Why Have the Dynamics of Labor Productivity Changed?

By Willem Van Zandweghe

The strength of the nascent economic recovery—and of the labor market—will depend importantly on labor productivity. By itself, faster productivity growth contributes to faster output growth. At the same time, stronger productivity gains allow firms to increase output without adding workers. Some analysts believe that faster productivity growth contributed to the "jobless recoveries" after the 1990-91 and 2001 recessions.

In recent years, the U.S. economy has undergone a change in the behavior of productivity over the business cycle. Until the mid-1980s, productivity growth rose and fell with output growth. But since then the relationship between these two variables has weakened, and they have even moved in different directions. For example, from the fourth quarter of 2007 to the second quarter of 2009, output in the nonfarm business sector fell at an average annual rate of 4.3 percent, while labor productivity grew 1.7 percent on average. Understanding the causes of this changed relationship is essential to gauging the outlook for productivity, jobs, and output in the current recovery.

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Fluctuations in productivity depend on two factors: the mix of shocks that drive the business cycle and the transmission of those shocks to output and labor market activity. Thus, two hypotheses stand out as plausible explanations for the change in the cyclical behavior of productivity.

First, a decline in the importance of supply shocks for the business cycle may have changed the relationship of productivity and output over the business cycle. Supply shocks are a driving force of output. For instance, an oil price increase raises the cost of production and leads firms to reduce the amount of output produced. Such shocks steer both output and productivity (output per hour) in the same direction. Consequently, if the importance of supply shocks for the business cycle diminished, the relationship between these variables would be weakened.

Second, structural changes in the labor market may have altered the transmission of shocks to the labor market and production. Specifically, a different labor market environment may have prompted firms to modify the way they meet their labor needs in response to shocks to the economy. For instance, diminished labor adjustment costs, such as hiring and firing costs, or increased uncertainty about future demand at the firm level may stimulate firms to adjust labor inputs more aggressively.

This article examines the shift in the behavior of labor productivity over the business cycle and assesses the supply shock and structural change explanations for the shift. The analysis finds that the importance of supply shocks in the business cycle has been stable over time. However, the behavior of productivity over the business cycle has shifted in response to both supply and demand shocks. Together, these results imply the shift in the business cycle behavior of productivity is most likely the result of structural changes in the labor market.[1]

The first section documents the shift in the cyclical behavior of productivity that occurred in the mid-1980s. The second section examines whether this shift can be explained by a diminished role of supply shocks in the business cycle. The third section evaluates whether the shift can be explained by structural changes in the labor market. The fourth section discusses the implications of the shift in cyclical productivity for the current recovery.

I.   THE CYCLICAL BEHAVIOR OF PRODUCTIVITY

To understand the relationship of productivity to output, this section introduces an accounting identity that relates output, productivity, and labor inputs. The section then documents changes in relationships among these variables—specifically, between productivity and output and between productivity and labor inputs in the nonfarm business sector. These changes occurred in the mid-1980s.

Productivity is measured as output per hour. Hence, in a recession productivity falls if total hours worked decline more slowly than output. Conversely, productivity rises if hours decline faster than output. Casual observation shows that productivity has behaved differently in recent recessions than in recessions until the 1980s. Chart 1 compares the evolution of productivity and output in the 1981-82 and the 2007-09 recessions.[2] In the most recent recession, productivity surged as firms scaled back hours more rapidly than output. In contrast, in the 1981-82 recession, which was also severe, productivity weakened slightly as hours declined somewhat more slowly than output.

Output decomposition

Firms can increase output either by producing more output per hour worked—that is, by increasing productivity—or by increasing the total hours worked. Total hours worked can be adjusted by varying the level of employment and by varying the hours per worker.[3] Thus, output can be decomposed into productivity and labor inputs in the following accounting identity:

$$Y=P+N+H.$$

On the left side of this relationship, Y denotes the logarithm of output per capita. On the right side, P measures the logarithm of output per hour worked, N denotes the logarithm of the number of persons employed per capita, and H stands for the logarithm of the average hours per worker. Output and employment are converted to per-capita terms by dividing them by the civilian noninstitutional population of age 16 years and older. These variables are referred to below as output, productivity, employment, and hours per worker.

Chart 1

OUTPUT AND PRODUCTIVITY IN THE 1981-82 AND 2007-09 RECESSIONS
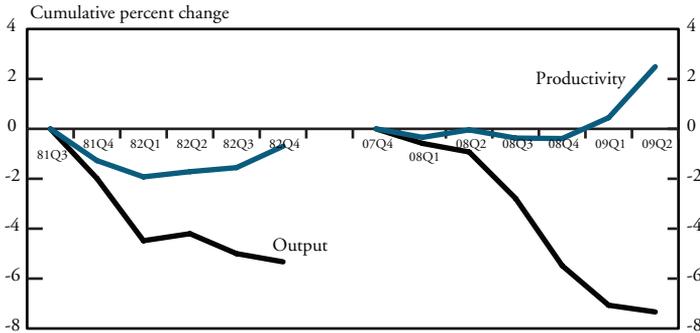
Source: Bureau of Labor Statistics; nonfarm business sector.

### *The changing cyclical behavior of productivity*

Output, productivity, and labor inputs fluctuate over time due to both the business cycle and long-term trends. Long-term trends reflect forces such as gradual increases in population, technology, and the capital stock. Consequently, assessing business cycle fluctuations requires removing the influence of long-term trends from the actual data.

Economists commonly use two methods to remove, or filter out, long-term trends, both of which are incorporated in this analysis. One method is to use growth rates of output, employment, hours per worker, and productivity as measures of business cycle components. The second is to use statistical filters that rely on long, weighted averages to capture and remove trend influences. These statistical filters, such as the widely used Hodrick and Prescott filter, allow for the possibility of gradual movements in trend growth rates over time.[4]

The cyclical components of output and productivity moved together over the business cycle until the 1981-82 recession (Chart 2). For example, during recoveries, both output and productivity rose. But during the expansion following the 1981-82 recession, cyclical productivity and output began to move in opposite directions.

This change in the business cycle behavior of productivity is more formally quantified by correlation coefficients for the periods before and since 1984.[5] Table 1 shows the correlations for productivity,

Chart 2
CYCLICAL OUTPUT AND PRODUCTIVITY
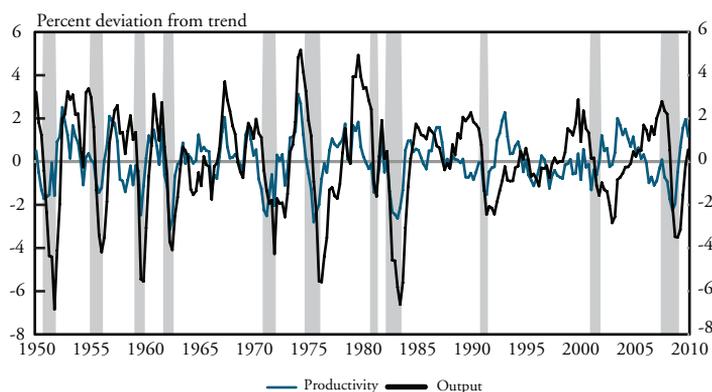
Note: Series' trends are removed with the Hodrick and Prescott filter.

Table 1
CORRELATIONS

	Growth rates			HP filter		
	Before 1984	Since 1984	Change	Before 1984	Since 1984	Change
Productivity-Output	0.75	0.47	-0.28***	0.64	-0.03	-0.75***
Productivity-Employment	0.13	-0.33	-0.46***	0.10	-0.60	-0.70***
Productivity-Hours	0.24	-0.24	-0.48***	0.51	-0.20	-0.71***
Output-Employment	0.71	0.61	-0.10*	0.81	0.79	-0.02
Output-Hours	0.61	0.46	-0.15**	0.76	0.78	0.02
Employment-Hours	0.42	0.38	-0.04	0.47	0.59	0.12*

Note: Variables are expressed in logarithms and growth rates are approximated by first differences. Test of equality of correlations across the two subsamples is based on Fisher's z-transformation. Significance at the 10, 5, and 1 percent level is denoted by *,**, and ***, respectively.

output, and labor inputs. To isolate business cycle components, the variables are either growth rates (the first two columns) or are expressed as deviations from the Hodrick and Prescott (HP) trend (the last two columns). The correlation between output and productivity falls sharply between samples and even changes sign when the business cycle components are measured with the HP filter. In that case, the correlation from 1948 to 1983 was 0.64. From 1984 to the second quarter of 2010, the correlation was -0.03. The falloff in the output-productivity

correlation reflects a decline in the correlations between productivity and labor inputs. These changed sign with both measures of business cycle fluctuations. For instance, when the HP filter is used, the productivity-employment and productivity-hours per worker correlations fell from 0.10 and 0.51, respectively, before 1984 to -0.60 and -0.20 since then. The correlations between output and labor inputs have remained highly positive across both periods.

A variance decomposition of output provides another way to see the changed cyclical behavior of productivity. Output is the sum of productivity and labor inputs. Thus, the variance of output is the sum of the variances of productivity, labor inputs, and their covariances. Table 2 shows the variance decomposition of output, again based on growth rates and business cycle components measured by the HP filter, for the periods before and since 1984.[6] In each column, the sum of the first six rows is equal to the variance of output, given in the last row. The last row shows that the volatility of output has declined since 1984; this decline is often called the Great Moderation. The rows above show that the decline in output volatility has been due in part to smaller fluctuations in productivity, employment, and hours per worker. But it has also been due to the shift in the cyclical behavior of productivity, which went from a positive covariance with labor inputs before 1984 to a negative covariance since then.

The variance decomposition thus shows that the changed cyclical behavior of productivity is associated with the following facts. Until the mid-1980s, changes in output were typically larger than changes in labor inputs, so productivity rose during expansions and fell during contractions. In contrast, since the mid-1980s the fluctuations in output have declined relative to those in labor inputs, weakening the procyclical behavior of productivity.[7]

The subsequent analysis explores why the correlation of productivity with output has dropped in the last 25 years compared with the preceding postwar period. Understanding this change in correlation requires an assessment of why the correlation of productivity with labor inputs has also fallen. The analysis considers two alternative explanations. First, the importance of supply shocks as a driving force of business cycle fluctuations may have diminished. Second, structural

Table 2
VARIANCE DECOMPOSITION OF OUTPUT

	Growth rates		HP filter	
	Before 1984	Since 1984	Before 1984	Since 1984
Var(Productivity)	0.99	0.43	1.56	0.80
Var(Employment)	0.72	0.37	3.21	1.93
Var(Hours)	0.13	0.09	0.30	0.23
2×Cov(Employment, Hours)	0.26	0.14	0.92	0.77
2×Cov(Productivity, Employment)	0.20	-0.27	0.34	-1.48
2×Cov(Productivity, Hours)	0.18	-0.09	0.69	-0.17
Sum = Var(Output)	2.48	0.67	7.01	2.07

Note: Variables are expressed in logarithms and growth rates are approximated by first differences. Var and Cov stand for variance and covariance, respectively. The numbers are multiplied by a factor 100^2.

changes in the labor market may have altered the responses of output, labor inputs, and hence productivity to different shocks.

II.   THE ROLE OF SUPPLY SHOCKS

Has the importance of supply shocks as a driver of the business cycle diminished since the mid-1980s? This section examines this explanation for the change in the business cycle behavior of productivity and finds that the relative importance of supply shocks to the business cycle has not declined.

Theoretical channel between supply shocks and productivity fluctuations

Supply shocks are the main impulse of cyclical fluctuations in output and productivity according to the Real Business Cycle theory (Prescott). This theory has greatly influenced macroeconomics since the 1980s for its assertion that business cycle fluctuations are the desirable outcome of consumers' and firms' decisions in the face of shocks to the economy. However, the role it assigns to supply shocks has become less prominent in much of the subsequent macroeconomic literature that studies the sources of business fluctuations.

An economic model of the relationship between production factors and output shows how supply shocks affect the relationship between output and productivity. As represented in the following production

function, output increases with technology (A), employment (N), and hours per worker (H):[8]

$$Y = \alpha \times (A+N+H).$$

Output increases if there are more workers or if each worker works longer hours, consistent with the positive correlation between output and the labor inputs documented in the previous section.

In addition, output rises if the technology level increases, creating more output per hour worked. Changes in technology, as broadly defined in common macroeconomic models of the business cycle, correspond to supply shocks. These shocks to technology (supply), which are not directly measurable, consist of any changes that permanently affect the transformation of factor inputs into output. For instance, a technology breakthrough that allows firms to produce more with the same amount of worker hours would be captured as an increase in the model variable A. In common macroeconomic models, technology shocks captured by the variable A also encompass other types of changes that affect the transformation of inputs into outputs, such as a drop in raw materials prices or a rise in the available capital per worker, possibly brought about by a cut in the tax rate on capital.

Finally, the coefficient α determines the returns to scale in production and is assumed positive but not greater than one. Accordingly, if a firm doubles the scale of production by doubling its total worker hours, production increases proportionally, but can at best be doubled.

The relationship of productivity with technology and the labor inputs can be derived by writing output in terms of productivity and labor inputs, using the accounting identity discussed in the previous section, and subtracting the number of workers and hours per worker from both sides of the production function:

$$P = \alpha \times A - (1 - \alpha) \times (N+H).$$

A higher level of technology tends to increase firms' output and productivity directly, which can lead to the positive correlation between output and productivity observed before 1984. However, the increase in technology also affects output and productivity indirectly via its effect on the level of labor inputs. Thus, the sign of the correlation will also depend on the response of labor inputs to the technology shock.[9] Labor inputs are positively related to output, but negatively related to

productivity, as the output and productivity equations show. Thus, if labor inputs rise due to a technology shock, output would expand further, but the rise in productivity would be dampened.[10] Likewise, if a technology shock leads to a short-run decline in labor inputs, the output expansion would be dampened and the rise in productivity amplified. Hence, technology shocks can generate the procyclical productivity shown in Table 1 for the period before 1984, provided the direct effect of the technology shock on output and productivity dominates the indirect influence from the labor inputs.

In contrast, if technology shocks are not important—consider, for example, the extreme case where A is always zero—then output can fluctuate only due to nontechnology shocks. These are demand shocks, such as shocks to monetary or fiscal policy or to consumer tastes. Suppose that a higher demand for goods and services leads to an expansion of output. To meet that output demand, firms must increase employment and hours per worker, pushing productivity in the opposite direction of output. The resulting business cycle pattern is in line with the correlations since 1984 (Table 1). That is, the association between productivity and output is weaker or even negative, and the correlation between productivity and the labor inputs is negative.

Empirical evidence

The role of technology shocks in driving fluctuations in productivity before and after 1984 can be assessed with a statistical model. The model is used to estimate the joint dynamics of productivity, employment, and hours per worker on the two data samples covering the periods 1948:Q1-1983:Q4 and 1984:Q1-2010:Q2.[11] The model relates the current value of each of these variables to the values of all variables over the past four quarters and to three error terms that capture unexplained variation. Each of the error terms of the estimated model is a combination of underlying, unobserved technology and nontechnology shocks.[12]

To recover these structural shocks from the error terms, it is assumed that only technology shocks can have a lasting effect on the level of productivity.[13] This is in line with the theoretical discussion in the previous section. The estimated model allows computing these technology shocks and evaluating whether their contribution to the cyclical

fluctuations in productivity, employment, and hours per worker has changed since 1984.

Chart 3 shows the model's estimate of the percentage of fluctuations in productivity growth at different horizons in the future that result from technology shocks. Such an exercise is usually referred to as a forecast-error variance decomposition. Both before and after 1984, a technology shock caused slightly more than 50 percent of the variance of productivity growth in the subsequent six years, with the remainder attributable to nontechnology shocks. At a one-year horizon, the relative importance of technology shocks in recent decades has fallen about 3 percent from the earlier period. Essentially, technology's contribution to the variance of productivity growth has remained at about one half in both periods. Hence, a diminished role of such shocks as a driving force in the business cycle cannot explain the change in the cyclical behavior of productivity.[14]

III. THE ROLE OF STRUCTURAL CHANGE IN THE LABOR MARKET

This section considers the second plausible explanation for the decline in the correlations of productivity with output and labor inputs: structural changes in the labor market. Such structural changes could alter the response of labor inputs, output, and thus productivity to supply or demand shocks. While the analysis of this article is concerned with the business cycle as a whole, recent jobless recoveries have created considerable interest in just the recovery phase of the business cycle. An accompanying box examines the relationship between the change in the cyclical behavior of productivity and jobless recoveries.

Theoretical channel between structural change in the labor market and productivity fluctuations

To assess how structural change may have altered the cyclical behavior of productivity, it is useful to first consider why productivity growth was procyclical until the mid-1980s. The most common explanation that does not involve supply shocks is the practice of labor hoarding by firms (Abel, Bernanke and Croushore).

Labor hoarding refers to the tendency to use workers less intensively in recessions than in booms. It reflects the desire by firms to smooth employment and paid hours per worker, despite fluctuations in output, to avoid labor adjustment costs. Such costs could reflect contractual

Chart 3

FLUCTUATIONS IN PRODUCTIVITY GROWTH ATTRIBUTABLE TO TECHNOLOGY SHOCKS

Percent

Legend: Before 1984 — Since 1984

Quarters-Ahead Forecast Horizon
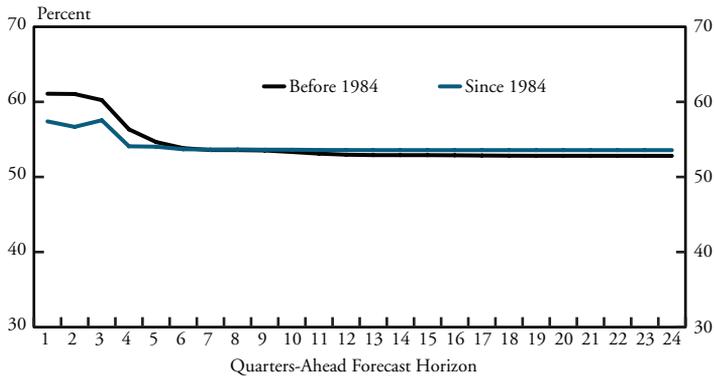
commitments that limit labor adjustment, the transactions costs of hiring and firing, the cost of holding an inventory of job-specific skills that may be needed quickly during an upturn, and the adverse effects of labor adjustment on morale (Fay and Medoff; Okun).[15]

Labor hoarding behavior is often described in terms of variations in unobserved worker effort.[16] If employee effort is less intense during downturns and more intense during booms, measured hours worked fluctuate less than their effective counterpart, which consists of measured hours adjusted for labor effort. As a result, output may expand and contract more than measured labor inputs, giving rise to procyclical movements in productivity. Thus, analogous to the theoretical discussion in the previous section, consider a production function that relates output to the effective labor input in the following way:

$$Y = \alpha \times (E + N + H).$$

As represented in this production function, output increases with worker effort (E), employment, and hours per worker. As before, the parameter α takes a value between zero and one.[17] For simplicity, the equation abstracts from the level of technology. A model of productivity is obtained by subtracting from output the number of workers and hours per worker:

$$P = \alpha \times E - (1 - \alpha) \times (N + H).$$

These output and productivity equations are identical to the ones introduced in the previous section, once the level of technology is sub-

Box

JOBLESS RECOVERIES AND THE SHIFT IN THE CYCLICAL BEHAVIOR OF PRODUCTIVITY

The first two recessions after the 1981-82 recession were followed by jobless recoveries, consisting of falling employment in the first four to six quarters following the end of the recession. In the current recovery, employment declined only two quarters subsequent to the trough in real GDP.[18] Productivity tends to increase in a jobless recovery, as output rises and employment falls. Thus, the jobless recoveries worked to counteract the decline in the correlation of productivity and output since the mid-1980s, while they exacerbated the decline in the correlation of productivity and employment.

Still, the weakened procyclical behavior of productivity since the mid-1980s can be reconciled with the jobless recoveries, because the period of jobless output growth pertained only to a fraction of the duration of the business cycle. Overall, the business cycles with jobless recoveries were cycles in which firms adjusted employment aggressively rather than smoothly. The size of employment fluctuations in the last three business cycles has actually increased relative to output fluctuations (Table 2).[19]

The possible factors that underlie the decline in labor hoarding since the mid-1980s—reduced labor adjustment costs and increased industry reallocation—are closely related to some proposed explanations of jobless recoveries.[20] First, a decline in labor adjustment costs allows firms not only to cut their labor inputs sharply during a recession, but also to wait and see the strength of the recovery before resuming hiring, rapidly if necessary (Schreft and Singh).[21] Second, recoveries with large reallocations among industries are characterized by new job creation rather than by recalling workers. But this new job creation is likely to take longer, as it involves a time-consuming process of matching workers to jobs in different industries, in different locations, and with different skill requirements (Groshen and Potter). Thus, the structural changes in the labor market that can explain the weakened relationship between productivity and output since the mid-1980s also provide

Box (continued)

possible explanations for the phenomenon of jobless recoveries. However, that phenomenon does not contribute to the decline in the procyclical behavior of productivity.

stituted for the effort level. However, there are two important conceptual differences.

First, an increase in the level of effort exerted by workers makes the economy's workforce more productive. But such an increase can hardly last indefinitely; worker effort eventually reverts to its average level.

Second, analogous to the determination of hours per worker, the effort level may be determined jointly by workers and firms. Firms that wish to hoard labor must elicit workers to vary their labor effort. This view implies that worker effort can be expected to respond to both supply and demand shocks.

As a consequence, productivity can move in the same direction or in the opposite direction of output, depending on the responsiveness of worker effort. For instance, a slowdown in demand would prompt a firm to adjust output, partly by reducing employment and hours per worker and partly by letting the remaining workers exert less effort. While the former tends to raise productivity, the latter tends to reduce it, as shown in the productivity expression above. Thus, if effort is reduced sufficiently relative to the measured labor inputs, the correlation of productivity with output and labor inputs is positive (as in Table 1, before 1984). In contrast, if worker effort is not very responsive to a demand shock, firms adjust output mainly by lowering employment and hours per worker—and thus raise productivity. Hence, in the absence of labor hoarding the correlation of productivity with output and labor inputs is negative (as in Table 1, after 1984).[22]

Labor hoarding may have declined since the mid-1980s due to two structural changes. The first change is a decline in labor adjustment costs. The second change is intensified reallocation across industries and a—possibly related—increase in firm-level uncertainty.

Labor adjustment costs can fall because of a decline in hiring and firing costs. Hiring cost reductions may be related to improved match-

ing of workers with jobs, reducing the time and expense of finding employees that fit the specific needs of a job. The rise of Internet-based job matching may have reduced this cost by making it easier for workers to find jobs and firms to find and compare job candidates.[23] Firing cost reductions may be related to declining trade union membership, which has likely diminished strong contractual job protections and high severance pay from employers.

Labor adjustment costs may have also decreased due to the increasing substitutability of labor and computers. In particular, this substitutability reduces the value of job-specific skills. While information technology complements highly educated workers engaged in abstract tasks and has less impact on low-skilled workers performing manual tasks, it substitutes for moderately educated workers performing routine tasks (Autor, Katz and Kearney). This "skill-biased technical change" has made the middle tier of white-collar workers particularly vulnerable to replacement by computers or outsourcing. By diminishing the value of certain job-specific skills, it may enable firms to readily adjust hours. Specifically, it may allow firms to engage in more dramatic cost-cutting during recessions and adjust hours more than proportionally to output (Gordon).

Indeed, evidence suggests that firms have increasingly turned to flexible types of labor inputs. For instance, temporary hiring, part-time hiring, and overtime—collectively known as just-in-time hiring—has gained in importance since the 1990-91 recession (Schreft and Singh). This evidence is consistent with the idea that employment adjustment has become less costly for firms.

The second structural change pertains to firms' outlook for their product demand. Even if labor adjustment costs have remained unchanged, firms may have become more willing to absorb those costs. They may perceive the decline in demand for their goods as more long-lasting in recent recessions, or the recovery of that demand as more uncertain.[24] In the 1960s and 1970s, business fluctuations were exacerbated by the Federal Reserve's go-stop policy. The Federal Reserve would stimulate employment in the "go" phase, until the public became concerned about inflation. Then interest rate hikes would initiate the "stop" phase to bring inflation down (Goodfriend). This policy cycle shaped the economy's response to shocks in a predictable way, arguably providing some degree of predictability for firms about the impact of a

recession on their industry.[25] In that case, firms could be more likely to let their workers sweep the factory floor until demand returned.

Since the early 1980s, firms' product demand may have become less predictable. Monetary policy has been widely seen as much more effective in stabilizing, rather than exacerbating, shocks to the economy. Partly as a result, intensified employment reallocation may have gained importance relative to temporary declines in employment in the recessions since the early 1980s. In the recessions up to that time, employment in most industries followed a cyclical pattern: job losses during the recession followed by gains in the recovery. In contrast, employment in many industries in the 2001 recession followed a different pattern: industries that lost jobs in the recession continued to lose jobs in the recovery, and industries that gained jobs in the recession continued to gain jobs in the recovery (Groshen and Potter).[26] The diminished contribution of temporary layoffs to the rise in the unemployment rate in the 1990-91 and 2001 recessions serves as further evidence. The 2007-09 recession also displayed a reduced reliance on temporary layoffs (Knotek and Terry).

In line with this evidence, some studies indicate that volatility has followed diverging trends at the aggregate and firm levels. While the growth rate of aggregate sales has become more stable, sales at the firm level have become more volatile (Comin and Mulani).[27] Hence, if a firm perceives the recession as heralding a permanent decline in its industry or as generating strong uncertainty as to whether its demand will recover, the firm has a strong incentive to cut hours and eliminate jobs despite the associated costs of adjustment.[28]

Empirical evidence

These structural changes can affect productivity fluctuations through a decline in labor hoarding. Unfortunately, it is difficult to find direct evidence of the role of structural change. There are no measures of the aggregate worker effort level to examine the role of labor hoarding. Moreover, the effort level is chosen jointly by employers and workers, in contrast to a shock. As a result, it cannot be identified in a model with as few assumptions as the supply shock discussed in the previous section.[29] However, this "endogeneity" of work effort suggests that if a decline of labor hoarding underlies the shift in the cyclical

Table 3

CORRELATIONS CONDITIONAL ON SUPPLY AND DEMAND SHOCKS

	Growth rates			HP filter		
	Before 1984	Since 1984	Change	Before 1984	Since 1984	Change
Supply Shocks						
Productivity-Output	0.89	0.87	-0.02	0.79	0.90	0.11***
Productivity-Employment	-0.60	-0.92	-0.32***	-0.66	-0.95	-0.29***
Productivity-Hours	-0.23	-0.84	-0.61***	0.06	-0.77	-0.83***
Output-Employment	-0.17	-0.61	-0.44***	-0.07	-0.75	-0.68***
Output-Hours	0.18	-0.50	-0.68***	0.57	-0.45	-1.02***
Employment-Hours	0.71	0.90	0.19***	0.52	0.85	0.33***
Demand shocks						
Productivity-Output	0.82	0.52	-0.30***	0.74	0.23	-0.51***
Productivity- Employment	0.45	-0.08	-0.53***	0.33	-0.17	-0.50***
Productivity-Hours	0.36	-0.04	-0.40***	0.65	0.14	-0.51***
Output-Employment	0.85	0.73	-0.12**	0.87	0.90	0.03
Output-Hours	0.63	0.55	-0.08	0.74	0.76	0.02
Employment-Hours	0.40	0.31	-0.09	0.43	0.56	0.13*

Note: Variables are expressed in logarithms and growth rates are approximated by first differences. Test of equality of correlations across the two subsamples is based on Fisher's z-transformation. Significance at the 10, 5, and 1 percent level is denoted by *,**, and ***, respectively.

properties of productivity, then these properties would change regardless of the type of shock that buffets the economy. That is, structural change in the labor market would likely lead to a shift in the correlations of productivity with output or labor inputs stemming from either supply or demand shocks.

The estimated model from the previous section allows computing the correlations conditional on supply shocks or demand shocks only. Feeding only the supply shocks or the demand shocks into the estimated model generates a time series of productivity growth, employment growth, and hours per worker growth conditional on only one type of shock.[30] The corresponding conditional output growth series can be computed by adding up growth in productivity, employment, and hours per worker, according to the definition of output in Section I.

These conditional time series can then be used to compute correlations conditional on supply shocks or demand shocks.[31]

The correlations of productivity and output and those of productivity and the labor inputs conditional on supply shocks (Table 3, Panel A) and demand shocks (Panel B) are computed before and after 1984. The results show a decline in the correlations of productivity and labor inputs, regardless of the type of shock. The correlation of productivity and output declines only when conditional on demand shocks.

As shown in Panel A, the relationship between productivity and output generated by supply shocks has strengthened since the mid-1980s. However, these shocks induce a much more negative relationship between productivity and labor inputs, especially hours per worker. The relationship between productivity and employment induced by supply shocks weakened less, as it was already quite negative before the mid-1980s. A negative correlation of productivity and aggregate hours or employment conditional on supply shocks is well-documented (Gali). However, since 1984 the relationship between productivity and hours per worker conditional on supply shocks has become almost as negative as that of productivity and employment.

The conditional correlations of output with the labor inputs also indicate that the response of hours per worker to a supply shock has become more similar to that of employment since the mid-1980s. The conditional correlation of output and employment is negative in both periods. In recent decades, supply shocks have also driven output and hours per worker in opposite directions. In particular, for business cycle components measured by the HP filter, the correlation between output and hours per worker was 0.57 before 1984 and -0.45 since then.

Panel B shows how the correlations have changed since 1984 conditional on demand shocks. The relationship between productivity and output generated by demand shocks has weakened significantly, which confirms that demand shocks are responsible for the decline in the unconditional productivity-output correlation.[32] In addition, the correlations between productivity and labor inputs have declined significantly conditional on demand shocks. These shocks generate a negative relationship between productivity and employment, in contrast to the preceding decades.

These results suggest that the shifts in correlations are due to structural change that altered the transmission of a shock to the labor market and thereby changed the response of productivity to different types of shocks. As argued above, structural changes in the economy that have resulted in less labor hoarding may explain the evidence in the table.

IV.   IMPLICATIONS FOR THE NASCENT RECOVERY

The analysis in the previous sections has shown that the cyclicality of productivity has declined significantly since the mid-1980s. What, then, are the implications for the current recovery?

Early in the current expansion, which likely began in the second half of 2009, employment continued to decline and productivity surged. Productivity expanded in the last three quarters of 2009 at an annual average rate of 7.1 percent, more than twice as fast as the average annual growth rate since 1995 of 2.6 percent. However, productivity growth proceeded at a more sluggish pace in the first half of 2010 (1.5 percent).

Although productivity was clearly boosted by falling hours worked in 2009, it also may have benefited from changes in technology, such as cost-saving reorganizations other than layoffs and cutbacks in hours. As the expansion continues to take hold, further improvements in technology will likely become increasingly difficult. Of course, such changes in technology are hard to predict.[33] Nonetheless, the last two expansions in the 1990s and 2000s likely benefited significantly from new information and communication technologies. As the productivity-enhancing benefits of the investments in information and communication technologies during the 1990s have probably played out, efficiency gains are not likely to maintain the rapid pace of the late 1990s and the first half of the 2000s (Jorgenson, Ho and Stiroh). The analysis suggests that productivity will benefit from better technology—relative to demand shocks—as it has in typical postwar business cycles. But changes in technology are unlikely to boost productivity enough to generate the strongly procyclical pattern seen before the mid-1980s. After all, productivity has lost its strongly procyclical character in recent decades, while the relative contribution of supply shocks to the business cycle has remained steady.

As argued above, structural changes in the labor market are a plausible explanation for the shift in the cyclical behavior of productivity. Such changes may have made worker effort less responsive to economic

conditions in recent decades. If that remains the case in the current expansion, the dynamics of productivity will be determined mainly by the growth in labor inputs. Specifically, a continuing rebound in hiring and hours per worker will dampen productivity growth. In turn, the diminished responsiveness of worker effort to economic activity implies that the dynamics of output will be determined mainly by the growth in labor inputs.

V.   CONCLUDING REMARKS

This article finds that the cyclicality of labor productivity has declined significantly since the mid-1980s. The decline in the correlation of productivity and output has taken place conditional on demand shocks. Associated with this decline are sharp drops in the correlation of productivity and labor inputs. In particular, the correlation of productivity and hours per worker displayed sharp declines conditional on all types of shocks. The shift in the business cycle behavior of productivity is most likely due to structural changes in the labor market. These changes may have induced firms to diminish the practice of labor hoarding.

Looking ahead, productivity growth should slow as the economic expansion proceeds. The expansion of output will then be driven mainly by gains in employment and hours per worker.

ENDNOTES

[1]The present article is related to recent papers by Gali and Gambetti and by Gordon, who also emphasize the shift in the cyclical behavior of productivity. Unlike Gordon's analysis, this article examines the role of supply shocks in generating that shift. The article extends the analysis of Gali and Gambetti in three respects. First, it allows the labor inputs to vary along the employment and hours per worker margins. Second, it includes data of the severe recession of 2007-09. Third, it analyzes structural changes in the labor market that may explain the shift in the cyclical behavior of productivity.

[2]The official arbiter of recessions in the United States, the National Bureau of Economic Research, has not yet declared the trough date of the recession at the time of writing. In Chart 1, the recession is assumed to end after the trough of output, which is in the second quarter of 2009.

[3]Employment and hours per worker are sometimes referred to as the extensive and intensive margin of labor, respectively.

[4]Convention is followed by setting the smoothing parameter of the Hodrick and Prescott filter to 1,600 for quarterly data.

[5]The break date of 1984 has been chosen to coincide with the year that is often identified as the beginning of the Great Moderation. This is in line with the date emphasized by Gali and Gambetti, and close to the break date of Gordon, which is 1986.

[6]Stiroh provides a similar variance decomposition, but he does not distinguish between the extensive and intensive margin of labor. His results are consistent with those reported in Table 2.

[7]The change in the size of employment fluctuations relative to output fluctuations is also reflected in Okun's law. Using a version of Okun's law that relates changes in the (un)employment rate to percent changes in output growth, Knotek finds that until the mid-1980s, an increase in the employment rate was associated with a rapid rate of real GDP growth (at least four percent). But since the mid-1980s, even moderate real GDP growth (two percent or higher) is associated with a rising employment rate. Gordon uses a version of Okun's law that relates the employment rate to a measure of the output gap. He likewise reports that the long-run response of the employment rate to changes in the output gap increased in the period since 1986.

[8]For simplicity, the production function omits the production factor capital. There are two ways to think about the role of capital in this analysis. First, the capital stock tends to be fairly constant over the business cycle, in which case it is not important for the purpose of business cycle analysis. This is arguably a good assumption for certain types of capital with a long life, such as structures. Second, capital may be viewed as embodying new technologies, in which case they may be

viewed as part of the technology level. This is arguably a reasonable assumption for equipment and software.

[9]The sign of the short-run response of labor to a technology shock is the subject of controversy in the empirical literature. Nonetheless, if one accounts for the trend changes in productivity, the data indicate that labor declines after a technology improvement (Fernald). The empirical results in Table 3 in the next section are in line with this finding.

[10]In principle, the indirect effect of a rise in labor inputs could dominate the direct effect of an increase in technology, thus generating a decline in productivity. This would render the technology shock explanation of procyclical productivity obsolete. However, this is not observed in the empirical results below. One reason for this is that the value of α is typically thought to be at least 2/3, so the productivity equation places more weight on the direct effect of the technology improvement than on the indirect effect of the labor inputs.

[11]The time series used cover the nonfarm business sector. The hypothesis of a unit root in the level of these variables cannot be rejected, so all variables enter the model in growth rates. Productivity growth exhibits some low-frequency co-movement with labor inputs, which is presumably not associated with the phenomenon of business cycles. This co-movement is controlled for by adjusting the growth rate of productivity for its average in the three sub-periods marked by 1973Q2 and 1997Q2 (Fernald).

[12] The model is a fourth-order vector autoregression model. The order is set equal to four following Christiano, Eichenbaum and Vigfusson; Fernald; Francis and Ramey; and Gali and Rabanal.

[13]The long-run identifying restriction follows Blanchard and Quah. Two additional assumptions are imposed. First, the variance of the technology and non-technology shocks is equal to one—a normalization—and second, the shocks are mutually uncorrelated. The technology shock is the only shock that is identified by these three assumptions. Since the two non-technology shocks are not separately identified they can only be referred to jointly.

[14]Gali and Gambetti also find that the role of technology shocks for productivity fluctuations did not diminish in relative importance since the mid-1980s. On the contrary, they find that technology shocks account for an increased share of productivity fluctuations in recent decades. This different finding could be due to differences in their methodology from the one described above. However, their result strengthens the finding that a decline in the relative importance of technology shocks is not a plausible explanation of the changed cyclical behavior of productivity.

[15]An alternative, less popular explanation of the procyclical behavior of productivity is based on the observation that certain tasks in the production process support production but do not contribute directly to output when they are performed. Examples are training or the maintenance of equipment. If firms assign

more workers to such tasks during a downturn, then fewer such tasks will remain during the upturn. As a result, labor inputs fluctuate less than output, and productivity moves in the same direction as output. In this view, firms choose to smooth labor even though they can freely adjust it.

[16]More generally, labor hoarding describes the idea of variable factor utilization. This need not be limited to the production factor labor; the flow of capital services also depends on the utilization rate of the capital stock. Moreover, unlike for worker effort, aggregate measures of the capital utilization rate are available. However, a commonly used measure, the Federal Reserve Board's measure of total capacity utilization, suggests that changes in the cyclical properties of capacity utilization are not a good explanation of the shift in the cyclical behavior of productivity. Capacity utilization, available from 1967 onward, is highly procyclical before and since 1984 (using the HP filter), and the volatility of capacity utilization relative to that of output did not decline.

[17]Yet another possible explanation of procyclical productivity is the presence of increasing returns to scale in production, which corresponds to a parameter greater than one. This explanation is not pursued further as a source of structural change, because it is difficult to justify a large shift in this parameter.

[18]The current recovery does not seem to be jobless, yet at the time of writing (the third quarter of 2010) it is too early to assess how rapid the pace of job growth will be.

[19]The variance of employment fell by less than half since 1984, whereas the variance of output fell by substantially more than half. Consequently, the variance of employment relative to the variance of output has increased.

[20]The reasons for the decline in labor hoarding suggested above are related to structural explanations of jobless recoveries. However, cyclical explanations of jobless recoveries have also been proposed. Bachmann argues that the jobless recoveries of the 1990s and 2000s were related to the shallowness of the preceding recessions. In particular, he shows that following a mild downturn, firms may first wish to increase hours per worker rather than employment because hiring is costly. Kahn argues that the first jobless recovery was due in part to an anemic recovery of output. Although some of these studies consider the behavior of productivity during the jobless stage of the recovery, they do not study the behavior of productivity over the business cycle.

[21]Firms may also have waited longer before shedding workers at the onset of the 1990-91 and 2001 recessions than in previous postwar recessions.

[22]A large enough decline in labor hoarding behavior suffices to explain the shift in correlations in Table 1. However, structural changes in the labor market may even have tended to raise worker effort during recent recessions. For instance, firms' ability to retain the most productive workers during a recession may have improved as a result of reduced worker protections since the 1980s.

[23]Evidence that Internet-based search has increased the efficiency of job matching remains scarce. Stevenson presents evidence that Internet-based search increases the likelihood to switch jobs for employed workers.

[24]Increased firm-level uncertainty about demand may also have diminished the role of non-production or support work, which is the explanation of pro-cyclical productivity that does not rely on labor adjustment costs. That is, if a firm views the recovery of its demand as highly uncertain, it is less likely to as-sign workers to temporary non-production activities such as maintenance. That would lead to a decline in the correlation of productivity and output.

[25]Despite this policy cycle, recessions were times of intensified industry real-location even before the 1980s. For instance, the oil price shocks of 1973 and 1979-80 may have had long-lasting effects on particular industries. Davis and Haltiwanger find that oil price shocks in the 1970s and 1980s gave rise to sub-stantial reallocation in manufacturing.

[26]The account of increased reallocation across industries has been criticized by Aaronson, Rissman and Sullivan. They disagree with Groshen and Potter's measure of industry reallocation, and argue that better measures do not point to an increase in reallocation in the 1990-91 and 2001 recessions compared with preceding ones.

[27]Akin to the criticism on the industry reallocation story, the account of in-creased firm-level volatility has been criticized by Davis, Haltiwanger, Jarmin and Miranda for relying on a sample of only publicly traded firms. Using an employ-ment-based measure of firm-level volatility, they argue that the rise in the volatility of publicly-held firms is dominated by a decline in the volatility of privately-held firms.

[28]Increased firm-level volatility since the mid-1980s may also accelerate the reallocation of capital across firms, from plants that shut down to more produc-tive ones. This would raise productivity in a downturn, thus contributing to the decline in the correlation of productivity and output.

[29]Gali and van Rens analyze an economic model with worker effort to ex-plain the vanishing procyclicality of productivity.

[30]The demand shocks that are uncovered by the estimated model consist of the two nontechnology shocks, which in turn consist of a combination of struc-tural disturbances such as shocks to monetary and fiscal policy and consumer tastes, as mentioned above. The demand shocks can be interpreted as such be-cause they do not affect productivity in the long run.

[31]To compute the correlations of HP-filtered conditional time series, the growth rates are converted back to logarithms of the levels and then their HP trend is removed.

[32]Gali and Gambetti also confirm that nontechnology (demand) shocks are largely responsible for the decline in the correlation between productivity and aggregate hours and between productivity and output. However, they do not dif-ferentiate between the intensive and extensive margin of labor.

[33]Even average productivity growth is difficult to forecast. For instance, Jor-genson, Ho and Stiroh foresee possible scenarios of average productivity growth ranging between 1.4 percent and 2.8 percent in the decade 2006-2016. Congres-

sional Budget Office (CBO) (Table 2-2) projects potential productivity growth of 1.7 percent in the period 2010-2014.

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