Reallocation and the Changing Nature of Economic Fluctuations

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Abstract

We document five important changes in the nature of economic fluctuations that have occurred in recent decades: output volatility has declined significantly (the “Great Moderation”); job growth has been much weaker following the last three recessions (“Jobless Recoveries”); labor productivity turned from strongly procyclical to acyclical; temporary layoffs accounted for a much smaller fraction of the increase in unemployment in the last three recessions; and the “efficiency wedge” declined in importance relative to the “labor wedge.” We argue that these changes are related phenomena that call for a common explanation. To that end, we construct a model of labor reallocation and show that a decline in the importance of aggregate shocks relative to reallocative shocks can simultaneously account for these facts.

Keywords: Reallocation; Great Moderation; Productivity; Business Cycles

JEL Classifications: E24, E32

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1 Introduction

Robert Lucas (1977) famously wrote that “One is led by the facts to conclude that, with respect to the qualitative co-movements among series, business cycles are all alike.” This general observation has served as a guidepost for modern research on economic fluctuations. Models are typically evaluated on the basis of how well they can reproduce a number of empirical moments, under the implicit assumption that these moments are themselves time-invariant. However, the facts now lead one to conclude that this assumption is no longer true: key features of business cycles—both qualitative and quantitative—have changed. It is important, both for the macroeconomic models that we build and for the policy guidance that we take from them, that we understand the economic forces that account for these changes.

We highlight five features of U.S. business cycles that have changed. Some of them have received more attention than others. Moreover, the changes that have received considerable attention have commonly been analyzed in isolation. We highlight all five of them simultaneously because we believe that the common timing of these changes is more than mere temporal coincidence—they are related economic phenomena that require a common explanation.

1. The volatility of output and other economic aggregates declined significantly in the mid-1980s. This broad-based decline in volatility has been dubbed the “Great Moderation” and has been the focus of a substantial body of research.\(^1\)

2. Following the last three recessions, job growth has been considerably more anemic when compared to earlier post-war recessions—the “Jobless Recovery” phenomenon.\(^2\) It is worth noting that these three jobless recoveries all occurred subsequent to the 1984 date that is commonly associated with the advent of the Great Moderation.

3. Labor productivity switched from strongly procyclical prior to 1984 to acyclical or mildly countercyclical in the period since 1984. The co-movements between

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\(^1\)Key contributions to the work on the Great Moderation include Kim and Nelson (1999), McConnell and Perez-Quiros (2000), Stock and Watson (2003), Jaimovich and Siu (2009), Davis and Kahn (2008).

\(^2\)Papers that have examined the Jobless Recovery phenomenon include Groshen and Potter (2003), Bachmann (2009), Gordon and Baily (1993), and Aaronson et al. (2004).
productivity and labor market aggregates (e.g. hours, employment, and unemployment) also switched signs at the same time.³

4. Unemployment associated with temporary layoffs, which prior to 1984 accounted for a significant portion of the spike in total unemployment that occurred during recessions, has declined in importance since then.⁴ In the last three recessions, nearly the entire spike in unemployment has been accounted for by permanent layoffs.

5. The “labor wedges” and “efficiency wedges” that are obtained from a business cycle accounting exercise have experienced a shift in relative importance, with the “efficiency wedge” declining in importance relative to the “labor wedge.”

As we show below, these changes are stark. As such, some of them have garnered substantial attention, and a rich body of research has offered competing explanations. However, typically the attempts to understand the causes of these changes have considered each of them in isolation. A significant drawback of this piecemeal approach is that a potentially compelling explanation for one of the facts often carries with it other implications that run contrary to one or more of the other facts. For example, Gali and van Rens (2010) propose an explanation of the vanishing procyclicality of productivity that is based on reduced hiring frictions. Firms respond to a positive demand shock in their model by increasing labor, which causes labor productivity to fall due to diminishing returns. A reduction in hiring frictions could, according to their theory, lead to a stronger response of employment to demand shocks, which would amplify this countercyclicality of labor productivity to such an extent that it would swamp the procyclicality stemming from technology shocks. The difficulty with this explanation is that smaller hiring frictions are inconsistent with the Jobless Recovery phenomenon and would seem to imply larger responses to shocks, contrary to the observed moderation in output volatility.

As another example, explanations for the rise of the Jobless Recovery phenomenon (e.g. Bachmann (2009)) often rely on an increase in labor hoarding. According to

³Papers that have addressed this change in the cyclicality of productivity include Gali and van Rens (2010), Barnichon (2010), Schaal (2010), and Hall (2007).
⁴This fact was pointed out in Faberman (2008).
this hypothesis, if firms increasingly retain redundant workers during a downturn, then hiring during the recovery will be increasingly weaker. However, a greater role for labor hoarding implies, counterfactually, that labor productivity should have become more procyclical, since hoarded labor will make measured productivity fall more sharply during downturns and recover more rapidly during recoveries.

These examples demonstrate that existing theories struggle to simultaneously account for the five changes that we highlighted above. However, we contend that they are indeed related phenomena and that it is possible to understand them all as different parts of a broader change in the functioning of the economy. The emergence of the jobless recoveries, the changing cyclicality of labor productivity, and the relatively greater role for the labor wedge all suggest that there was a change in the nature of, and the causes of, the drop in labor inputs that typically occurs during recessions. We argue that shocks to the economy that precipitate the reallocation of workers (across sectors, geographic regions, professions, etc.) can account for all three features. First, displaced workers who must reallocate are more likely to endure lengthy unemployment spells, or repeated unemployment spells, which contributes to jobless recoveries. Second, the frictions associated with reallocation will naturally generate a wedge between workers’ marginal rate of substitution and the marginal product of labor, i.e. the “labor wedge.” Third, following a reallocative shock, employment declines in adversely affected sectors (or regions, or professions) and grows in improving sectors, causing labor productivity to increase.

While the response of the economy to reallocative shocks is qualitatively similar to the observed features of post-1984 U.S. business cycles, the question remains: what accounts for the change relative to the pre-1984 period? We argue that the decline in the importance of aggregate shocks (productivity shocks that affect all sectors, regions, etc.) relative to reallocative shocks can account for the change. Foerster et al. (2011) present empirical evidence that supports this changing relative importance of aggregate and reallocative shocks.

To explore this hypothesis, we construct a model in which economic fluctuations result from both aggregate and reallocative shocks. The model combines key elements of the models in Rogerson (1988) and Lucas and Prescott (1974). Households’ labor
is assumed to be indivisible and there are employment lotteries as in Rogerson (1988). Households consume a composite consumption good that is made by combining intermediate goods produced on two distinct “islands.” Island-specific productivity shocks precipitate reallocation of workers from one island to the other, and there are frictions that make this reallocation process a time-consuming activity, resulting in “reallocation unemployment.” In addition to the island-specific productivity shocks, there are also aggregate shocks that take the form of a two-state Markov process, with the states roughly corresponding to “normal” times and “recessions.” The sector-specific productivities also follow Markov processes, and have transition matrixes parameterized such that a movement from the good to the bad aggregate state triggers a stochastic 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 an elevated level of reallocative activity.

The model behaves much like a one-sector growth model when aggregate shocks are large relative to reallocative shocks. While there is some reallocation across sectors during economic downturns, the aggregate shocks dominate and so productivity is procyclical. Employment falls mostly due to the indivisibility of labor, as some workers remain idle while aggregate conditions are poor. Those workers quickly return to employment (in the same sector) when aggregate conditions improve, and thus employment reductions and recoveries are sharp and quick. Movements in the efficiency wedge are large relative to the labor wedge. These features accord with the pre-1984 period.

With more dampened aggregate shocks, reallocative shocks play a relatively more important role during downturns, and the model economy behaves quite differently. Note first that diminished aggregate shocks will deliver a decline in overall output volatility (the Great Moderation). Moreover, average productivity could become countercyclical because during downturns, when employment and output are low, labor productivity rises as labor is reduced on the relatively less productive island and gradually increased on the more productive island. Because a larger fraction of the unemployment during a downturn is “reallocation unemployment,” which is associated with frictions that make the reallocation time-consuming, employment recoveries are more drawn out (“Jobless Recovery”). The greater role for “reallocation unemployment” also implies that perma-
nent layoffs will account for a larger fraction of layoffs during downturns. Furthermore, we show that reallocation introduces a wedge in the model’s intratemporal first-order condition for labor supply, since employment on the island with improved productivity is constrained to be less than the number of workers currently located on the island. This labor wedge will be relatively more important than the efficiency wedge when reallocative shocks are relatively more important than aggregate shocks. All of these implications that arise from a diminished role for aggregate shocks are qualitatively consistent with the changes in the data that occurred around 1984.

To demonstrate the model’s ability to account for the changing nature of fluctuations, we undertake a simple quantitative exercise in Section 4. We pick values for the parameters of the model to fit certain long run features of the US data. We consider two parameterizations of the shock processes. In the first, which is meant to match the pre-1984 volatility of output, aggregate shocks are relatively large. For this parameterization, we show that labor productivity is strongly procyclical and is also positively correlated with labor input. In the second, we reduce the volatility of the aggregate shock so as to match post-1984 output volatility. For this parameterization, we observe that the cyclicality of productivity drops significantly and that the volatility of the efficiency wedge drops sharply relative to the volatility of the labor wedge. In addition, we show that employment recoveries are relatively more drawn out in the version of the model with smaller aggregate shocks.

Having shown that the model with smaller aggregate shocks does a good job of matching the changes post-1984, in Section 4 we also look at the welfare consequences of the different shock configuration. We find that welfare is higher under the pre-1984 parameterization with larger aggregate shocks. Though this may seem surprising, the intuition for this finding is fairly straightforward. For reasonable values of the elasticities of substitution and labor supply, higher shock volatility actually presents an opportunity—households can achieve the same level of average hours by working more when the state is good and less when the aggregate state is poor. This results in average labor productivity being higher when the shock volatility is higher, leading to more consumption on average and higher overall welfare. This finding has potentially important implications for policymakers. In particular, it highlights the point that lower volatility
does not necessarily imply higher welfare.

The remainder of this paper is organized as follows. Section 2 provides evidence on the changes to economic fluctuations that were outlined above. 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 research.

2 Evidence on the Changes in the Nature of Economic Fluctuations

In this section, we document the stark changes in U.S. business cycles discussed above. Because labor reallocation plays an important role in the model that we develop below, we also present some evidence on the importance of sectoral reallocation of labor over the business cycle.

Unless otherwise noted, the data used in the analysis span the period from 1948 through the end of the 2010, 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 the standard smoothing parameter of 1600.

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 deviation of HP filtered real GDP. The sharp drop in this statistic that occurred in the mid-1980s visually jumps out in the picture. There is some evidence of an upward jump 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. 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 0.017 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.

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 below 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.
2.3 The Reduced Cyclicality 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. Since 1984, average labor productivity has become acyclical and the correlation of productivity with various labor market variables has become negative. Figure 3 plots 40-quarter rolling correlations between real output and productivity and between total hours worked and productivity.

We measure average labor productivity as output per hour in the non-farm business sector.

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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 uptick in volatility associated with the Great Recession, both of these correlations display an upward tick at the end of the sample, though they both remain well below their pre-1984 levels.\(^6\)

<table>
<thead>
<tr>
<th>Correlation</th>
<th>1947-1983</th>
<th>1984-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corr(Output, Productivity)</td>
<td>0.58</td>
<td>0.05</td>
</tr>
<tr>
<td>Corr(Hours, Productivity)</td>
<td>0.20</td>
<td>-0.44</td>
</tr>
<tr>
<td>Corr(Employment, Productivity)</td>
<td>0.09</td>
<td>-0.51</td>
</tr>
<tr>
<td>Corr(Unemployment, Productivity)</td>
<td>-0.24</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Table 1: Correlations of productivity with other key aggregates.

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 correlations 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 essentially uncorrelated with output, strongly negatively correlated with both hours and employment, and strongly positively correlated with the unemployment rate.

### 2.4 The Changing Nature of Layoffs

Another stark change in the nature of business cycles since the mid-1980s can be seen in the behavior of layoffs. 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 “permanent” unemployment, which measures workers who have lost jobs and do

\(^6\)This uptick at the end of the sample only became noticeable with data revisions that were released in the spring of 2011.
not expect to be re-hired by the same firm. These data are available beginning in 1967 and are shown in Figure 4 below.

![Graph showing permanent and temporary layoffs](image)

**Figure 4:** Permanent and Temporary Unemployment Rates

The striking feature of Figure 4 is the near disappearance of the cyclicality 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 permanent unemployment 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.

### 2.5 The Labor and Efficiency Wedges

Chari et al. (2007) propose a simple “business cycle accounting” approach to understanding economic fluctuations that can serve as a guide for helping to refine and develop quantitative models. Their procedure is essentially to take the first-order conditions from a stochastic neoclassical growth model with variable labor and to calculate the residuals that account for the degree to which the data do not fit the first-order conditions. These residuals are called “wedges” and they can be fed back into the model as a driving force to help determine which shocks and frictions are quantitatively the most important for explaining observed fluctuations. Given that the second moments of many key aggregate series have changed substantially since the mid-1980s, it is worthwhile to examine how the times series properties of the wedges have changed.
Because the stochastic growth model that forms the basis for the procedure is well
known, we eschew a detailed exposition of the underlying prototype model; instead, we
just focus on the first-order conditions that emerge as the solution to the decentralized
equilibrium. We assume that preferences are separable and are logarithmic over con-
sumption and linear in utility, and that production takes place with a constant returns
to scale Cobb-Douglas technology. We abstract from trend growth. The first-order
conditions are as follows:

\[ \phi = \psi_{l,t} \frac{1}{C_t} \left( 1 - \alpha \right) \frac{Y_t}{L_t} \]  

\[ \psi_{l,t} \frac{1}{C_t} = \beta E_t \left( \frac{1}{C_{t+1}} \left( \psi_{e,t+1} \alpha \frac{Y_{t+1}}{K_{t+1}} + (1 - \delta) \psi_{I,t+1} \right) \right) \]  

\[ Y_t = \psi_{e,t} K_t^\alpha L_t^{1-\alpha} \]  

\[ Y_t = C_t + I_t + \psi_{g,t} \]

Equation (1) is the static first-order condition for labor supply, with \( \phi \) denoting
the disutility of labor and \( \alpha \) denoting capital’s share of income; (2) is the consumption
Euler equation; (3) is the production function; and (4) is an accounting identity. The \( \psi \)s
are the “wedges”—\( \psi_{e,t} \) is the “efficiency wedge” and resembles a standard TFP shock;
\( \psi_{l,t} \) is the “labor wedge” and resembles a distortionary tax on labor income; \( \psi_{g,t} \) is
the “spending wedge” and resembles a shock to government spending; and \( \psi_{I,t} \) is the
“investment wedge” and is isomorphic to a tax on investment.

We limit our focus here to the efficiency and labor wedges, \( \psi_{e,t} \) and \( \psi_{l,t} \), as these are
by far the most important sources of variation in the data. Following equation (1), we
construct a measure of (the natural log of) the labor wedge, \( \psi_{l,t} \) by subtracting the log of
GDP to total consumption ratio (from the NIPA accounts) from the log of total hours.
The parameters \( \alpha \) and \( \phi \) only affect the scale and therefore need not be calibrated. In a
similar way, we use data on capital and labor (we use John Fernald’s series for capital)
to recover a measure of (the log of) the efficiency wedge, \( \psi_{e,t} \) in equation 3. Figure 5
below plots the HP filtered time series of the wedges.
Three important facts are visibly apparent from the figure. First, the efficiency wedge is quite procyclical, whereas the labor wedge is strongly countercyclical, with no visibly apparent shift in the cyclicality of either series after 1984. Second, a significant reduction in the volatility of the efficiency wedge is apparent after 1984. Finally, there appears to be no reduction in the volatility of the labor wedge.\textsuperscript{7} Indeed, the largest absolute movement in this wedge occurs in the most recent recession.

Table 2 shows the volatilities of these two (HP detrended) wedges for the full sample and for the two sub-samples. We observe that there was no change in the unconditional volatility of the labor wedge across the two sub-samples. The main change that can be seen is that the efficiency wedge is slightly more than half as volatile in the post-1984 period as in the earlier period.

<table>
<thead>
<tr>
<th></th>
<th>Full sample</th>
<th>1947-1983</th>
<th>1984-2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor wedge std. deviation</td>
<td>0.015</td>
<td>0.015</td>
<td>0.015</td>
</tr>
<tr>
<td>Efficiency wedge std. deviation</td>
<td>0.013</td>
<td>0.015</td>
<td>0.009</td>
</tr>
</tbody>
</table>

Table 2: Standard deviation of labor and efficiency “Wedges”

To summarize, fluctuations in the efficiency wedge have become significantly less

\textsuperscript{7}Gali et al. (2007) show that in standard monetary DSGE models poor monetary policy manifests itself as time-varying price markups, which in those models show up as variations in the labor wedge. It is worth noting that one of the more popular explanations for the Great Moderation—improved monetary policy—would imply, in New Keynesian models such as that of Gali et al. (2007), a reduction in the volatility of the labor wedge. As we show here, no such reduction occurred.
important post-1984, with little change in the volatility of the labor wedge. In light of the changing correlational patterns observed in the aggregate data, this conclusion should not be too surprising. In particular, the conditional correlation of productivity and output in response to an efficiency wedge shock in the prototype model is positive, whereas it is negative in response to a labor wedge shock. Thus, a declining relative importance of the efficiency wedge will automatically lead to a lower unconditional correlation between productivity and output. As such, a reduction in the volatility of the efficiency wedge shocks can simultaneously explain the reduced volatility of output as well as the changing cyclicality of productivity.

2.6 Labor Reallocation

Given the importance of labor reallocation, and reallocative shocks, in the model below, we discuss the evidence on the cyclical properties of sectoral reallocation of labor. The goal here is not necessarily to show that there has been a change in the nature of this reallocation, but rather to show that this reallocation tends to be concentrated during recessions.

The idea that recessions may be associated with elevated levels of reallocation of workers and resources across different sectors of the economy goes back to at least Lilien (1982). Lilien uses the dispersion of employment growth rates across sectors as an indicator of the extent of reallocative activity. Specifically, let \( g_{i,t} = \ln N_{i,t} - \ln N_{i,t-1} \) be the quarterly growth rate of the level of employment in sector \( i \) at time \( t \). Let \( g_t \) be defined similarly for aggregate private employment. Further, let \( s_{i,t} = \frac{N_{i,t}}{N_t} \) be sector \( i \)'s share of aggregate employment at time \( t \) and \( \mu_i \) be the time series average growth rate of sectoral employment relative to aggregate employment growth, \( g_{i,t} - g_t \) (e.g., this will be negative for a declining sector like manufacturing). Lilien’s measure of reallocation is then the share-weighted standard deviation of net sectoral growth rates:

\[
\sigma^L_t = \left[ \sum_{i=1}^{M} s_{i,t} (g_{i,t} - g_t - \mu_i)^2 \right]^{\frac{1}{2}}
\]  

(5)

where \( M \) denotes the number of sectors. We take the ten one-digit SIC industries as a
benchmark, so $M = 10$. Figure 6 shows this measure using quarterly data.

![Figure 6](image)

**Figure 6:** This figure shows the Lilien (1982) measure of reallocation, constructed as described in the text.

Lilien argued that if recessions were caused by an increase in reallocative activity then we should expect spikes in this measure of dispersion near recessions. The evidence in Figure 6 is consistent with this story, as the dispersion measure is clearly countercyclical. However, Figure 6 also seems to suggests that post-1984 recessions have been accompanied by *less* reallocation (the spikes during these later recessions are smaller). We contend, however, that the Lilien measure is a poor indicator of the level of reallocative activity because it does not reflect the *permanence* of changes in sectoral employment. For example, if a sector of the economy contracted sharply in one year and recovered back to its initial employment in the following year, the Lilien measure would be high in each year, even though no lasting reallocation actually took place. Thus, the decrease in volatility in this statistic could simply reflect a reduction in the volatility of aggregate shocks. Abraham and Katz (1986) criticized the Lilien measure along similar lines, pointing out that even if recessions were purely the result of aggregate shocks, with no accompanying reallocation across sectors, the dispersion measure would still spike if some sectors were naturally more cyclically sensitive.

We therefore propose an alternative approach, based on Davis (1987), to assess the extent to which changes in sectoral employment actually represent enduring reallocation of resources across different sectors. Let $s = 1, \ldots, S$ index sectors, and let $\Delta_H \ln x_t = \ln x_t - \ln x_{t-H}$, for some scalar $H$ and variable $x$. Let $n_t$ be aggregate employment and
\( n_{s,t} \) be employment in sector \( s \) at time \( t \). Davis’ measure is:

\[
\sigma_t^H = \sum_{s=1}^{S} \left( \frac{\ln n_{s,t}}{\ln n_t} \right) \left( \Delta_1 \ln n_{s,t} - \Delta_1 \ln n_t \right) \left( \Delta_H \ln n_{s,t-1} - \Delta_H \ln n_{t-1} \right)
\]

(6)

This measure is essentially the share-weighted covariance between current relative employment growth and lagged relative employment growth over an \( H \) period horizon. A large, positive value of this measure indicates that patterns of current reallocation are similar to past patterns of reallocation. In contrast, smaller, or negative, values of this measure indicate that current reallocation is working to reverse past patterns of reallocation. To the extent that enduring reallocation is an important feature of recessions, we would expect this measure to be high in the periods immediately after recessions, as the sectors hit hardest during the recession will continue to do relatively poorly as the recovery takes hold and the reallocative processes plays out. In contrast, if some sectors simply have different cyclical sensitivities, as in the Abraham and Katz (1986) story, we would expect low or negative values of this series in the periods after a recession, as those sectors hit hardest during the recession will tend to bounce back fastest during the recovery.

Figure 7 plots this series for \( H = 4 \) using quarterly employment data for the one digit SIC sectors (other reasonable values of \( H \) result in a fairly similar picture). The fact that
the series spikes around the time of almost all post-war recessions lends credence to the fact that enduring reallocation of resources is an important feature of the business cycle. That is, this measure indicates that sectors that fare poorly during recessions tend to continue to do poorly (in a relative sense) during the subsequent recovery. Moreover, in contrast with the Lilien measure, which suggested a smaller role for reallocation in recent recessions, this Davis measure suggests that reallocation has, if anything, become more important in the post-1984 period—in the pre-Moderation recessions, this series jumps down immediately after the end of the recession and frequently goes negative; in contrast, in the post-Moderation recessions, this series tends to remain elevated for an extended period and never turns negative.

We have provided evidence on the five features of business cycles that changed around 1984. The model introduced in the next section seeks to provide a unified account of those changes. The fact that labor reallocation is concentrated during recessions, as we have also documented here, plays an important role in the model.

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. Other models which focus on the role of reallocation in business cycles can be found in Long and Plosser (1983), Long and Plosser (1987), Williamson (1990), Phelan and Trejos (2000), and Shimer (2007).

We begin our discussion of the model by describing the production side of the economy. There are two islands, which represent different sectors of the economy. On each island \( i \) there is a representative firm that produces intermediate good \( i \) 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 competitive firms.
utilizing the following technology:

\[ Y_t = \left( X_{1,t}^{\sigma_{-1}} + X_{2,t}^{\sigma_{-1}} \right)^{\frac{\sigma}{\sigma-1}}. \]

There is a continuum of infinitely lived households of measure 1. The households face a consumption/saving decision and a labor supply decision, and seek to maximize

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

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.\(^8\) The disutility of labor, \( \nu(l_t) \) is increasing and convex 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, 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 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

---

\(^8\)Given the assumed separability between consumption and leisure, we assume log utility so that the model is consistent with balanced growth.
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 exact same frictions that individual households face—reallocating
workers from one island to the other is time-consuming. An example of such a friction
is the need for re-training in sector-specific skills. 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 pass through a spell of “reallocation unemployment”
while engaged in activities that make them employable in the other sector. 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.\(^9\)

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,” where
frictions make the transition from one island to another a time-consuming process. 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. That
is, holding island-specific productivities constant, if, for example, 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.

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

---

\(^9\)This 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.
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

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

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

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

$K_{1,t} + K_{2,t} = K_t$

$L_{1,t} \leq N_{1,t}$

$L_{2,t} \leq N_{2,t}$

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

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

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

$N_{1,0}, N_{2,0}, K_0$ given

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 contingent on the period $t-1$ information set). The fourth and fifth constraints require that employment on each island not exceed the number of workers allocated to that island. The fifth and sixth 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 last constraint imposes that the workers available to be reallocated can only be reallocated to one island or the other. Finally, note that 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” ($U_{r,t} = 1 - N_{1,t} - N_{2,t}$).

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. The Bellman equation can then be expressed as:

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

$$+ \beta EV(N'_1, N'_2, K', \xi')$$

s.t.: $C + K' \leq \left( X_{1}^{\frac{\sigma-1}{\sigma}} + X_{2}^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}} + (1 - \delta)K$

$$X_i = A z_i K_i^\alpha L_i^{1-\alpha}, \quad i = \{1, 2\}$$

$$K_1 + K_2 = K$$

$$L_1 \leq N'_1$$

$$L_2 \leq N'_2$$

$$N'_1 \leq N_1 + \lambda(1 - N_1 - N_2)$$

$$N'_2 \leq N_2 + \lambda(1 - N_1 - N_2)$$

$$N'_1 + N'_2 \leq N_1 + N_2 + \lambda(1 - N_1 - N_2)$$

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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 8: Graphical depiction of the “island” model

Before turning to a quantitative analysis of the model, it is worthwhile to discuss its qualitative features. Figure 8 graphically depicts the basic structure of the model economy. The two types of shocks will generate decidedly different responses by 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 8, 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 reallocate shocks the model becomes a two-sector version of the Hansen (1985) general equilibrium model of indivisible labor with employment lotteries.

Now consider a purely reallocate 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 “reallocative unemployment.” That is, the desire to reallo-
cate 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. As such, employment will recover
much more slowly following a reallocative shock. The response of labor productivity
will also look much different for a reallocative 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, productivity increases in response to the
reallocative shock. This also implies that productivity will be less strongly correlated
with output and employment. In addition, reallocative shocks will generate a labor
wedge because some of the constraints in the planner’s problem will bind—in particular,
the planner will not be able to employ the desired number of workers on the productive
island, resulting in a discrepancy between the marginal products on each island and an
observed labor wedge in the aggregated data. In the absence of the reallocation frictions,
the marginal products of both factors would be equalized across islands.

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. In particular, we pa-
parameterize much of 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 a Markov process with $q$ distinct points, with $z_j > z_{j-1}$ for $1 \leq j \leq q$. 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, for $j > q/2$, island one is relatively more productive than island two, and vice-versa for $j < q/2$. If $q$ is even, then at $j = q/2$, 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 productivity 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 would imply 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. This structure is meant to capture enduring reallocation, similar to that which was documented in Section 2.

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 correlation 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 captures the fact that recessions have differential impact on sectors, and is necessary to replicate the observed cyclical patterns of both the Lilien (1982) and Davis (1987) measures of sectoral reallocation. Note that the goal of the paper is not to explain why labor reallocation is concentrated during recessions, but rather to understand the implications of that fact. Thus, we do not attempt to derive this result endogenously, but rather we impose it exogenously by
assuming this particular shock structure.\textsuperscript{10}

The transition matrix for $A$ is parameterized to match the frequency and duration of US recessions (as defined by the NBER). In particular, the average duration of expansions is 33 quarters, 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 points).

With this structure in place for the stochastic processes, we turn to selecting other parameter values. Although the model is somewhat stylized, and 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.

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 sectors 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 sector. 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 sector, 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.\textsuperscript{10}

\textsuperscript{10}See Ramey (1991), Hall (1991), Caballero and Hammour (1996), 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.
This value is similar to parameterizations used in quantitative models featuring Lucas and Prescott (1974) type search.\textsuperscript{11}

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 sectors. 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 sectors, 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.\textsuperscript{12}

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 $z$). 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 reduces the correlation). However, our model cannot simultaneously match both moments. 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

\textsuperscript{11}See Alvarez and Shimer (2011) for a further discussion of some of this literature.
\textsuperscript{12}Clark and Summers (1979) show that a large fraction of unemployment spells end very quickly, which exerts a strong downward effect on 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.
we take is to consider three 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 3 shows some 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.

<table>
<thead>
<tr>
<th></th>
<th>Pre-1984 data</th>
<th>Calibration 1</th>
<th>Calibration 2</th>
<th>Calibration 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>s.d.(output)</td>
<td>0.020</td>
<td>0.020 (0.004)</td>
<td>0.020 (0.004)</td>
<td>0.020 (0.004)</td>
</tr>
<tr>
<td>s.d.(output)/s.d.(emp)</td>
<td>1.0</td>
<td>1.515 (0.081)</td>
<td>1.298 (0.18)</td>
<td>1.33 (0.09)</td>
</tr>
<tr>
<td>corr(output, prod)</td>
<td>0.58</td>
<td>0.88 (0.112)</td>
<td>0.60 (0.22)</td>
<td>0.72 (0.13)</td>
</tr>
<tr>
<td>corr(emp, prod)</td>
<td>0.21</td>
<td>0.718 (0.172)</td>
<td>0.22 (0.22)</td>
<td>0.41 (0.19)</td>
</tr>
<tr>
<td>corr(unemp, prod)</td>
<td>-0.22</td>
<td>-0.601 (0.152)</td>
<td>-0.15 (0.18)</td>
<td>-0.31 (0.16)</td>
</tr>
<tr>
<td>s.d.(efficiency wedge)</td>
<td>0.015</td>
<td>0.012 (0.003)</td>
<td>0.011 (0.002)</td>
<td>0.011 (0.002)</td>
</tr>
<tr>
<td>s.d.(labor wedge)</td>
<td>0.015</td>
<td>0.015 (0.003)</td>
<td>0.021 (0.006)</td>
<td>0.018 (0.003)</td>
</tr>
</tbody>
</table>

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

In all three parameterizations we match the volatility of output exactly. In all calibrations the model fails to generate sufficient volatility in employment relative to output, which is a well-known shortcoming of many modern macro models. The three calibrations also 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 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—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.

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 facts 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 choose the gap between $A^H$ and $A^L$ to match the reduction in output volatility in the latter sample. Table 4 presents the key moments from the model simulation and from the post-1984 data. For this simulation we generate 5000 data sets with 110 observations each (110 corresponds to the number of observations in the post-1984 US data) and produce the numbers by averaging over the 5000 simulations.

<table>
<thead>
<tr>
<th></th>
<th>Post-1984 data</th>
<th>Change</th>
<th>Model</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>s.d.(output)</td>
<td>0.011</td>
<td>-0.009</td>
<td>0.011 (0.002)</td>
<td>-0.009</td>
</tr>
<tr>
<td>s.d.(output)/s.d.(emp)</td>
<td>0.64</td>
<td>-0.36</td>
<td>0.95 (0.081)</td>
<td>-0.38</td>
</tr>
<tr>
<td>corr(output, prod)</td>
<td>0.05</td>
<td>-0.53</td>
<td>-0.04 (0.32)</td>
<td>-0.76</td>
</tr>
<tr>
<td>corr(emp, prod)</td>
<td>-0.44</td>
<td>-0.65</td>
<td>-0.33 (0.26)</td>
<td>-0.77</td>
</tr>
<tr>
<td>corr(unemp, prod)</td>
<td>0.38</td>
<td>0.60</td>
<td>0.27 (0.21)</td>
<td>0.58</td>
</tr>
<tr>
<td>s.d.(efficiency wedge)</td>
<td>0.008</td>
<td>-0.007</td>
<td>0.004 (0.001)</td>
<td>-0.007</td>
</tr>
<tr>
<td>s.d.(labor wedge)</td>
<td>0.015</td>
<td>0.00</td>
<td>0.016 (0.004)</td>
<td>-0.002</td>
</tr>
</tbody>
</table>

Table 4: Comparison of the simulated model with the post-1984 data.

Although we have only changed the magnitude of the aggregate shocks, with the goal of matching the decline in output volatility (the top row), that one change can also
account for much of the changes in the other moments as well. In the data the volatility of hours relative to output increases sharply; this is also a feature of the model, and the magnitude of the change is almost identical. In both the model and the data, output switches from procyclical to roughly acyclical, 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. Finally, in the data the volatility of the efficiency wedge falls in half after 1984, while the volatility of the labor wedge remains the same. The model also replicates these changes. In short, simply reducing the magnitude of aggregate shocks relative to the size of the reallocative shock can account for the first, third, and fifth facts laid out in Section 2.

The model can also account for the jobless recovery phenomenon and the declining importance of temporary layoffs. To provide insight into those two aspects of the model, Figure 9 plots impulse responses of selected labor market variables to a negative aggregate shock in the model. 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.

There are several points worth highlighting. First, the response of reallocation unemployment is virtually the same in both simulations, whereas temporary unemployment

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13To 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.
reacts strongly in the “large shock” case but virtually disappears in the “small shock” simulation. To understand this, note that the desired overall reduction in employment is smaller in the small shock case, and this reduction is achieved entirely by the unemployment associated with reallocation, so that no additional temporary unemployment is necessary. This matches our fourth fact—temporary layoffs essentially disappear after 1984, while “permanent” layoffs remain roughly as volatile.

Second, the change in the relative composition of total unemployment—away from temporary unemployment and towards reallocational unemployment—can qualitatively account for the onset of jobless recoveries. Because temporary unemployment in the model is much less persistent than reallocation unemployment, the disappearance of temporary unemployment leads, through a simple compositional effect, to an increase in the persistence of aggregate unemployment. As the figure shows, the recovery of employment/unemployment in the wake of a recession is more drawn out in the smaller shock simulation than in the larger shock simulation. To put the difference in numbers, in the large shock/pre-1984 simulation, 57 percent of the jobs lost are re-gained within one year. In the small shock/post-1984 simulation, in contrast, only 48 percent of lost jobs are re-gained within a year.

Finally, it is worth noting that the response on impact of total unemployment in the two cases is not markedly different. In particular, the jump on impact by aggregate unemployment is only about 20 percent smaller in the small shock case. When compared with the 45% decline in output volatility, this result accords with the fact that the volatility of unemployment relative to output has increased in the post-1984 sample.

Our result that a reduction in the volatility of aggregate shocks can account for many of the changes in the nature of fluctuations post-1984 is fairly robust to different parameter values in the model. The two somewhat non-standard parameters are $\lambda$, the escape rate from reallocational unemployment, and $\sigma$, the elasticity of substitution between goods on the two islands. The correlations and volatilities in the model are quite robust to changes in these parameters in the neighborhood of their benchmark values. The switch in the cyclicality of productivity does require that $\sigma > 1$, so that the outputs of the two islands are substitutes and labor reallocates from the low to the high productivity island in a downturn. Given the central estimate of 3 in Broda and
Weinstein (2006), we do not view this as an issue. One result does hinge on the value of $\lambda$ and that is the emergence of jobless recoveries. Jobless recoveries in the post-1984 calibration arise due to a composition effect. Because temporary unemployment abates in the post-1984 calibration with small aggregate shocks, the persistence of overall unemployment post-1984 is driven mostly by the persistence of reallocational unemployment. For there to be much of a difference between the persistence of overall unemployment in the two calibrations, reallocational unemployment needs to be significantly more persistent than temporary unemployment, which requires a relatively low value of $\lambda$.

4.3 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.\textsuperscript{14} To do this, for the large aggregate shock and small aggregate shock parameterizations we simulate one million periods of data and calculate expected utility. The results are shown in Table 5, which also reports how the means of several key aggregates vary with the size of the aggregate shocks.\textsuperscript{15}

<table>
<thead>
<tr>
<th>Averages:</th>
<th>Large agg. shocks</th>
<th>Small agg. shocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>utility</td>
<td>1.0375</td>
<td>1.0259</td>
</tr>
<tr>
<td>output</td>
<td>5.5142</td>
<td>5.4560</td>
</tr>
<tr>
<td>consumption</td>
<td>4.2985</td>
<td>4.2507</td>
</tr>
<tr>
<td>employment</td>
<td>0.9793</td>
<td>0.9805</td>
</tr>
<tr>
<td>capital</td>
<td>60.7822</td>
<td>60.2628</td>
</tr>
<tr>
<td>labor prod.</td>
<td>5.6301</td>
<td>5.5645</td>
</tr>
</tbody>
</table>

Table 5: Welfare implications: average household utility and other key aggregates in the large and small aggregate shock parameterizations.

\textsuperscript{14}We thank Randy Wright for suggesting this exercise.\textsuperscript{15}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.
Average utility is actually higher in the large aggregate shock case—the model implies that the more volatile environment prior to 1984 achieved a higher level of welfare. To interpret the magnitude of the difference, it is useful to calculate the percentage by which consumption in the small shock case would have to be increased in order to achieve the same average utility as in the large shock case. It is easy to show that because we have log utility, the difference in the two average utilities also gives the consumption differential—i.e. consumption would have to be increased by 1.22%.

While at first this result might seem counterintuitive, the reason that more volatile 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. 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 5, 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 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 has changed in dramatic ways in the last twenty-five years. This paper has (i) documented the five important dimensions along which the business cycle has changed, (ii) argued that the changes call for a common explanation, (iii) developed an island model of labor reallocation that features aggregate shocks and reallocative shocks, and (iv) showed that the model can account for the changes in the business cycle when aggregate shocks decrease in size relative to reallocative shocks.

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). 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 25-30 years. 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 not account for these new facts. For example, labor productivity in that model is procyclical and strongly correlated with hours worked.

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.
References


