

# Reallocation and the Changing Nature of Economic Fluctuations\*

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## Abstract

The business cycle in the United States has changed in fundamental ways in the last three decades. Average labor productivity has gone from strongly procyclical to mildly countercyclical and labor market recoveries after the three most recent recessions have been weaker and more prolonged relative to earlier recessions. We consider the hypothesis that an increase in the importance of labor market mismatch during recessions can account for these changes. We build a model in which production takes place on two islands. Workers can costlessly move into and out of work within an island, but moving between islands requires passing through a longer period of unemployment. Aggregate shocks trigger relatively short-lived movements into and out of work within islands, whereas island-specific shocks lead to heightened mismatch and trigger reallocation across islands. Quantitatively, we show that a reduction in the importance of aggregate shocks—i.e. an increase in the relative importance of island-specific shocks which induce reallocation—can simultaneously account for lower output volatility, less procyclical productivity, slower labor market recoveries, and behavior of labor market variables consistent with the business cycles of the last thirty years.

*Keywords:* Reallocation; Mismatch; Great Moderation; Productivity; Business Cycles

*JEL Classifications:* E24, E32

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# 1 Introduction

The most recent recession in the United States has been characterized by acyclical or even countercyclical average labor productivity and a sluggish labor market recovery. A popular hypothesis, among both economists and policymakers, is that increased labor market mismatch may help to simultaneously account for these two facts. Understanding whether or not this channel helps to explain the data is important for policymakers: the desirability of countercyclical demand management policies may depend on the extent to which any shortfall in output and/or employment is attributable to mismatch.

In this paper we explore not only how mismatch has impacted the most recent recession, but its role in accounting for broader changes in the business cycle over the last several decades. Though Robert Lucas (1977) famously wrote that “business cycles are all alike,” the behavior of the business cycle in the United States since the early 1980s looks quite different than the earlier post-war period to which Lucas was referring. One well-known change in the nature of business cycles has been the marked decline in the volatility of output and other economic aggregates. This broad-based decline in volatility has been dubbed the “Great Moderation” and has been the subject of a substantial body of research. Another well-researched change is the so-called “Jobless Recovery” phenomenon—job growth following the three most recent US recessions has been considerably more anemic when compared to earlier recessions. Finally, average labor productivity, which was once robustly procyclical, is now acyclical or slightly countercyclical. These changes all took hold around the same time in the mid-1980s, suggesting that there is more than mere temporal coincidence linking them.

The emergence of jobless recoveries and the changing cyclicity of average labor productivity suggests that there has been a change in the nature of, and the causes of, the drop in labor input that typically occurs during recessions. The mismatch hypothesis holds that recessions are periods in which the attributes of workers and firms—sectors, geographic regions, skills, etc.—are increasingly out of sync. This mismatch generates a need for reallocation, and the process of reallocating labor during recessions can potentially account for the changes in the business cycle mentioned above. Through a compositional effect, a reallocation of labor away from lower productivity uses towards higher productivity uses leads to higher productivity in the aggregate. To the extent

that this reallocation occurs when aggregate output is low, this mechanism would contribute to less procyclical labor productivity. Moreover, the time-consuming nature of the means by which the mismatch is overcome—geographic relocation, skill acquisition, sectoral reallocation, etc.—implies that the subsequent recovery of employment could be weak and prolonged, contributing to an observed “jobless recovery.”

To better explore the mismatch hypothesis and its relation to the observed changes in the US business cycle, we construct a model with two different “islands” of production. The islands represent the various dimensions of potential mismatch. Production takes place on each island using capital and labor, with islands subjected to both island-specific and aggregate productivity shocks. Households consume a composite good made by combining the outputs of each island, and supply labor indivisibly but with employment lotteries as in Rogerson (1988). Because we focus on labor reallocation, we assume that capital and goods are costless to transport between islands, but labor is not. While workers can costlessly transition between work and non-work within an island, we assume that when workers move between islands they are unable to work for a (stochastic) period of time, as they acquire new skills or relocate geographically.<sup>1</sup>

In response to a negative *aggregate* productivity shock (one that affects both islands), the model behaves very much like a one-sector real business cycle model. With a low marginal product of labor, there will be a reduction in employment (since labor is indivisible) on both islands, and hence a reduction in aggregate employment. Both island-specific and aggregate labor productivity will fall. As soon as aggregate conditions improve, workers on each island will transition back to work, so that the observed aggregate employment recovery will be relatively quick. In contrast to an aggregate productivity shock, a shock that triggers a change in the *relative* productivities of the two islands will precipitate a movement of workers between the islands. Aggregate employment and output decline following a reallocative shock of this sort, while aggregate productivity rises as workers transition to a relatively more productive use. The more time-consuming is the reallocation process, the more prolonged will be the response of aggregate employment.

Actual business cycles in our model economy result from a mix of both aggregate and

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<sup>1</sup>The period of time needed to reallocate is made stochastic in order to reduce the dimensionality of the state space, as described in more detail in Section 3.

island-specific shocks. Because the responses to the two kinds of shocks are qualitatively so different, it is natural to explore whether the changing nature of business cycles can be explained by a change in the relative importance of the two shock processes. Based on a factor analysis of detailed industry-level production data, Foerster et al. (2011) present empirical evidence that the Great Moderation has mainly been driven by a reduction in the volatility of aggregate shocks, with little or no change in the volatility of industry-specific shocks. In our model, a reduction in the volatility of aggregate shocks, and thus an increase in the *relative* importance of island-specific shocks, is likely to lower the overall cyclical nature of productivity and may lead to slower aggregate employment dynamics, for the reasons discussed above. Thus, we explore whether a reduction in the volatility of aggregate shocks can explain the observed changes in economic fluctuations over the last several decades. It might seem unusual, in the wake of a such a severe recession as the most recent one, to consider a reduction in the volatility of aggregate shocks. However, what matters for the cyclical nature of labor productivity and the speed of employment recoveries in our model is not the absolute magnitude of shocks, but rather the relative contributions of aggregate and island-specific shocks. Thus, while in our benchmark quantitative exercises we only alter the magnitude of aggregate shocks, our core hypothesis about the change in the relative importance of shocks does not preclude the observance of large recessions.

While it seems clear that a decline in the relative importance of aggregate shocks will lead to qualitative changes consistent with what is observed in the aggregate data, it is unclear how important this change may be quantitatively. To assess that, we conduct quantitative simulations of the model. We assume that the aggregate productivity shock follows a two-state Markov processes, with the states roughly corresponding to “normal times” and “recessions.” The transition matrix of the aggregate state is set to match the average incidence and duration of recessions in the data. The island-specific productivities also follow Markov processes, with the transition matrixes parameterized such that a movement from the good to the bad aggregate state triggers a persistent change in the relative productivities of the two islands. This is a simple way to model the fact that business cycle troughs are associated with both a deterioration of overall economic conditions and asymmetric effects on different sectors and regions.<sup>2</sup> This shock structure

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<sup>2</sup>See the discussion in Section 2.4 for a discussion of evidence on the cyclical nature of reallocation.

also can produce a countercyclical labor wedge, which is an important empirical feature of business cycle data, as shown by Chari et al. (2007) and others.

To explore whether the model can account for these changes in the nature of business cycles as a consequence of a shift in the relative importance of aggregate and reallocative shocks, we first pick parameters of the model to match certain moments from post-war US data from 1948-1983. As our baseline quantitative experiment, we then change only the magnitude of the aggregate productivity shock to match the observed decline in aggregate output volatility in the post-1984 period. The model is able to nearly perfectly match the declines in the correlations between labor productivity and output/employment that are observed in the post-1984 data. For example, in the data, the correlation between output and productivity goes from 0.58 in the 1948-1984 period to -0.08 since 1984. In our model, the correlation goes from 0.72 with large aggregate shocks to -0.05 when aggregate shocks are smaller. With smaller aggregate shocks our model also generates slower aggregate labor market recoveries in the post-1984 calibration, with labor market recoveries about one quarter slower on average.

The model also does well at accounting for changes in the nature of fluctuations that have received less attention, but which are nevertheless significant. First, it captures the quantitative behavior of the “wedges” identified from a business cycle accounting exercise in the pre- and post-1984 periods. In the data, the volatility of the “efficiency” wedge has declined while the volatility of the “labor wedge” has remained roughly constant. Reducing the magnitude of aggregate productivity shocks in the model produces exactly this pattern. Second, the model also does a good job of capturing the behavior of different kinds of non-employment. In the data, the volatility of “temporary layoffs” has essentially disappeared post-1984, while the volatility of “permanent layoffs” has remained roughly the same, as documented by Faberman (2008). A key feature of our model is that it features two kinds of unemployment: unemployment while remaining on a given island and unemployment associated with moving between islands. In our quantitative experiments, in the calibration with smaller aggregate shocks the volatility of island-specific unemployment nearly vanishes. If we interpret “island-specific” and “inter-island” unemployment as “temporary” and “permanent” layoffs, respectively, then this is another dimension along which the hypothesis of a decreasing importance of aggregate shocks, relative to reallocative shocks, can account for the changing nature

of business cycles.

The insights into the nature of business cycles that we can obtain from understanding the changes that occurred in the 1980s can inform us about the recent recession and the subsequent anemic recovery. The model's success in quantitatively capturing many of the changes suggests that mismatch is an important element of economic downturns. This has potentially important implications for policymakers, as the nature of recoveries from downturns is distinct when mismatch is a prominent factor, as compared with a case of deficient aggregate demand.

The remainder of this paper is organized as follows. Section 2 documents the important changes in the nature of the business cycle and reviews some of the related literature. In addition, it discusses the growing empirical and theoretical literature on the role of reallocation and mismatch, broadly defined, in accounting for poor labor market performance. Section 3 lays out the model and Section 4 carries out quantitative exercises to show that the model, and the diminished importance of aggregate shocks, can account for the facts. The final section concludes by briefly discussing the broader implications of our findings and suggesting avenues for future research.

## 2 Background Evidence and Related Literature

In this section we present the evidence for the key changes in the nature of economic fluctuations that the paper seeks to understand. While most of these changes have previously been documented, the goal of the present paper is to understand them jointly as related phenomena.<sup>3</sup> Since it lies at the heart of our hypothesis regarding what accounts for those changes, we also discuss the empirical evidence on the importance of labor market mismatch and reallocation during economic downturns.

### 2.1 Reduction in Output Volatility – The Great Moderation

It has been well-documented that output and other economic aggregates became less volatile in the middle of the 1980s. Figure 1 plots the 40-quarter forward rolling standard

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<sup>3</sup>In contrast, most of the existing research in these areas has focused on the different changes in isolation. An exception is Berger (2012), who seeks a joint explanation of the simultaneous decline in the cyclical productivity and the onset of jobless recoveries.

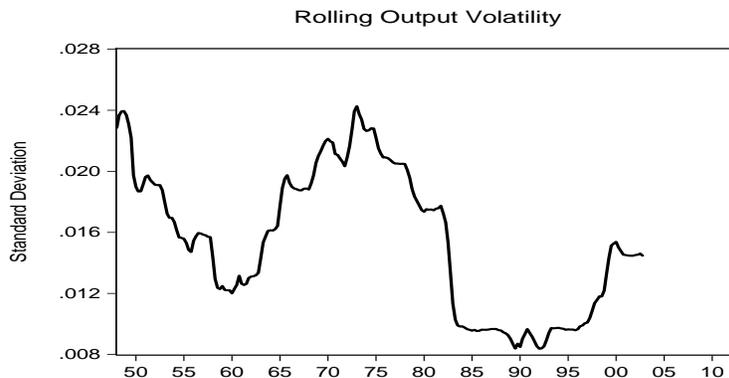


Figure 1: 40-quarter forward rolling standard deviation of HP filtered real GDP.

deviation of the cyclical component of real GDP.<sup>4</sup> The sharp drop in this statistic that occurred in the mid-1980s visually jumps out in the picture. There is some evidence of an uptick in this rolling standard deviation near the end of the sample, a product of the most recent recession. Even at the very end of the sample, however, the volatility of output still remains well below its heightened levels of the 1970s.

Stock and Watson (2003) identify 1984 as the break point for the volatility of output. Throughout the remainder of the paper, we adopt this date as the dividing line when splitting the sample into an earlier and a later sub-sample. The standard deviation of real output in the first sub-sample is 0.020; in the later sub-sample it is 0.011. Including or excluding the Great Recession period does not have much effect on the later sub-sample volatility. Excluding the period 2008-2012 leaves the post-1984 output volatility at 0.010.

Many other aggregate series also experienced drops in volatility during this period, though the magnitudes of the changes are not all the same. For example, the volatility of total hours worked fell from 0.021 in the early sample to 0.018 in the more recent sub-sample. This is noteworthy because it implies that the volatility of hours *relative to output* has increased significantly since 1984, which is, of course, closely related to the changing cyclical nature of average labor productivity. Also, while the moderation is a ubiquitous feature of aggregate data, declining volatility is not readily apparent at more disaggregated levels. For example, Comin and Philippon (2006) document that

<sup>4</sup>Unless otherwise noted, the data used in the analysis span the period from 1948 through the end of the 2012, are quarterly in frequency, seasonally adjusted, and expressed in natural logs where appropriate. We isolate the cyclical component of series using the HP filter with smoothing parameter of 1600.

volatility of sales growth at the firm level has actually increased in the post-1984 period, and argue that the decline in aggregate volatility is mostly driven by a decline in co-movements across sectors. This evidence is consistent with Foerster et al. (2011), who use a dynamic structural factor model to show that the decline in aggregate volatility is mostly driven by aggregate shocks, with little change in the magnitude or importance of industry-specific shocks.

An extensive review of research on the Great Moderation is beyond the scope of this paper, but it is nevertheless worth highlighting a few key contributions. The reduction in volatility in the mid-1980s was first pointed out by Kim and Nelson (1999) and McConnell and Perez-Quiros (2000). Clarida et al. (2000) suggest improved monetary policy as a potential explanation. Stock and Watson (2003) use time series techniques and ultimately come down on the side of “good luck”—in the form of smaller shocks—as the most compelling explanation for the moderation. Jaimovich and Siu (2009) argue that demographic trends, in particular the age composition of the labor force, can account for roughly a quarter of the decline in output volatility. Davis and Kahn (2008) emphasize better inventory management as a way to reconcile lower aggregate volatility with little change in observed consumption risk.

## 2.2 Jobless Recoveries

The recoveries from the three post-1984 recessions in the US have been associated with substantially more anemic labor markets than recessions earlier in the post-war period. Figure 2 demonstrates this. It plots the behavior of the civilian unemployment rate and total hours worked (non-farm business sector) around the six most recent NBER-defined recessions. In the three recessions immediately preceding 1984, both unemployment and hours start to recover almost immediately after the end of the recession. In the three most recent recessions, in contrast, unemployment remains at elevated levels and total hours remain low for years after the output recovery is well underway.

One of the first papers to study the jobless recovery phenomenon was Gordon and Baily (1993), who first noted the unusually tepid labor market recovery after the 1990-1991 recession. Groshen and Potter (2003) noted a similarly laggard labor market performance after the 2001 recession, and argued that structural change, which they define as the reallocation of workers across industries, could help explain the jobless recovery.

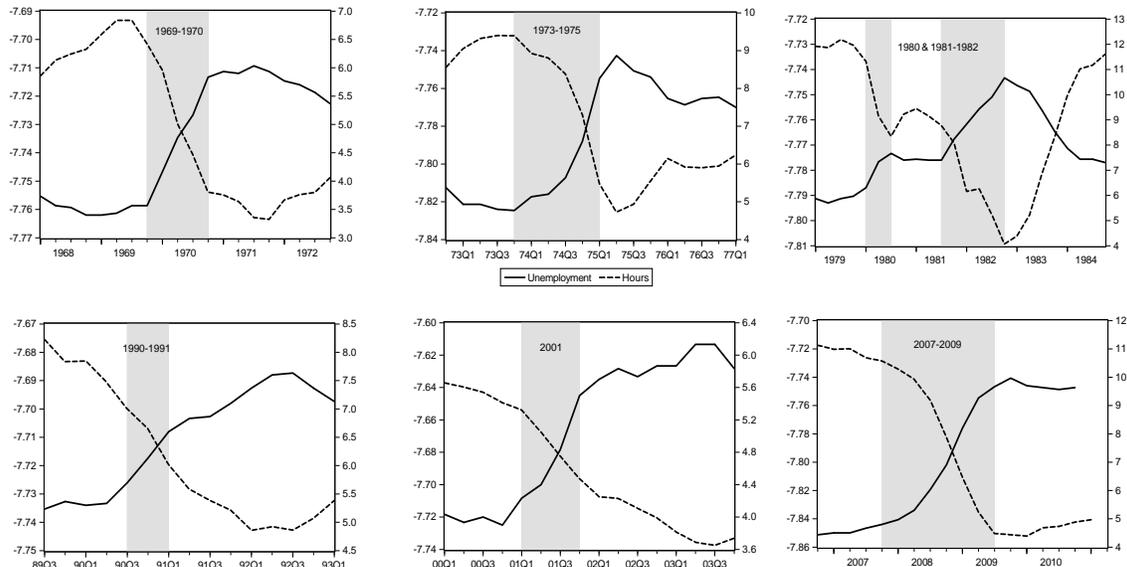


Figure 2: Unemployment & Hours in Six Recent Recessions

Aaronson et al. (2004) point out differences in household and establishment level labor market indicators in informing conclusions about jobless recoveries. Bachmann (2009) constructs a quantitative model with fixed adjustment costs, and argues that in such a framework it is natural for small recessions, e.g. the 1991 and 2001 downturns, to be followed by weak employment growth. Berger (2012) builds a model in which firms grow “fat” during booms and utilize recessions as times to trim their labor force, leading to improved productivity alongside a weak labor market recovery in the first stages of the upswing in output.

### 2.3 The Reduced Cyclicity of Productivity

Until recently it has been elevated to the level of stylized fact that average labor productivity is strongly procyclical. However, this is no longer the case. In fact, since 1984 average labor productivity has become mildly countercyclical and the correlation of productivity with various labor market variables has become quite negative.<sup>5</sup> Figure 3 plots 40-quarter rolling correlations between real output and productivity and between total hours worked and productivity.

<sup>5</sup>We measure average labor productivity as output per hour in the non-farm business sector. Use of alternative measures of the numerator (e.g. real GDP instead of output in the non-farm business sector) yields very similar results. Using employment instead of total hours in the denominator makes these correlations larger in absolute value, but with a large drop of about the same magnitude still occurring in the mid-1980s.

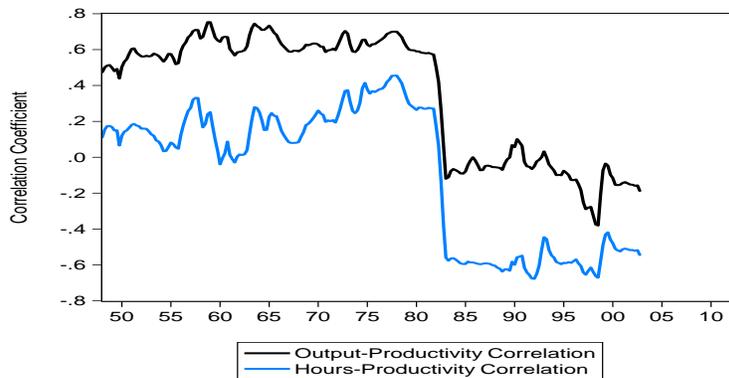


Figure 3: 40-quarter forward rolling correlations between HP filtered productivity and (i) output and (ii) hours.

Table 1: Correlations of productivity with other key aggregates.

	1947-1983	1984-2012
Corr(Output, Productivity)	0.58	-0.08
Corr(Hours, Productivity)	0.20	-0.52
Corr(Employment, Productivity)	0.10	-0.58
Corr(Unemployment, Productivity)	-0.24	0.47

Productivity abruptly switched from strongly correlated with output to slightly negatively correlated at precisely the same time output volatility fell in the mid-1980s. Likewise, the correlation between productivity and hours, which was mildly positive until 1984, became strongly negative after 1984. As with the increase in volatility associated with the Great Recession, both of these correlations display a mild upward tick at the end of the sample, though they both remain well below their pre-1984 levels.

Table 1 shows correlation coefficients between productivity and other variables, both pre- and post-1984. In the pre-1984 period, the correlation between output and productivity was about 0.6, and the correlation of productivity with hours was 0.2 and with employment was 0.1. Unemployment was negatively correlated with productivity. These correlations are drastically different in the more recent period, with productivity mildly negatively correlated with output, strongly negatively correlated with both hours and employment, and strongly positively correlated with the unemployment rate. Alternative measures of economic activity and/or labor market intensity yield similarly large changes between sub-samples. The post-1984 correlations are not driven by, or unique to, the Great Recession period. Excluding the 2008-2012 period from the later sub-sample, for example, the correlation between output and productivity is -0.07.

Hall (2007), Gali and Gambetti (2009), and Barnichon (2010) are among the first papers to highlight the drastic change in the co-movements between average labor productivity with measures of aggregate economic activity and labor input. In addition to documenting the fact, Barnichon (2010) constructs a model with nominal rigidities and endogenous labor effort to try to make sense of the reversal in the cyclicalities of productivity. In his model technology shocks generate a positive correlation between productivity and unemployment—because of nominal rigidities demand does not rise sufficiently following a productivity shock and unemployment rises. In contrast, aggregate demand shocks induce a negative correlation between average productivity and unemployment—when demand is high, firms utilize employees more intensively and post more vacancies, leading to higher observed productivity and lower unemployment. He proposes a decline in the volatility of demand shocks after 1984 as the result of the declining cyclicalities of productivity. In a reduced form sense, the mechanism accounting for the switch in the cyclicalities of productivity is similar to that in our model—a compositional shift away from shocks inducing procyclical productivity towards shocks leading to countercyclical productivity—though the structural interpretations of his mechanism and ours are quite different. Moreover, he does not attempt to make sense of jobless recoveries and the potential connection with productivity.

Gali and van Rens (2010) propose a model to account for the decline in the cyclicalities of productivity based on reduced labor market frictions. While a potentially compelling explanation for the reversal in the cyclicalities of productivity, on its own a decline in labor market frictions does not square well with slower labor market recoveries and it is difficult to quantitatively generate a substantial decline in output volatility as a consequence of smaller labor market frictions. Schaal (2010) builds a search and matching model and shows that increased idiosyncratic risk at the firm level can help explain the coexistence of high productivity and high unemployment. As noted earlier, Berger (2012) builds a model with countercyclical restructuring, which aims to simultaneously account for jobless recoveries and reduced cyclicalities of productivity. He argues that the decline of unions in the early 1980s made it easier for firms to shed unproductive workers during downturns, and can thus explain the changed cyclicalities of productivity that occurred around that time.

## 2.4 Labor Market Mismatch and Reallocation

A key feature of the model and hypothesis explored in this paper is that downturns are periods of increased mismatch between the characteristics of workers and the composition of jobs, and that an increase in the relative importance of labor market reallocation during those downturns can account for the broader changes in the nature of fluctuations that were just discussed. Accordingly, it is worthwhile to highlight the many empirical and theoretical contributions to our understanding of the role of mismatch and reallocation.

As a starting point, it is important to distinguish between the way in which mismatch, and the need for reallocation of workers and jobs, affects the cyclical properties of the labor market, from the way in which changes in the structure of the economy can affect the long-run natural rate of unemployment. With regard to the latter, studies such as Lazear and Spletzer (2012) have argued that the most recent recession has not resulted in an increase in the “structural unemployment” that would come about due to a compositional shift toward industries or demographic groups that tend to exhibit higher average unemployment rates. The focus here, however, is on how increases in mismatch affect the cyclical dynamics of the response to an adverse shock. In other words, mismatch does not result in a permanent shift in the unemployment rate, but the process of adjustment and reallocation that is associated with mismatch alters the nature of the recovery from a recession, relative to a recession in which unemployment is not associated with any need for reallocation.

Recent research into the idea that recessions are periods of heightened need for reallocation is not without antecedents. In the early 1980s there was a similar burst of research into the cyclical role of reallocation, motivated in large part by the influential paper by Lilien (1982). Lilien found that employment growth rates at the sectoral level become more dispersed during recessions, taking it as evidence of an increase in reallocative activity. Abraham and Katz (1986) countered that it was not necessarily indicative of reallocative activity, pointing out that even if recessions were purely the result of aggregate shocks, with no accompanying reallocation across sectors, the dispersion in employment growth rates would still spike during recessions if some sectors were naturally more cyclically sensitive. Davis (1987) subsequently showed that there was evidence of actual reallocation, since the sectoral employment growth rates tended to be

positively correlated with themselves over a period of several years—they did not reverse themselves as they would if they were driven purely by different cyclical sensitivities.

The more recent empirical literature has come at the question from a variety of directions. Hornstein (2012) provides evidence that is particularly suggestive. He uses evidence on unemployment durations to make inferences about the role that reallocation plays in labor market fluctuations. Unemployment durations can rise during recessions either because the job-finding rates fall for all workers, or because those who are entering unemployment during the recession are predominately workers with lower job-finding rates. Using a hazard model that allows for both ex-ante and ex-post heterogeneity among unemployed workers, Hornstein can identify the relative contributions of movements in the entry and exit rates (into and out of unemployment) of long-term and short-term unemployed workers to the overall variation in the unemployment rate. He finds that the increase in the incidence of long-term unemployment and the decrease in the exit rate among the long-term unemployed accounts for a large part (over two-thirds) of unemployment rate fluctuations, especially for the period from 1987 to 2010. With regard to the most recent recession, he concludes that “the unemployment rate increase in the 2007-09 recession ... is consistent with structural reallocation as an important source of unemployment.”

Wiczer (2013) provides evidence that the heterogeneity that accounts for the differences in unemployment spell durations is related to occupations. Specifically, he shows that dispersion in unemployment duration, across occupations, increases significantly in downturns, which supports the view that recessions are especially tough on certain occupations. More generally, the results suggest that recessions are times when a higher proportion of unemployment spells are of the difficult-to-overcome variety that may be associated with the need to change occupations, and fewer spells are of the temporary-bump-in-the-road variety.

An alternative empirical approach to assessing variations in reallocative activity would be to measure more directly the extent of mismatch at different points in time. The data requirements for this sort of exercise are demanding, as one would ideally utilize evidence, at a rather detailed and disaggregated level, on the locations and occupations of workers and of jobs. Moreover, it can be difficult to identify a worker’s ideal occupation; a natural way to identify one’s occupation would be to observe the occu-

pation of his or her last job, but that job may not accurately reflect the worker’s true ideal occupation. Another difficulty arises from the fact that an unemployed worker’s location is determined by their current location, even though that location may have already changed since the previous job—reallocation may have already occurred, and thus the data would indicate an understated need for reallocation.

In spite of these data difficulties, Sahin et al. (2012) have nevertheless taken this more direct approach to assessing mismatch, using the JOLTS and HWOL databases for information on job openings, and the CPS for information on the characteristics of unemployed workers. They use the planner’s solution to a multi-sector model of production to determine the ideal allocation of workers across sectors (region, occupation, etc.) and then measure mismatch as the difference between that idealized allocation and the actual allocation. The extra unemployment that exists in the actual allocation is identified as “mismatch unemployment.” While the scope of their analysis is limited by the shortness of their data on job openings, they find that “mismatch can explain 1/3 of the recent rise in the U.S. unemployment rate since 2006.”

Mehrotra and Sergeyev (2012) employ a different empirical strategy, but arrive at similar conclusions. They conduct a factor analysis of sectoral employment to identify sectoral shocks. Their sectoral shock index is strongly countercyclical (and has a higher mean during the post-1984 period). Moreover, they conclude that these sectoral shocks can explain the recent outward shift of the Beveridge curve, and that sectoral shocks can account for 1.4 percentage points of the recent rise in unemployment. In a related paper, Fujita and Moscarini (2013) argue that after accounting for people who are recalled into their previous jobs, estimates of the matching function yield a very different picture of the cyclical properties of matching efficiency. In particular, they conclude that “labor market mismatch in 2008-2010 is considerably larger than the conventional measure would suggest.”

As with the empirical work on mismatch and reallocation, there is a long history of theoretical work that has attempted to understand the process of labor market reallocation, and its implications for understanding the economy. A subset of this work, such as the classic paper by Lucas and Prescott (1974) or more recent examples like Alvarez and Veracierto (2000), has examined the impact of sectoral reallocation of labor on the long-run, or steady-state, performance of the economy. Others, such as Long and

Plosser (1983), Rogerson (1987), Williamson (1990), Phelan and Trejos (2000), Shimer (2007), and Chang (2012) focus on the impact of mismatch and sectoral reallocation on business cycle dynamics.

Although it only considers steady-state equilibrium, the recent paper by Alvarez and Shimer (2011) is related to the current paper in that it distinguishes between different types of unemployment: “rest” unemployment, which is similar to the current paper’s short-lived unemployment among workers who do not need to reallocate, and “search” unemployment, which corresponds to the unemployment spells associated with the difficult process of reallocation. Carrillo-Tudela and Visschers (2013) examine a similar model, but distinguish between unemployment associated with (1) reallocation across occupations, (2) search within an occupation, or (3) respite from a temporarily depressed occupation. Moreover, by utilizing the solution method proposed in Menzio and Shi (2011), they are able to examine the roles of the different types of unemployment over the business cycle (and not just in steady-state).

### 3 Model

This section introduces an island model of labor reallocation, in the spirit of Lucas and Prescott (1974), that features both island-specific productivity shocks and aggregate productivity shocks. Frictions impede the reallocation of workers that is desired following island-specific shocks that change the relative productivity of islands.

We begin our discussion of the model by describing the production side of the economy. There are two islands where production takes place. These islands could represent different sectors, regions, industries, or occupations. Though it would be conceptually straightforward to extend the analysis to several islands, for computational tractability we focus on just two. On each island  $i$  there is a representative firm that produces an intermediate good using the technology  $X_{i,t} = A_t z_{i,t} K_{i,t}^\alpha L_{i,t}^{1-\alpha}$ , where  $A_t$  is an aggregate shock that is common to both islands,  $z_{i,t}$  is the productivity shock specific to island  $i$ , and  $L_{i,t}$  and  $K_{i,t}$  are the labor and capital utilized on island  $i$ .  $A_t$  and  $z_{i,t}$  both follow Markov processes. The intermediate goods from the two islands are transformed into a final good by a competitive firm utilizing the following CES technology:

$$Y_t = \left( X_{1,t}^{\frac{\sigma-1}{\sigma}} + X_{2,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

The economy is populated by a continuum of infinitely lived households of measure 1. These households are physically located in one of three states: on one of the two islands or in an intermediate state between the islands. Household labor can only be supplied on the island in which the household currently resides; moving to the other island requires first passing through the intermediate state for a period of time. The lost productive time in the intermediate state could represent explicit search, retraining, or moving.

The households face a consumption/saving decision and a labor supply decision, and seek to maximize the present discounted value of flow utility,

$$E_0 \sum_{t=0}^{\infty} \beta^t (\ln c_t - \nu(l_t))$$

Where  $c_t$  is the household's consumption,  $l_t$  is the household's labor supply, and  $\beta < 1$  is the household's discount factor.<sup>6</sup> The disutility of labor,  $\nu(l_t)$ , is an increasing and convex function in  $l_t$ . Finally, a household's labor supply is assumed to be indivisible:  $l_t \in \{0, 1\}$ .

We assume that there are complete asset markets that allow households to insure perfectly against the idiosyncratic risks that they face (due to shocks to the productivity of the island on which they work, loss of income while reallocating, etc.). In addition, we assume that there are employment lotteries as in Rogerson (1988). These assumptions allow us to identify the competitive equilibrium as the outcome of a social planning problem in which the planner has preferences:

$$E_0 \sum_{t=0}^{\infty} \beta^t (\ln C_t - \phi L_t)$$

Where  $\phi = \nu(1) - \nu(0)$ . When discussing household preferences we used lowercase  $c_t$  and  $l_t$ , but here, for the social planner, we can express preferences in terms of aggregates, which are denoted using uppercase variables. This is appropriate because the lotteries and perfect insurance, along with the fact that there is a unit measure of households,

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<sup>6</sup>Given the assumed separability between consumption and leisure, we assume log utility so that the model is consistent with balanced growth.

mean that household and aggregate consumption are the same. Likewise, because there is a unit measure of households,  $L_t$  is both aggregate employment as well as the fraction of households with  $l_t = 1$ .

Complete asset markets and employment lotteries render household heterogeneity irrelevant: we need not know the identities of the households that are allocated to the two islands, nor the identities of the households that are unemployed. However, while the identities of the households in these different situations do not matter, the overall distribution of households across states does matter. That is, the key decisions for the social planner relate to the distribution of workers over different employment states: (i) what fraction of the workers to allocate to the two islands and (ii) what fraction of the workers on each island to assign to be employed. Of course, in making these decisions the social planner faces the same frictions that individual households face—reallocating workers from one island to the other is time-consuming. We model these types of frictions and the time-consuming nature of reallocation by assuming that when workers move from one island to the other, they must first pass through the intermediate state, and a spell of “reallocation unemployment,” while engaged in activities that make them employable on the other island. Workers stochastically escape this reallocation spell at the exogenously given rate  $\lambda$ , and we assume that when they escape they can choose which island to move to.<sup>7</sup>

In this environment, workers at a point in time are in one of three situations: (i) located on an island and employed, (ii) located on an island and unemployed, but with the possibility of a frictionless transition back to employment on that island, and (iii) not located on an island, but rather in the state of “reallocation unemployment.” To understand the second situation, note that the planner may choose not to employ some workers on an island, while also not reallocating those workers to the other island. For example, holding island-specific productivities constant, if aggregate productivity is temporarily low, then it may be optimal for the planner to reduce employment on each island (due to the indivisibility of labor and the disutility associated with work) without initiating any reallocation.

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<sup>7</sup>This assumption simplifies the model by eliminating the need to keep track of which island each worker in the reallocation process originally came from. Workers will move in response to island-specific shocks, and will move from the less productive to the more productive island, but it is possible that the island-specific shocks will reverse again before the worker escapes the reallocation process, in which case the worker would like to return to the original island.

To maintain tractability, and to focus attention on the role of labor market frictions, we assume that capital can be transferred from one island to another with no frictions. Thus, the social planner enters a period with an aggregate stock of capital, chosen in the previous period, which it can allocate to the two islands after observing the current period's island-specific productivities. Capital depreciates at rate  $\delta$ .

The timing of events within a period is as follows. Period  $t$  begins with  $N_{1,t-1}$  and  $N_{2,t-1}$  workers located on each island and an aggregate capital stock  $K_t$ . After aggregate productivity  $A_t$  and the island-specific productivities  $z_{1,t}$  and  $z_{2,t}$  are revealed, the planner makes several simultaneous decisions. First, the planner decides how many workers to allocate to the two islands in the current period,  $N_{1,t}$  and  $N_{2,t}$ . This decision is constrained by the fact that at most  $\lambda(1 - N_{1,t-1} - N_{2,t-1})$  in total can be added to the two islands. Second, the planner decides how many of the  $N_{1,t}$  and  $N_{2,t}$  workers on each island will be employed, i.e.  $L_{1,t}$  and  $L_{2,t}$ , and how much of the aggregate capital stock,  $K_t$ , to utilize on each island, i.e.  $K_{1,t}$  and  $K_{2,t}$ . Finally, given these choices of inputs, the total output of the final good is determined and the planner must decide how to allocate it between consumption  $C_t$  and the next period's aggregate capital stock  $K_{t+1}$ .

The social planner's problem then is to choose history-contingent sequences for the vector of choice variables  $\{L_{1,t}, L_{2,t}, N_{1,t}, N_{2,t}, K_{1,t}, K_{2,t}, K_{t+1}, C_t\}$  in order to maximize:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t (\ln C_t - \phi(L_{1,t} + L_{2,t}))$$

$$\text{s.t.: } C_t + K_{t+1} \leq \left( X_{1,t}^{\frac{\sigma-1}{\sigma}} + X_{2,t}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} + (1 - \delta)(K_{1,t} + K_{2,t}) \quad (1)$$

$$X_{i,t} = A_t z_{i,t} K_{i,t}^{\alpha} L_{i,t}^{1-\alpha}, \quad i = \{1, 2\} \quad (2)$$

$$K_{1,t} + K_{2,t} = K_t \quad (3)$$

$$L_{1,t} \leq N_{1,t} \quad (4)$$

$$L_{2,t} \leq N_{2,t} \quad (5)$$

$$N_{1,t} \leq N_{1,t-1} + \lambda(1 - N_{1,t-1} - N_{2,t-1}) \quad (6)$$

$$N_{2,t} \leq N_{2,t-1} + \lambda(1 - N_{1,t-1} - N_{2,t-1}) \quad (7)$$

$$N_{1,t} + N_{2,t} \leq N_{1,t-1} + N_{2,t-1} + \lambda(1 - N_{1,t-1} - N_{2,t-1}) \quad (8)$$

$$N_{1,0}, N_{2,0}, K_0 \text{ given} \quad (9)$$

The first constraint is the aggregate resource constraint. The next constraint imposes the production technologies for the two intermediate goods. The third constraint states that the sum of the capital on the two islands in period  $t$  must be equal to the period  $t$  aggregate capital stock (which was chosen in period  $t - 1$ ). The fourth and fifth constraints require that employment on each island not exceed the number of workers allocated to that island. The sixth and seventh constraints state that the total number (measure) of workers on an island must be less than the sum of the number of workers already there in the previous period and the workers who successfully exited the reallocation process in the previous period. The eighth constraint imposes that the workers available to be reallocated can only be reallocated to one island or the other. Finally, the initial allocation of workers is, like the initial capital stock  $K_0$ , exogenously given and must satisfy  $N_{1,0} + N_{2,0} \leq 1$ .

Note that there are three types of unemployed workers: workers located on island 1, but not employed ( $U_{1,t} = N_{1,t} - L_{1,t}$ ); workers located on island 2, but not employed ( $U_{2,t} = N_{2,t} - L_{2,t}$ ); and workers in “reallocation unemployment” ( $U_{r,t} = 1 - N_{1,t} - N_{2,t}$ ). We can define total island-specific unemployment as the sums of unemployment on each island:  $U_{s,t} = U_{1,t} + U_{2,t}$ . Aggregate unemployment can be defined as:  $U_t = 1 - L_{1,t} - L_{2,t}$ .

It is straightforward to express this social planning problem as a dynamic programming problem. The state variables are the number of workers allocated to the two islands at the beginning of the period,  $N_1$  and  $N_2$ , the aggregate capital stock  $K$ , and the values of the aggregate and idiosyncratic shocks. To simplify notation, let  $\xi_t = \{A_t, z_{1,t}, z_{2,t}\}$  denote the vector of shocks. We can express the problem recursively as a Bellman equation:

$$V(N_1, N_2, K, \xi) = \max_{L_1, L_2, N'_1, N'_2, K_1, K_2, K', C} \ln C - \phi(L_1 + L_2) + \beta EV(N'_1, N'_2, K', \xi')$$

s.t. (1)-(9)

We solve this problem numerically using standard techniques. Specifically, we create a grid of values for  $N_1$ ,  $N_2$ , and  $K$  and then iterate on the Bellman equation above until it converges. Evaluating the value function at points between the gridpoints for  $N_1$ ,  $N_2$ , and  $K$  requires interpolation; we use a simplicial 2-D linear interpolation (see Judd (1998), p. 242).

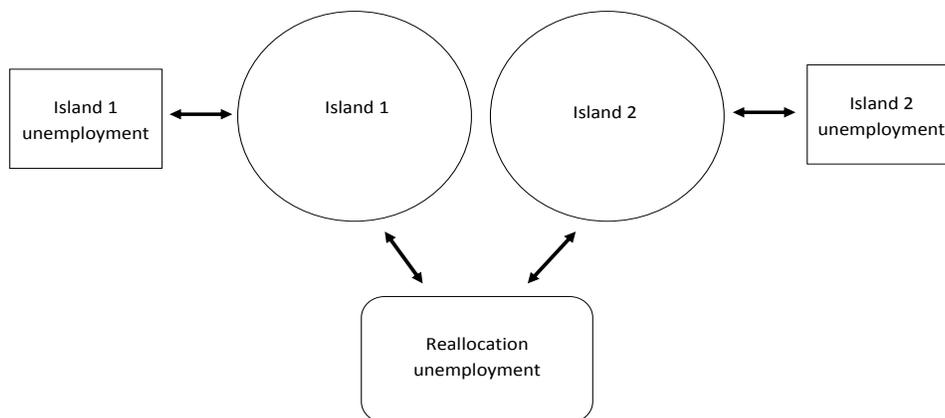


Figure 4: Graphical depiction of the “island” model

Before turning to a quantitative analysis of the model, it is worthwhile to discuss its qualitative features. Figure 4 graphically depicts the basic structure of the model economy. The two types of shocks will generate different responses of aggregate employment, productivity, and output. Consider a negative aggregate shock, holding the relative productivities of the two islands constant. The indivisible labor and employment lotteries assumptions mean that employment on both islands will decline while aggregate productivity remains low. In terms of Figure 4, some workers move to the rectangles on the sides—they temporarily move out of employment, but remain on the same island. However, when aggregate productivity recovers, these unemployed workers quickly return to employment on the same island. As a result, employment, output, and productivity all decline and then quickly recover together. In essence, in the absence of reallocative shocks the model becomes a two-sector version of the Hansen (1985) general equilibrium model of indivisible labor with employment lotteries. As such, changes in  $A_t$  will map into a standard Solow residual or “efficiency wedge” in the parlance of Chari et al. (2007).

Now consider a purely reallocative shock that increases the productivity of one island relative to the other, while leaving aggregate productivity unaffected. This type of shock will generate what we call “relocative unemployment.” That is, the desire to reallocate workers from the relatively less productive island to the relatively more productive island means that workers must pass through a time-consuming process of reallocation, represented in the figure by the cell on the bottom. To the extent that workers must

spend a significant period of time (in expectation) in the reallocation spell, employment might recover much more slowly following a reallocative shock. The response of average labor productivity to a reallocation shock will also look different than the response to an aggregate shock. Labor can be quickly reduced on the less productive island, thus driving back up the marginal product of labor on that island. Because labor only slowly moves to the more productive island, the marginal product there also remains high. As a result, average productivity will temporarily increase in response to the reallocative shock. Therefore, conditional on a reallocative shock, aggregate productivity will be less strongly correlated with aggregate output and employment than in the case of an aggregate shock.

While the aggregate productivity shock will generate what looks like an efficiency wedge, in our model a reallocative shock will generate a labor wedge, which is an important feature of US business cycle data, both pre- and post-1984. Chari et al. (2007) define the labor wedge in the data as the residual from the static first-order condition that equates the marginal rate of substitution between labor and consumption with the marginal product of labor that would obtain in a standard RBC model. In our model, the first-order conditions of the planner’s problem for the choice of labor on each island are:

$$\begin{aligned} u'(C) \frac{\partial Y}{\partial L_1} &= \phi + \mu_1 \\ u'(C) \frac{\partial Y}{\partial L_2} &= \phi + \mu_2 \end{aligned}$$

Here  $\mu_1$  and  $\mu_2$  are the Lagrange multipliers on the constraints that employment on islands 1 and 2 not the exceed population on that island. If there were no reallocation friction, these constraints would never bind—hence  $\mu_1 = \mu_2 = 0$  would hold at all times and the marginal products of labor on each island would be equalized in equilibrium. Because of the assumption of Cobb-Douglas production, the marginal and average products are proportional to one another. Equal average products on each island in turn imply equality to the aggregate average product of labor. This would mean that there would exist an aggregate representation of the conventional static first-order condition for labor supply in which the marginal rate of substitution between labor and consumption, e.g.  $\frac{\phi}{u'(C)}$ , would always be equal to the aggregate marginal product of labor—there would be

no labor wedge. If there is a desire to reallocate, caused by a change in the  $z_i$ , however, these constraints may bind, which would lead to the marginal products of labor on each island being different from one another and leading to an observed residual from the static first-order condition of a neoclassical growth model.

## 4 Quantitative Analysis

In this section, we analyze the model quantitatively and show that it is capable of replicating many features of actual US data documented above. We parameterize the model to match certain long run features of US data. We then consider two parameterizations of the relative magnitudes of the shock processes. In one, aggregate shocks are large relative to idiosyncratic shocks; in the other, aggregate shocks are smaller. We show that the former is roughly consistent with the pre-1984 US data, while the latter configuration accords well with the post-1984 data.

### 4.1 Calibration

We begin by specifying stochastic processes for the exogenous state variables. In the interest of using as parsimonious a specification as possible, we assume that aggregate productivity takes on two values:  $A^H > A^L$ . Loosely speaking, one can think of these two states as governing the “regime” of the aggregate economy, with  $A^H$  interpreted as “normal” times and  $A^L$  associated with “recessions.”

The island-specific productivities follow Markov processes with  $q$  distinct points, with  $z_j > z_{j-1}$  for  $1 < j \leq q$ . Since what matters is the relative productivity of the two islands, we do not need to consider the  $q^2$  possible productivity combinations, but rather we can limit the number of productivity configurations to  $q$  states. That is, if island one has productivity  $z_j$ , then island two has productivity  $z_{q+1-j}$ . For example, if  $q$  is even, then for  $j > q/2$ , island one is relatively more productive than island two, and vice-versa for  $j < q/2$ . If  $q$  is odd, then at  $j = (q + 1)/2$ , the islands are equally productive.

The transition matrix for the configuration of the relative  $z$ 's is such that, conditional on being in state  $j$ , whenever the state changes there is a 50 percent chance of going to state  $j + 1$  and a 50 percent chance of going to state  $j - 1$ . Hence a movement up to

state  $j + 1$  means that island one becomes relatively more productive than island two. At the end points ( $j = 1$  or  $j = q$ ), there is a 50 percent chance of going up (or down) and a 50 percent chance of staying in that state. In the absence of the end points, this structure implies that expected future island specific productivity is equal to the current island specific productivity. The lack of expected mean reversion ensures that there will be strong motivation to reallocate labor across islands whenever the  $z$  state changes.

The exogenous state vector,  $\xi$ , can be written as the Kronecker product of the aggregate and island-specific productivity states:  $\xi = A \otimes z$ , which will have  $2 \times q$  elements. We impose a particular correlational structure between the aggregate and island-specific states. In particular, we assume that the  $z$  state can only change when  $A$  goes from high to low (i.e. enters a “recession”). That is, the onset of a recession is a mix of aggregate and reallocative shocks. This configuration is isomorphic to assuming that there are only shocks to island productivities, but that there is a component of those island productivities that is correlated across islands, which would effectively amount to an aggregate shock. A reduction in the correlations of the sector-specific shocks would then be tantamount to a reduction in the magnitude of aggregate shocks. Under either interpretation, the fact that island-specific shocks occur alongside negative aggregate disturbances helps to account for the fact that recessions have distinct impacts on different parts of the economy (e.g. Lilien (1982) and Abraham and Katz (1986)) and that the pace of labor reallocation is an important component of cyclical unemployment rate fluctuations (e.g. Davis (1987)).<sup>8</sup> This shock structure also can account for the fact that cross-sectional measures of output and productivity dispersion at the plant and industry levels are countercyclical (e.g. Bloom et al. (2012)) and helps produce a countercyclical labor wedge (by the mechanisms discussed above).

The transition matrix for  $A$  is parameterized to match the frequency and duration of post-war US recessions (as defined by the NBER). In particular, the average duration of expansions is 33 quarters and the average duration of a recession is 11 months. As noted above, conditional on entering a recession, there is a 50 percent chance of  $z$  going from  $z_j$  to  $z_{j+1}$  and a 50 percent chance of going to  $z_{j-1}$  (with the caveat about end

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<sup>8</sup>See Ramey (1991), Hall (1991), Caballero and Hammour (1996), and Aghion and Saint-Paul (1998) for more on the idea that recessions are similar to the yellow caution flag in auto racing, in that they are the optimal time for a “pit stop”—that is, the optimal time to make adjustments and reallocate resources due to the lower opportunity cost of doing so.

points). We will return to parameterizing the size of the shocks—essentially the gaps between grid points for both  $A$  and  $z$ —momentarily.

With this structure in place for the stochastic processes, we turn to selecting other parameter values. Although the model is rather parsimonious, we can parameterize the model in such a way as to match several features of the US economy. We take the unit of time to be one quarter. As such, we set the household’s subjective discount factor to  $\beta = 0.99$ . The depreciation rate  $\delta$  is set to 0.02 and the capital share of the production function for intermediate goods,  $\alpha$ , is set to 0.33. The parameter  $\phi$  is set so as to ensure that in a non-stochastic version of the model, with  $A = A^H$  and  $z_1 = z_2$ , employment on each island would be 1/2 and hence there would be “full” employment in aggregate. We take this approach, rather than targeting a mean value of unemployment equal to its empirical counterpart, because the model does not capture the search unemployment that accounts for the natural rate. As such, the fluctuations in unemployment in our model can be interpreted as cyclical deviations from the natural rate of unemployment. For our quantitative exercises, it is important that steady-state employment be close to one; otherwise the economy will converge to a distribution in which there exist “reserves” of non-employed workers on each island who can quickly transition into and out of work on an island in response to island-specific shocks, thereby making reallocation unnecessary.

The parameter  $\sigma$  measures the degree of substitutability between the two intermediate goods, and thus governs the extent to which it is desirable to reallocate resources across islands in response to a change in relative productivities. A value of  $\sigma = \infty$  indicates perfect substitutes; in this case it would always be optimal, in the absence of reallocation frictions, to shift all inputs to the more productive island. A value of  $\sigma = 0$ , on the other hand, indicates perfect complements; in this case it would be optimal to reallocate resources toward the *less* productive island, so as to equalize the production of the two intermediate inputs. We set  $\sigma = 3$  based on evidence in Broda and Weinstein (2006), who provide estimates of this parameter from five digit SITC data for the US. This value is similar to parameterizations used in quantitative models featuring Lucas and Prescott (1974) islands.<sup>9</sup> As long as  $\sigma > 1$ , so that the intermediate goods are substitutes, our quantitative results are fairly similar. For more on sensitivity to this

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<sup>9</sup>See Alvarez and Shimer (2011) for a further discussion of some of this literature.

parameter, see the robustness section below.

The rate at which workers stochastically escape reallocation and become employable,  $\lambda$ , will be lower the greater are the frictions that make it difficult for workers to switch islands. Numerous factors can impede workers in this way, such as the need to acquire new skills or the need to re-locate to a different region. Empirical work—such as Jacobson et al. (1993) and Ruhm (1991)—that looks at the impact on earnings of a job displacement, which is probably in many ways similar to the experience of a worker who is forced to switch islands in our model, indicates that the impact is felt for many years. In particular, Jacobson et al. (1993) find that earnings two years after a displacement are roughly 50 percent below pre-displacement earnings. We choose  $\lambda$  to match this number in the model for average earnings losses among workers who switch from employment on one island to reallocation unemployment. In our model this implies a value of  $\lambda = 0.1$ . While this may seem low in light of the average duration of unemployment spells in the data, it is important to keep in mind that unemployment resulting from the need to switch sectors is rather different than the “average” spell of unemployment, which includes frictional and seasonal unemployment, and which is typically very short in duration.<sup>10</sup> We also consider robustness to this parameter below.

Finally, we must parameterize the size of the aggregate shocks (the gap between  $A^H$  and  $A^L$ ) and the size of the reallocative shocks (the size of the gaps between the grid points in  $z$ ). Conditional on the size of reallocative shocks, we choose the size of the aggregate shock to match the volatility of aggregate output in the pre-1984 sample. The size of the reallocative shock is closely tied to two different statistics: the volatility of the labor wedge (larger reallocative shocks increase the volatility), and the correlation of labor productivity with output (larger reallocative shocks reduce the correlation). Our model has difficulty in exactly matching both moments simultaneously. In particular, choosing a reallocative shock that can match the volatility of the labor wedge results in a correlation between labor productivity and output that is too high, and choosing a reallocative shock that can match that correlation results in a labor wedge that is too volatile relative to the data. The approach that we take is to consider three pa-

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<sup>10</sup>Clark and Summers (1979) show that a large fraction of unemployment spells end very quickly, which significantly reduces mean and median unemployment durations. They also argue that longer term unemployment, as well as separations followed by exit from the labor force, account for a significant fraction of unemployment.

parameterizations: one that matches the volatility of the labor wedge, one that matches the correlation of labor productivity and output, and an intermediate case that falls in between the first two.

## 4.2 Quantitative Results

For the purpose of this simulation we generate 5000 different data sets with 144 observations each, which corresponds to the number of quarterly observations in the pre-1984 sample period (we employ a “burn-in” period of 100 observations to reduce sensitivity to starting values). Table 2 shows summary statistics from the pre-1984 data as well as the same statistics averaged over the 5000 different simulations for each of the three different calibrations. Numbers in parentheses are standard deviations across the simulations. All variables are logged and HP filtered, both in the data and in the model simulations. The efficiency and labor wedges are calculated by applying the “business cycle accounting” procedure of Chari et al. (2007) to aggregate data generated from the model.<sup>11</sup>

In all three parameterizations we match the volatility of output exactly. The three calibrations fail to generate enough volatility in the efficiency wedge relative to the data, though this discrepancy is not statistically significant. Moreover, we do not view this as too troubling given the parsimonious process for  $A_t$ —with rather infrequent changes—that we have assumed. The model does quite well on three key statistics of interest—the correlations of employment, output, and unemployment with productivity. In the data both output and hours are strongly correlated with productivity, while unemployment is negatively correlated with productivity. This is also a feature in all three calibrations. Calibration 2 comes very close to hitting all three of these correlations exactly; this comes at the expense of a labor wedge that is too volatile. Calibration 1 produces correlations of these variables with productivity that are too high relative to the data, though it hits the volatility of the labor wedge exactly. Calibration 3 reaches a middle ground—

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<sup>11</sup>In particular, the efficiency wedge is measured as the difference between log aggregate output and share-weighted aggregate inputs as if there were a Cobb-Douglas aggregate production function, e.g.  $\tau^{efficiency} = \ln Y - \alpha \ln K - (1 - \alpha) \ln N$ . We use as our measure the total factor productivity series from Fernald (2012). The labor wedge is constructed similarly using aggregate variables and Hansen (1985) preferences; ignoring constants, it is  $\tau^{labor} = -\ln\left(\frac{C}{Y}\right) - \ln N$ . We construct an empirical measure of the labor wedge using the consumption-output ratio and total hours per capita in the non-farm business sector, where our measure of consumption is non-durables plus services.

Table 2: Comparison of the simulated model with the pre-1984 data.

	Pre-1984 data	Calibration 1	Calibration 2	Calibration 3
s.d.(output)	0.020	0.020 (0.004)	0.020 (0.004)	0.020 (0.004)
corr(output, prod)	0.58	0.88 (0.112)	0.60 (0.22)	0.72 (0.13)
corr(emp, prod)	0.21	0.718 (0.172)	0.22 (0.22)	0.41 (0.19)
corr(unemp, prod)	-0.22	-0.601 (0.152)	-0.15 (0.18)	-0.31 (0.16)
s.d.(efficiency wedge)	0.015	0.012 (0.003)	0.011 (0.002)	0.011 (0.002)
s.d.(labor wedge)	0.015	0.015 (0.003)	0.021 (0.006)	0.018 (0.003)
corr(eff. wedge, output)	0.86	0.97 (0.07)	0.91 (0.05)	0.93 (0.04)
corr(lab. wedge, output)	-0.63	-0.91 (0.05)	-0.87 (0.17)	-0.87 (0.05)

productivity is slightly too procyclical (correlation with output of 0.72 as opposed to 0.58 in the data) and the labor wedge is slightly too volatile (volatility of 0.018 in the model versus 0.015 in the data). In the data the efficiency wedge is strongly positively correlated with output while the labor wedge is quite countercyclical. All three calibrations match these facts qualitatively, though the correlations in the model tend to be a bit too high in absolute value.

We next turn to evaluating the hypothesis of whether or not a reduction in the magnitude of aggregate shocks (i.e. a reduction in the gap between  $A^H$  and  $A^L$ ) can account for the changes documented in Section 2. To do so we fix all parameters at their baseline values for the pre-1984 simulation (we use calibration 3 from above to represent the pre-1984 economy), and re-calibrate the gap between  $A^H$  and  $A^L$  to match the reduction in output volatility in the latter sample. Table 3 presents the key moments from the model simulation and from the post-1984 data. For this simulation we generate 5000 data sets with 116 observations each (116 corresponds to the number of observations in the post-1984 US data) and produce the numbers by averaging over the 5000 simulations.

Although we have only altered the magnitude of the aggregate shocks, with the goal of matching the decline in output volatility (the top row), that one difference can also account for much of the changes in the other business cycle moments as well. In both the model and the data, average labor productivity switches from procyclical to mildly countercyclical, while employment goes from positively correlated with productivity to negatively correlated. In addition, unemployment goes from negatively correlated with productivity to positively correlated. The magnitude of these changes in the model is quite similar to the magnitude in the data.

Table 3: Comparison of the simulated model with the post-1984 data.

	Post-1984 data	Change	Model	Change
s.d.(output)	0.011	-0.009	0.011 (0.002)	-0.009
corr(output, prod)	-0.08	-0.66	-0.05 (0.32)	-0.77
corr(emp, prod)	-0.58	-0.79	-0.33 (0.26)	-0.77
corr(unemp, prod)	0.47	0.71	0.27 (0.21)	0.58
s.d.(efficiency wedge)	0.008	-0.007	0.004 (0.001)	-0.007
s.d.(labor wedge)	0.016	0.01	0.016 (0.004)	-0.002
corr(eff. wedge, output)	0.63	-0.20	0.83 (0.08)	-0.10
corr(lab. wedge, output)	-0.83	-0.20	-0.93 (0.07)	-0.06

Our quantitative model also does well at capturing changes (or the lack thereof) in the time series properties of the “wedges.” As can be seen in Table 3, in the post-1984 period the efficiency wedge, or Solow residual, has become significantly less volatile, with its standard deviation dropping by about half relative to the earlier period. In contrast, the volatility of the labor wedge has remained roughly constant, and if anything has slightly increased. Our model captures exactly these patterns in the data—the labor wedge remains roughly as volatile when the aggregate shock is smaller, while the efficiency wedge drops in volatility. In terms of correlations of the wedges with output, in the data the efficiency and labor wedges remain procyclical and countercyclical, respectively, but the correlation between the efficiency wedge and output becomes less positive post-1984 and the correlation of the labor wedge with output becomes more negative. This same pattern emerges in our model simulations—with smaller aggregate shocks, the efficiency wedge becomes less procyclical and the labor wedge becomes more countercyclical.

Table 4: Relative volatilities of employment and output.

	Pre-1984	Post-1984	Change
<i>Data:</i> s.d. (emp)/s.d.(output)	1.00	1.56	0.56
<i>Model:</i> s.d. (emp)/s.d.(output)	0.75 (0.09)	1.05 (0.08)	0.40

In addition to replicating these facts about the wedges, our model also does well in accounting for a couple of other facts about the labor market. Table 4 shows that the volatilities of labor market variables relative to output have substantially increased in post-1984 data, with the ratio of hours volatility to output volatility rising from 1.00 to

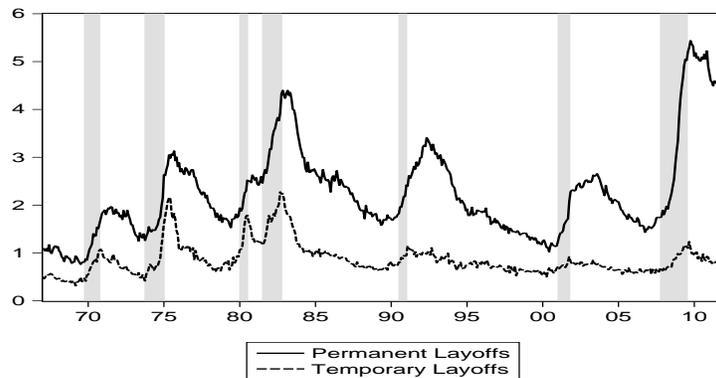


Figure 5: Unemployment Rates Among Workers Experiencing Permanent and Temporary Layoffs

1.56. Though the model fails to generate sufficient volatility of labor market variables relative to output in both subsamples—a well-known difficulty in many business cycle models—the lower aggregate shock parameterization does well at accounting for the *change* in the relative volatility observed in the data.

A central feature of our model is that it introduces different types of unemployment. We refer to these different types of unemployment as “island-specific” unemployment, whereby individuals do not work but remain on the same island, and “reallocation” unemployment in which individuals must pass through a time intensive spell of unemployment before being able to work again. Loosely, these different kinds of unemployment would map into unemployment of different durations in the data, with island-specific unemployment being more transitory while reallocation unemployment is more persistent and difficult to recover from. In the household survey, the BLS asks unemployed respondents to report their reason for unemployment. These responses allow one to identify unemployment due to “temporary” layoffs, which typically counts furloughed workers, and unemployment due to “permanent layoffs,” which measures workers who have lost jobs and do not expect to be re-hired by the same firm. These data are available beginning in 1967 and are shown in Figure 5.

The striking feature of Figure 5 is the near disappearance of the volatility of temporary layoffs in the post-1984 period. In the early part of the sample, both temporary and permanent layoffs spike during recessions. After 1984, there is virtually no spike in temporary layoffs around recessions, while the bursts of permanent layoffs remain large (and increasingly persistent). The increases in unemployment from permanent layoffs

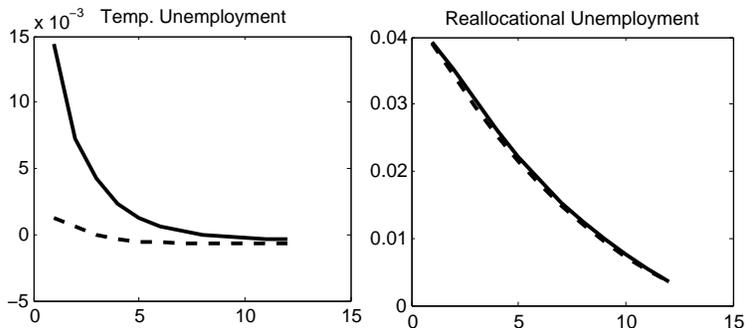


Figure 6: This figure shows the responses of temporary/island-specific and reallocative unemployment for the two shock configurations; the solid line shows the large/pre-1984 aggregate shock parameterization, while the dashed line shows the small/post-1984 aggregate shock value.

around the 1990-1991 and 2001 downturns are especially large relative to past recessions when considering the relative mildness of the output declines in those episodes. The lack of movement in the temporary unemployment series around each of the last three recessions is equally striking.

Figure 6 shows impulse responses of “temporary,” or “island-specific,” unemployment,  $U_{s,t}$ , and “reallocation” unemployment,  $U_{r,t}$ , to a negative aggregate shock in the model.<sup>12</sup> The solid lines are the responses under the “large shock” case (again, we use calibration 3), which corresponds to the pre-1984 period, while the dashed lines are for the “small shock” case, meant to capture the post-1984 period. In the model, the response of reallocation unemployment is virtually the same in both simulations, whereas “temporary” unemployment reacts strongly in the larger shock simulation but virtually disappears in the smaller shock simulation. To understand this, note that for the smaller shock simulation the desired overall reduction in employment in response to the negative shock is achieved (almost) entirely by the unemployment associated with reallocation, so that no additional temporary unemployment is necessary. In other words, the model matches the fact, elucidated in Figure 5, that there has been a switch in the composition of cyclical unemployment away from “temporary/transitory” layoffs towards more persistent job loss.

Finally, we turn attention to the model’s ability to match the “Jobless Recovery”

<sup>12</sup>To generate these responses, we simulated a data set with 40,000 observations and averaged over the responses of temporary and reallocative unemployment to each negative aggregate shock, conditional on their having been no other subsequent negative aggregate shock during the ensuing 12 periods. The responses are expressed as absolute deviations from the values in the period prior to the aggregate shock.

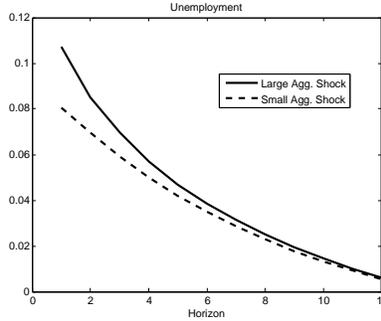


Figure 7: This figure shows the average response of aggregate unemployment to a recession in the two shock configurations.

phenomenon that has characterized each of the last three US recessions. Figure 7 plots the model response of total unemployment to a recession shock in both the small (dashed line) and large (solid line) aggregate shock configurations. The change in the relative composition of total unemployment—away from temporary unemployment and towards reallocation unemployment, as shown in our model for Figure 6—qualitatively helps to account for the onset of jobless recoveries.

Because temporary unemployment in the model is less persistent than reallocation unemployment, the near disappearance of temporary unemployment leads, though a composition effect, to an increase in the overall persistence of aggregate unemployment when aggregate shocks are smaller. The impulse responses of total unemployment to a recession shock in the two shock configurations are shown in Figure 7. The main difference in the responses for the two aggregate shock configurations are at short forecast horizons. In the large shock configuration, there is a larger initial spike than in the smaller shock case, with much of the initial jobs lost recovered within a few quarters. This spike and recovery reflects movements of temporary unemployment, which are virtually absent in the smaller shock case. After several quarters, temporary unemployment is back to its pre-shock value in expectation, and the dynamics of unemployment look the same whether the initial aggregate shock was large or small. In the large shock simulation, it takes 3.3 quarters to recover half of the initial jobs lost at the trough. In the smaller shock simulation, in contrast, it takes about 4.2 quarters. Put differently, the smaller aggregate shock specification generates a labor market recovery that is about one quarter slower on average. This is qualitatively in line with the nature of labor market recoveries after the last several recessions, though the jobless recovery generated in the model is weaker than those observed in the data.

Table 5: Sensitivity analysis:  $\sigma$ .

	$\sigma = 2.8$		$\sigma = 3.2$	
	Large Shocks	Small Shocks	Large Shocks	Small Shocks
s.d.(output)	0.020 (0.003)	0.010 (0.002)	0.020 (0.003)	0.011 (0.002)
corr(output,prod)	0.76 (0.09)	0.06 (0.30)	0.71 (0.14)	-0.15 (0.33)
corr(emp,prod)	0.49 (0.15)	-0.25 (0.25)	0.39 (0.19)	-0.44 (0.27)
corr(unemp,prod)	-0.38 (0.13)	0.21 (0.20)	-0.29 (0.16)	0.35 (0.21)
s.d.(efficiency wedge)	0.011 (0.002)	0.004 (0.001)	0.011 (0.002)	0.004 (0.001)
s.d.(labor wedge)	0.018 (0.003)	0.014 (0.004)	0.018 (0.004)	0.017 (0.005)

### 4.3 Robustness

The two parameters that are especially difficult to calibrate in our model are  $\lambda$ , which governs the average amount of time out of the work force required to switch islands; and  $\sigma$ , which governs the substitutability between goods produced on the two islands. In this section we discuss how our quantitative results are impacted by different values of these parameters. For these exercises we consider small perturbations in  $\lambda$  or  $\sigma$ , holding all other parameter values fixed at their baseline values (calibration 3 above). That is, we do not re-calibrate shock magnitudes to match moments when we change  $\lambda$  or  $\sigma$ . For small perturbations, holding the other parameter values fixed is reasonable and allows us to focus cleanly on how the moments of the simulated model vary with  $\lambda$  and  $\sigma$ .

In Table 5 we present selected moments for two different values of  $\sigma$  (the baseline value was 3), both for the large and small aggregate shock configurations. The value of  $\sigma$  has little effect on the volatilities of output, the efficiency wedge, or the labor wedge. There are some small quantitative effects on the correlations of productivity with output and labor inputs. Qualitatively, these correlations move with  $\sigma$  in an intuitive direction.  $\sigma$  governs the willingness to substitute between the goods produced on each island, and the willingness to substitute drives factor reallocation, which dampens the observed cyclical of average labor productivity. As can be seen in the table, a higher value of  $\sigma$  is associated with (i) smaller positive correlations of labor productivity with output and labor inputs in the large aggregate shock case, and (ii) larger changes in these correlations in moving to the smaller aggregate shock configuration. These differences are nevertheless not quantitatively large, and the qualitative movements are the same as in our baseline parameterization.

Table 6 shows selected moments for two different values of  $\lambda$  (the baseline value was

Table 6: Sensitivity analysis:  $\lambda$ .

	$\lambda = 0.08$		$\lambda = 0.12$	
	Large Shocks	Small Shocks	Large Shocks	Small Shocks
s.d.(output)	0.020 (0.003)	0.011 (0.002)	0.020 (0.003)	0.011 (0.003)
corr(output,prod)	0.73 (0.11)	-0.06 (0.30)	0.75 (0.12)	-0.09 (0.30)
corr(emp,prod)	0.42 (0.16)	-0.35 (0.25)	0.46 (0.17)	-0.36 (0.24)
corr(unemp,prod)	-0.29 (0.13)	0.28 (0.20)	-0.36 (0.15)	0.30 (0.20)
s.d.(efficiency wedge)	0.011 (0.002)	0.004 (0.001)	0.011 (0.002)	0.004 (0.001)
s.d.(labor wedge)	0.018 (0.003)	0.016 (0.004)	0.018 (0.004)	0.017 (0.004)

0.10) for the large and small aggregate shock configurations. The moments shown in the table are all close to the values from our baseline experiments. The size of  $\lambda$  has little effect on the volatility of output. The changes in the correlations of output and labor inputs with productivity when moving from large to small shocks are a little bigger when  $\lambda$  is larger. What drives the reversal in the cyclicity of productivity when aggregate shocks are smaller is the ability and willingness to substitute labor to more productive uses. The larger is  $\lambda$ , the less costly it is to move workers across islands. Hence, relatively more reallocation takes place, leading to a larger change in the cyclicity of productivity. The volatility of the efficiency and labor wedges are roughly unaffected by  $\lambda$ .

The parameter  $\lambda$  also affects the speed of labor market recoveries in the wake of a recession. Lower values of  $\lambda$  lead to slower overall recoveries because it takes longer, in expectation, for workers to reallocate between islands. Arguably, the dimension along which our model does the least well is in accounting for jobless recoveries. As noted above, when just changing the magnitude of aggregate shocks our model predicts about a one quarter slow down in labor market recoveries. One might be tempted to think that a lower value of  $\lambda$  would improve the model’s performance along this dimension. However, if the lower value of  $\lambda$  applies to both the small and large aggregate shock cases, it turns out that the relative speed of recovery is roughly the same across the two aggregate shock configurations. This is because  $\lambda$  only affects reallocation unemployment, and after a couple of quarters subsequent to a shock it is this type of unemployment that accounts for most of the movement in aggregate employment/unemployment. The only real difference in aggregate labor market movements across the two simulations is what happens immediately after a shock to “temporary,” or island-specific, unemployment—in the large aggregate shock case there is a bigger movement in this than in the small

Table 7: Welfare implications

Averages:	Large agg. shocks	Small agg. shocks
utility	1.0375	1.0259
output	5.5142	5.4560
consumption	4.2985	4.2507
employment	0.9793	0.9805
capital	60.7822	60.2628
labor productivity	5.6301	5.5645

shock case. In a sense, the reason the model has a difficult time in generating a substantial jobless recovery comes not from its inability to generate a slow labor market recovery in the later period, but rather from an insufficiently strong response of temporary unemployment when aggregate shocks are larger. As is common to many models studying the business cycle dynamics of employment, the model does not generate particularly large movements in temporary unemployment in response to an aggregate shock.

#### 4.4 Welfare Implications

Given the model’s success in capturing the changes that have occurred, we utilize the model to assess the impact on welfare of a reduction in the volatility of aggregate shocks.<sup>13</sup> To do this, we calculate a compensating variation—the percentage by which consumption in the stationary equilibrium of the small shock parameterization would have to change in order to achieve the same average utility as in the large shock parameterization.<sup>14</sup> Table 6 reports the average utilities, along with the means of other key aggregates, for the two parameterizations.<sup>15</sup> As the table indicates, average utility is actually higher in the large aggregate shock case. As a result, the compensating variation is positive; consumption in the small shock parameterization must be increased 1.14% in order to achieve the same average utility as in the large shock parameterization.

While at first this result might seem counterintuitive, the reason that more volatile

<sup>13</sup>We thank Randy Wright for suggesting this exercise.

<sup>14</sup>To calculate average utility for the stationary equilibria of the two parameterizations, we simulate one million periods of consumption and employment, then average over the million periods of realized utility.

<sup>15</sup>Note that these values are based on a quarterly calibration. This quarterly frequency accounts for the fact that the average capital to output ratio in the model (11.8) is more than four times the standard annual target of 2.5. The curvature in the final goods production function,  $\sigma$ , further increases the steady-state values relative to a standard growth model.

aggregate technology shocks can actually increase welfare is fairly straightforward. When the household is not too averse to variation in consumption and in labor effort, more volatile technology shocks present an opportunity.<sup>16</sup> That is, inputs can be increased when productivity is high, and reduced when productivity is low, resulting in higher average productivity. This can be seen in the statistics in Table 7, which show that average labor productivity is higher in the large shock case. As a result, inputs—employment and capital—are also higher on average, as are output and consumption. When interpreting these results, it is worth pointing out that in a comparison of stationary equilibria such as this, the transitional costs (in the form of foregone consumption) of accumulating the higher level of capital are not taken into account, and must be weighed against the overall welfare gain. These results nevertheless have potentially important policy implications. Among other things, they point out that lower volatility is not always a good thing, and that policy-makers should not necessarily target low volatility as a normative goal.

## 5 Concluding Thoughts

The business cycle in the United States has changed in important ways in the last three decades. This paper has sought to understand whether a relative increase in the importance of labor market mismatch can help explain these changes. We developed an island model with both aggregate and island-specific shocks. Moving labor from one island to another is costly in terms of time spent unable to work. We consider a quantitative experiment in which aggregate shocks decline in importance relative to island-specific shocks. This one change allows the model to simultaneously account for lower aggregate output volatility, decreased cyclicalities of average labor productivity, and slower labor market recoveries in the wake of a recession, as well as some other facts consistent with the last several recessions.

The results here are important for at least two reasons. First, if quantitative macro models ignore the changes that have occurred, then they will be designed with the goal of accounting for an outdated set of moments (whether via calibration or estimation).

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<sup>16</sup>The possibility can be welfare-enhancing is explored more extensively, in the context of a variety of DSGE models, in Lester et al. (2013).

That is, by ignoring the dramatic changes that have occurred, and thus attempting to explain data for the entire postwar period, these quantitative models will do a poor job of accounting for the behavior of macro aggregates during the last three decades. As such, we would not want to put much faith in the predictions or policy implications drawn from these models. Indeed, leading state-of-the-art macro models that are used for policy analysis, such as Smets and Wouters (2007), do rather poorly at accounting for the changes that have occurred. For example, labor productivity in that model at estimated parameter values is procyclical and positively correlated with hours worked, even when the model is estimated only using data from post-1984.<sup>17</sup>

Second, our analysis has important implications for economic policy. If recessions are increasingly about reallocation, then this raises the question of how aggressive countercyclical demand management policies should be. Stimulating demand through aggressive monetary easing or fiscal expansion may only serve to postpone the necessary reallocation of resources; it could also have longer term adverse consequences concerning productivity growth and human capital accumulation. Finally, our quantitative model suggests that the Great Moderation might have been associated with a reduction in welfare. This highlights the point that lower volatility need not necessarily be an appropriate normative goal of policy-making.

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<sup>17</sup>The Smets and Wouters (2007) model is estimated with Bayesian methods using observed data on output growth and the level of labor input. Average labor productivity is not an observable variable in their model. Using their parameter estimates from the later sub-sample, the correlations between HP filtered output and labor hours with average labor productivity are 0.64 and 0.11, which are far off from their actual values in the post-1984 sample period.

## References

- AARONSON, D., RISSMAN, E., AND SULLIVAN, D. G. (2004), “Can sectoral reallocation explain the jobless recovery?”, *Economic Perspectives, Federal Reserve Bank of Chicago*, **28**, 36–49.
- ABRAHAM, K. G. AND KATZ, L. F. (1986), “Cyclical Unemployment: Sectoral Shifts or Aggregate Disturbances?”, *Journal of Political Economy*, **94**, 507–22.
- AGHION, P. AND SAINT-PAUL, G. (1998), “On the Virtue of Bad Times: An Analysis of the Interaction between Economic Fluctuations and Productivity Growth”, *Macroeconomic Dynamics*, **2**, 322–344.
- ALVAREZ, F. AND SHIMER, R. (2011), “Search and Rest Unemployment”, *Econometrica*, **79**, 75–122.
- ALVAREZ, F. AND VERACIERTO, M. (2000), “Labor-Market Policies in an Equilibrium Search Model”, in “NBER Macroeconomics Annual 1999, Volume 14”, NBER Chapters, pages 265–316 (National Bureau of Economic Research, Inc).
- BACHMANN, R. (2009), *Understanding Jobless Recoveries*, Ph.D. thesis, Yale University.
- BARNICHON, R. (2010), “Productivity and Unemployment over the Business Cycle”, *Journal of Monetary Economics*, **57**, 1013–1025.
- BERGER, D. (2012), “Countercyclical Restructuring and Jobless Recoveries”, Technical report, Yale University.
- BLOOM, N., FLOETOTTO, M., JAIMOVICH, N., SAPORTA-EKSTEN, I., AND TERRY, S. J. (2012), “Really Uncertain Business Cycles”, Working Paper 18245, National Bureau of Economic Research.
- BRODA, C. AND WEINSTEIN, D. E. (2006), “Globalization and the Gains from Variety”, *The Quarterly Journal of Economics*, **121**, 541–585.
- CABALLERO, R. J. AND HAMMOUR, M. L. (1996), “On the Timing and Efficiency of Creative Destruction”, *The Quarterly Journal of Economics*, **111**, 805–52.
- CARRILLO-TUDELA, C. AND VISSCHERS, L. (2013), “Unemployment and Endogenous Reallocation over the Business Cycle”, Technical Report 7124, IZA Discussion Paper.
- CHANG, B. (2012), “A Search Theory of Sectoral Reallocation”, Technical report, University of Wisconsin.
- CHARI, V. V., KEHOE, P. J., AND MCGRATTAN, E. R. (2007), “Business Cycle Accounting”, *Econometrica*, **75**, 781–836.
- CLARIDA, R., GAL, J., AND GERTLER, M. (2000), “Monetary Policy Rules And Macroeconomic Stability: Evidence And Some Theory”, *The Quarterly Journal of Economics*, **115**, 147–180.

- CLARK, K. B. AND SUMMERS, L. H. (1979), “Labor Market Dynamics and Unemployment: A Reconsideration”, *Brookings Papers on Economic Activity*, pages 13–72.
- COMIN, D. A. AND PHILIPPON, T. (2006), “The Rise in Firm-Level Volatility: Causes and Consequences”, in “NBER Macroeconomics Annual 2005, Volume 20”, NBER Chapters, pages 167–228 (National Bureau of Economic Research, Inc).
- DAVIS, S. J. (1987), “Fluctuations in the pace of labor reallocation”, *Carnegie-Rochester Conference Series on Public Policy*, **27**, 335–402.
- DAVIS, S. J. AND KAHN, J. A. (2008), “Interpreting the Great Moderation: Changes in the Volatility of Economic Activity at the Macro and Micro Levels”, NBER Working Papers 14048, National Bureau of Economic Research.
- FABERMAN, R. J. (2008), “Job flows, jobless recoveries, and the Great Moderation”, Working Papers 08-11, Federal Reserve Bank of Philadelphia.
- FERNALD, J. (2012), “A quarterly, utilization-adjusted series on total factor productivity”, Working Paper Series 2012-19, Federal Reserve Bank of San Francisco.
- FOERSTER, A. T., SARTE, P.-D. G., AND WATSON, M. W. (2011), “Sectoral versus Aggregate Shocks: A Structural Factor Analysis of Industrial Production”, *Journal of Political Economy*, **119**, 1 – 38.
- FUJITA, S. AND MOSCARINI, G. (2013), “Recall and Unemployment”, Working paper series, Yale University.
- GALI, J. AND GAMBETTI, L. (2009), “On the Sources of the Great Moderation”, *American Economic Journal: Macroeconomics*, **1**, 26–57.
- GALI, J. AND VAN RENS, T. (2010), “The Vanishing Procyclicality of Labor Productivity”, IZA Discussion Papers 5099, Institute for the Study of Labor (IZA).
- GORDON, R. J. AND BAILY, M. N. (1993), “The Jobless Recovery: Does it Signal a New Era of Productivity-Led Growth?”, *Brookings Papers on Economic Activity*, **1993**, 271–316.
- GROSHEN, E. L. AND POTTER, S. (2003), “Has structural change contributed to a jobless recovery?”, *Current Issues in Economics and Finance, Federal Reserve Bank of New York*, **9**.
- HALL, R. E. (1991), “Labor Demand, Labor Supply, and Employment Volatility”, *NBER Macroeconomics Annual*, **6**, 17–62.
- HALL, R. E. (2007), “How Much Do We Understand about the Modern Recession?”, *Brookings Papers on Economic Activity*, **38**, 13–30.
- HANSEN, G. D. (1985), “Indivisible labor and the business cycle”, *Journal of Monetary Economics*, **16**, 309–327.

- HORNSTEIN, A. (2012), “Accounting for unemployment: the long and short of it”, Working Paper 12-07, Federal Reserve Bank of Richmond.
- JACOBSON, L. S., LALONDE, R. J., AND SULLIVAN, D. G. (1993), “Earnings Losses of Displaced Workers”, *American Economic Review*, **83**, 685–709.
- JAIMOVICH, N. AND SIU, H. E. (2009), “The Young, the Old, and the Restless: Demographics and Business Cycle Volatility”, *American Economic Review*, **99**, 804–26.
- JUDD, K. L. (1998), *Numerical Methods in Economics*, number 0262100711 in MIT Press Books (The MIT Press).
- KIM, C.-J. AND NELSON, C. R. (1999), “Has The U.S. Economy Become More Stable? A Bayesian Approach Based On A Markov-Switching Model Of The Business Cycle”, *The Review of Economics and Statistics*, **81**, 608–616.
- LAZEAR, E. P. AND SPLETZER, J. R. (2012), “The United States Labor Market: Status Quo or A New Normal?”, Working Paper 18386, National Bureau of Economic Research.
- LESTER, R., PRIES, M., AND SIMS, E. (2013), “Volatility and Welfare”, Working paper, Univ. of Notre Dame.
- LILIEN, D. M. (1982), “Sectoral Shifts and Cyclical Unemployment”, *Journal of Political Economy*, **90**, 777–793.
- LONG, J., JOHN B AND PLOSSER, C. I. (1983), “Real Business Cycles”, *Journal of Political Economy*, **91**, 39–69.
- LUCAS, R. E. (1977), “Understanding business cycles”, *Carnegie-Rochester Conference Series on Public Policy*, **5**, 7–29.
- LUCAS, R. J. AND PRESCOTT, E. C. (1974), “Equilibrium search and unemployment”, *Journal of Economic Theory*, **7**, 188–209.
- MCCONNELL, M. M. AND PEREZ-QUIROS, G. (2000), “Output Fluctuations in the United States: What Has Changed since the Early 1980’s?”, *American Economic Review*, **90**, 1464–1476.
- MEHROTRA, N. R. AND SERGEYEV, D. (2012), *Sectoral Shocks, the Beveridge Curve and Monetary Policy*, Ph.D. thesis, Columbia University.
- MENZIO, G. AND SHI, S. (2011), “Efficient Search on the Job and the Business Cycle”, *Journal of Political Economy*, **119**, 468 – 510.
- PHELAN, C. AND TREJOS, A. (2000), “The Aggregate Effects Of Sectoral Reallocations”, *Journal of Monetary Economics*, **45**.
- RAMEY, V. A. (1991), “Nonconvex Costs and the Behavior of Inventories”, *Journal of Political Economy*, **99**, 306–34.

- ROGERSON, R. (1987), “An Equilibrium Model of Sectoral Reallocation”, *Journal of Political Economy*, **95**, 824–34.
- ROGERSON, R. (1988), “Indivisible labor, lotteries and equilibrium”, *Journal of Monetary Economics*, **21**, 3–16.
- RUHM, C. J. (1991), “Are Workers Permanently Scarred by Job Displacements?”, *American Economic Review*, **81**, 319–24.
- SAHIN, A., SONG, J., TOPA, G., AND VIOLANTE, G. L. (2012), “Mismatch Unemployment”, Working Paper 18265, National Bureau of Economic Research.
- SCHAAL, E. (2010), “Uncertainty, Productivity and Unemployment in the Great Recession”, Working paper, Princeton University.
- SHIMER, R. (2007), “Mismatch”, *American Economic Review*, **97**, 1074–1101.
- SMETS, F. AND WOUTERS, R. (2007), “Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach”, *The American Economic Review*, **97**, 586–606.
- STOCK, J. H. AND WATSON, M. W. (2003), “Has the business cycle changed?”, *Proceedings*, pages 9–56.
- WICZER, D. (2013), *Long-Term Unemployment: Attached and Mismatched?*, Ph.D. thesis, University of Minnesota.
- WILLIAMSON, S. D. (1990), “Sectoral Shifts, Labor Market Sorting, and Aggregate Fluctuations”, *International Economic Review*, **31**, 935–52.