Imperfect information, lagged labor adjustment and the Great Moderation*

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July 29, 2009

Abstract

This paper first documents the increase in the time lag with which labor input reacts to output fluctuations ("the labor adjustment lag") that is visible in US data since the mid-1980s. We show that a lagged labor adjustment response is optimal in a setting where there is uncertainty about the persistence of shocks and where labor input is costly to adjust. We then present evidence that both the nature of shocks hitting the economy as well as labor adjustment costs may have changed during the 1980s in a direction that could explain the observed increase in the lag. Finally, we argue that the increased labor adjustment lag has the potential to explain some macroeconomic puzzles that characterize post-1984 US data, such as the reduced procyclicality of labor productivity and the reduction in output volatility (known as the Great Moderation).

Key words: imperfect information, labor adjustment, jobless growth, option value of waiting, Great Moderation

JEL-classifications: E24, E32, J23, J24

1 Introduction

The last two economic recoveries (the ones that started in 1991 and 2001) were markedly different from their predecessors: contrary to all previous recoveries, they

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*We thank Eric Bartelsman and Larry Christiano for useful discussions. Any errors are of course ours.
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were not accompanied by a simultaneous increase in employment - very much to the confusion and surprise of most economists. Although we do have a name for this phenomenon (it is generally referred to as a "jobless recovery" or "jobless growth"), there is no agreement yet on its roots.

What is less well-known however, is that besides jobless recoveries, the 1990s and 2000s also brought recessions that were initially relatively job preserving. Putting these two observations together, the empirics seem to suggest that the lag with which labor input responds to the business cycle (henceforth referred to as "the labor adjustment lag"), went up substantially in the 1980s. The causes and consequences of this development lie at the heart of this paper.

To explain the lagged response of labor input to the business cycle we develop a theory based on the option value of waiting. As is well-known from the investment literature, there exists an option value to waiting in a stochastic imperfect information setting where investment decisions are costly to reverse. Although most applications of this idea have so far focused on investment decisions in physical capital (cf. the text book treatment of Dixit and Pindyck (1994) and the references therein), this story similarly applies to labor markets. After all, in the presence of labor adjustment costs, hiring and firing decisions also become costly to undo. This elicits cautious behavior on behalf of the employer when he is for example uncertain about the persistence of the shocks that drive the business cycle. In such an environment, employers show a delayed response to shocks as the positive option value to waiting induces them to await the nature of the shock (persistent or transitory?) before making any decisions that are costly to reverse. It will be shown in this paper that in such a setting, the employment cycle will lag the business cycle.

Uncertainty about the persistence of economic shocks plays an important role in reality. There, it is always trivial to identify the nature of shocks in hindsight, but when they occur, persistent and transitory shocks have proved to be hard to distinguish from each other. This is for example nicely illustrated by the following quote from Jean-Philippe Cotis, former chief economist of the OECD, on the recovery of the 2001 recession. In December 2002 he wrote in the OECD Observer:

"The world recovery appears more hesitant and less widespread than expected. Activity bounced back early in 2002 but then lost momentum, in a context of weakening consumer and business confidence. This pattern of fits and starts is not unusual in the initial stages of a recovery but it has been associated with a further deterioration of equity and financial markets."1

The truth is however that the NBER Business Cycle Dating Committee announced in July 2003 that the recession ended already in November 2001. The shocks that hit the economy during 2002 thus turned out to be of a transitory nature, which was apparently not clear to the OECD on impact.

Similarly, it has also proved to be difficult to recognize persistent negative shocks when they actually occur. Consider the following quote by Federal Reserve Chairman Ben Bernanke from March 2007:

"Although the turmoil in the subprime mortgage market has created severe financial problems for many individuals and families, the implications of these developments for the housing market as a whole are less clear (...) At this juncture, however, the impact on the broader economy and financial markets of the problems in the subprime market seems likely to be contained."\(^2\)

That the above prediction has not quite materialized goes without saying.

To address this particular type of uncertainty, which is neglected in most existing models, we build a simple two-period model with imperfect information in Section 4 of this paper. After working through the appropriate cases in Section 5, Section 6 shows that only the combination of informational imperfections and labor adjustment costs leads to a lagged labor input response. In Section 7, we will try to give an answer to the quintessential question why the labor adjustment lag has increased in the 1980s. Subsequently, Section 8 discusses the link between the lengthening of the lag and some macroeconomic puzzles, such as the Great Moderation and the vanishing procyclicality of labor productivity. Finally, Section 9 concludes.

But first, Section 2 illustrates the existence of and increase in the labor adjustment lag since the mid 80s, after which Section 3 discusses the related literature.

2 The labor adjustment lag

2.1 Raw data

As noted in the introduction, all recoveries before the 1990/1 recession were basically accompanied by an increase in the number of people employed. This is shown in Figure 1, which illustrates the evolution of employment over the cycle. It displays the employment level several months before and after the start of the recovery ("the

\(^{2}\)http://www.federalreserve.gov/newsevents/testimony/bernanke20070328a.htm
trough"), relative to the level of employment at the trough.\textsuperscript{3} The figure also depicts the employment response after the 1990/1 and 2001 recessions. The difference between the two series is clear: while all recoveries before 1990 were accompanied by a strong increase in employment, the last two recoveries have been essentially jobless.\textsuperscript{4,5}

\textsuperscript{3}This section uses the NBER postwar recession dates being: November 1948-October 1949; July 1953-May 1954; August 1957-April 1958; April 1960-February 1961; December 1969-November 1970; November 1973-March 1975; January 1980-July 1980; July 1981-November 1982; July 1990-March 1991; and March 2001-November 2001. The NBER Business Cycle Dating Committee defines a recession as "(...) a significant decline in economic activity spread across the economy, lasting more than a few months, normally visible in real GDP, real income, employment, industrial production, and wholesale-retail sales." (See http://www.nber.org/cycles.html.) However, as noted by Blanchard and Simon (2001), the NBER dating of peaks and troughs can be approximated pretty well by a simple rule that defines the beginning of a recession by two consecutive quarters of negative growth. Equivalently, the beginning of an expansion is defined by two consecutive quarters of positive growth following a recession.

\textsuperscript{4}The monthly employment data are taken from the St. Louis Fed database and contain the total nonfarm payrolls. The data are only seasonally adjusted. Constructing the graph using the HP-filtered series (with $\lambda = 129,600$ for monthly data as suggested by Ravn and Uhlig (2002)) shows essentially the same picture (graph available upon request). As dispersion around the average pre-1990 line is very small, we only display the average.

\textsuperscript{5}Although not displayed in the figure due to space-limitations, employment did eventually catch up after the 1990/1 and 2001 recessions. For example, 2.5 years after the 1990/1 trough, employment had risen by 2.6 percent relative to its level at the trough. The recovery from the 2001 recession was even slower, with employment being only 2.9 percent higher four years after the start of the recovery. Obviously, the trend in employment plays a distorting role here which will be corrected for in Section 2.2.
Figure 1: Response of employment to economic fluctuations

Figure 1 also shows that the employment response to recessions differs between the two time periods: the pre-1990 recessions were accompanied by a stronger reduction in employment than the recessions of 1990/1 and 2001. The occurrence of jobless growth thus seems to have been accompanied by the introduction of recessions that were initially relatively job preserving. Apart from pointing at the lower volatility of the employment series since the 1980s (for example reported in Galí and Gambetti (2009)), this evidence also points at the possibility that employment has started to respond with a greater lag to GDP than before.

It is however important to realize that the lack of an employment response on the extensive margin does not need to have important implications for productivity and output: after all, labor input changes on the extensive margin are to a large extent (if not perfectly) substitutable with labor input changes on the intensive margin of hours worked. Therefore, we repeat the above analysis using data on total hours worked in the economy. This results in the following figure, broadly consistent with Figure 1.\(^6\)

\(^6\)These data are taken from Francis and Ramey (2008) and are unfortunately only available at a quarterly frequency. Again, the depicted result is robust to using the HP-filtered series underlying Figure 4 (with \(\lambda = 1,600\); graph available upon request) and dispersion around the pre-1990 line is small.

\(^7\)As with employment, hours worked did eventually catch up after the 1990/1 and 2001 recessions. 2.5 years after the 1990/1 trough, the number of hours worked was 2.3 percent higher. The same holds for hours worked four years after the 2001 recession. Again, the trend in hours worked plays an undesirable role here which will be addressed in the next section.
To investigate our conjecture that the lag between GDP and labor input went up in the 1980s further, we next resort to an analysis of the cyclical component of the data.

### 2.2 Filtered data

#### 2.2.1 Time domain evidence

The previous subsection used raw data (that was only seasonally adjusted) and may therefore be distorted by the presence of a trend. To get around this issue, and to ensure that moments are well-defined, this section focuses at the cyclical component of the data by looking at the cross-correlation between the HP-filtered series.\(^8\) Using all available postwar data (from 1947Q1 to 2008Q4) results in the following cross-correlogram.\(^9\)

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\(^8\)The quarterly data are taken from the St. Louis Fed database. For GDP we use the seasonally adjusted output in chained 2000-Dollars, while we use the same employment measure as before - only now the quarterly averages of the monthly data. The correlations are based upon the cyclical component of the data only, obtained by logging and subsequently HP-filtering (with \(\lambda = 1600\)) the raw data.

\(^9\)As the cross-correlogram uses all available data (not just data around recessions), we picked a break point somewhere between the 1982 recovery and the 1991 jobless one. In particular, we chose 1984Q1 as this is the estimated starting date of the so-called ‘Great Moderation’ (cf. McConnell...
This figure indeed suggests that employment responds with a greater lag to GDP since 1984Q1: while employment before 1984Q1 correlates mostly with GDP one quarter ago, the peak correlation occurs at two quarters in the post-1984Q1 sample. More markedly, the persistence in the employment-lagged GDP correlation is also much stronger since 1984. Following the RBC-literature in assuming that movements in GDP (henceforth referred to as "the business cycle") are driven by technology shocks, the evidence in Figure 3 also implies that employment responds with a greater lag to technology shocks since the 1980s.\textsuperscript{10,11}

Repeating the analysis using data on total hours worked produces a picture that looks roughly the same:

\textsuperscript{10}Stiroh (2009) gives some support for this hypothesis; he reports that the correlation between hours worked and technology shocks has indeed gone down since the mid-1980s. This issue is however greatly complicated by the fact that technology shocks are difficult to measure in reality, for example due to factor hoarding.

\textsuperscript{11}Note that our assumption that the business cycle is primarily driven by technology shocks is heavily debated since Galí’s (1999) contribution (see Galí and Rabanal (2005) for an overview of this debate). As we will argue in the conclusion, this assumption is however not essential for our story to hold.
2.2.2 Frequency domain evidence

The lead-lag relationship between output and employment can also be analyzed in the frequency domain.\textsuperscript{12} This may be the more natural thing to do as we are focusing at the cyclical properties of the data and enables us to capture the lead-lag relationship at each frequency in a single number, called the phase statistic. In addition, the phase statistic also allows us to distinguish explicitly between for- and backward phase shifts. After all, the evidence presented in the previous section is somewhat open to interpretation as the cross-correlograms displayed in Figures 3 and 4 also show an increased correlation between employment and led GDP.

As is well-known, the spectrum of a time series $x_t$ at frequency $\omega$, $S_{xx}(\omega)$, is defined as the Fourier-transform on the autocovariances $\gamma_{xx,j}$ of the series (where $j$ indicates the lag), divided by $2\pi$. That is:

$$S_{xx}(\omega) = \frac{1}{2\pi} \sum_{j=-\infty}^{\infty} \gamma_{xx,j} e^{-ij\omega},$$

where $i$ is the imaginary number $\sqrt{-1}$.

Analogously, we can also calculate the cross-spectrum between two time-series $x_t$ and $y_t$. It equals the Fourier-transform on the cross-covariances $\gamma_{xy,j}$ of the two

\textsuperscript{12}See Granger and Hatanaka (1964) and Koopmans (1974), upon which this section heavily draws, for comprehensive textbook treatments of (cross-)spectral analysis.
series divided by $2\pi$:

$$S_{xy}(\omega) = \frac{1}{2\pi} \sum_{j=-\infty}^{\infty} \gamma_{xy,j} e^{-i\omega j}$$

The cross-spectrum can be decomposed into a real part (the co-spectrum, $c_{xy}(\omega)$) and an imaginary part (the quadrature spectrum, $q_{xy}(\omega)$):

$$S_{xy}(\omega) = c_{xy}(\omega) + iq_{xy}(\omega)$$

Twice the co-spectral density equals the covariance between the components that are in phase at frequency $\omega$, while the twice the quadrature spectral density gives the covariance between the components that are in quadrature (i.e. a quarter of the cycle out-of-phase in either direction) at that frequency.

From this decomposition we can calculate the phase statistic as:

$$\varphi_{xy}(\omega) = \arctan \left( \frac{q_{xy}(\omega)}{c_{xy}(\omega)} \right)$$

This statistic gives us the lead of $y$ over $x$ at frequency $\omega$. It is expressed as a fraction of the cycle.

Applying this to the HP-filtered series for output and employment yields the following graph.\(^{13}\)\(^{14}\)

\(^{13}\)As the HP-filter is a symmetric two-sided filter it does not induce a phase shift (Baxter and King, 1999). HP-filtering thus does not distort the data along the dimension we are interested in.

\(^{14}\)The phase statistics were calculated by using the Tukey-Hamming smoothing algorithm. The window span was set equal to a standard value of approximately 15% of the number of data points. This implies the span length equals 21 for the pre-1984 sample and 15 for the post-1984 sample.
To interpret the graph it should be noted that a positive value of the phase statistic implies that output leads employment at that frequency; a negative value implies the opposite. As can be seen from the figure, output leads employment over most frequencies. Furthermore observe that the phase lead of output over employment went up over all frequencies since 1984 (except for the very low ones). Following the evidence from the time domain, this thus suggests that the lag with which employment responds to output fluctuations went up in the mid-80s. In particular, the average phase statistic over all frequencies roughly doubled: it went up from an average value of 0.17 for the pre-1984 period, to a value of 0.32 for the period after 1984.

Figure 6 shows the same graph for output and total hours worked.
This figure shows essentially the same picture as Figure 5, which only looked at the extensive margin. However, the increase in the average phase statistic based upon the total number of hours worked is even more dramatic: it goes up from an average value 0.02 for the pre-1984 sample (indicating that output and employment moved almost contemporaneously over this period), to 0.44 over the post-1984 period.

2.3 Summing up

In this section we have presented evidence that the labor adjustment lag went up somewhere in between the 1982 recovery and the one starting in 1991. The lag is present at the extensive margin and robust to including the intensive margin. We therefore conclude that the increase in this lag is not the result of an increased reliance of employers to adjust their labor input on the hours margin. This confirms the finding of several other studies, namely that the intensive margin is relatively unimportant for changing labor input in the US. This is probably due to the fact that the US already have a high share of full-time workers as a result of which it

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15Note that we do not employ any formal significance tests. Engemann and Owyang (2008) however report that the behavior of employment over the last two recessions has indeed been statistically different from its behavior over the previous ones. In particular, they conclude that "employment growth now lags the output trough by an extended period" (p. 16).

16See for example Gertler, Sala and Trigari (2008) who estimated a Frisch-elasticity of zero for the intensive margin.
is difficult and costly to increase their work week.\footnote{The Fair Labor Standards Act requires that workers covered by the act receive at least 1.5 times their regular hourly wage for all hours worked in excess of a 40 hours work week.} Consequently, we will abstract from the hours-margin and focus at the extensive margin instead in the remainder of the paper.

3 Related literature

So far, the literature has come up with several explanations for lagged labor adjustment, most of them particularly focusing at jobless recoveries. First of all, some have pointed at the role played by structural change (\textit{cf.} Groshen and Potter, 2003). They argue that the changing economic environment over the last decades has forced fired workers to undergo time consuming career changes, resulting in jobless recoveries. The problem with their explanation is however that sectoral reallocation has actually \textit{declined} over the last two recessions compared to all previous ones (Aaronson, Rissman and Sullivan, 2004), as a result of which this theory predicts the exact opposite of what has been observed in practice. In addition, this explanation cannot explain the simultaneous occurrence of job preserving recessions depicted in Figure 1.

Second, Andolfatto and MacDonald (2004) attribute jobless growth to the fact that a new technology impacts different sectors of the economy unevenly and is slow to diffuse. However, as there is no evidence that the impact of innovations suddenly changed somewhere between the last "job driven" recovery in 1982 and the first jobless-one in 1991, their model cannot explain why there was no jobless growth before the 1991-recession.

Bachmann (2009) has constructed a DSGE-model in which employers can generate a jobless recovery by adjusting their labor input along the intensive (rather than on the extensive) margin. Although plausible, this effect does not seem to have played a role in the recent two jobless recoveries as they do not show an increase in the total number of hours worked either (see the evidence in Figure 2).

Finally, Koenders and Rogerson (2005) relate the occurrence of jobless growth to organizational issues within firms. They start from the observation that the two most recent recessions are special in that they both followed upon unusually long expansions. Assuming that organizational inefficiencies accumulate during these expansions, Koenders and Rogerson (2005) argue that the two most recent recessions were used by firms to eliminate the accumulated inefficiencies by reducing their levels of employment. But because reorganizations had been postponed for so long, the length of the last two recessions was not sufficient to remove all inefficiencies - thereby
leading to jobless growth. The problem with this explanation however is that it also predicts that the last two recessions should have been accompanied by relatively large reductions in levels of employment (see Koenders and Rogerson (2005), Figure 1). However, a quick glance at our Figure 1 shows that the exact opposite is the case.

To overcome the difficulties with existing theories, we construct a model based upon imperfect information to explain the stylized facts. The key of our story is that there exists an option value to waiting for employers when labor adjustment is costly and when employers are uncertain about the persistence of shocks. This gives rise to a labor adjustment lag, that materializes in the form of jobless recoveries and job preserving recessions as the data suggest.

We view our explanation as complementary to the one offered by Van Rens (2004). As Koenders and Rogerson (2005), he also stresses the importance of organizational issues within firms, but assumes that reorganization requires the input of labor rather than the shedding of labor as in Koenders and Rogerson (2005). In Van Rens (2004), production requires the input of both productive activities (say working on the assembly line) as well as organizational ones (cleaning up the factory hall). By allowing firms to relocate workers from organizational tasks to productive activities, Van Rens adds an extra margin along which firms can temporarily increase production at the beginning of a recovery without hiring extra workers. In his model, the postponement of labor adjustment is optimal as firms want to minimize the net present value of labor adjustment costs. However, after a while, the depletion of the stock of organizational capital starts to harm production (the factory hall has become a mess) as a result of which labor is shifted back to organizational activities and additional hiring is necessary after all. Different from our explanation, his does not include the option value of waiting and even holds in a completely deterministic setting.

A contribution conceptually related to the current one is Bentolila and Bertola (1990). In a stochastic continuous-time setting they also note the existence of the option value of waiting for an employer in the presence of labor adjustment costs: in their model, hiring implies that a firm gives up the call option to delay the hiring decision, while it acquires the put option to fire the new employee in the future. In that setting, they show that labor adjustment costs lower the volatility of the level of employment - a result that is contained by our model (see Section 6). Contrary to the current paper, Bentolila and Bertola (1990) however do not touch upon the role played by imperfect information as a result of which they do not establish the link with lagged labor adjustment.
4 Model

As in Van Wijnbergen (1985, who applies the idea of the option value of waiting to trade reform issues), we analyze the problem in a simple two period setting. The structure of the model is as follows: the model is populated by a large pool of potential employees (sufficiently large to prevent the stock of employees from becoming a binding constraint) along with a continuum of small firms (each too small to affect prices in the economy). Consequently, the wage rate is determined exogenously.\textsuperscript{18} At the beginning of period 1, the economy is hit by a positive productivity shock. In particular, the level of productivity unexpectedly rises from $A_0 = A$ to $A_1 = A + \xi$, where $\xi < A$.\textsuperscript{19} After the occurrence of the shock, each firm gets to set its level of employment $N_1$ with which it enters the production stage. It produces according to the following production function:

$$Y_t = A_t N_t^\alpha$$

Here $\alpha \in (0, 1)$ captures the notion of decreasing returns to labor. For convenience, we abstract from capital accumulation in this short-run analysis. Output is sold at a competitive goods market at a fixed price, normalized to 1.

When the productivity shock $\xi$ materializes in period 1, it is however not immediately clear whether this shock is permanent or transitory. This will only become clear at the beginning of period 2 when $A_2$ materializes. In particular, with exogenous probability $\theta$ (which is known to the rational agents in the model) the shock is fully persistent which implies that $A_2 = A + \xi$. However, there is a probability $(1 - \theta)$ that the shock was purely transitory in which case $A_2 = A$ again. In this way we model the fact that agents are uncertain about the duration of booms and recessions in reality; only by observing next period’s state, they obtain more information about the persistence of a shock. Graphically, the shock structure of the model can then thus be depicted as follows:

\textsuperscript{18}This assumption could easily be relaxed without affecting our results. The only condition that is important is that the uncertainty about the nature of shocks is not fully shifted to the workers via the wage rate, as employers then do not care about it anymore. Nash bargaining, widely used for the determination of wages in labor market theories (see e.g. Pissarides (2000, chapter 1)), for example satisfies this condition.

\textsuperscript{19}Every statement in the paper applies \textit{mutatis mutandis} to negative productivity shocks.
The employer discounts the future at factor $\beta \in [0,1)$. The firm’s objective function then reads:

$$\max_{N_1, N_2} A_1 N_1^\alpha - wN_1 + \beta E_1 \{A_2 N_2^\alpha - wN_2\}$$

From here on, we distinguish between four cases: first, we will consider the benchmark case in which there are no labor adjustment costs and where the employer thus has full flexibility. In this setting, the firm can costlessly reset its employment level at the beginning of period 2, after the nature of the shock has been revealed. Subsequently, we will introduce a role for the informational imperfection by considering the case in which the employer has to commit. In this setting, he must set both his first- and second-period level of employment in period 1 already. Hence, at the time of his decision, he does not know yet whether the shock is persistent or not. Next, we will add labor adjustment costs by considering the limiting case in which the employer looses the opportunity to adjust his labor input at the beginning of the second period. Effectively, this represents a case of infinite labor adjustment costs. Finally, we will also consider the remaining case in which there are infinite labor adjustment costs, but where employers are perfectly able to distinguish persistent shocks from transitory ones.
5 The cases

5.1 Case I: flexibility, no labor adjustment costs

Suppose that there are no labor adjustment costs and that the employer has full flexibility in setting his desired level of employment each period. The employer then sets his period 1 employment level directly after the occurrence of the shock. When doing this, he knows already that he will get the opportunity to reset his employment level costlessly at the beginning of period two, after the nature of the shock has been revealed. Consequently, the informational imperfection is not binding and the employer solves a dynamic programming problem. His period 2 problem then reads:

$$\max_{N_2} A_2 N_2^\alpha - w N_2$$

The first-order condition implies that, conditional upon observing $A_2$:

$$N_2^f (A_2) = \left[ \frac{\alpha A_2}{w} \right] \frac{1}{1-\alpha}$$  \hspace{1cm} (1)

where the superscript $f$ indicates that this is the solution under flexibility.

Given the employer’s optimal response in period 2 in equation (3), his period 1 problem reads:

$$\max_{N_1} (A + \xi) N_1^\alpha - w N_1 + \beta \left[ \theta (A + \xi) \left[ \frac{\alpha (A + \xi)}{w} \right] \frac{1}{1-\alpha} + (1 - \theta) A \left[ \frac{\alpha A}{w} \right] \frac{1}{1-\alpha} \right]$$

$$- \beta \left[ \theta w \left[ \frac{\alpha (A + \xi)}{w} \right] \frac{1}{1-\alpha} + (1 - \theta) w \left[ \frac{\alpha A}{w} \right] \frac{1}{1-\alpha} \right]$$

which leads to the following first-order condition:

$$N_1^f = \left[ \frac{\alpha (A + \xi)}{w} \right] \frac{1}{1-\alpha}$$  \hspace{1cm} (2)

Note that his period 1 hiring decision is independent of $\theta$, the probability that the shock survives into the second period. This is due to the fact that the employer can costlessly reset his employment level after the revelation of the nature of the shock. Consequently, he does not have to take the persistence issue into account in period 1 already.
5.2 Case II: commitment, no labor adjustment costs

We now introduce a role for the informational imperfection by assuming that the employer must set his period 2 level of employment in period 1 already. Consequently, when the employer sets his level of employment for periods 1 and 2, he does not know yet whether the productivity shock $\xi$ is persistent or not.

In this case, his problem reads:

$$\max_{N_1, N_2} [A + \xi] N_1^\alpha - wN_1 + \beta E_1 \{A_2 N_2^\alpha - wN_2\}$$

As $E_1 \{A_2\} = A + \theta \xi$, we can rewrite this problem as:

$$\max_{N_1, N_2} [A + \xi] N_1^\alpha - wN_1 + \beta [(A + \theta \xi) N_2^\alpha - wN_2]$$

The associated first-order conditions imply that the employer chooses to set the following levels of employment in period 1:

$$N_1^c = \left[\frac{\alpha(A + \xi)}{w}\right]^\frac{1}{1-\alpha}$$

$$N_2^c = \left[\frac{\alpha(A + \theta \xi)}{w}\right]^\frac{1}{1-\alpha},$$

where the superscript $c$ refers to the fact that this is the solution under commitment.

5.3 Case III: infinite labor adjustment costs under imperfect information

Now we add labor adjustment costs to the model. In particular, we assume that there only exist two-period employment contracts and that additional hiring at the beginning of period 2 is not possible. Effectively this represents the limiting case of infinite labor adjustment costs over the time period to which the informational imperfection applies (i.e. over periods 1 and 2). The employer is now no longer able to alter his labor input at the beginning of period 2 as a result of which $N_2 = N_1$. His problem then reads:

$$\max_{N_1} (A + \xi) N_1^\alpha - wN_1 + \beta E_1 \{A_2 N_1^\alpha - wN_1\}$$
As $E_1 \{ A_2 \} = A + \theta \xi$, we can rewrite this problem as:

$$\max_{N_1} (A + \xi) N_1^\alpha - (1 + \beta) w N_1 + \beta (A + \theta \xi) N_1^\alpha$$

The associated first-order condition implies that the employer sets his level of employment for both periods according to:

$$N_1^{\infty, im} = N_2^{\infty, im} = \left[ \frac{\alpha [(1 + \beta) A + (1 + \beta \theta) \xi]}{(1 + \beta) w} \right]^{\frac{1}{1-\alpha}}, \quad (5)$$

where the superscript $\infty, im$ refers to the fact that this is the solution under infinite labor adjustment costs and imperfect information. This intuition for this equation should be clear. Do note that first-period hiring is increasing in the probability that the positive productivity shock is persistent, $\theta$: after all, if it is highly likely that next period’s productivity level will be high again, the employer decides to guard himself against this by hiring more employees in period 1 already as he cannot hire additional ones at the beginning of period 2.

### 5.4 Case IV: infinite labor adjustment costs under perfect information

Finally we also consider the remaining possible case, namely the case in which firms do have perfect information but face infinite labor adjustment costs. Here, we have to distinguish between two subcases: one in which employers know that the shock is fully persistent, and one in which employers know that the shock is purely transitory.\(^{20}\)

**Subcase 1: Persistent shock**

In this case the problem reads:

$$\max_{N_1} \ (1 + \beta) (A + \xi) N_1^\alpha - (1 + \beta) w N_1$$

The first-order condition then implies:

$$N_1^{\infty, p} = N_2^{\infty, p} = \left[ \frac{\alpha (A + \xi)}{w} \right]^{\frac{1}{1-\alpha}}, \quad (6)$$

where the superscript $\infty, p$ indicates that this is the level of employment set under infinite labor adjustment costs in response to a fully persistent shock.

\(^{20}\)Note that these cases are effectively already covered under Case III by setting $\theta = 0$ or $\theta = 1$. 

18
By comparing this solution to the first period hiring decision without labor adjustment costs (equations (1) and (3)), one can see that employers in the latter case act as if the shock is fully persistent. This is the case as they do not care about the persistence of the shock: employers know that they will be able to reset their level of employment at the beginning of period 2 without any cost.

**Subcase 2: Transitory shock**

In this case the problem reads:

\[
\max_{N_1} \left[ (1 + \beta)A + \xi \right] N_1^\alpha - (1 + \beta)wN_1
\]

The first-order condition implies that the associated level of employment equals:

\[
N_1^{\infty,t} = N_2^{\infty,t} = \left[ \frac{\alpha \left( (1 + \beta)A + \xi \right)}{(1 + \beta)w} \right]^{\frac{1}{\alpha}},
\]

where the superscript \( \infty,t \) refers to the fact that this is the solution under infinite labor adjustment costs to a purely transitory shock.

Together, equations (6) and (7) show that the employer’s behavior under infinite labor adjustment costs in the presence of imperfect information (represented by equation (5)) is basically a weighted average between the corresponding solutions under perfect information. The particular weight placed on the two cases is the probability that the shock is persistent or not, \( \theta \).

## 6 Results

We are now ready to prove the main results of this paper.

**Proposition 1 (Option value of waiting)** *In the presence of informational imperfections (i.e. as long as \( \theta \in (0,1) \)), there exists a positive option value to having the opportunity to await the nature of the productivity shock.*

**Proof.** The pure option value of waiting can be obtained by subtracting the expected value under commitment from the expected value under flexibility. The expected value for the employer under flexibility reads:

\[
V(N^f) = (1 + \beta \theta)(A + \xi) \left[ \frac{\alpha (A + \xi)}{w} \right]^{\frac{\alpha}{1-\alpha}} - (1 + \beta \theta)w \left[ \frac{\alpha (A + \xi)}{w} \right]^{\frac{1}{1-\alpha}}
\]

\[
+ \beta(1-\theta) \left[ A \left[ \frac{\alpha A}{w} \right]^{\frac{\alpha}{1-\alpha}} - w \left[ \frac{\alpha A}{w} \right]^{\frac{1}{1-\alpha}} \right]
\]

(8)
Similarly, the expected value for the employer under commitment reads:

\[ V(N^c) = (A + \xi) \left[ \frac{\alpha(A + \xi)}{w} \right]^{\frac{\alpha}{1-\alpha}} - w \left[ \frac{\alpha(A + \xi)}{w} \right]^{\frac{1}{1-\alpha}} \]

\[ + \beta \left[ (A + \theta\xi) \left[ \frac{\alpha(A + \theta\xi)}{w} \right]^{\frac{\alpha}{1-\alpha}} - w \left[ \frac{\alpha(A + \theta\xi)}{w} \right]^{\frac{1}{1-\alpha}} \right] \]  \hspace{1cm} (9)

Subtracting (9) from (8) results in the following expression, representing the option value of waiting:

\[ \Omega \equiv V(N^f) - V(N^c) \]

\[ = (1 + \beta\theta) (A + \xi) \left[ \frac{\alpha(A + \xi)}{w} \right]^{\frac{\alpha}{1-\alpha}} - (1 + \beta\theta) w \left[ \frac{\alpha(A + \xi)}{w} \right]^{\frac{1}{1-\alpha}} \]

\[ + \beta (1 - \theta) \left[ A \left( \frac{\alpha A}{w} \right)^{\frac{\alpha}{1-\alpha}} - w \left( \frac{\alpha A}{w} \right)^{\frac{1}{1-\alpha}} \right] \]

\[ - (A + \xi) \left[ \frac{\alpha(A + \xi)}{w} \right]^{\frac{\alpha}{1-\alpha}} + w \left[ \frac{\alpha(A + \xi)}{w} \right]^{\frac{1}{1-\alpha}} \]

\[ - \beta \left[ (A + \theta\xi) \left[ \frac{\alpha(A + \theta\xi)}{w} \right]^{\frac{\alpha}{1-\alpha}} - w \left[ \frac{\alpha(A + \theta\xi)}{w} \right]^{\frac{1}{1-\alpha}} \right] \]

The equation for the option value has its roots at \( \theta = 0 \) and \( \theta = 1 \) (which is intuitive as there is no uncertainty at the endpoints). As the second derivative of \( \Omega \) with respect to \( \theta \) is negative due to the concavity of the production function (\( \alpha < 1 \)), the option value is strictly positive over the domain \( \theta \in (0, 1) \) by Rolle’s theorem.

The option value reaches its maximum for the value of \( \theta \) at which the variance of the underlying process reaches its maximum. Since we assumed a Bernoulli distribution, which has variance \( \theta (1 - \theta) \), the option value reaches its maximum at \( \theta = \frac{1}{2} \); at that value the uncertainty about the persistence of the shock reaches its maximum, and so does therefore the value of being able to wait.

Figure 8 shows the option value for different values of \( \theta \) and \( \alpha \). Note that the option value also increases in \( \alpha \) since a higher \( \alpha \) implies higher marginal costs of labor and therefore a higher cost of just guessing wrong.
**Proposition 2 (Labor adjustment lag)** The combination of informational imperfections with labor adjustment costs leads to a lagged response of labor input to productivity shocks.

**Proof.** Compare the firm's first-period hiring decision under infinite labor adjustment costs and imperfect information (equation (5)), with the firm's first-period hiring decision under perfect information, without labor adjustment costs (equation (2)). As \( \theta < 1 \Rightarrow N_1^{\infty,im} < N_1^f \) in case of a positive productivity shock. Equivalently, in the converse case of a negative productivity shock \( \theta < 1 \) ensures that \( N_1^{\infty,im} > N_1^f \). However, as soon as it becomes clear that the shock is fully persistent, we are in Case IV and end up at the fully flexible solution (compare equations (1) and (6)). Repeating this result (i.e. pasting it behind itself iteratively to mimic an infinite horizon setting) shows that the cycle for labor input lags the technology shock cycle. ■

Figure 9 illustrates the proof graphically. In the figure, a dashed line indicates the time period during which the nature of the shock is not known yet. (Hence, the first positive productivity shock occurs at time \( t = 1 \), but the fact that the shock is permanent only becomes clear at \( t = 2 \).) As can be seen from the figure, the model equations imply that labor input does not adjust immediately to the optimal level as long as the nature of the shock is unknown (see points 1, 3 and 5 - consistent with equation (5)). However, as soon as the nature of the shock is revealed, labor input is set at its optimal level (points 2 and 4 - consistent with equation (6)).

---

Figure 8: Option value of waiting for the employer in the \((\alpha, \theta)\)-space
Figure 9: lagged labor input response under imperfect information and labor adjustment costs

Note by comparing equations (2) and (3) that the period 1 solution under commitment is equal to the solution under full flexibility. Hence, the informational imperfection alone is not enough to generate a labor adjustment lag: for that it needs to be combined with labor adjustment costs. The informational imperfection alone only affects the period 2 decision, to which it applies. The period 1 decision remains unaffected as it can costlessly be undone in the absence of labor adjustment costs. Consequently employers can freely respond to the first-period productivity shock, without worrying about its persistence. When there are labor adjustment costs, employers do not want to respond to temporary movements as it is costly for them to reverse their actions in the next period - when they know that things are as before again.

Equivalently, equations (6) and (7) show that labor adjustment costs alone aren’t sufficient to generate lagged labor adjustment either. In that case, firms either increase employment all the way when they realize that a shock is persistent or, if they know that the shock is only temporary, they set their level of employment somewhere in between the level of employment chosen absent any shocks and the employment level they would have picked after a persistent shock. This shows that labor adjustment costs alone only lead to a muted labor input response following shocks that do not have a unit root. This result is consistent with the theoretical result obtained in Bentolila and Bertola (1990) and the empirical evidence presented in Bertola (1990).

It is thus the combination of informational imperfections and labor adjustment costs that ensures that labor input lags the cycle. Unfortunately, only the perfect
information environment is studied in most labor market models (such as the search-and matching model, described in for example Pissarides (2000)), as a result of which both the option value of waiting and the labor adjustment lag in the labor market are basically neglected in current analyses.

7 Why has the labor adjustment lag increased?

Now that we have pointed at the existence of the labor adjustment lag and investigated its potential causes, the key question is: why has the lag with which labor input is adjusted increased since the 1980s?

As shown in the previous section, a labor adjustment lag basically results from two ingredients: labor adjustment costs and imperfect information on the persistence of shocks. Therefore, to answer the question why the lag went up in the 1980s, it is natural to look for changes in these two ingredients that occurred around that time. In this section, we consider both of them in turn.

7.1 Labor adjustment costs

The most obvious candidates in the labor adjustment costs-category are the direct hiring and firing costs or restrictions that firms incur when adjusting their labor force. As surveyed by the OECD (1999, Table 2.1), there has been only one major change in the US in this respect over the relevant time period. It became effective in 1989 - so during the boom in which the labor adjustment lag lengthened. In that year, the Worker Adjustment and Reassignment Notification Act was installed. This act requires firms with more than 100 workers affected by plant closures or mass layoffs to give a 60 days’ notice to employees concerned. Although it is unlikely that this act alone is responsible for the increase in the lag with which labor adjustments are made (especially since there have probably also been developments working in the opposite way), it is something that works in the observed direction and hence could have contributed to it.

A more subtle notion of labor adjustment costs may however also play a role here. Over the years, the knowledge intensive service sector has become of greater total relevance for the US economy. Consequently, the - what we will refer to as - implicit labor adjustment costs (i.e. a firm’s intrinsic reluctance to fire workers) may have gone up: after all, in a knowledge intensive industry, firms have invested in the

\[21\] The development of the internet is for example something that is likely to have eased the hiring of new workers for employers.
accumulation of firm specific human capital of their employees, which would be lost if the employee is fired. This provides another incentive for firms to hold on to their employees during downturns, next to explicit hiring and firing costs.

Two observations from Figure 10, which displays the separation and job finding probabilities in the US over time, provide some support for the idea that the process of labor adjustment has changed over the years. First, the separation probability shows a clear downward trend since the early 80s. Second, the separation rate has essentially been acyclical during the last two recessions (Hall, 2005; Shimer, 2005). Where all pre-1990 recessions were accompanied by an upward spike in the separation rate, this is no longer the case for the two post-1990 recessions. Instead, during these recessions the increase in unemployment was mainly brought about by a decrease in the job finding rate. In addition, Faberman (2008) reports that US labor adjustments occur much slower and smoother since 1984, which is consistent with what one would expect if either explicit or implicit labor adjustment costs went up.

Together, these observations suggest an increased reluctance of firms to quickly adjust their labor force since the 1980s and deserve further attention in future research.

Figure 10: separation and job finding probabilities (data are from Shimer (2005)). Shaded areas correspond with the NBER recession dates.
7.2 Clarity of information

Another reason why the labor adjustment lag could have increased, is by an increase in the uncertainty about the persistence of shocks. In the language of our two-period model: as the variance of next period’s expected productivity level is maximized for \( \theta = \frac{1}{2} \) (when all shocks occurring are equally likely to persistent or transitory through the eyes of the agents), so is the option value of awaiting the nature of the shock, as a result of which it becomes more attractive for employers to postpone decisions with some element of irreversibility in it.

There is indeed evidence that this type of uncertainty, which has to be distinguished from volatility, has increased since the 1980s:\(^{22}\) Campbell (2007) notes, by looking at the Survey of Professional Forecasters (SPF), that macroeconomic predictability has declined significantly since 1984. Similar findings are reported by Schuh (2001, who also uses the SPF), D’Agostino, Giannone and Surico (2006, who look at both the SPF and the Federal Reserve’s Greenbook) and Tulip (2005, who uses forecasts from the Greenbook). The latter notes that "the predictable component of output growth has virtually disappeared. Although output was highly variable in the 1970s and early 1980s, most of this variation was predicted. In contrast, variations since the late 1980s have been surprises" (Tulip, 2005: p. 12). Campbell (2007: p. 199) on his turn reports that "the information content of current conditions has (...) declined" since 1984, which is consistent with an increase in the confusion about the persistence of shocks.\(^{23}\)

But has this increased uncertainty really had an impact on agents in the economy? Well, in any case it seems to have played a complicating role for the highly respected economists on the NBER Business Cycle Dating Committee: where the pre-1990 peaks and troughs were announced with an average lag of 7.5 months, it took about twice as long before the committee was certain that a recession had started or ended in the post-1990 period: since then, the announcement lag equals 14.8 months on average.\(^{24}\) In this light it seems reasonable to assume that "ordinary" agents, who monitor the economic situation less carefully and probably rely substantially on the information provided by the NBER, are more uncertain about the current state and direction of the US economy as well. The finding by Kim and Nelson (1999; that

---

\(^{22}\)A variable can be highly volatile, but perfectly predictable. Consider for example the seasonal fluctuations in output that account for about 85 percent of total output variability, but which are almost perfectly predictable (Beaulieu and Miron, 1992).

\(^{23}\)A similar development seems to have been going on with respect to inflation. Atkeson and Ohanian (2001), Fisher, Liu and Zhou (2002) and Orphanides and Van Norden (2005) all find that the predictability of inflation has gone down since 1984.

\(^{24}\)See the announcement dates on http://www.nber.org/cycles.html.
the gap between growth rates during booms and recessions has narrowed since 1984, thereby making these phases harder to distinguish from each other) corresponds with this idea.

To sum all evidence up, it seems that shocks are surrounded by noisier signals on their persistence since the 1980s - potentially just as a result of "bad luck". In the language of our two-period model this implies that $\theta$ has moved towards $\frac{1}{2}$. Consequently, the option value of waiting increased and employers simply have to wait longer before they can make well-informed decisions. This may explain why D’Agostino, Giannone and Surico (2006) find that the decline in overall predictability does not seem to extend to the labor market. There, the presence of the option value of waiting may have induced employers to "absorb" the increased uncertainty through their inaction region.

8 Is the labor adjustment lag the answer to some macroeconomic puzzles?

As will be argued below, theory predicts that an increase in the lag with which labor input is adjusted should have substantial implications for certain macroeconomic variables, such as labor productivity and the volatility of output. In this section we will describe the theoretical predictions with respect to these variables and show that these predictions are consistent with the puzzling behavior that these variables have displayed in reality since the 1980s.

8.1 The Great Moderation

It is well-known that the volatility of several macroeconomic variables (in particular that of output) has reduced significantly since the 1980s. This stylized fact is generally referred to as "the Great Moderation". The fact that the timing of the Great Moderation (often estimated to lie somewhere around 1984; cf. McConnell and Perez-Quiros (2000)) roughly coincides with the introduction of the labor adjustment lag (which must lie somewhere between the 1982 recession and the 1990/1 one), suggests that the two observations may be related. One explanation would be as follows.

Before the 1990/1 recession, a persistent positive productivity shock would increase output (assumed to be produced according to $y_t = \exp(z_t)k_t^{\alpha}h_t^{1-\alpha}$) for two distinct reasons: first, directly because technology $z_t$ went up, and second because labor input $h_t$ would soon follow. After all, until the 1990/1 recession, technology
and labor input were roughly in phase and basically moved hand in hand with each other. However, since the 1990/1 recession, labor input responds with a greater lag to the business cycle (assumed to be driven by technology shocks) as a result of which the data show a decrease in the contemporaneous correlation between productivity shocks and labor input (Stiroh, 2009). Consequently, when a productivity shock hits, output shows a much more muted response: initially output only increases directly through the increase in $z_t$. And only after a while (when it has become clear that the shock indeed is persistent) output goes up because of additional hiring. So as a result of the increase in the labor adjustment lag, the cycles for technology and employment are no longer in phase with each other. Consequently, the cycles of the two production inputs amplify each other less than they did before. This suggests that the business cycle should have become more muted but more persistent since the 1980s. And, as noted in Stock and Watson (2005), this is exactly what we have observed in reality.

We test our hypothesis that the labor adjustment lag may have contributed to the Great Moderation in a DSGE-setting via the following experiment. Consider a standard RBC-model (closely following King and Rebelo (2000)), where the representative household faces the following optimization problem:

$$\max_{\{c_t, h_t, k_{t+1}\}} \sum_{t=0}^{\infty} \beta^t \left[ \frac{c_t^{1-\nu} - 1}{1-\nu} + \frac{\vartheta}{1-\eta} [(1 - h_t)^{1-\eta} - 1] \right]$$

s.t. $y_t = \exp(z_t) k_t^{\alpha} h_t^{1-\alpha}$

- $k_{t+1} = (1 - \delta) k_t + i_t$
- $y_t = c_t + i_t$
- $z_{t+1} = \rho z_t + \varepsilon_{t+1}$, $\varepsilon_t \sim \mathcal{N}(0, \sigma^2)$

The associated first-order conditions read:

1. $\partial c_t \ : \ c_t^{1-\nu} = \lambda_t$ \hspace{1cm} (10)
2. $\partial h_t \ : \ \vartheta (1 - h_t)^{1-\eta} = (1 - \alpha) \lambda_t \exp(z_t) k_t^{\alpha} h_t^{1-\alpha}$ \hspace{1cm} (11)
3. $\partial k_{t+1} \ : \ \lambda_t = \beta E_t \left\{ \lambda_{t+1} \left[ \alpha \exp(z_{t+1}) k_{t+1}^{\alpha} h_{t+1}^{1-\alpha} + (1 - \delta) \right] \right\}$ \hspace{1cm} (12)

Here, $\lambda_t$ measures the time $t$ marginal utility of wealth.

---

$^{25}$As emphasized before in Section 2, this debated assumption is not essential for our story. More on this in the conclusion.
The model (in which each period corresponds with one quarter in reality) is calibrated using standard values in the literature (see Table 1). The preference parameter for leisure \( \vartheta \) is set equal to 3.48, to match the fact that US agents spend about 20 percent of their available time on market production. Finally, the standard deviation of the productivity shock (\( \sigma \)) is set such that the standard deviation of the simulated series for output matches its US pre-1984 data equivalent of 0.02 (as reported by Galí and Gambetti (2009)).

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Interpretation</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha )</td>
<td>Output elasticity of capital</td>
<td>0.33</td>
</tr>
<tr>
<td>( \beta )</td>
<td>Quarterly discount rate</td>
<td>0.99</td>
</tr>
<tr>
<td>( \delta )</td>
<td>Quarterly depreciation rate</td>
<td>0.025</td>
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<tr>
<td>( \eta )</td>
<td>Labor supply elasticity</td>
<td>1</td>
</tr>
<tr>
<td>( \vartheta )</td>
<td>Preference for leisure</td>
<td>3.48</td>
</tr>
<tr>
<td>( \nu )</td>
<td>Coefficient of relative risk aversion</td>
<td>1</td>
</tr>
<tr>
<td>( \rho )</td>
<td>AR-coefficient on productivity process</td>
<td>0.95</td>
</tr>
<tr>
<td>( \sigma )</td>
<td>Standard deviation of productivity shock</td>
<td>0.015</td>
</tr>
</tbody>
</table>

Table 1: Calibration

However, as noted by Van Rens (2004), the standard RBC-model fails in not generating lagged labor adjustments. There is almost perfect comovement between employment and the business cycle and the response of employment is largest on impact of the productivity shock: in the standard RBC-model described above, \( \text{corr}(y, h) = 0.9802 \), whereas the pre-1984 data imply a value of 0.8808. In the post-1984 sample this correlation is even lower, equaling 0.8148.

But is a lagged labor input response quantitatively able to explain the reduction in output volatility? To investigate this, we propose the following fix to bring the procyclicality of labor input down to its post-1984 value of 0.8148. We introduce the lag in a very mechanical way by altering the production function so that it only includes lagged labor input. Total output then follows \( y_t = \exp(z_t)k_t^\alpha h_{t-1}^{1-\alpha} \), where \( i \) is the lag-length. As a result, first-order conditions (11) and (12) change into:

\[
\begin{align*}
\partial h_t & : \quad \vartheta (1 - h_t)^{-\eta} = (1 - \alpha) \beta^i \lambda_{t+i} \exp(z_{t+i}) k_{t+i}^\alpha h_t^{-\alpha} \quad \text{(11a)} \\
\partial k_{t+1} & : \quad \lambda_t = \beta E_t \left\{ \lambda_{t+1} \left[ \alpha \exp(z_{t+1}) k_{t+1}^{\alpha-1} h_{t+1}^{1-\alpha} + (1 - \delta) \right] \right\} \quad \text{(12a)}
\end{align*}
\]

The implications for the standard deviation of output are shown in Figure 11.
Figure 11: standard deviation of output as function of the labor adjustment lag

As the figure shows, a labor adjustment lag indeed reduces output volatility. More importantly, when the model’s correlation between output and labor input approximately matches its post-1984 data equivalent at \( i = 8 \), the model’s standard deviation of output roughly matches its post-1984 data equivalent as well (equal to 0.0094 (Galí and Gambetti, 2009) and indicated by the dashed line in Figure 11).

However, a lag of eight quarters seems implausibly long. This therefore asks for a more realistic and structural model that generates a lagged labor input response. As shown in Andolfatto (1996, Table 1) introducing labor market matching frictions à la Pissarides (2000) does not solve the problem for a standard RBC-model: in that case, the contemporaneous correlation between output and total hours worked still equals 0.96. One possibility to fix this problem would be to build a DSGE-model featuring labor adjustment costs along with permanent and transitory shocks.\(^{26}\) When agents are only able to distinguish between the two types of shocks by solving a signal extraction problem via collecting more information over time, we suspect (based upon our analytical results in Section 6 of this paper) that a labor adjustment lag will result. We leave this for future work.

Relating our finding that the labor adjustment lag has the potential to explain the Great Moderation to our discussion in Section 7 suggests two novel hypothesis on the sources of the Great Moderation. First, it may be a result of higher (implicit) labor adjustment costs since the 1980s due to for example the increased importance of high-skilled labor. Note that part of this hypothesis can be tested cross-sectionally.

\(^{26}\)Essentially, this is an infinite horizon version of our model in Section 4.
as it implies that countries with higher labor adjustment costs should display lower output volatility. And as reported by Merkl and Schmitz (2009), this is indeed the case. The question whether (implicit) labor adjustment in the US really went up in the 1980s however remains.

Second, and contrasting with the "good luck hypothesis" advocated by among others Stock and Watson (2005), our results point toward the possibility of a "bad luck hypothesis": potentially because of bad luck, shocks have been surrounded by more noise about their persistence since the mid-80s, as a result of which a given shock has induced smaller contemporaneous fluctuations in factor inputs - and hence output - since. Note that our hypothesis conditions on the size of the shocks. Conditional on that, it does imply that a given persistent shock leads to greater macroeconomic fluctuations if the fact that the shock is persistent, is realized upon impact.

Hereby, we take an intermediate stand in the debate regarding the question whether the Great Moderation is caused by smaller shocks hitting the economy since the 1980s or by weaker propagation of a given shock. In our view the nature of the shocks hitting the economy has changed (from clear to noisy), thereby weakening the propagation of these shocks through the economy. Note that this "bad luck" hypothesis is able to give an explanation for the paradoxical situation that the reduction in macroeconomic volatility seems to have been accompanied by a decrease in predictability: in our hypothesis, the decrease in predictability has actually caused the reduction in macroeconomic volatility! This also suggests that the Great Moderation has been accompanied by a reduction in macroeconomic efficiency, as agents have not been able to respond efficiently to shocks on impact due to a lack of clear information.

8.2 The cyclicality and volatility of labor productivity

Besides the volatility of output, the volatility and cyclicality of US labor productivity have also shown puzzling behavior since the mid-1980s (cf. Galí and Gambetti

\footnote{Proponents of the "good luck hypothesis" argue that the Great Moderation is simply a result of good luck in that the economy was not hit by any major shocks over the moderation period.}

\footnote{A similar hypothesis is developed in independent work by Bullard and Singh (2009), who explain the Great Moderation via a learning mechanism. They argue that "regimes (recessions and expansions) which are closer together pose a more difficult inference problem for agents. The agents then take actions which are not as extreme as they would be under complete information. The result is a moderating force in the economy" (p.16, part in italics added).}

\footnote{Stock and Watson (2002) argue the former, while Giannone, Lenza and Reichlin (2008) favor the latter explanation.}
In particular, these studies report that both the volatility and cyclicality of labor productivity went down since 1984. As labor productivity is nothing more than an accounting identity (by definition it equals total output divided by labor input), simple arithmetic implies that an increase in the lag between output and labor input should have significant implications for its behavior. This can be shown most easily by conducting a simple sine-experiment, similar to the one in Wen (2004). First, assume that the cyclical component of the employment series follows:

\[ n_t = \sin(\omega t) \]

Similarly, the cyclical component of output is assumed to be generated by:

\[ y_t = \mu \sin(\omega t + \phi) \]

Here, the parameter \( \mu \) allows us to capture the empirical fact that output is slightly more volatile than employment, while setting \( \phi = 0 \) results in a labor input lag.

Now consider Figure 12, which is generated by setting \( \omega = 0.2 \) and \( \phi = 0 \) such that output and labor input are in phase with each other, which approximates the situation before the 1990/1 recession. We set \( \mu \) equal to 1.2 such that the standard deviation of employment relative to that of output roughly matches its empirical counterpart of 0.85.

![Figure 12: Cyclicality without labor adjustment lag](image)

Next to the series for output and employment, Figure 8 also shows the implied behavior of labor productivity \( p \equiv y - n \). As can be seen from the figure, labor productivity is perfectly procyclical, i.e. \( corr(y, p) = 1 \).
Next, we approximate the situation after 1984 by introducing a labor input lag by setting $\phi > 0$, say equal to 0.5. As can be seen from Figure 13, this simple experiment predicts that the introduction of the lag has important implications for the behavior of labor productivity: in particular, the cyclicality of labor productivity goes down (in this case $corr(y, p) = 0.58$), while the volatility of labor productivity relative to that of output goes up.

![Figure 13: Cyclicality with labor adjustment lag](image)

These predictions correspond very well with the empirical evidence presented Galí and Van Rens (2009). They report that the correlation between output and labor productivity went down from its pre-1984 level of 0.87 to a significantly lower post-1984 level of 0.72. We can match this decline exactly by setting $\phi = 0.115$ to approximate the situation before 1984 and picking $\phi = 0.22$ to capture the situation after. Broadly in line with the evidence presented in Section 2, this also suggests that the labor input lag doubled between the 1982 recession and the 1990/1 one.

Finally, the data also show an increase in the standard deviation of labor productivity relative to that of output, as predicted by our experiment: according to Galí and Gambetti (2009), this value went up from a pre-1984 level of 0.45 to a value of 0.55 in the post-1984 period.

9 Conclusion

In this paper, we have presented evidence that the lag with which labor input reacts to output fluctuations went up in the 1980s, thereby bringing jobless recoveries and
recessions that were relatively job preserving to the US economy. We have shown that this lagged response is optimal in a setting where labor input is costly to adjust and where employers are uncertain about the persistence of shocks that drive the business cycle.

To explain the increase in this lag, we have therefore looked for changes in the adjustment process of labor input and macroeconomic predictability since the mid-1980s. And in both cases these changes seem to be there. Since the early 1980s, the separation rate has shown a downward trend and has basically turned acyclical, which could be explained by an increased reluctance of firms to fire workers as a result of higher (implicit) labor adjustment costs. Over the same period, macroeconomic predictability has shown a remarkable decline, suggesting that the clarity of information about the persistence of shocks has gone down.

We finally show that the labor adjustment lag has the potential to explain two macroeconomic puzzles that characterize US data since the mid-1980s. It is for example able to explain the reduction in the procyclicality of labor productivity that has kicked in over this period. Regarding the simultaneous reduction in output volatility (referred to as "the Great Moderation"), we show that this could be explained by the fact that agents have become slower in adjusting their labor input in response to shocks. Consequently, the exogenous shock-part and the endogenous factor input-part of the production function are no longer in phase with each other, as a result of which they amplify each other less than they did before, leading to smaller fluctuations in output. Note in this respect that the analysis employed in this paper similarly applies to capital investments, as they also contain some element of irreversibility. Therefore, it would be interesting to investigate whether capital investment also responds with a longer lag to shocks since the mid-1980s. If so, then this would add to the moderating effect already exercised by the lagged response of labor input. Here, one runs however into the problem that capital is hard to measure in practice.

As emphasized several times before, we have followed the RBC-literature throughout the paper in assuming that business cycles are driven by technology shocks and that labor input rises in response to a positive technology shock. But both of these assumptions are challenged by Galí (1999) and are still the subject of a lively debate (see Galí and Rabanal (2005) for an overview). They are however not essential for our story. What is essential, is that agents in the economy are uncertain about the persistence of shocks that drive the business cycle. Whether they occur at the supply or demand side is not important. Only the interpretation would be slightly different: in a demand shock driven model, our theory would be one of labor hoarding and we leave this for future work.
Finally, this paper also points at several directions for future research. For example, has the reluctance to fire workers really gone up in the US since the 1980s, as suggested by the circumstantial evidence presented in Section 7.1? And why has macroeconomic predictability come down since the mid-1980s? Is this just a result of bad luck or is there for example a link with the change in the conduct of monetary policy since the Volcker-period? And will predictability remain low in the future or will it increase again?

Hopefully, we will be able to answer these questions in future research.

10 Literature


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