn out to be good. Then $p^g(Z',Z,\Phi) = \pi^g(Z')\mu\theta(Z,\Phi)^{1-\lambda}$ and $p^b(Z',Z,\Phi) = (1-\pi^g(Z'))\mu\theta(Z,\Phi)^{1-\lambda}$.

Given these job-finding rates for the workers, the probability of filling jobs with bad and good matches must be

$$q^b(Z',Z,\Phi) = \frac{p^b(Z',Z,\Phi)U_t}{V(Z,\Phi)} \tag{10}$$

and

$$q^g(Z',Z,\Phi) = \frac{p^g(Z',Z,\Phi)U_t}{V(Z,\Phi)} \tag{11}$$

Note that the rates q^b and q^g can be written as functions of Z', Z, and Φ only, since U can be calculated a function of Φ, using (2).

2.5 Wage determination

Following much of the matching literature, we assume that the wage is determined by Nash bargaining, at the beginning of each period, over the surplus arising from the match. Bargaining occurs not only at new matches, but also at continuing matches, on a period-by-period basis.

We assume that bargaining occurs at the "sectoral" level. A sector is some subset of firms that all have the same type z; it is large compared to individual workers and firms but is small compared to the economy as a whole. In each sector, all workers bargain together as a union. Firms also band together for bargaining. We simplify the bargaining situation by assuming that the definition of a sector is independent between one period and the next, which implies that the union's problem is entirely static.[5]

Workers' unions maximize the sum of all members' utilities. In order to define the wage bargaining problem, we will have to calculate the worker's value function for any possible wage, instead of defining it only for the equilibrium wage, as we did earlier in the worker's Bellman equation. If an employed worker receives the wage w during a given period (and expects the equilibrium wage thereafter), then her surplus, relative to the value of unemployment, is

$$\Sigma^W(w,s,a;\Omega) \;=\; \max_c \; u(c,1-h(s)) + \beta E\{W(s',a';\Omega')|s,\Omega\} \;-\; W(0,a,\Omega) \tag{12}$$

$$\text{s.t.} \quad (1),\ (3),\ (4), \quad a' = Ra + w - c, \quad \text{and} \quad a' \geq -\overline{a}$$

We assume that unions value the utilities of their members equally, so that they attempt to maximize the average surplus of their members. Thus a union's surplus is

$$\Sigma^U(w,s;\Omega) \;=\; \int \Sigma^W(w,s,a;\Omega)\Phi(s,da) \tag{13}$$

We define the firm's surplus likewise, for any given wage w during one period, taking as given the equilibrium wage in future periods. Given that the option of separation has value zero,

$$\Sigma^F(w,z;\Omega) \;=\; y(z;Z) \;-\; \tau(\Omega) \;-\; w + \frac{1}{R}E\{J(z';\Omega')|z,\Omega\} \tag{14}$$

$$\text{s.t.} \quad (1),\ (3),\ \text{and}\ (7)$$

In principle, firms' unions also average over their members' surpluses; but since a does not enter the firms' surplus function, averaging leaves the surplus unchanged.

[5]The "sectoral" bargaining assumption is made purely for technical convenience. By making unions regroup in new sectors each period, we eliminate any union-specific effects of one period's bargaining outcome on the next period's game. By averaging over individuals, we eliminate any dependence of the wage on a given worker's asset holdings. In theory, individual assets could affect both this period's and future wages, but dealing with these complications is beyond the scope of this paper.

The workers' bargaining weight is denoted $\sigma \in (0,1)$. Thus the Nash bargaining problem (for $z \in \{1,2\}$) is

$$w(z,\Omega) = \underset{w}{\operatorname{argmax}} \left[\Sigma^U(w,z;\Omega)\right]^{\sigma} \left[\Sigma^F(w,z;\Omega)\right]^{1-\sigma} \tag{15}$$

3 Fiscal policy

As emphasized in the introduction, by endogenizing employment, and thus idiosyncratic risk, we can go a step beyond measuring the costs of business cycles: we can also study the effects of countercyclical fiscal policy on output, employment, and welfare. However, the space of possible fiscal policies is extremely large. For example, even when we restrict ourselves to time-independent flat taxes, the tax rate τ can still, in general, depend on the aggregate state variable (Z,Φ). Since it is already challenging to compute our infinite-dimensional equilibrium conditional on a given fiscal policy, searching for the optimal policy in an infinite-dimensional space of rules is not tractable.

Thus, it is essential to simplify our policy space before we search for an optimum. First, we leave the optimal level of government spending for future research: we simply calibrate a realistic constant level G. Next, we reduce the remaining aspects of fiscal policy to a few parameters that we believe capture the most interesting tradeoffs.

Constant G with fluctuating productivity will force taxes to be countercyclical unless we allow the government to run a countercyclical deficit. For simplicity, we require that the deficit depend only on the aggregate productivity shock Z. This can be justified by assuming the existence, at some initial date $t=0$, of a market for time-independent insurance against future productivity shocks Z_t. We assume that at $t=0$, both the government and the capitalists are "behind the veil of ignorance", with no information about the initial realization of Z. Thus at this time, the capitalists are willing to sell any amount $\hat{X}$ of unconditionally fair insurance paying $X(Z^1) \equiv (2\pi_{12}/(\pi_{12}+\pi_{21}))\hat{X}$ to the government in bad times, and $X(Z^2) \equiv -(2\pi_{21}/(\pi_{12}+\pi_{21}))\hat{X}$ in good times. We will explore the welfare consequences of different levels of insurance $\hat{X}$ that could be chosen by the government.

Like the deficit, we restrict the unemployment insurance payment to be a function of Z only, with mean $\overline{b}$ and variability indexed by $\hat{b}$:

$$w(0,\Omega) \equiv b(Z) \equiv \overline{b} + \frac{2\pi_{12}}{\pi_{12}+\pi_{21}}\hat{b}\mathbf{1}_{Z=Z^1} - \frac{2\pi_{21}}{\pi_{12}+\pi_{21}}\hat{b}\mathbf{1}_{Z=Z^2} \tag{16}$$

We can then avoid introducing bonds by assuming that taxes adjust to balance the budget in every period. Moreover, while we have written the tax rate as a general function of Ω, under our fiscal policy it easily reduces to $\tau(\Omega) \equiv \tilde{\tau}(Z,U)$. That is, it depends on the technology shock and the unemployment rate, but not on the asset distribution, as we can see from the government budget constraint:

$$G + b(Z_t)U_t \quad = \quad X(Z_t) + \tilde{\tau}(Z_t,U_t)(1-U_t) \tag{17}$$

As we emphasized above, eliminating bonds implies only a small loss of generality in our model because the unconditionally fair insurance transfers $X(Z)$ take the place of the government saving and dissaving that would occur in a more realistic and complete model.

Thus, our fiscal policy space has three dimensions. $\hat{X}$ indexes the countercyclicality of the government deficit, $\hat{b}$ indexes the countercyclicality of the unemployment benefit, and $\overline{b}$ represents the average level of UI. (Notice that our notation has expressed all these variables in the same units.) To better understand the set of allowed policies, it helps to consider Figure 1, which illustrates the policy space conditional on a given average benefit level $\overline{b}$.

Note that the tax on labor $\tilde{\tau}(Z,U)$ and unemployment subsidy $b(Z)$ both act as wedges between the cost and benefit of working. Their sum is a measure of the total distortion of employment in this economy. In order to understand the intertemporal effects of fiscal policy, it will be helpful to observe whether the total distortion $\tilde{\tau}(Z,U) + b(Z)$ is procyclical or countercyclical: that is, whether these distortions stabilize or destabilize employment, respectively.[6]

At the origin in the graph, the government always runs a balanced budget, and pays a constant UI benefit, so the tax rate must rise in recessions. Thus the overall fiscal policy stance is destabilizing: $\tau + b$ is lower in booms than in recessions. We therefore might expect welfare to improve if we instead make the deficit countercyclical, moving along the horizontal axis to the point (labelled in Fig. 1) where not only benefits, but also taxes are smoothed over the cycle. To be more precise, we cannot smooth taxes exactly in our proposed policy space, since by calculating them as a residual we make them depend on U as well as Z. Thus the point we label as "tax smoothing" is that which achieves the same average tax rate in booms and recessions:

$$E(\tau|Z^1) \quad = \quad E(\tau|Z^2) \tag{18}$$

when benefits are also smoothed ($\hat{b} = 0$).

Hence, rightward movements in Figure 1 represent increases in the countercyclicality of the deficit and in the procyclicality of taxation and distortions. Movements straight upward in the graph increase the countercyclicality of benefits, also making taxes and distortions more countercyclical. It is also interesting to consider the effects of northeast movements in the graph. When the axes are defined in the same units, a movement in the $+45^o$ direction approximately represents a lump sum aggregate insurance transfer. That is, if UI payments are increased by ϵ in recessions, and taxes are decreased by ϵ in recessions, then distortions are unchanged, so employment and should be approximately unchanged, and the government deficit should rise by approximately ϵ per capita. Thus the curve we call "constant distortions" in the graph, which we define as

$$E(\tau|Z^1) + b(Z^1) \quad = \quad E(\tau|Z^2) + b(Z^2) \tag{19}$$

[6]Note that our focus is on supply-side stabilization, rather than demand-side stabilization by raising government spending to stimulate "aggregate demand". Aggregate demand policies would do nothing to alter output in this model, because our risk-neutral capitalists' demand for goods is perfectly elastic. That is, government spending perfectly "crowds out" private spending in our framework.

has a slope of approximately one. Points to the right of the curve have total distortions procyclical, so fiscal policy stabilizes employment and output; points to the left have countercyclical distortions and are destabilizing. Movements upwards along the curve represent increased countercyclical lump sum payments from the government to workers, transferring an aggregate insurance payment directly into the pockets of workers.

This fiscal policy space lets us evaluate the gains from running a deficit to smooth taxes and distortions. It also allows us to go further, making distortions procyclical, which could partially eliminate (or even reverse) the fluctuations in employment and output. But the government also might want a countercyclical deficit for a different reason: rather than spending its deficit on cyclical changes in distortions, it could instead spend it insuring households against the aggregate technology shock (an insurance market which, by assumption, is missing in our economy). By seeing whether welfare improves in the horizontal direction, or in the $+45^o$ direction, we can see whether tax smoothing, or employment smoothing, or filling in the missing aggregate insurance market best summarizes optimal policy. We explore these issues by computing equilibrium over a grid of possible cyclical policies $\hat{X}$ and $\hat{b}$, and we also consider changing the average unemployment benefit $\overline{b}$.

4 Computing equilibrium

We compute this model, for any given fiscal policy $(\hat{X}, \hat{b}, \bar{b})$, with the general equilibrium backwards induction algorithm proposed by Reiter (2002). The algorithm makes use of the fact that if next period's value functions are known, then this period's equilibrium can be computed for any given aggregate state $\Omega = (Z, \Phi)$. Thus, in principle, we can work backwards to find the general equilibrium (just as the standard backwards induction algorithm works backwards to find the solution of a single optimization problem). In practice we must solve for equilibrium over a grid of possible values of Ω, and then interpolate when we need to evaluate the value function elsewhere. Moreover, since Φ is infinite-dimensional, we must look for an adequate way to describe it by a finite list of statistics. This issue is familiar from other recent approaches to computing heterogeneous agent models, like those of Krusell and Smith (1997, 1998) and den Haan (1997).

The algorithm consists of the following steps.

1. Choose a vector m of moments (or other statistics) which approximately represent the distribution Φ.

2. Construct a grid $\mathcal{M}$ over possible values of these moments, where equilibrium will be evaluated: $\mathcal{M} \equiv \{m_1, m_2, \ldots, m_g\}$.

3. Choose a mapping $\hat{\Phi}(m)$ that uniquely defines a distribution Φ for any given value of the moments m.

4. Initialize the value functions W and J to $W_0 \equiv 0$ and $J_0 \equiv 0$ for some final period T.

5. Assume that the time t equilibrium implies value functions W_j and J_j. For each aggregate state (Z, m) in the grid $\{Z^1, Z^2\} \times \mathcal{M}$, solve for the time $t-1$ equilibrium, assuming that the time $t-1$ distribution is $\hat{\Phi}(m)$. Call the resulting time $t-1$ value functions W_{j+1} and J_{j+1}.

6. Repeat step 5 until W and J converge.

As the calculation progresses, one can alter the chosen set of moments m or the moments-to-distributions mapping $\hat{\Phi}$ for consistency with the simulated dynamics.

The backwards induction step (5.), in which we calculate equilibrium at each point in the aggregate grid, requires more detailed discussion. Thus, suppose we have performed j time iteration steps, so that we know the jth iterates of the value functions, W_j and J_j (the time t values). Then we can perform the following fixed-point calculation to find the $j+1$st iterate of the equilibrium, including W_{j+1} and J_{j+1} (the time $t-1$ values).

5A. Choose a point (Z, m) in the aggregate grid $\{Z^1, Z^2\} \times \mathcal{M}$. Assume that the current (time $t-1$) aggregate state is $\Omega = (Z, \hat{\Phi}(m))$. Calculate the associated tax rate $\tilde{\tau}(Z, U)$, using equation (17).

5B. Guess the next period's conditional distributions $\Phi' = T(Z, \Phi, Z')$. In other words, guess each element of the moment vector $m' = T^m(Z, m, Z')$

which would result from the time $t-1$ state Ω, conditional on transition to each possible $Z' \in \{Z^1, Z^2\}$ at t.

5C. Using the surplus equations (12), (13), (14), and the worker's Bellman equation (5), calculate the surplus functions $\Sigma^W(w, z, a, \Omega)$, $\Sigma^U(w, z, \Omega)$, $\Sigma^F(w, z, \Omega)$, and the unemployment value function $W(0, a, \Omega)$ for the current point Ω.

5D. Given the surplus functions Σ^U and Σ^F, solve the Nash bargaining problem to calculate the wage $w(z; \Omega)$.

5E. Plug the wage into the Bellman equations (5) and (8) to update the value functions W and J; also calculate the consumption policy $c(s, a, \Omega)$.

5F. Using the consumption policy function c and the wage function w to calculate the implied beginning-of-next-period asset holdings a', update the moment vector $m' = T^m(Z, m, Z')$ associated with each $Z' \in \{Z^1, Z^2\}$.

5G. Iterate on steps 5C-5F until the time $t-1$ equilibrium converges. (In other words, find a fixed point of the mapping from the guessed time t vectors m' to the true time t vectors m'.)

5H. Repeat steps 5A-5G for all grid points in $\{Z^1, Z^2\} \times \mathcal{M}$.

Note that steps (5C.) and (5E.) involve evaluating the time t value functions W_j and J_j at the guessed time t moment vectors m'. These future moments will not normally lie in the aggregate grid $\{Z^1, Z^2\} \times \mathcal{M}$, so interpolation is required. For further details on the algorithm, see Reiter (2002).

5 Welfare criterion

Since we are working with a dynamic, stochastic, heterogeneous agent model, we must specify carefully how we weight payoffs over time, states, and agents (both workers and capitalists). We sum the utility of all workers with equal weights. As for the capitalists, since they are risk neutral and competitive, they are indifferent to all new job formation in this model. However, they also own the initial stock of existing jobs, and the value of this asset will vary with changes in policy. Therefore we add the value of these existing jobs into our social welfare function, converting them into utility units by multiplying by workers' average marginal utility of consumption. We will see, though, that the value of existing jobs plays only a small role in our welfare calculations.

As a benchmark, we compute social welfare in the equilibrium of a static economy in which the aggregate shocks are shut off. That is, the probability that any new job is good, and the aggregate component of labor productivity, are both set to their unconditional means. The deficit is set to zero ($\hat{X} = 0$), and UI is set to a constant level $\overline{b}_0$. Since there is no aggregate uncertainty, this model converges over time to a steady state distribution of assets and employment which we call $\overline{\Phi}$, with a level of social welfare $\overline{\mathcal{V}}$.

We first compare this to an analogous economy with the aggregate shocks switched on, which we call the dynamic benchmark. We continue to assume a balanced budget ($\hat{X} = 0$) and the same constant unemployment benefit $\overline{b}_0$. The state of this economy fluctuates over time, so for comparability we evaluate its welfare at the static benchmark distribution $\overline{\Phi}$, and we average over the two possible initial shocks Z_0. That is, using the notation $V(Z, \Phi|\hat{X}, \hat{b}, \overline{b})$ to represent the social welfare of the dynamic economy in any given aggregate state (Z, Φ), given any fiscal policy $(\hat{X}, \hat{b}, \overline{b})$, our dynamic benchmark welfare measure is[7]

$$\mathcal{V}^* \equiv \frac{\pi_1}{\pi_1 + \pi_2} V(Z^1, \overline{\Phi}|0, 0, \overline{b}_0) + \frac{\pi_2}{\pi_1 + \pi_2} V(Z^2, \overline{\Phi}|0, 0, \overline{b}_0) \tag{20}$$

Note that since we evaluate social welfare at $\overline{\Phi}$, the dynamic benchmark welfare measure $\mathcal{V}^*$ implicitly includes the value of the transition path from the fixed initial distribution $\overline{\Phi}$ to the new fluctuating distribution of distributions that results from the shocks.

To clarify units, we express the cost of business cycles as a loss of consumption, as in Lucas (1987, 2003). That is, we calculate the permanent proportional change Δ^* in workers' consumption distribution which would yield the same social welfare loss as that caused by business cycles:

$$\mathcal{V}^* - \overline{\mathcal{V}} = E_{\bar{\Phi}} \left[\frac{u(c(1 + \Delta^*), 1 - h)}{1 - \beta} \right] - E_{\bar{\Phi}} \left[\frac{u(c, 1 - h)}{1 - \beta} \right] \tag{21}$$

[7] Recall that $\overline{\mathcal{V}}$ and $V(Z, \Phi|\hat{X}, \hat{b}, \overline{b})$, by definition, both include the value of the stock of jobs.

The expectation operator $E_{\bar{\Phi}}$ in this equation refers to cross-sectional averages in the static benchmark economy.

The welfare effects of all other policies $(\hat{X}, \hat{b}, \overline{b})$ are likewise evaluated at the static benchmark distribution, and averaged over possible initial shocks:

$$\mathcal{V}(\hat{X}, \hat{b}, \overline{b}) \equiv \frac{\pi_1}{\pi_1 + \pi_2} V(Z^1, \overline{\Phi} | \hat{X}, \hat{b}, \overline{b}) + \frac{\pi_2}{\pi_1 + \pi_2} V(Z^2, \overline{\Phi} | \hat{X}, \hat{b}, \overline{b}) \tag{22}$$

As we did for the dynamic benchmark policy, we compute certainty equivalent consumption costs for all other policies, relative to the steady state benchmark. The welfare impact of policy $(\hat{X}, \hat{b}, \overline{b})$ is written as $\Delta(\hat{X}, \hat{b}, \overline{b})$, and is defined by the following equation:

$$\mathcal{V}(\hat{X}, \hat{b}, \overline{b}) - \overline{\mathcal{V}} = E_{\bar{\Phi}} \left[\frac{u(c(1 + \Delta(\hat{X}, \hat{b}, \overline{b})), 1 - h)}{1 - \beta} \right] - E_{\bar{\Phi}} \left[\frac{u(c, 1 - h)}{1 - \beta} \right] \tag{23}$$

6 Parameterization

Our parameterization is described in Table 1. The parameters are chosen to match certain empirical observations that are essential for our policy exercises. In particular, we want our model to be consistent with data on cyclical and policy-induced variations in unemployment. We also want our model to generate a realistic asset distribution of workers, with a reasonable degree of risk aversion on the part of our agents, because all these factors appear important for the welfare effects of the fiscal policies we study.

Productivity fluctuations

In order to calculate the welfare impact of stabilization, our model must produce quantitatively realistic cycles in unemployment, since variations in idiosyncratic risk are crucial for our arguments about the welfare effects of stabilization. Similarly, to calculate the welfare impact of unemployment insurance, it is essential that the effect of changed unemployment benefits in our model be consistent with that observed in the data.

In previous work (Costain and Reiter 2003), we pointed out that Pissarides' (2000) influential matching framework has trouble reproducing these key aspects of the behavior of unemployment: it either underpredicts unemployment variation over the business cycle, or overpredicts unemployment variation in response to changes in the UI benefit. Like Shimer (2004A, B) and Hall (2003), we showed that sticky wages could potentially resolve this puzzle; but since we do not have a good microfoundation for sticky wages, we prefer to solve the puzzle differently. As we showed in our earlier paper, it is helpful to allow for match-specific productivity. Concretely, there are "bad jobs" and "good jobs" in the model, and we assume that in times of high aggregate productivity, a higher fraction of the newly created jobs are good ones.[8] To see why this helps the model match the data, consider the extreme case in which aggregate technology shocks have no effect on the productivity of existing jobs, and affect production only through the increased productivity of new jobs. Then a firm which hires when the aggregate shock is good expects the productivity of the job to remain good as long as the job lasts. However, it also knows that the outside option of workers will fall whenever a bad aggregate shock hits. Thus, *ceteris paribus*, expected discounted profitability of a vacancy rises more in response to a positive shock in a model with embodied technology than it does in the standard matching model where technology is disembodied. Therefore hiring and unemployment vary more with the cycle.

Thus we adopt this technology specification in the present paper (making "good" jobs more plentiful in good times) because it helps us obtain a volatile unemployment rate over the cycle without exaggerating the effects of UI policy. We assume that jobs are bad ($z = 1$) or good ($z = 2$), and we assume the productivity depends primarily on the idiosyncratic quality of the job, rather than the aggregate shock. Thus we set $y(z, Z) = 1 + a(z) + A(Z)$, where $a(z) = -0.15$ if $z = 1$, and 0.15 if $z = 2$, and where $A(Z) = -0.0075$ if $Z = Z^1$, and 0.0075 if $Z = Z^2$. Notice that this choice of parameters normalizes the (unweighted) average of a worker's monthly productivity to unity. This parameterization attributes about half of the aggregate productivity fluctuations to the aggregate shock on existing jobs, and the rest to the fluctuations

[8] In Costain and Reiter (2003), we assumed that in times of high (low) aggregate productivity, all new jobs are good (bad), and called this "embodied technical progress". The formulation in the present paper is somewhat more general.

in job composition. This formulation came out best in Costain and Reiter (2003) in explaining the unemployment variations both over the cycle and in response to policy.

We set both aggregate transition probabilities π_{12} and π_{21} to an annual rate of 1/3, so that recessions and booms are equally likely, and a full cycle lasts six years on average.

Labor market

We assume equal elasticities of unemployment and vacancies in our matching function ($\lambda = 0.5$), in line with empirical evidence (see the literature review in Petrongolo and Pissarides 2001). To avoid introducing arbitrary inefficiencies, we likewise set workers' bargaining share to $\sigma = 0.5$. Thus if fiscal policies were nondistortionary, and financial markets were perfect, our matching market would be efficient (Hosios 1991).

We target an average unemployment of 6%, typical of the postwar US, and we target an average fraction of good jobs equal to 2/3, so that even though most new hires are in bad jobs, most ongoing jobs are good. For job separation, we target an average rate of 0.25 per year (in line, for example, with Shimer 2004A), but we allow good and bad jobs to separate at different rates. We set the rate for bad jobs as high as 40% annually ($\delta^b = 0.0416$ per month) and adjust the rate for good jobs so as to match the above average ($\delta^g = 0.0147$ per month). We normalize the probability of a good hire in recessions to $\pi^g(Z^1) = 0$. The parameters $\pi^g(Z^2)$ (the fraction of good hires in booms) and p^{prom} (the probability of promotion from a bad to a good job) are chosen such that 1) on average, 2/3 of jobs are good; and 2) in good times, the probability of promotion is slightly higher than the probability of an unemployed worker finding a good job, so that the employed never want to quit to search for a better job. This results in $\pi^g = 0.119$ and $p^{prom} = 0.0238$ per month.

The remaining technical parameters of the matching technology, μ and κ, were chosen so that we hit an unemployment rate of 6% and a probability of the firm to fill a vacancy of about 0.5 per month. This latter value is only a normalization, since the overall level of vacancies relative to matches can be rescaled without consequences for the solution of the model. The important technical issue is to ensure all transition probabilities are well below 1.

Within-period utility

We choose a CRRA utility function with a Stone-Geary component:

$$u(c, 1-h) = \frac{[(c-\bar{c})(1-h)^{\alpha_l}]^{1-\gamma}}{1-\gamma} \tag{24}$$

Chetty (2004), p.33, estimates a risk-aversion parameter for unemployed agents of 4.75. This is very high in a pure CRRA function, but appears more plausible if we assume that households have some fixed expenditures (mortgage, children's education) and that their income when unemployed is not much higher (if at all) than those spending needs. This is captured by the Stone-Geary part of the utility function. It allows us to attain a fairly high degree of risk aversion in equilibrium for unemployed households, without having to impose an unreasonably high degree of curvature γ in general. We set $\gamma = 2$ and $\bar{c} = 0.2$ (around 20% of the marginal product of labor), and obtain an average marginal risk aversion of about 3 for the unemployed, and a bit more than 2.5 for the employed.

We assume that working requires time $h(1) = h(2) = 1/3$, while searching requires time $h(0) = 1/10$. We choose α_l such that the current surplus of an average worker of having a job rather than being unemployed is about 25% of labor productivity. This value was found in Costain and Reiter (2003) to give the right response of unemployment to the variation in unemployment benefits, and is confirmed in the present, more complicated model.

Discounting and financial markets

We fix the interest rate by assuming that capitalists' annual discount rate is $R^{-1} = 1.05^{-1}$. We assume that workers' liquidity constraint is $\underline{a} = 0$. We choose workers' annual discount rate, $\beta = 0.92$, so that they hold a realistic level of assets, in spite of their high risk aversion; in equilibrium these parameters imply that they will accumulate a few months' worth of liquid assets.

Fiscal policy

We assume that government spending is $G = 0.188$, roughly 20% of output, which is in line with US federal public expenditure. We set the baseline unemployment benefit level to $\bar{b} = 0.32$, which implies a 40% replacement ratio in our static benchmark economy, close to the estimate of the average replacement ratio reported in Engen and Gruber (1995). The countercyclicality of the deficit, $\hat{X}$,and the countercyclicality of the unemployment benefit will be varied systematically to find the optimal policy regime.

7 Simulation results

7.1 Steady state

Our static benchmark economy is described in Table 2. This economy is defined by setting the probability that new matches are good to its average level $\overline{\pi^g} \equiv \frac{\pi_{21}}{\pi_{12}+\pi_{21}}\pi^g(Z^1) + \frac{\pi_{12}}{\pi_{12}+\pi_{21}}\pi^g(Z^2) = 0.0595$. Likewise, we set the aggregate component of productivity to its average $\frac{\pi_{21}}{\pi_{12}+\pi_{21}}A(Z^1) + \frac{\pi_{12}}{\pi_{12}+\pi_{21}}A(Z^2) = 0$. Fiscal policy in the static benchmark is given by the constant unemployment benefit $\overline{b}_0 \equiv 0.32$. This specification eliminates all aggregate uncertainty, so the economy converges to a steady state. In the steady state, the unemployment rate is 5.8%, the monthly probability of finding a job is 0.389, and two-thirds of those employed have good jobs. Output is 0.990 and the average product of labor is 1.050. The wage is 0.840 in good jobs, and 0.729 in bad jobs. The tax on labor is $\tau = 0.209$.

The static benchmark asset distribution $\overline{\Phi}$, which is pictured in Figure 2, has mean 2.402 (that is, roughly three months' worth of wages) and standard deviation 0.961. The distribution of consumption has mean 0.784 and standard deviation 0.078. On average, relative risk aversion is 2.704, while for the unemployed, mean relative risk aversion is 3.195, substantially lower than the estimates of relative risk aversion of the unemployed (between 4 and 5) obtained by Chetty (2004). In this sense, we are being conservative in our estimates of the cost of consumption variation.

The table further decomposes the distributions of assets and consumption: conditional on unemployment, mean consumption falls to 0.553 and the standard deviation of consumption is 0.065. This contrasts with the much lower standard deviation of consumption conditional on employment, which is 0.028

for bad jobs and 0.017 for good jobs. The standard deviation of consumption is higher for the unemployed both because the standard deviation of assets is higher for the unemployed, and because the marginal propensity to consume is higher for the unemployed, as we see in the consumption policy functions pictured in Figure 3. We also see in Figure 3 that when a badly-employed worker with conditional mean assets 1.507 loses his job, his consumption falls by 22.1%. For a worker in a good job, with conditional mean assets 2.911, the fall in consumption is 25.6%. In spite of these decreases, an unemployed worker eventually runs his assets down to zero. If he starts his unemployment spell with the average assets of an employed worker, it takes him roughly nine months to run out of assets.

7.2 Costs of business cycles

The long-run average behavior of our dynamic benchmark equilibrium is described in Table 3. This economy has the same parameters as the static benchmark, and the same fiscal policy ($\hat{X} = \hat{b} = 0, \overline{b} = 0.32$), except that now the probability that a new job is good fluctuates between $\pi^g(Z^1) = 0$ and $\pi^g(Z^2) = 0.119$, and the aggregate productivity component fluctuates between $A(Z^1) = 0.0075$ and $A(Z^2) = -0.0075$.

In this economy, the mean unemployment rate is 6.0%. Conditional on good times ($Z = Z^2$), the mean unemployment rate is 5.4%, while conditional on bad times, it is 6.5%. The probability of job finding, per month, has mean 0.415 in good times, and mean 0.339 in bad times. In Figure 4, we graph the resulting distribution of unemployment spell lengths in the dynamic benchmark and static benchmark economies.[9] While the mean unemployment rate is only 1.2 times higher in recessions than in booms, Figure 4 shows that the probability of remaining unemployed for nine months (roughly the time needed to run out of assets) is three times higher in recessions than in booms.

[9]The graph shows the probability distributions over spell lengths conditional on remaining in the good state, bad state, or static economy forever. These probabilities are simply powers of $1 - p$, where p is the probability of job finding.

Taking unconditional averages, the probability of remaining unemployed for nine months is fifty percent higher in the dynamic benchmark economy than in the static benchmark.

Thus business cycles substantially increase the probability of long unemployment spells, and thereby increase the probability of large falls in consumption. However, this is not the only increase in risk caused by the fluctuations: the volatility of the wage increases too, which turns out to be an important factor in our results. We calculate that the average wage in booms is 0.878 for good jobs and 0.755 for bad jobs, while in recessions it is 0.814 and 0.701, respectively. Thus the wage variation across aggregate states is about half as big as the variation between bad and good jobs.

Table 3 also gives some summary statistics for the distributions of assets and consumption associated with the dynamic benchmark economy, in which we can see the impact of the increased risk. The mean and standard deviation of the unconditional distributions of assets and consumption are reported.[10] In the same lines, the means and standard deviations conditional on recession ($Z = Z^1$) or boom ($Z = Z^2$) are stated. Thus we see that while the average cross-sectional standard deviation of consumption is only marginally higher in the dynamic economy than in the static economy, average consumption varies from 0.808 in booms to 0.711 in recessions; and with this increased risk, assets are 15% higher on average than in the static economy. The remaining lines of the table report the means and standard deviations for agents in the three employment states. For example, workers in good jobs in booms have mean consumption 0.851, while unemployed workers in recessions have mean consumption 0.540.

Thus we note several conflicting impacts on workers' long-run welfare in this economy. Suffering greater risk, they build up substantially more assets than in the static baseline economy. Greater assets give them a more advantageous

[10]While the static benchmark economy converges to a steady state distribution $\overline{\Phi}$, the dynamic economy has a constantly changing distribution Φ_t. Thus the standard deviation of assets 1.282 reported in Table 3 is the mean, over time, of the cross-sectional standard deviations of the distributions Φ_t.

position in wage bargaining, so the wage is 0.5% higher in this economy than in the static economy. With a higher wage, firms hire less, so the unemployment rate is 0.2 percentage points higher on average in the dynamic benchmark economy. In spite of the higher unemployment, workers' consumption is 0.6% higher on average than in the static economy, both because the wage is higher, and because they have more interest income.

All these issues affect the social welfare difference between the static and dynamic economies, but Tables (2) and (3) are not directly comparable since the statistics in Table 3 are evaluated at a higher level of assets. To isolate the effects of imposing productivity shocks, we should start the two economies from the same initial conditions: that is, we should include transition dynamics in our welfare measure. This is what is done by the welfare measure of equation (21), which can be interpreted as the cost of switching on the aggregate shocks, starting from the steady state $\overline{\Phi}$ of the static benchmark. We calculate the cost numerically by searching for the proportional change Δ^* in workers' consumption distribution which would lead to the same loss in welfare as that caused by switching on business cycles. We find that cycles impose a loss equivalent to $\Delta^* = -0.233\%$ of baseline average consumption.

7.2.1 Discussion

These welfare gains are quite large by the standards of Lucas (2003), who says he believes that the gains from macroeconomic stabilization are probably "one or two orders of magnitude smaller" than one-tenth of one percent of consumption. For more perspective on the size of the gains from completely eliminating cycles, we can use Lucas' formula for an upper bound on the benefits of eliminating cycles in a representative agent economy:

$$\frac{1}{2} * \text{relative risk aversion} * \text{variance of log consumption} \tag{25}$$

In our simulation, average relative risk aversion is 2.7, and total consumption (which is output minus vacancy costs) has a coefficient of variation of approximately 0.018, slightly less than the variability of output. Thus Lucas' bound suggests that the welfare gains should be at most $0.5 * 2.7 * (0.018)^2 \approx 0.043\%$ of consumption, less than a fifth of the gains we calculate.

However, aggregate consumption is only part of the story, since it includes the consumption of the risk-neutral capitalists. *Workers'* consumption is in fact even more variable, with a coefficient of variation of 0.033. Using this higher measure of consumption variability, Lucas' bound implies welfare gains of at most $0.5 * 2.7 * (0.033)^2 \approx 0.15\%$ of consumption, roughly two thirds of our estimate of the welfare gains from eliminating cycles. The volatility of workers' consumption results from the even greater volatility of the wage, which has a coefficient of variation of 4.1%, reflecting the deterioration of workers' bargaining position in recessions due to decreased assets and increased unemployment risk. Thus even though our model is calibrated to produce reasonable output fluctuations, it turns out to generate substantial aggregate consumption risk for workers, given the high degree of wage flexibility implied by Nash wage bargaining.

Another insight into the size of our welfare gains comes from comparing these to the losses implied by eliminating variation in labor supply. Note that in the absence of frictions, it would be beneficial in our "real business cycle" economy to work more when productivity is high and less when productivity is low. Fixing mean productivity, and fixing mean labor, the gain in mean output from making productivity vary by $\pm\epsilon_y$ between booms and recessions, and labor vary by $\pm\epsilon_n$ between booms and recessions, is $\epsilon_y \epsilon_n$. In our dynamic benchmark, $\epsilon_y = 0.012$, and $\epsilon_n = 0.006$. Eliminating this fluctuation (without changing means) would lower average output by $0.012 * 0.006 = 0.0072\%$, tiny compared with our welfare gains from stabilization.

In summary, we find that the welfare costs of cycles are modest, but are nonetheless around 32 times larger than the purported *gains* from making labor procyclical in a real business cycle context. We next ask how much of the welfare loss associated with cycles can be eliminated by fiscal policy.

7.3 Optimal stabilization

Figure 5 is a contour plot[11] of the social welfare function, for a variety of cyclical fiscal policies. Each contour line represents a change in welfare equivalent to 0.02% of static benchmark consumption. All policies considered in the graph hold mean unemployment insurance at its benchmark level $\overline{b} = 0.32$. We vary the government's deficit in recessions from $\hat{X} = 0$ to $\hat{X} = 0.08$ per capita (approximately 8% of output per worker). We also compare different amounts of time variation in the UI benefit, ranging from $\hat{b} = -0.006$ (lowering the benefit by 0.6% of output per worker in recessions) to $\hat{b} = 0.04$ (raising the benefit by 4% of output per worker in recessions).

The dynamic benchmark economy is at the origin in the graph. The optimal policy (conditional on mean benefits $\overline{b}$) has $\hat{X} \approx 0.04$ and $\hat{b} \approx -0.003$: a deficit of roughly 4% of output per worker, and an unemployment benefit that is very slightly procyclical. This optimal economy is described in Table 4. We see that this policy goes far beyond tax smoothing: taxes are strongly procyclical, at 0.245 in booms and only 0.172 in recessions. In the graph we also plot the line of constant total distortions (average taxes plus benefits the same in recessions and booms, plotted by interpolating our simulation results). We see that the optimal policy is to the right of the curve of constant distortions, deep in the region of employment stabilization.

The procyclical tax policy at the optimum substantially smoothes the unemployment rate and other variables, which allows much lower precautionary saving. Mean unemployment in recessions is 6.1%, while in booms it is 5.5%; thus unemployment varies half as much as in the dynamic benchmark. Wages in good and bad jobs are 0.848 and 0.734 in recessions and 0.832 and 0.724 in booms. Average consumption is almost completely smoothed: it is 0.782 in recessions and 0.785 in booms. Average assets are thus much lower, at 2.201 in the stabilized economy, compared to 2.746 in the dynamic benchmark.

[11] We calculate social welfare in simulated economies on a grid over $\hat{X}$ and $\hat{b}$, then interpolate the welfare function by fitting a Chebyshev polynomial. The graph shows contour lines of the interpolated welfare function.

The welfare differential of this economy, compared to the static benchmark, is $\Delta(0.04, -0.003, 0.32) = -0.046\%$ of static benchmark consumption. Stated differently, optimal stabilization of the dynamic benchmark economy increases welfare by 0.233% - 0.046% = 0.187% of consumption. Thus, in our model, around eighty percent of the welfare cost of business cycles can be eliminated by stabilization.

7.3.1 Discussion

A simple way to understand the welfare effects of stabilizing fiscal policy is just to count contour lines in the graph, and decompose the welfare gains by looking at the curve of constant distortions. About a quarter of the welfare improvement occurs as we move right from the dynamic benchmark to the point where taxes (and benefits) are perfectly smooth, which requires $\hat{X} \approx 0.005$. Table 7 shows that this policy reduces the welfare loss associated with business cycles from 0.233% to 0.205% of baseline average consumption.

About half the welfare improvement can be obtained by moving northeast along the line of constant distortions, that is, by passing along lump-sum insurance payments against the aggregate shock to the workers. This policy corresponds to $\hat{X} \approx 0.03$ and $\hat{b} \approx 0.02$. Since distortions are constant over the cycle, the countercyclical deficit in this equilibrium does not stabilize unemployment: the unemployment rate is 1.2 percentage points higher in recessions than in booms, approximately the same difference as in the dynamic benchmark economy. The welfare impact of this policy is reported in Table 7 under the heading "Aggregate insurance": the welfare loss from business cycles falls to only 0.096% of baseline consumption. In principle, part of this welfare improvement could be achieved by private markets selling insurance against aggregate shocks. However, in an economy where such markets are not observed, one reason a government might wish to run a deficit during a recession would be to pass along to the public an insurance payment against the aggregate shock.

But intuitively, fair insurance payments against the aggregate shock are a very blunt instrument for smoothing individual consumption. Such payments are harmful for the unemployed in booms, because they involve cutting taxes and increasing benefits in recessions, but raising taxes and decreasing benefits in booms. Therefore, we see that the direction of optimal policy is nowhere near the line of constant distortions. Instead, another quarter of the welfare gains are obtained as we move down off the line of constant distortions to the optimal point $\hat{X} \approx 0.04$, $\hat{b} \approx -0.003$. This policy reduces the welfare cost of business cycles to only 0.046% of baseline consumption. Thus it is better for the government to pass along the revenue from the deficit it runs in recession by cutting taxes and maintaining benefits fixed, instead of simply paying it out as a lump-sum transfer. This optimal policy is strongly stabilizing: total distortions are much lower in recessions, so that the unemployment rate is only 0.6 percentage points higher in recessions than in booms, and wages and consumption are almost completely smoothed over the cycle.

7.4 Lower unemployment insurance

Finally, we also consider the effects of lowering the mean level of the unemployment benefit, thus decreasing total labor market distortions. Table 5 reports the effects of lowering mean UI to $\bar{b} = 0.28$, without stabilization ($\hat{X} = 0$ and $\hat{b} = 0$). With lower distortions, unemployment falls from 6.0% in the static baseline, where the replacement ratio is approximately 40%, to 5.5% when $\bar{b} = 0.28$ (a replacement ratio of $0.28/0.824 \approx 34\%$). These numbers imply a semielasticity of unemployment with respect to the replacement ratio of 1.4 in our model, close to Layard and Nickell's (1999) point estimate of 1.3.

In addition to the fall in unemployment, we see other strong signs of greater efficiency in this economy. Taxes fall from 0.211 in the dynamic benchmark to 0.205 with lower UI. Output rises by 0.4%, and wages rise by 1.6%. In other words, even though lower UI, by itself, worsens the worker's bargaining position, it has a strong enough effect on unemployment that wages rise in equilibrium. Average consumption rises by 0.75% compared to the dynamic benchmark, and the variation in average consumption between recessions and booms is essentially unchanged. Given their lower unemployment benefits, workers are forced to save substantially more in order to smooth their consumption; workers increase their buffer stocks of assets in this model by 36% compared to the dynamic benchmark. Note that this increase in assets is partially responsible for the large rise in long run average consumption, and also is one of the factors that helps hold up the wage.

In Table 7, these efficiency gains are reflected in social welfare. Social welfare in an economy with cycles, and with $\bar{b} = 0.28$, is just 0.0201% lower than welfare in the static benchmark; in other words, it is much higher than in the dynamic benchmark with $\bar{b} = 0.32$. This gain is unevenly distributed: the unemployed are worse off, compared with the dynamic benchmark. But workers as a whole are better off than in the dynamic benchmark, and capitalists' welfare also increases substantially. Further welfare gains can be obtained by stabilizing the economy as well, as we see in Table 6 and in the last line of Table 7. With lower unemployment insurance, the optimal level of stabilization is even higher: the government should run a countercyclical deficit of 5% of output per worker, $\hat{X} = 0.05$, with acyclical benefits $\hat{b} = 0$. The effects of stabilization on unemployment, wages, asset holdings, and consumption are similar to those we found for the case of $\bar{b} = 0.32$. Social welfare, compared to the static benchmark as a consumption equivalent, rises to $\Delta(0.05, 0, 0.28) = +0.133\%$.[12]

8 Conclusions

This paper has constructed a model with the main elements we consider necessary for evaluating the costs of business cycles. Aggregate fluctuations are driven by shocks to productivity. The idiosyncratic labor income process is modeled by including a matching function and wage bargaining. Workers try to smooth away their labor income risk through precautionary saving. Our parameterization emphasizes fitting the variability of unemployment and choosing risk aversion and discount rates to obtain a reasonable liquid asset

[12] In future versions of this paper we hope to be able to report the overall optimal policy $(\hat{X}, \hat{b}, \bar{b})$.

distribution. In this framework, switching on aggregate shocks increases unemployment risk and wage variability. Therefore, business cycles decrease social welfare, by an amount equivalent to diminishing all workers' consumption by 0.233%.

In this economy, the government can provide unemployment insurance out of labor income taxes, and thus it also has tools to stabilize cycles. We allow the government to choose from a simple set of fiscal policy rules which ensure budget balance over time but allow the option of deficits in some periods. Given our benchmark UI replacement ratio of 40%, we find that the government's optimal policy involves a deficit of 4% of output per worker in recessions. This permits much lower taxes in recessions than in booms, which stabilizes firms' hiring decisions. Half the cyclical variation in unemployment is eliminated, together with most time variation in average wages and average consumption, and most of the welfare cost of business cycles.

We also find a social welfare improvement from lowering the mean UI benefit. Starting from our benchmark economy with cycles, a six-percentage-point decrease in the replacement ratio raises social welfare almost back to the level of the benchmark economy *without* cycles. Consumers then face greater risk, but respond by a substantial increase in saving, and consume more on average. With lower UI, optimal stabilization policy is even more aggressive, suggesting that stabilization and insurance are at least partially substitutes.

Our results suggest that even if business cycles are driven by productivity shocks, output fluctuation implies nontrivial welfare costs if there is market incompleteness. Our stabilization policy leads to welfare gains almost 30 times larger than the increase in output associated with the procyclicality of labor supply in our model. Given the relative magnitudes of these two effects, we suspect our basic result that "real business cycles" should be stabilized will be robust to substantial changes in parameters and model specification. However, there are many aspects of the stabilization versus insurance problem which deserve further study. Important generalizations include allowing for uncertainty and policy lags, and explicitly incorporating physical capital. Analogous models in contexts of wage stickiness, price stickiness, and capacity constraints are also of interest.

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Table 1: Parameters.

Aggregate shocks		
Shock arrival rate	$\pi_{12} = \pi_{21}$	$1 - (2/3)^{(1/12)}$
Parameters of worker's problem		
Credit constraint	$\overline{a}$	0
Discount factor	β	0.92
Relative risk aversion	γ	2
Essential consumption	$\underline{c}$	0.2
Value-of-time parameter	α_l	1.983
Time cost working	$h(1) = h(2)$	1/3
Time cost searching	$h(0)$	0.1
Parameters of capitalist's problem		
Interest rate	$R - 1$	0.05
Vacancy cost	κ	0.2824
Productivity variation good/bad match	$a(z)$	±0.15
Productivity variation boom/recession	$A(Z)$	±0.0075
Matching and bargaining parameters		
Matching function coefficient	μ	0.4308
Unemployment elasticity of matching	λ	0.5
Worker's bargaining share	σ	0.5
Probability of good match in recessions	$\pi^g(Z^1)$	0
Probability of good match in booms	$\pi^g(Z^2)$	0.119
Prob. of promotion to good match	p^{prom}	0.0238
Separation rate of bad matches	δ^b	0.0416
Separation rate of good matches	δ^g	0.0147
Fiscal policy parameters		
Government spending	G	0.188
Other policy parameters	$\overline{b}$, $\hat{b}$, $\hat{X}$	variable

Table 2: Static benchmark equilibrium.

Employment and output:		
Unemployment benefit	$\overline{b}$	0.32
Tax rate	τ	0.209
Unemployment	U	0.058
Employment in bad jobs	N^b	0.314
Employment in good jobs	N^g	0.628
Output	$N^b y(1) + N^g y(2)$	0.990
Average product of labor	$(N^b y(1) + N^g y(2))/N$	1.050
Average wage	w	0.803
Workers' asset distribution:[1]		
Mean		2.402
Standard deviation		0.961
Mean, for unemployed		1.728
St. dev., for unemployed		0.953
Mean, employed in bad jobs		1.507
St. dev., employed in bad jobs		0.642
Mean, employed in good jobs		2.911
St. dev., employed in good jobs		0.803
Workers' consumption distribution:		
Mean		0.784
Standard deviation		0.078
Mean of relative risk aversion		2.755
Mean consumption, for unemployed		0.552
St. dev., for unemployed		0.065
Mean, employed in bad jobs		0.731
St. dev., employed in bad jobs		0.028
Mean, employed in good jobs		0.832
St. dev., employed in good jobs		0.017

[1]Assets as multiple of numeraire.

Table 3: Dynamic benchmark equilibrium.

	Mean, overall	*Mean, recession*	*Mean, boom*
Employment and output:			
Unemployment benefit	0.32	0.32	0.32
Government deficit	0	0	0
Tax rate	0.210	0.215	0.204
Unemployment	0.060	0.065	0.054
Employment in bad jobs	0.313	0.325	0.301
Employment in good jobs	0.626	0.608	0.644
Output	0.988	0.970	1.005
Average product of labor	1.050	1.038	1.062
Average wage	0.807	0.774	0.839
Workers' asset distribution:[1]			
Mean	2.746	2.449	3.049
Standard deviation	1.282	1.174	1.390
Mean, for unemployed	2.046	1.779	2.313
St. dev., for unemployed	1.261	1.142	1.380
Mean, employed in bad jobs	1.791	1.589	1.993
St. dev., employed in bad jobs	0.919	0.833	1.005
Mean, employed in good jobs	3.292	2.980	3.603
St. dev., employed in good jobs	1.115	1.011	1.220
Workers' consumption distribution:			
Mean	0.789	0.771	0.808
Standard deviation	0.079	0.084	0.073
Mean, for unemployed	0.563	0.540	0.586
St. dev., for unemployed	0.065	0.066	0.063
Mean, employed in bad jobs	0.738	0.718	0.758
St. dev., employed in bad jobs	0.032	0.033	0.031
Mean, employed in good jobs	0.837	0.824	0.851
St. dev., employed in good jobs	0.020	0.021	0.020

Welfare, compared to static benchmark: $\boldsymbol{\Delta}^* =$ **-0.233%** of consumption.

[1]Assets as multiple of numeraire.

Table 4: Equilibrium under optimal stabilization.

	Mean, overall	*Mean, recession*	*Mean, boom*
Employment and output:			
Unemployment benefit	0.320	0.317	0.323
Government deficit	0	0.040	-0.040
Tax rate	0.208	0.172	0.245
Unemployment	0.058	0.061	0.055
Employment in bad jobs	0.315	0.330	0.300
Employment in good jobs	0.627	0.609	0.645
Output	0.989	0.974	1.004
Average product of labor	1.050	1.037	1.062
Average wage	0.803	0.808	0.798
Workers' asset distribution:[1]			
Mean	2.201	2.265	2.137
Standard deviation	0.987	1.014	0.961
Mean, for unemployed	1.579	1.607	1.550
St. dev., for unemployed	0.973	0.995	0.952
Mean, employed in bad jobs	1.414	1.461	1.368
St. dev., employed in bad jobs	0.659	0.676	0.642
Mean, employed in good jobs	2.657	2.767	2.547
St. dev., employed in good jobs	0.831	0.832	0.830
Workers' consumption distribution:			
Mean	0.784	0.782	0.785
Standard deviation	0.078	0.081	0.075
Mean, for unemployed	0.552	0.547	0.558
St. dev., for unemployed	0.065	0.066	0.065
Mean, employed in bad jobs	0.731	0.731	0.731
St. dev., employed in bad jobs	0.028	0.029	0.028
Mean, employed in good jobs	0.832	0.834	0.830
St. dev., employed in good jobs	0.018	0.017	0.018

Welfare, compared to static benchmark: **-0.046%** of consumption.

[1]Assets as multiple of numeraire.

Table 5: Equilibrium with lower UI.

	Mean, overall	*Mean, recession*	*Mean, boom*
Employment and output:			
Unemployment benefit	0.28	0.28	0.28
Government deficit	0	0	0
Tax rate	0.205	0.210	0.200
Unemployment	0.055	0.060	0.050
Employment in bad jobs	0.314	0.327	0.301
Employment in good jobs	0.629	0.611	0.647
Output	0.992	0.975	1.009
Average product of labor	1.050	1.038	1.062
Wage	0.820	0.787	0.853
Workers' asset distribution:[1]			
Mean	3.728	3.449	4.055
Standard deviation	1.703	1.630	1.776
Mean, for unemployed	2.907	2.642	3.172
St. dev., for unemployed	1.683	1.596	1.769
Mean, employed in bad jobs	2.520	2.319	2.720
St. dev., employed in bad jobs	1.286	1.227	1.345
Mean, employed in good jobs	4.414	4.145	4.683
St. dev., employed in good jobs	1.502	1.429	1.575
Workers' consumption distribution:			
Mean	0.805	0.788	0.823
Standard deviation	0.079	0.085	0.074
Mean, for unemployed	0.578	0.557	0.600
St. dev., for unemployed	0.068	0.071	0.064
Mean, employed in bad jobs	0.751	0.732	0.770
St. dev., employed in bad jobs	0.039	0.041	0.036
Mean, employed in good jobs	0.852	0.840	0.865
St. dev., employed in good jobs	0.025	0.025	0.024

Welfare, compared to static benchmark: **-0.020%** of consumption.

[1]Assets as multiple of numeraire.

Table 6: Equilibrium under lower UI, with stabilization.

	Mean, overall	*Mean, recession*	*Mean, boom*
Employment and output:			
Unemployment benefit	0.28	0.28	0.28
Government deficit	0	0.05	-0.05
Tax rate	0.204	0.157	0.250
Unemployment	0.054	0.057	0.051
Employment in bad jobs	0.316	0.330	0.301
Employment in good jobs	0.631	0.614	0.648
Output	0.993	0.979	1.008
Average product of labor	1.050	1.037	1.062
Wage	0.813	0.829	0.796
Workers' asset distribution:[1]			
Mean	3.029	3.222	2.848
Standard deviation	1.392	1.473	1.310
Mean, for unemployed	2.284	2.402	2.165
St. dev., for unemployed	1.370	1.444	1.295
Mean, employed in bad jobs	1.996	2.114	1.878
St. dev., employed in bad jobs	0.995	1.050	0.941
Mean, employed in good jobs	3.620	3.888	3.352
St. dev., employed in good jobs	1.210	1.252	1.168
Workers' consumption distribution:			
Mean	0.796	0.800	0.793
Standard deviation	0.079	0.082	0.077
Mean, for unemployed	0.564	0.565	0.564
St. dev., for unemployed	0.070	0.070	0.069
Mean, employed in bad jobs	0.741	0.746	0.735
St. dev., employed in bad jobs	0.035	0.035	0.035
Mean, employed in good jobs	0.844	0.851	0.838
St. dev., employed in good jobs	0.022	0.021	0.023
Welfare, compared to static benchmark: **+0.133%** of consumption.			

[1]Assets as multiple of numeraire.

Table 7: Effects of policies on social welfare.

Policy			*Social welfare**	*Welfare change attributable to:*				
$\hat{X}$	$\hat{b}$	$\overline{b}$		*All workers*	*Unemployed*	*In bad jobs*	*In good jobs*	*Capitalists*
Dynamic benchmark:								
0	0	0.32	-0.233%	-0.234%	-0.016%	-0.081%	-0.137%	+0.0009%
Tax smoothing:								
0.005	0	0.32	-0.205%	-0.208%	-0.014%	-0.072%	-0.122%	+0.0022%
Aggregate insurance:								
0.03	0.02	0.32	-0.096%	-0.099%	-0.0067%	-0.033%	-0.059%	+0.0032%
Optimal stabilization:								
0.04	-0.0030	0.32	-0.046%	-0.055%	-0.0039%	-0.019%	-0.032%	+0.0091%
Lower UI:								
0	0	0.28	-0.020%	-0.125%	-0.021%	-0.062%	-0.042%	+0.105%
Lower UI, with stabilization:								
0.05	0	0.28	+0.133%	+0.019%	-0.011%	-0.011%	+0.041%	+0.114%

*Welfare effects, compared to static benchmark, as percent of average consumption.

Fig. 1: Policy space, conditional on average UI benefits

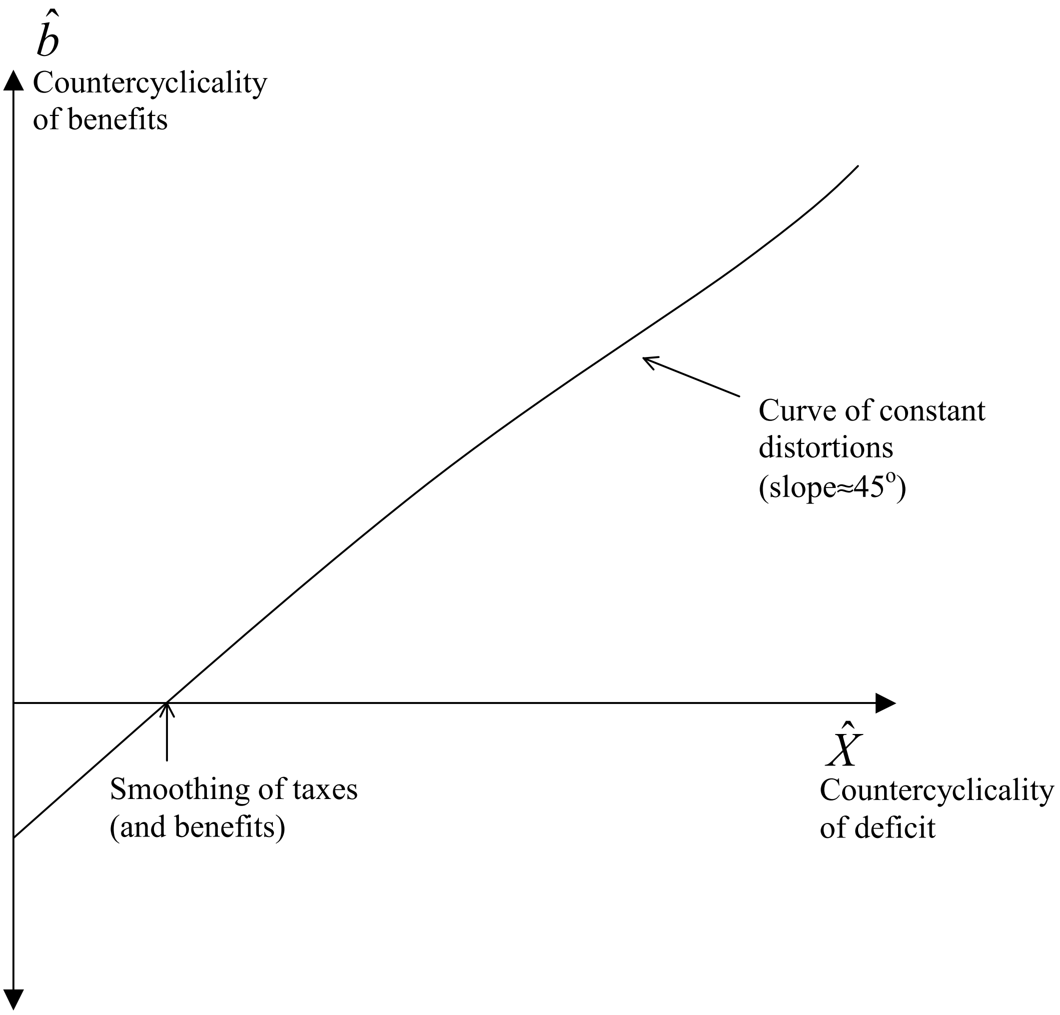

Fig. 2: Asset c.d.f. of unemp (solid), bad emp (dash), good emp (dash dot)

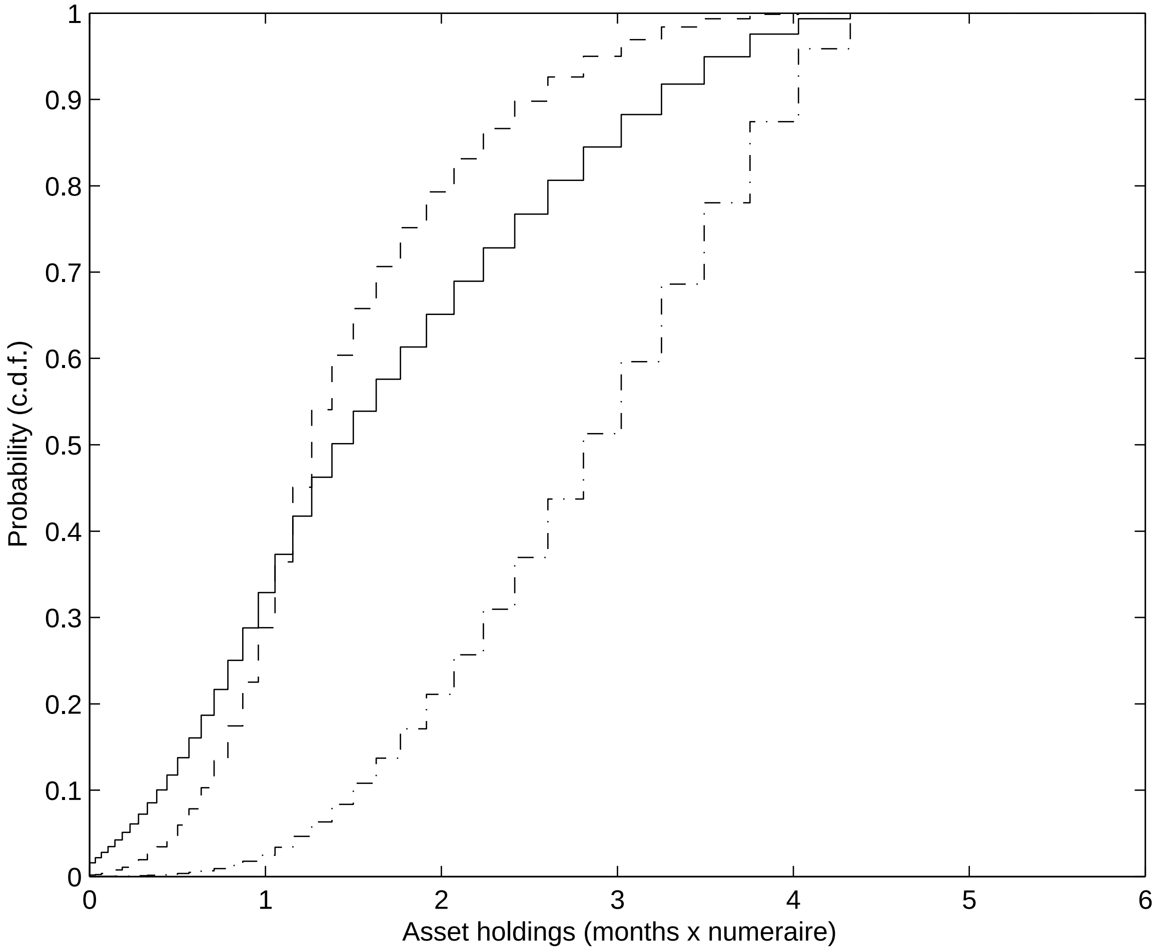

Fig. 3: Consumption policy of unemp (solid), bad emp (dash), good emp (dash dot)

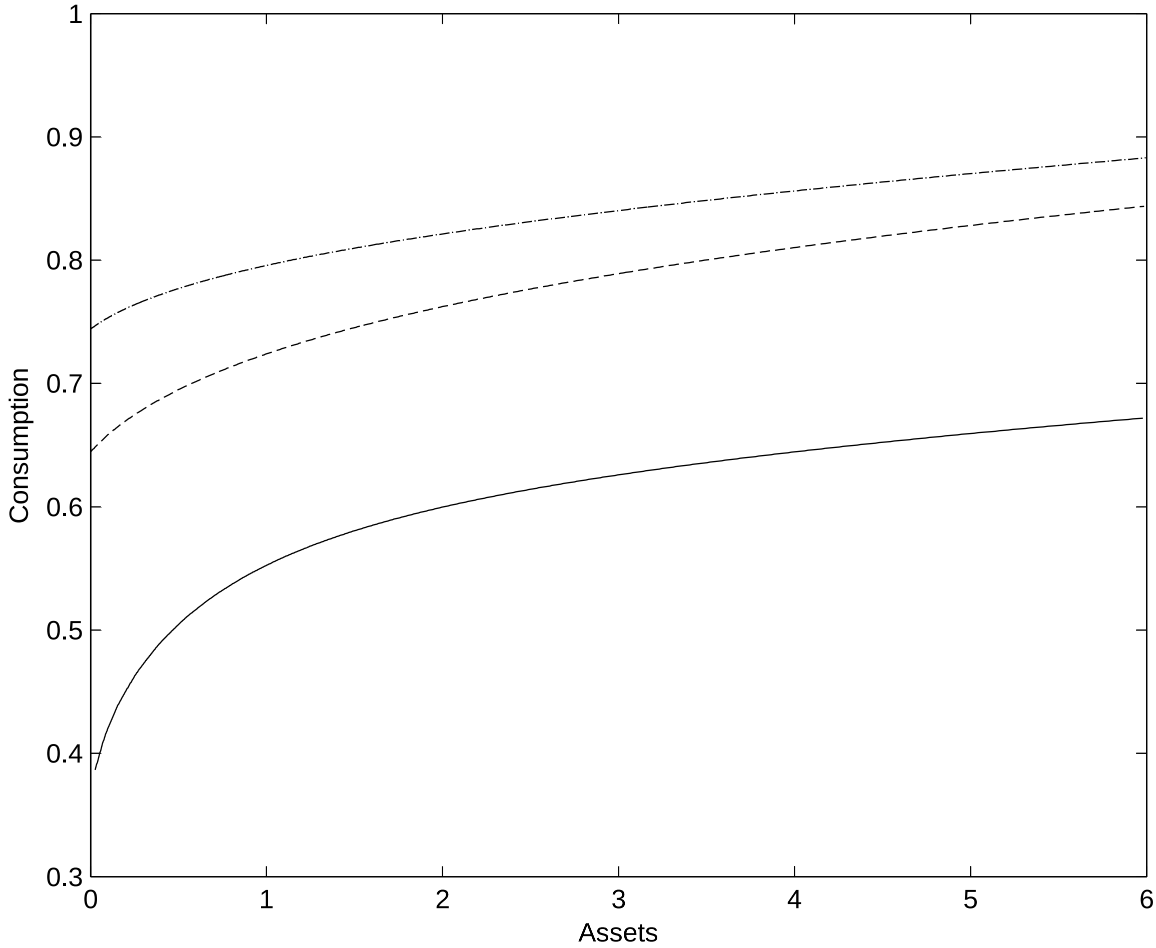

Fig. 4: Unemployment duration probabilities. Solid: boom; dashed: recession; dotted: static.

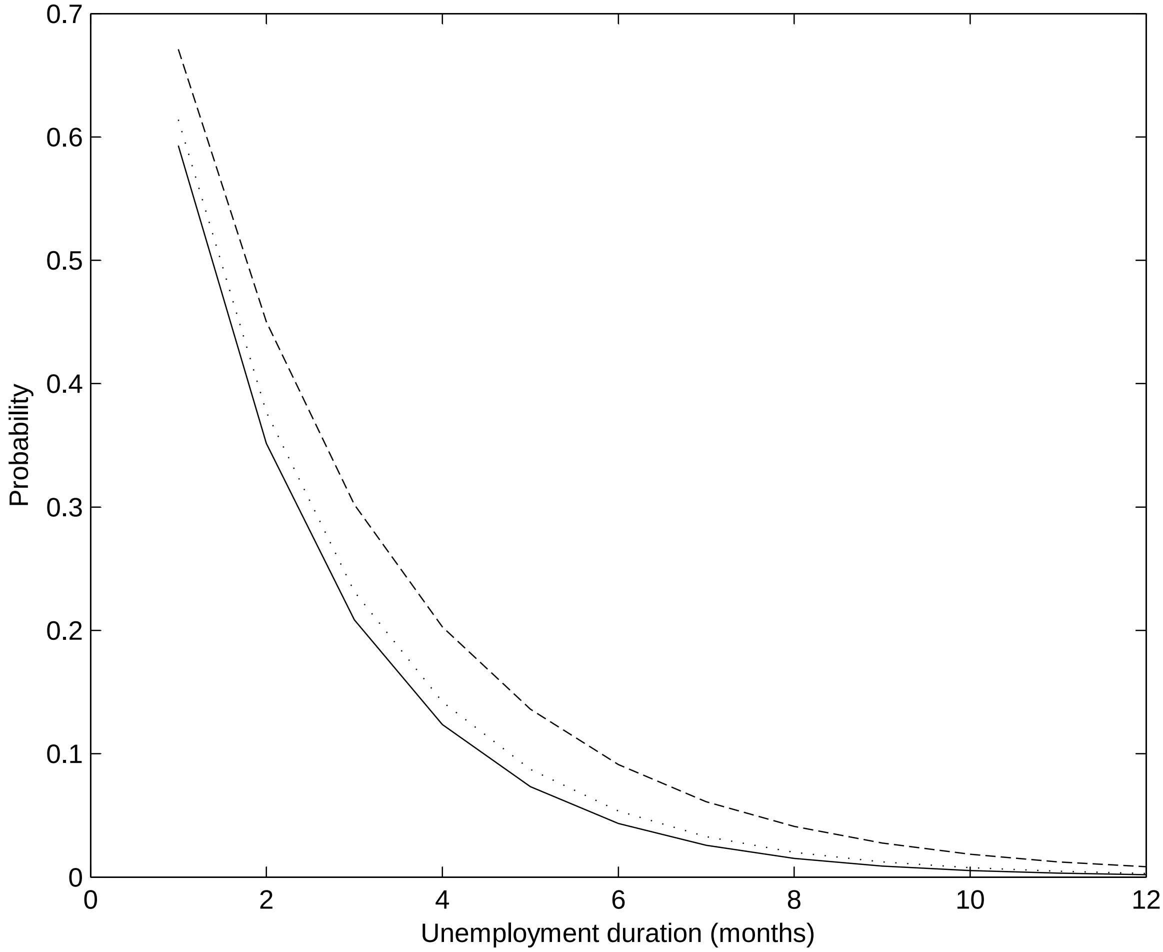

Fig. 5: Social welfare as function of policy