Are the high-growth recovery periods over?*

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Abstract

We present evidence about the loss of the so-called "plucking effect", that is, a high-growth phase of the cycle typically observed at the end of recessions. This result matches the popular belief, presented informally by different authors, that the current recession will have permanent effects, or that the current recession will have an L shape versus the old-time recessions that have always had a V shape. Furthermore, we show that the loss of the "plucking effect" can explain part of the Great Moderation. We postulate that these two phenomena may be due to changes in inventory management brought about by improvements in information and communications technologies.

Keywords: Business cycle characteristics, Great Moderation, High-growth recovery.

JEL Classification: E32, F02, C22

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1 Introduction

The NBER has recently declared that the third quarter of 2007 was the beginning of a recession period for the US economy. Nowadays, the real debate on the current recession focuses on when and how the recession will finish. We concentrate on this paper on how we should expect that the recession will finish that is, whether it will be a "V-shaped" or a "L-shaped" recession. The former type of recessions refers to the case in which the economy springs back rapidly from its slump whereas the latter type refers to the case in which the economy faces a period of flat or at best slowly improving performance. The economic implication of facing each of these types of recoveries is evident. The V-shaped recessions are viewed as evidence in favor of the Friedman's plucking model (see Friedman [11]), in which output cannot exceed a ceiling level but it is occasionally plucked downward by recessions which have only temporary effects. On the contrary, recessions which are followed by flat recoveries are viewed as having permanent effects on the level of production.

As documented by Kim and Nelson [20], the US recessions were usually followed by periods of high growth. This is a common belief among many academics and policymakers. For example, according to the February 28th 2009 statement of the Council of Economic Advisors of President Obama:[1]

> "...a key fact is that recessions are followed by rebounds. Indeed, if periods of lower-than-normal growth were not followed by periods of higher-than-normal growth, the unemployment rate would never return to normal."

These high recovery periods are also behind all the papers that find evidence that the GDP is trend stationary, such as Campbell and Mankiw [5] or Cheung and Chinn [6]. If GDP comes back to the long-run trend, after each separation due to a recession, a high recovery period has to compensate the effects of the recession.

However, this paper shows that recently, the business cycle recoveries have turned to be L-

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[1]Council of Economic Advisors [8].

shaped so the periods following recessions are now characterized not by high growth but by lower growth than in the course of the expansion. In Figure 1 we can observe the decline in the relevance of the high recovery phase of the cycle. While the end of the seven recessions prior to mid-eighties were characterized by above average growth rates, the two recessions after that date were followed by growth rates below average. An important consequence of the disappearance of this high recovery phase is that recessions have now the potential to have long run effects on the economy.[2]

Even though we formalize this finding, some of the intuition of our results is already in the economic press. For example, according to Krugman [21]:

> "[If] the experience of the last 20 years is any guide, if the US economy is facing a recession, the prospect for the next recovery is not a rapid phase of high growth. On the contrary, it is a springing back with slowly improving performance. In addition, the effects of this recession are expected to be permanent."

Noticeably, the disappearance of the high-growth recovery of business cycles coincides with the period of the Great Moderation early documented by McConnell and Perez Quiros [23], and Kim and Nelson [19] and dated in 1984. In this paper we present evidence to show that these two phenomenon affecting the US business cycle dynamics may be related. According to our measures, about one third of the high volatility of output growth before 1984 can be explained by the existence of the high recovery phase. Furthermore, by means of a counterfactual exercise, we show that when this phase is removed from the business cycle dynamics, the statistical evidence for a structural change in the volatility output decreases dramatically.

In addition, we postulate that both the loss of the third phase and the volatility reduction can in part share the same economic sources which are related to changing business practices. As documented by Sichel [24], the existence of the high recovery phase of the business cycle could be linked to inventory accumulation. In addition, Kahn, McConnell and Perez Quiros [17] also

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[2]Sichel [24] as well as Kim and Murray [18] documented the inexistence of the third phase after the 1991 recession.

analyze the role of inventory management as the source of reduction in output growth volatility, and the work of Davis and Kahn [9] and Kahn [16] directly relates the stockout avoidance motive to hold inventories (see, among others, Kahn [15]) to the Great Moderation. These authors postulate that until the early eighties firms maintain inventories to avoid stockouts. Under this theory, inventories reduce the opportunity costs of not servicing demand even at the cost of paying a price for holding the inventories which increases the volatility of output above that of sales. In periods of low demand inventories are low because the probability of stockout is low. As the economy exits the recessionary state, firms increase production not only to satisfy a growing demand but also to replenish inventories above the level they had during the recession. Accordingly, this process would explain the coexistence of periods of relatively high growth of production above the growth of sales right at the beginning of the expansions together with periods of high volatility.

At the same time, these authors acknowledge that since the early eighties, the rapid improvements in information technology have led firms to rationalize the use of inventories. According to the so-called production smoothing theory, firms decide to hold inventories to reduce production costs. Thus, in periods of low demand, the marginal cost of production would be low and firms would increase their production level and accumulate inventories to respond to periods of high demand. This high demand would be serviced out of inventories and, therefore, the firm would not need to incur in high production costs. This change in inventory management would explain both the loss of the third phase and the volatility reduction in output growth.

Putting the volatility reduction and the changes in the form of the recoveries on the same ground may also give some new insights in the debate about considering the recent economic developments as evidence of the end of the Great Moderation. Of course, the conclusions of this debate depend on the particular theories used to explain the observed reduction in volatility. For example, the recent shocks in oil prices could provide evidence in favor of the end of the Great Moderation if the Great Moderation is explained with good luck theories as in Ahmed, Levin, and Wilson [1]. The recent financial turmoil could also imply that the Great Moderation is over if we think the

Great Moderation was associated with better financial intermediation as in Dynan, Elmendorf, and Sichel [10]. In addition, the changes in liquidity management adopted to react against the shadow of the recession could also put in danger the Great Moderation if the reduction in volatility was due to good practices in monetary policy, as in Clarida, Galí and Gertler [7].

On the contrary, if we maintain the hypothesis of the Great Moderation as a mainly technical feature associated with the change in inventory investment, the only thing that we could expect is that production will follow sales but it will not add additional volatility thanks to the new techniques in inventory management. If we believe this theory, the Great Moderation never implied the end of the business cycle as it could be derived from other explanations developed in the literature. In fact, this Great Moderation in its original formulation was found even in Japan in 1976 (see McConnell and Perez Quiros [22]), an economy where nobody ever considered that the business cycle was dead. Then, according to this interpretation of the Great Moderation, the recent turmoils imply an increase in volatility of GDP that will not be additionally increased by the change in inventory accumulation. This line of research never said that business cycle disappeared but that most of the Great Moderation came from changes in business practices that made business more productive and efficient, but that never eliminated recessions or the pain they cause.

Before ending this introduction, it is important to point out that this is not a paper on the causes of the Great Moderation. We consider that the evidence shown in McConnell and Perez Quiros [22], Kahn, McConnell and Perez Quiros [17], Davis and Kahn [9] and Kahn [16] is enough to seriously consider the hypothesis of better inventory management as a potential explanation of the reduction of volatility.[3] In this paper we go further on the implications of this hypothesis putting together the effect of changes in inventory management not only on the reduction in volatility but

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[3] Herrera and Pesavento [14] find evidence against the inventories hypothesis. However, the fact that they use disaggregated data as pointed out in Davis and Kahn [9] imply that their results are potentially misleading. The reason is that it is impossible to judge whether measured changes in inventory behavior reflect genuine shifts or simply result from less meaningful relocation of inventories between sectors.

also on the disappearance of the high-growth recovery of business cycles and, therefore, on the expected L-shape for the next recovery phase.

The rest of the paper is organized as follows. Section 2 provides support to the disappearance of the high growth recovery with data on GDP. Section 3 presents a counterfactual exercise to gauge the importance of the high recovery phase in explaining the volatility of GDP growth. Section 4 relates these two phenomena with inventory management and Section 5 concludes.

2 Recoveries and the business cycle

This section includes evidence about the disappearance of the third or high-growth phase of the cycle after the mid eighties. We first present some descriptive statistics that summarize this evidence and then produce a more rigorous treatment of the data.

2.1 Descriptive statistics

Figure 1 presents the growth rate of GDP for the period 1953.1 to 2006.4.[4] Just looking at the figure, we can observe a systematic high-growth period after most of the recessions. In order to carefully examine the existence of the high-growth recovery phase, Figure 2 presents the average growth rates of GDP in recessions (represented by the column labelled "rec" in the figure) together with the average growth rates in expansions (represented by the horizontal line). It also shows the average growth rates for different quarters in the expansions. Thus, the column labelled "1-2" measures the average growth rate of GDP during the first two quarters of all the expansions in the sample; the column labelled "3-4" measures the average growth rate of GDP during the third and fourth quarters of all the expansions, and so on. We can see how during the first two quarters after a recession the growth rate of GDP is much larger than the average growth rate within expansions.

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[4]We end up the sample in 2006.4 in order to have only complete cycles. We do not include data of 2007 since this year marks the beginning of a new recession that we have not completely observed.

In particular, during the first two quarters of an expansion the economy grows on average at 1.47 percent as compared with the overall expansionary growth rate of 1.01 percent. Once the expansion gets on its way, the average growth rates basically coincide with the average of that phase of the cycle.

Figure 3 illustrates the disappearance of this very high-growth phase after the end of a recession. It presents the average growth rate of the first two quarters after each of the recessions documented by the NBER. For reference, the dates of the corresponding recession appear on the label of each column. To highlight the changes observed at the end of the sample, we subtract the average growth rates in expansions for the whole sample, equal to 1.01 percent. As it is evident in the figure, right after every recession before 1984.1 the US economy grew at a higher rate than the average growth rate of expansions. This phenomenon of a third phase changed for the expansions that followed the recessions of the 90s and the beginning of the 21st century. In the first two quarters of those expansions the economy grew around 0.4 percent below the average growth rate of the expansions in the sample.

Figure 4 presents an equivalent graph as Figure 3 but for recessions. It shows the average growth rate of GDP for the first two quarters of each recession minus the average growth rate of all recessionary quarters in the sample. Unlike Figure 3, we cannot discover any discernible pattern in this series. This evidence points to the conclusion that the mid 80s have brought a change on the way the economy recovers from recessions and not on the way the economy exits the expansions.

We can provide more evidence on the disappearance of the third phase by looking at the evolution of certain business cycle features within the sample considered. Following Harding and Pagan [13] we assume business cycles to be a recurrent sequence of recessions and expansions identified by peaks and troughs. In Figure 5, a *peak* (point P) represents the top of economic activity and indicates the end of an expansion. A *trough* (point T) corresponds to the bottom of economic activity and characterizes the end of a recession. With this figure in mind, the *duration* of an expansion is measured as the number of quarters between a trough and the following peak.

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Furthermore, the *amplitude* of an expansion measures how deep it is and is computed as the vertical distance between points T and P.[5] Additionally, another feature of the cycle is the *excess* defined as the difference between the actual accumulated gain in GDP during the expansion and the accumulated gain that would have occurred if the expansion had been linear. This feature is represented by the grey areas in Figure 5. This measure approximates the steepness of the expansion. When the excess is positive, as it happens on the left panel of Figure 5, the expansion is convex with a steep beginning and a flat end. This is the case in the presence of a third phase of the cycle. On the contrary, with a negative excess the expansion is smooth at the beginning and becomes sharper at the end. This case is represented on the right panel of Figure 5.

Table 1 presents these business cycle characteristics for the sample considered using as peaks and troughs the dates determined by the NBER dating committee. The first line includes these statistics for the whole sample between 1953.1 and 2006.4. The duration of expansions is about 20 quarters while the duration of recessions is below 4 quarters. Expansions mean a gain of about 20 percent with respect the GDP in the initial trough while recessions represent a loss of less than 2 percent of the initial GDP. Furthermore the excess is positive (1.32 percent) providing evidence for the existence of a third phase of the cycle. On the other hand, recessions seem to be linear with an excess close to zero.

The second and third line show these same statistics computed for the subsamples before and after 1984.1, respectively. We can see how after 1984 expansions are longer (they last 30 quarters instead of 18) and recessions shorter (they go from 3.7 quarters to 2.5). Also the amplitude of expansions is larger (23.8 percent as compared with 19.4 percent) while that of recession is smaller (they go from -2.1 percent to -0.5 percent). However, the only feature that has really changed signs is the excess of expansions going from a positive number (1.75 percent) before 1984.1 to a negative number (-0.18 percent) after that date. Thus, expansions have gone from having a steep

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[5] The statistics for recessions are symmetric. However because of the evidence presented in Figures 3 and 4, we concentrate only on expansions.

beginning and flat end to have a smooth beginning and sharper end. Lines 4 to 12 in Table 1 document these statistics for each of the recessions in the sample. We can see how the positive excess is a constant feature of all expansions before 1984 and negative thereafter. However, we do not observe such sharp behavior in recessions.

The previous analysis deserves two additional comments. The first comment is related to the potential dependence of the result on the particular business cycle chronology of the NBER. In a recent paper Camacho, Perez Quiros and Saiz [4] propose a bootstrap procedure to extract business cycle characteristics which is robust to the dating method. Using industrial production series, they also find evidence in favor of a change in the excess of expansions from 0.54 percent to -0.04 percent which occurs around the same date. The second comment is related to the international evidence of the loss of the high recovery phase after the recessions. These authors also documented the change in the excess of expansions for the industrial production series of most OECD countries. On average, they find that the excess of expansions falls from 0.05 percent to -0.12 percent in the nineties.[6]

2.2   Formal analysis

In this section we will use several econometric techniques to test for the existence of a third phase within business cycles in the US. We can start by running the following regression estimated by Sichel [24],

$$y_t = \alpha_0 + \alpha_1 NBER_t + \alpha_2 TS_t + u_t, \tag{1}$$

where y_t represents the growth rate of GDP, $NBER_t$ is a dummy variable taking a value of 1 if period t corresponds to a recession as described by the NBER dating committee, and TS_t is another dummy variable equal to 1 if period t is one of the first two quarters of an expansion. The

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[6]Note that Camacho, Perez Quiros and Saiz [4] define excess as linear minus actual. For easy interpretation, we reverse the sign of their figures.

estimation results are (standard deviations in parenthesis),

$$\widehat{y}_t = \underset{(0.06)}{0.97} - \underset{(0.15)}{1.47}\,NBER_t + \underset{(0.18)}{0.51}\,TS_t. \qquad (2)$$

These results imply that the normal growth rate in expansions is 0.97 percent. This growth rate falls to -0.5 percent in recessions (when the variable $NBER_t$ takes value equal to 1) but rises to 1.48 percent in the two first quarters of the expansions. The estimations in expression (2) provides evidence of the existence of a third phase of high growth.

Building on the estimations of expression (1), we could include the possibility of a change in the third phase before and after the structural break in volatility. For that, we estimate the following model,

$$y_t = \alpha_0 + \alpha_1 NBER_t + \alpha_2 TS_t + \alpha_3 TS_t B_t + u_t, \qquad (3)$$

where B_t is a dummy variable equal to 1 for periods after 1984.1. The results are as follows,

$$\widehat{y}_t = \underset{(0.06)}{0.97} - \underset{(0.15)}{1.47}\,NBER_t + \underset{(0.20)}{0.76}\,TS_t - \underset{(0.48)}{1.15}\,TS_t B_t. \qquad (4)$$

As we can see, for the period before 1984.1, the growth rate in the two first quarters of expansions rises to 1.73 percent, almost twice as much of the normal growth rate of expansions. However, for the period of low volatility the economy grows only at 0.58 percent at the beginning of expansions. Therefore, these results present evidence for the elimination of the third phase after the structural break in volatility.

Although suggestive, the previous results are subject to a very basic criticism. These estimations assume that the sequence of expansions and recessions as captured by the variable $NBER_t$ are completely exogenous and available to the analyst in real time. These assumptions are not realistic. First, there is a lag in the publication of recession dates. For example, the NBER took almost two years to publish the date of the last trough in November 2001. Second, and most important, the NBER uses information on the growth rate of GDP to establish the dates of peaks an troughs and, therefore, the sequence of recessions is an endogenous variable.

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To get around these problems we allow the empirical model to determine when the economy

is located on the different phases of the cycle. One possibility is to use a variant of the Markov

Switching model proposed by Hamilton [12]. In such a model it is possible to identify the phase

of the cycle with an unobservable variable, s_t. In particular, we use the specification of Boldin [3]

and include the possibility that this unobservable variable can take three values associated with

the three states the economy can fall in: expansion (when $s_t = 0$), recession (when $s_t = 1$), or

third phase (when $s_t = 2$). Furthermore, we assume that these three states translate into three

different average GDP growth rates so that we can write

$$y_t = \mu(s_t) + \varepsilon_t \tag{5}$$

with $\varepsilon_t \sim N(0, \sigma^2)$. Thus, the economy presents three average growth rates of GDP depending on

the value taken by the state variable s_t. So, if the data follow the economic intuition behind the

idea of business cycles we should observe that $\mu(2) > \mu(0) > \mu(1)$.

The last element that needs to be specified is the transition matrix governing the unobserved

Markov chain s_t. Let the probabilities of staying in each state be as follows

$$prob(s_t = 0 | s_{t-1} = 0) = p(0)$$

$$prob(s_t = 1 | s_{t-1} = 1) = p(1)$$

$$prob(s_t = 2 | s_{t-1} = 2) = p(2).$$

To apply this model to our analysis we need to design the entries in the transition matrix of the

unobserved Markov chain so that the third phase does not follow an expansion, that a recession

does not follow the third phase and that an expansion does not follow a recession. This amounts

to imposing the following conditional probabilities:

$$prob(s_t = 2 | s_{t-1} = 0) = prob(s_t = 1 | s_{t-1} = 2) = prob(s_t = 0 | s_{t-1} = 1) = 0. \tag{6}$$

The first column of Table 2 presents the results of estimating the previous model. This table

shows that the data moves between three states characterized by growth rates of 0.80 percent,

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-0.41 percent and 1.87 percent, which could be interpreted, respectively, as the expansionary, recessionary and third phases of the cycle. Notice these estimations are very close to the ones we obtained in expression (2) assuming the sequence of expansions and recessions was known.

Next, we include in the estimation the possibility of a structural break in volatility by allowing the variance of the residuals to be different before and after 1984.1. That is, we assume

$$\varepsilon_t \sim N(0, \sigma_t^2) \tag{7}$$

where $\sigma_t^2 = \sigma_1^2$ if $t \leq 1983.4$ and $\sigma_t^2 = \sigma_2^2$ if $t \geq 1984.1$. Furthermore, we allow for this different growth rates after the structural break in volatility by estimating different growth rates for the three states before and after 1984.1. This way, the average growth rate of GDP in state s_t and subsample j will be denoted $\mu_j(s_t)$ where $j = 1$ if $t \leq 1983.4$ and $j = 2$ if $t \geq 1984.1$.

The estimations of the model with the break in volatility are presented on the second column of Table 2. As we can see, augmenting the model improves significantly the value of the likelihood function. A likelihood ratio test rejects the hypothesis of equal models with a p-value of 0.00. To identify the states of the Markov switching process as business cycle phases, we use Figure 6. This figure shows the filtered probabilities of the state variable being in each of the three states. We observe how the probabilities of the state variable taking value 1 are close to 0 except on those quarters identified as recessions by the NBER when the probabilities take very high values. On the other hand, the probabilities of $s_t = 0$ are close to 1 on those quarters identified as expansions by the NBER. These probabilities drop to 0 when recessions start and go back to high values only several quarters after the end of recessions. Finally, the probabilities of the state variable taking value 2 are significantly different from 0 only on the first quarters of expansions. Tentatively, we will call these states as expansions ($s_t = 0$), recessions ($s_t = 1$), and third phase ($s_t = 2$).

These estimations also allow us to compute the expected duration of the three phases of the cycle. For a Markov chain, the expected duration of state s_t is $1/[1 - p(s_t)]$. Thus, the expected duration of expansions, recessions and the third phase are, respectively, 12, 4, and 2 quarters

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approximately. The expected duration of expansions is much larger than that of recessions wile the third phase only covers the two quarters following the end of recessions. In addition, it is worth noting that the expected duration of the third phase that characterizes the beginning of the expansions coincides with the duration that was used to examine the existence of a high recovery phase in figures 2 to 4 and to construct the dummy variable TS_t which is related to the existence of the third phase.

We now compare the estimations for the periods before and after the structural change in volatility. The estimations for the high volatility subsample (estimated variance of 0.77) imply that the growth rate of expansions is 1.12 percent while in recessions the economy grows at -0.28 percent. During the third phase the growth rate of GDP rises to 1.73 percent, higher than both the average of the period and the average of expansions. However, these estimations present a different situation after 1984.1 (estimated variance of 0.17). Expansions now generate a lower growth rate of 0.94 while during recessions in this period the US grows at 0.14, faster than before 1984.1. Furthermore, the most dramatic difference appears in the growth rate during the third phase. In the period of low volatility during the third phase the economy grows just at 0.58 which is not only lower than the growth rates of expansions but also than the average of the period. Thus, with the Great Moderation, the third phase has changed from being a period of high growth to a period of lower than average growth. Noticeably, these two phenomena are contemporaneous.

The consequences of this analysis are as follows: although the US economy has more moderate recessions after the volatility reduction of the mid eighties, the implications of these recessions for the level of output have become more permanent. Many authors linked the third phase with the ability of the economy to return to its growth path making recessions a pure transitory phenomenon. Our evidence shows that not only this third phase has disappeared but following a recession the economy now grows at a rate lower than average making it impossible to rapid return to the previous growth path. Hence, the form of the recoveries has changed from being V-shaped to being L-shaped after the mid eighties.

3   Recoveries and the Great Moderation

In this section we present evidence that links the loss of the third phase of the cycle with the occurrence of the Great Moderation. It is well known that output growth volatility has diminished after the mid-eighties. To characterize the effect of the Great Moderation on the GDP growth rate between 1953.1 and 2006.4, the first column of Table 3 includes several statistics. To start with, the Kolmogorov-Smirnoff test rejects the hypothesis that the growth rates of GDP have been generated by the same distribution before and after 1984.1 (statistic of 0.25 and critical value of 0.17). With respect to the average of GDP growth rate, it is 0.8 percent, dropping to -0.49 percent during recessions and rising to 1.01 percent during expansions (the difference is statistically significant with p-value of 0.00). However, the average growth rate before 1984, 0.82 percent, is not statistically different from that after 1984, 0.77 percent (p-value of 0.35). With respect to the standard deviation, it is 0.92 in recessions which is not statistically different than in expansions, 0.84 (p-value of 0.30). Unlike the averages, though, there are statistically significant differences in the volatility before 1984.1, 1.14, and after that date, 0.50 (p-value of 0.00). This fact can be seen in the differences between the first and the third quartiles of the growth rate before and after the structural change. Finally, Table 3 also presents the results of the supremum, exponential and average tests of structural change in the variance of GDP growth as used in McConnell and Perez Quiros [23]. In line with the results in that paper but using updated samples, we reject the hypothesis of equal variances and date the turning point in 1984.1.

To what extent the loose of the high growth recovery and the volatility reduction are related? To answer this question we propose the following exercises. First, we study whether changes in the estimated expected growth rates of US GDP have contributed significantly to the reduction in volatility. To perform such an exercise, we compute the estimated expected growth rate for each quarter as the average growth rate of each state multiplied by the probability of being in each state.[7] We compute a series for this expected growth rate using the estimated coefficients

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[7] According to our empirical model, GDP growth would be this expected value plus a white noise. Thus, what

for each subsample together with the evolution of the probabilities of being on each state for each quarter of the sample. The estimated series is shown on Figure 7 which reveals a clear reduction in volatility after 1984.1. To check whether this reduction is statistically significant, we compute the supremum, exponential and average tests of structural change in the variance of this series. All these tests show p-values of 0.00 and there fore we reject the hypothesis of equal variances. Thus, there is a structural change in the variance of the estimated expectation of the series of GDP growth.

Second, we want to check to what extent the loss of the third phase of the business cycle is able to explain the reduction in the volatility of the GDP growth rates. We answer this question by generating series with diminishing variance but without the observed changes in the behavior of the third phase and checking its effect in the observed volatility. We perform this counterfactual exercise as follows. To start with the analysis, we generate two sets of 1000 series of simulated growth rates. One set of the series tries to simulate the low volatility subsample. Thus, each of these 1000 series includes 96 draws (the number of observations between 1984.1 and 2006.4) of shocks from a normal distribution with a variance of 0.17 as in the subsample after the structural break. To generate this series of simulated growth rates we combine these shocks with the estimated mean growth rates for the three states as measured by the coefficients $\mu_2(0)$, $\mu_2(1)$, and $\mu_2(2)$ equal to 0.94, 0.14 and 0.58, respectively. The change of states is governed by the estimated transition with parameters $p(0) = 0.91$, $p(1) = 0.77$, and $p(2) = 0.61$.

The other set of 1000 series intends to simulate an scenario with a high variance of shocks but without the existence of a third phase of the business cycle. Thus, each of these series includes 124 draws (the number of observations between 1953.1 and 1983.4) of shocks from a normal distribution with a variance of 0.77 as in the first subsample of the dataset, before the structural break in volatility. In this case, instead of using the mean growth rates for the third phase estimated with the first subsample, we compute a new mean growth rate with similar characteristics than in the

we call third phase is built implicitly on the expected value of GDP growth and not on the noise.

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second subsample. With these computed means we seek to isolate the reduction in volatility from the change in the dynamics among the three phases of the cycle. To construct such mean we look at the differences between the growth rates of the three phases in the low volatility subsample. After 1984.1 the difference in growth rates between expansions and recessions is 0.80 percentage points (that is, 0.94 percent in expansion minus 0.14 percent in recessions). In addition, the difference between the growth rate in the third phase and the growth rate in recessions is 0.44 percentage points (that is, 0.58 percent in the third phase minus 0.14 percent in recessions). Thus, during the Great Moderation, the ratio of the difference in growth rates of the third phase as compared with recessions and the difference of expansions as compared with recessions is 0.55 (0.44 divided by 0.80).

Clearly, the estimated growth rate in the third phase for the period before 1984.1, $\mu_1(2) = 1.73$, does not satisfy the same factor of proportionality with respect to the growth rates of expansions ($\mu_1(0) = 1.12$) and recessions ($\mu_1(1) = -0.28$). Before 1984.1, the difference in growth rates between expansions and recessions is 1.40 (that is, 1.12 percent in expansions minus -0.28 percent in recessions) while the difference in growth rates between third phases and recessions is much larger and equal to 2.01 percentage points (that is, 1.73 percent in the third phase minus -0.28 percent in recessions). Now we want to find the growth rate in a hypothetical third phase whose difference with the growth rate in recessions is scaled down by a factor of 0.55 with respect to the difference in growth rates between expansions and recessions, as it happens after 1984.1. This difference between growth in the third phase and growth in recessions would be 0.55 of 1.40 percent, or 0.77 percentage points. This means that the growth rate of such hypothetical third phase should be 0.49 percent (i.e. -0.28 percent plus 0.77 percent) instead of 1.73 which is the actual growth in the third phase prior to the volatility reduction. Call this constructed growth rate $\widetilde{\mu}_1(2)$.

We then generate the series of simulated growth rates using the draws of shocks with high variance together with the estimated and constructed mean growth rates for the three states as measured by the coefficients $\mu_1(0) = 1.12$, $\mu_1(1) = -0.28$, and $\widetilde{\mu}_1(2) = 0.49$. As before, the change

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of states is governed by the estimated transition with parameters $p(0) = 0.91$, $p(1) = 0.77$, and $p(2) = 0.61$. The average variance across these 1000 simulated series of growth rates is 0.97. This variance represents a reduction of 33 percent with respect to the variance of the series with the estimated growth rate of the third phase of $\mu_1(2) = 1.73$. Thus, if we impose a third phase for the first subsample to be proportional to that of the second subsample, the estimated variance will diminish by one third.

A formal way of evaluating the empirical impact of the elimination of the third phase of the cycle on the reduction in the volatility of the series of GDP growth rates is to test for a structural break in the variance for each of the 1000 pair of series. We apply sequentially the tests to these 1000 replications by assuming that we do not know the moment of the break and keep the maximum. Although the two sets of series have been produced with draws from distributions with different variances, not including the third phase eliminates evidence of the change in volatility in 40% of the simulations. Furthermore, in 14 percent of the rest of simulations where a structural break is found, the estimated break is more than two years away from the true change in volatility. In other words, if the rapid recovery were eliminated from the first subsample the structural break in variance would have probably never be found.

4 The role of inventory management

The previous sections have documented two stylized facts associated with GDP growth rates in the US after the Second World War. First, there has been a change towards a greater stability as defined by a sudden reduction in the volatility of growth rates. Second, business cycles no longer show the high growth phase that used to characterize the beginning of expansions. The simultaneous occurrence of these two facts, at about the mid 80s, suggests that they may have a connection. In this section, we provide evidence to support the idea that these two facts emerged from changes in business practices.

4.1 Inventories and the third phase

We now pursue the idea that the disappearance of the high recovery phase has been associated with a change in the behavior of inventory investment and not of sales. Figures 8 and 9 present, respectively, the contribution to GDP growth of both sales and inventory investment during recessions and for different quarters of expansions together with the average contribution in expansions. Comparing these figures with Figure 2, we can see how the sales contribution to GDP growth does not exhibit the third phase which was evident for GDP. The average contribution of sales at the beginning of the expansions is very similar to the overall average for the expansion as a whole. On the contrary, the contribution of inventories is unusually high on the first two quarters of the expansion. While the average contribution in expansions is 0.06 percentage points, the average contribution during the first two quarters of the expansions is 2.31. This points towards the hypothesis that the existence of a third phase of growth is linked to inventory investment.

Let x_t be the contribution of sales to GDP growth. We could run a similar regression as in (1) to test the relation of the third phase with sales and inventory investment in a more formal way. The estimation of such a regression provides the following results:

$$\widehat{x}_t = \underset{(0.20)}{3.85} - \underset{(0.52)}{4.02} \, NBER_t - \underset{(0.66)}{0.05} \, TS_t. \tag{8}$$

This expression indicates that the contribution of sales to GDP growth in expansions is 3.85 percentage points while in recession (when the variable $NBER_t$ takes value 1) the contribution is reduced to -0.17 percentage points. However, unlike the estimation in (2), the dummy variable TS_t is not statistically significant in this case. Thus, the data shows that for the contribution of sales to GDP growth the first two quarters of each expansion are not different than the rest of the expansion itself. If instead we run the regression with the contribution of inventory investment, variable z_t, the result is

$$\widehat{z}_t = \underset{(0.16)}{0.12} - \underset{(0.41)}{1.69} \, NBER_t + \underset{(0.52)}{2.18} \, TS_t. \tag{9}$$

That is, inventory investment is unusually important in GDP growth during the first two quarters of

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the expansions. Although the contribution of inventories to growth is very low and not statistically significant in expansions, it grows to 2.18 and becomes highly significant if we only consider the first two quarters of expansions.

As a last check that sales have nothing to do with the third phase, nor with the Great Moderation, we run a Markov-switching model similar to the one in column 2 of Table 2 but using data for the growth of sales instead of GDP growth. The model is governed by an unobserved state variable with three states (expansion, recession ad third phase) and is allowed for a structural break in the variance in 1992.4 (the date estimated by the tests presented above). We also allow for the means of the states to be different before and after the volatility break. Figure 10 presents the filtered probabilities of each state. With this figure, we can identify the first two states with expansions and recessions respectively. This is so because of the probabilities that the variable $s_t = 0$ are high in quarters identified as expansions by the NBER while the probabilities that the variable $s_t = 1$ are high in quarters identified as recessions by the NBER. However, the quarters where the state $s_t = 2$ is more likely are quite disperse, without any persistence and difficult to interpret. Finally, the probability of staying in the third state, $p(2)$, is estimated to be only 0.23 which corroborates a lack of persistence of this state for sales.

4.2 Inventories and the Great Moderation

Following the lines suggested by McConnell and Perez Quiros [23], we analyze the causes of the Great Moderation by decomposing GDP into its components. The first decomposition considers GDP as the sum of sales plus the change in inventories. The second column of Table 3 (labelled "V") presents some descriptive statistics plus tests of structural change in volatility for this variable. These tests provide evidence against a structural change in the volatility of the growth of sales as responsible for the structural change in the volatility of GDP growth. The p-values of the tests are much larger (they run from 0.02 to 0.09). Most importantly, had it been a change in the volatility of the growth of sales, it would have happened almost 10 years after the structural break in the

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volatility of GDP growth, around 1992.4. This fact leads to the conclusion that the structural break in GDP could be associated with a change in inventory investment.

Table 3 also presents statistics for the decomposition of GDP into goods production (third column, labelled "B"), services (fourth column, labelled "S") and structures (fifth column, labelled "EST"). We can see how the only variable whose behavior coincides with that of GDP is the production of goods. It is only for this variable that the structural break is situated close to 1984.1 (in fact it is estimated to occur on 1983.4). It is interesting to note that the sales of goods (included in column 6, labelled "VB" on Table 1) do not include a structural break.

Once we have checked that it is the production of goods the component of GDP sharing a similar structural break, it would be interesting to see whether the change occurs in the production of durable or nondurable goods. Column seventh on Table 3, labelled "BND", shows the results for the production of nondurable goods. Although the data produces a break in the volatility of the series on 1985.1, this change is not statistically significant. On the contrary, the production of durable goods (column eighth, labelled "BD") presents a statistically significant break also on 1985.1. With this evidence we can conclude that it is the different behavior in inventory investment, and in particular in the inventory of durable goods, what can be behind the observed changes in the volatility of GDP growth.

Finally, another piece of evidence results from analyzing the contribution of inventories to GDP growth. Let z_t be the part of GDP growth attributable to inventory investment. Regressing this variable on a constant and the dummy variable $NBER_t$ determining the recessionary quarters we obtain the following estimation

$$\widehat{z}_t = \underset{(0.16)}{0.33} - \underset{(0.42)}{1.89} NBER_t. \tag{10}$$

That is, during expansions, inventories contribute 0.33 percentage points to GDP growth. However, during recessions inventories reduce GDP growth by 1.89 percentage points. This amplifying effect of inventories has also changed with the Great Moderation. If we augment the previous regression

by including the dummy variable B_t discriminating between observations before and after 1984.1, we obtain the following:

$$\widehat{z}_t = \underset{(0.22)}{0.54} - \underset{(0.48)}{2.21}\,NBER_t - \underset{(0.32)}{0.44}\,B_t + \underset{(0.11)}{1.07}\,NBER_tB_t. \tag{11}$$

This estimation shows that although inventories contributed to 0.54 percent of GDP growth during expansions in the high volatility period, they now contribute 0.10 percentage points in the expansions after the Great Moderation. Similarly, while inventories reduced GDP growth by 2.21 percentage points in recessions before 1984.1, now they contribute to reducing GDP growth by only 1.14 percentage points during recessions.

4.3   Economic interpretation

So far in this section, we have shown that sales share with GDP the dynamic of recessions and expansions. However it seems that sales do not exhibit the behavior that GDP presents during the third phase of the cycle, nor the sudden reduction in volatility experienced by GDP growth on 1984.1. The explanation of these two phenomena appears to be found in the behavior of inventory investment.

The main reason to hold inventories proposed in the literature is the so-called stockout avoidance theory proposed by Kahn et al. [17], which draws on earlier work by Kahn [15] and Bils and Kahn [2] and has been recently re-stated in Kahn [16] to avoid some counterfactuals implications of the previous formulations.[8] In an economy where production must be decided upon before demand is known, and if demand is correlated over time, firms will also find it profitable to accumulate inventories anticipating future high demand. Thus, as firms tend to overproduce in response to positive demand shocks, this theory predicts output to be more volatile than sales and inventory investment to be positively correlated with sales.

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[8]Kahn [16] re-state the stockout avoidance theory to avoid the conterfactuals implications that "better information" had on the volatility of sales. In particular, it changes from production-to-stock firms to production-to-order.

Figure 11 shows the dynamic variances of GDP growth and the contribution of sales to GDP growth. Figure 12 presents the dynamic correlations between the contributions to GDP growth of sales and inventory investment. Both series are computed using a six year window. As we can see, output has gone from being more volatile than sales to be equally or less volatile. Furthermore, the correlation between sales and inventory investment has gone from being mostly positive to be continuously negative. Interestingly, both changes have occurred in the mid 80s, right after the beginning of the Great Moderation and the loss of the high recovery phase.

Looking at the theories that rationalize the use of inventories, it seems that firms have changed their need to hold inventories. According to Kahn [16], this change could have been motivated by the improvements in the production and information technologies observed in the mid 80s. Improvements in technologies of information and communication have allowed firms to externalize the production process making this production process more flexible to the market conditions. Furthermore, improvements in the information technologies (bar codes, digital technologies, client fidelization programs, and the like) allow firms to know in a more timely fashion changes in the tastes and needs of their buyers. All these changes reduce the production lags and, therefore, reduce the need to maintain a inventory stock positively correlated with the level of sales to satisfy the demand of clients.

5 Conclusions

For many economists, the Great Moderation is interpreted as good news. As cycles are now smoother, the negative effect of recessions is also smaller. However, this paper presents evidence that the high growth recoveries observed after the mid eighties are no longer present in the last two expansions. Recoveries, that were "V-shaped", have become "L-shaped". Hence, although recessions are now not as deep as before 1984, it takes the economy longer to recover. Many economists, which viewed the rapid recoveries from recessions as evidence in favor of transitory

effects of recessions, would interpret this result as if the effect of recessions have become permanent.

We have also shown evidence that links both phenomena to changes in the behavior of inventory investment. Before the middle of the 80s inventories contributed to amplify business cycles increasing the volatility of production over sales while after the mid 80s inventory investment reduced the volatility of production over sales. Thus, inventory management seems to have switched from trying to avoid stockouts to allow a smoother production process. A part of the explanation of this change in attitude towards inventory management could arrive from the generalization of practices linked to the information technologies. Thus, firms do not need to maintain costly inventories to satisfy their demand but can order their products to other firms down the production line. This externalization together with the introduction of improvements like the bar codes and digital technology have reduced production lags. Furthermore improvements in information technology have provide firms with more knowledge of changes in consumer tastes and needs. All these changes reduce the need to hold inventories to avoid stockouts and the opportunity costs associated with not servicing the demand.

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Table 1. Business cycle features

Period	Duration		Amplitude (%)		Excess (%)	
	expans.	recess.	expans.	recess.	expans.	recess.
53.1-06.4	20.33	3.44	20.37	-1.74	1.32	-0.02
53.1-83.4	17.57	3.71	19.39	-2.10	1.75	-0.25
84.1-06.4	30.00	2.50	23.78	-0.46	-0.18	-0.04
I (54.3)	13	4	12.41	-2.61	1.78	-0.40
II (58.3)	8	3	10.89	-3.27	1.68	-0.50
III (61.2)	35	3	41.00	-0.55	2.91	-0.15
IV (71.1)	12	4	14.97	-0.18	0.73	0.26
V (75.2)	20	5	20.69	-3.17	1.44	0.27
VI (80.4)	4	2	4.22	-2.23	0.58	-0.47
VII (83.1)	31	5	31.56	-2.69	3.13	-0.80
VIII (91.2)	40	2	33.65	-1.27	-0.32	-0.06
IX (02.1)	20	3	13.91	0.35	-0.04	-0.03

Note. For the period 84.1-06.4 we have only considered data for the last two expansions. Periods I to IX refer to 54.3-57.3, 58.3-60.2, 61.2-69.4, 71.1-73.4, 75.2-80.1, 80.4-81.3, 83.1-90.3, 91.2-01.2, and 02.1-06.4 for expansions and 53.3-54.2, 57.4-58.2, 60.3-61.1, 70.1-70.4, 74.1-75.1, 80.2-80.3, 81.4-82.4, 90.4-91.1, and 01.2-01.4 for recessions. For reference, the initial quarter of the corresponding recession is included in parenthesis.

Table 2. Estimation of Markov-switching model

	MS1		MS2		MS3	
	value	std. err.	value	std. err.	value	std. err.
$\mu_1(0)$	0.80	(0.07)	1.12	(0.18)	1.10	(0.09)
$\mu_1(1)$	-0.41	(0.18)	-0.28	(0.24)	0.05	(0.17)
$\mu_1(2)$	1.87	(0.23)	1.73	(0.33)	0.88	(0.44)
$\mu_2(0)$			0.94	(0.07)	0.87	(0.06)
$\mu_2(1)$			0.14	(0.23)	0.36	(0.13)
$\mu_2(2)$			0.58	(0.24)	1.26	(0.34)
σ_1^2	0.66	(0.04)	0.77	(0.13)	0.46	(0.06)
σ_2^2			0.17	(0.03)	0.13	(0.03)
$p(0)$	0.93	(0.02)	0.91	(0.04)	0.93	(0.03)
$p(1)$	0.68	(0.10)	0.77	(0.08)	0.81	(0.07)
$p(2)$	0.71	(0.09)	0.61	(0.19)	0.23	(0.36)
$\ln(L)$	-69.3		-49.7		-18.3	

Note. The columns labelled "MS1" and "MS2" refer to different specifications for GDP growth rate, with and Without structural change in 1984.1. The columns labelled "MS3" refer to the growth rates of sales.

Table 3. Statistics for GDP and components

|	GDP	V	B	S	EST	VB	BD	BND	VBD	VBND
Business cycle facts										
Mean										
total	0.80	0.80	0.90	0.79	0.56	0.90	1.25	0.67	1.24	0.66
recessions	-0.49	-0.10	-1.33	0.44	-1.12	-0.41	-3.40	0.06	-1.49	0.33
expansions	1.01	0.94	1.27	0.85	0.84	1.12	2.01	0.76	1.69	0.71
test[1]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
before	0.82	0.82	0.86	0.98	0.59	0.86	1.23	0.70	1.20	0.67
after	0.77	0.86	0.95	0.70	0.48	1.00	1.29	0.62	1.33	0.64
test[1]	0.35	0.31	0.35	0.00	0.38	0.22	0.45	0.35	0.37	0.39
Standard deviation										
total	0.92	0.74	1.75	0.62	2.33	1.26	3.70	1.52	2.49	0.89
recessions	0.84	0.82	1.71	0.82	2.85	1.36	4.42	1.55	2.67	1.12
expansions	0.74	0.61	1.47	0.56	2.10	1.10	2.94	1.50	2.15	0.83
test[2]	0.30	0.02	0.20	0.00	0.01	0.09	0.00	0.71	0.08	0.02
before	1.14	0.83	2.13	0.95	2.56	1.35	4.57	1.72	2.76	0.97
after	0.50	0.42	1.11	0.35	1.35	0.99	1.94	1.19	1.77	0.74
test[2]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Change in volatility										
Wilconxon test for equality in quartiles before and after 1984.1										
First quartile										
total	0.30	0.34	-0.15	0.49	-0.68	0.22	-0.25	-0.30	0.02	0.20
before	0.15	0.23	-0.50	0.47	-0.89	0.12	-1.07	-0.45	-0.12	0.20
after	0.50	0.48	0.34	0.50	-0.23	0.42	0.25	-0.30	0.11	0.17
test[3]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Third quartile										
total	1.30	1.25	2.01	1.05	1.87	1.61	3.24	1.51	2.71	1.13
before	1.71	1.37	2.29	1.44	2.08	1.63	3.85	1.61	2.82	1.25
after	1.10	1.05	1.78	0.69	1.20	1.58	2.48	1.42	2.51	1.05
test[3]	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.03	0.05	0.00
Kolmogorov-Smirnov test of equality of distributions before and after 1984.1										
statistic	0.25	0.19	0.18	0.35	0.19	0.15	0.21	0.09	0.11	0.11
crit. value	1.17	0.18	0.17	0.18	0.19	0.18	0.17	1.17	0.17	0.17
Tests of structural change										
date	84.1	92.4	83.4	70.1	94.1	91.4	85.1	85.1	90.4	86.1
supremum[4]	0.00	0.09	0.01	0.02	0.05	0.99	0.01	0.35	0.68	0.93
exponential[4]	0.00	0.04	0.00	0.00	0.02	0.89	0.00	0.13	0.51	0.68
average[4]	0.00	0.02	0.00	0.00	0.03	0.86	0.00	0.08	0.50	0.64

Note. The series are GDP, final sales (V), goods production (B), production of services (S), production of structures (EST), final goods sales (VB), production of durable goods (BD), production of nondurable goods (BND), sales of durable goods (VBD) and sales of non durable goods (VBND). The *p*-values refer to the following null hypothesis: (1) means are not different, (2) Barlett test for equal standard deviations, (3) quartiles are the same, and (4) McConnel and Pérez Quirós test of no change in volatility.
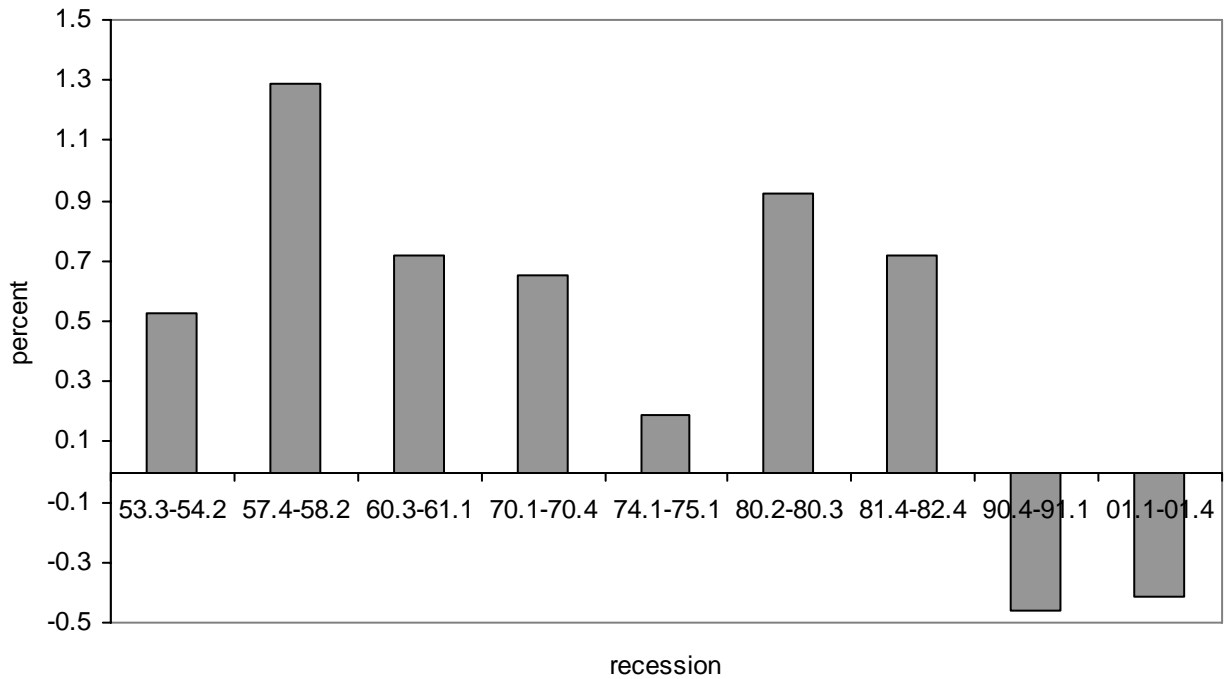
Figure 1: GDP growth rates 1953.1-2006.4
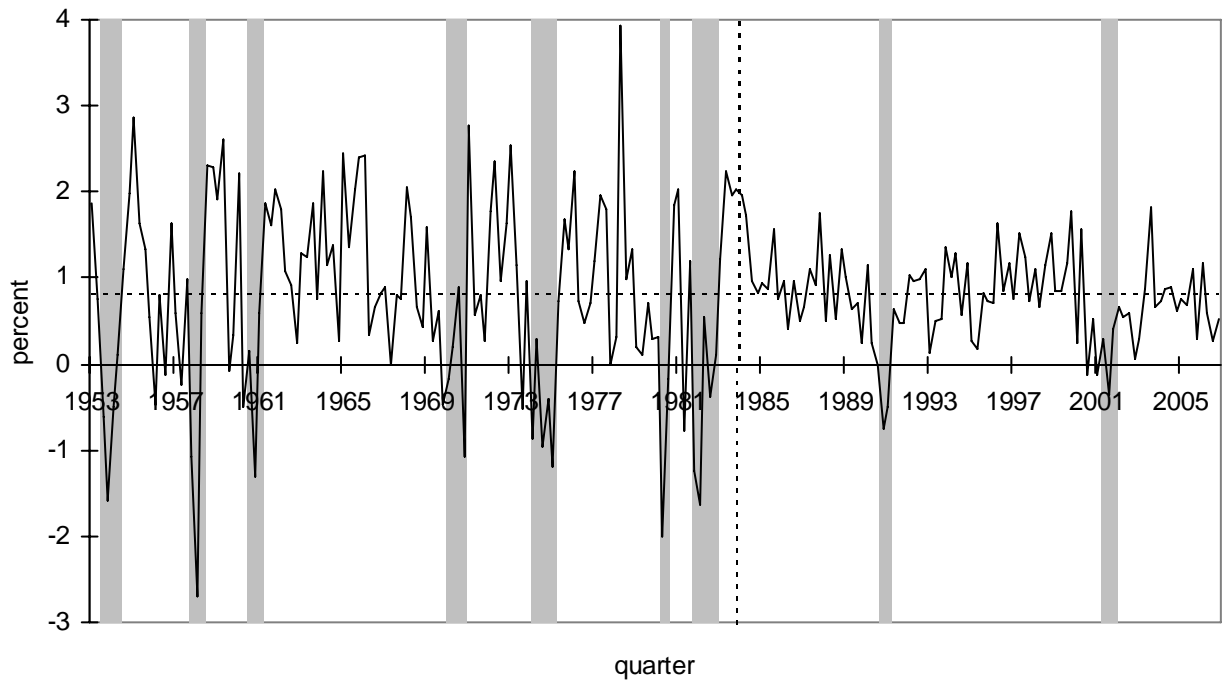
Note: Shaded areas correspond to recessions as documented by the NBER. The vertical discontinuous line refers to 1984.1. The horizontal discontinuous line represents the average growth rate of the whole sample.

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Figure 2: Growth rates for different quarters of the cycle
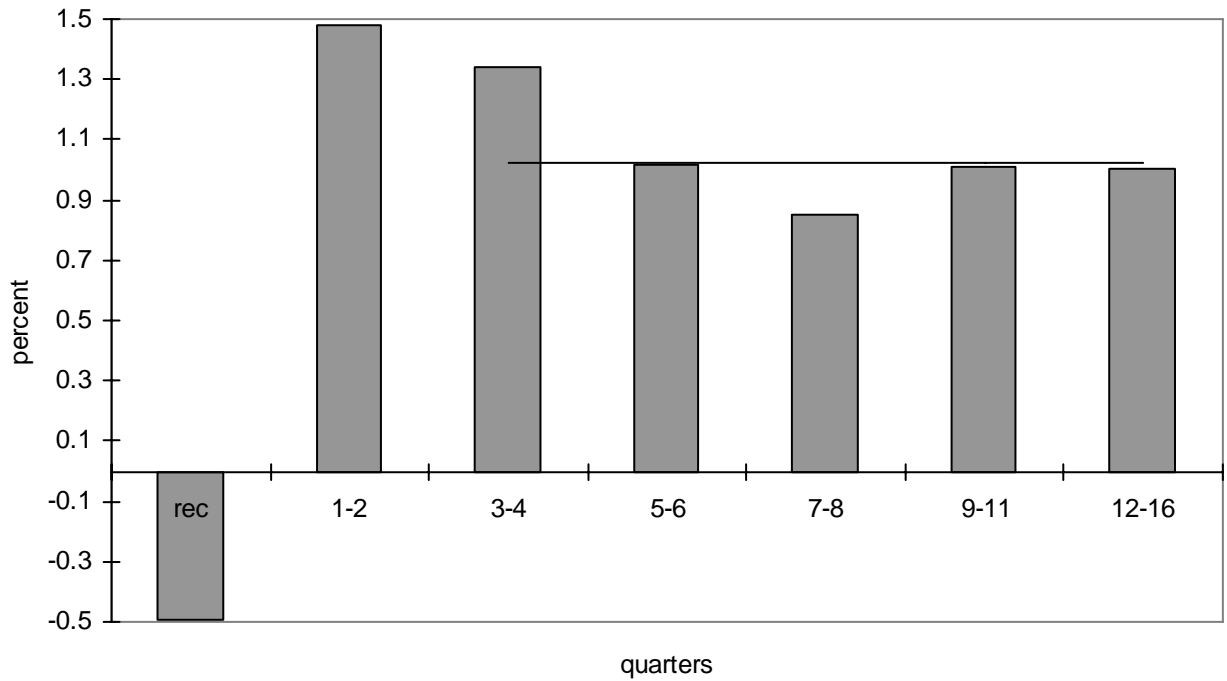
Note: Average growth rates for recessions and for different quarters in expansions.

Figure 3: Relative growth rate in the first two quarters of expansions

Note: Average growth rates for the first two quarters of expansions minus the average growth rate of expansions.

Figure 4: Relative growth rates for twe first two quarters of recessions
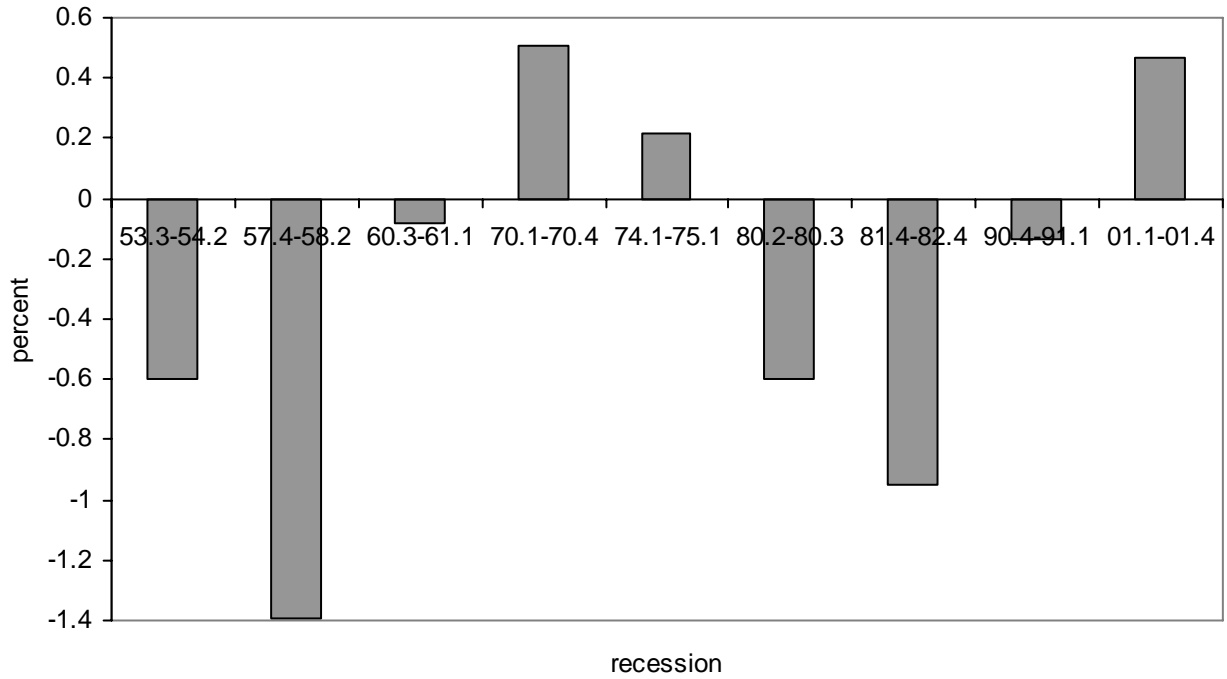
Note: Average growth rates for the first two quarters of recessions minus average growth rate of recessions.

Figure 5: Stylized cycles
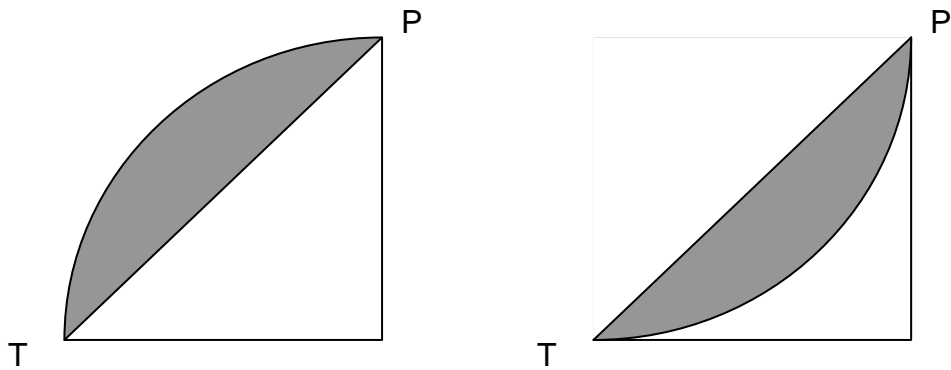
Note: The letter P refers to the peak of the cycle while the letter T refers to the trough.

Figure 6: Filtered probabilities for the growth rate of GDP
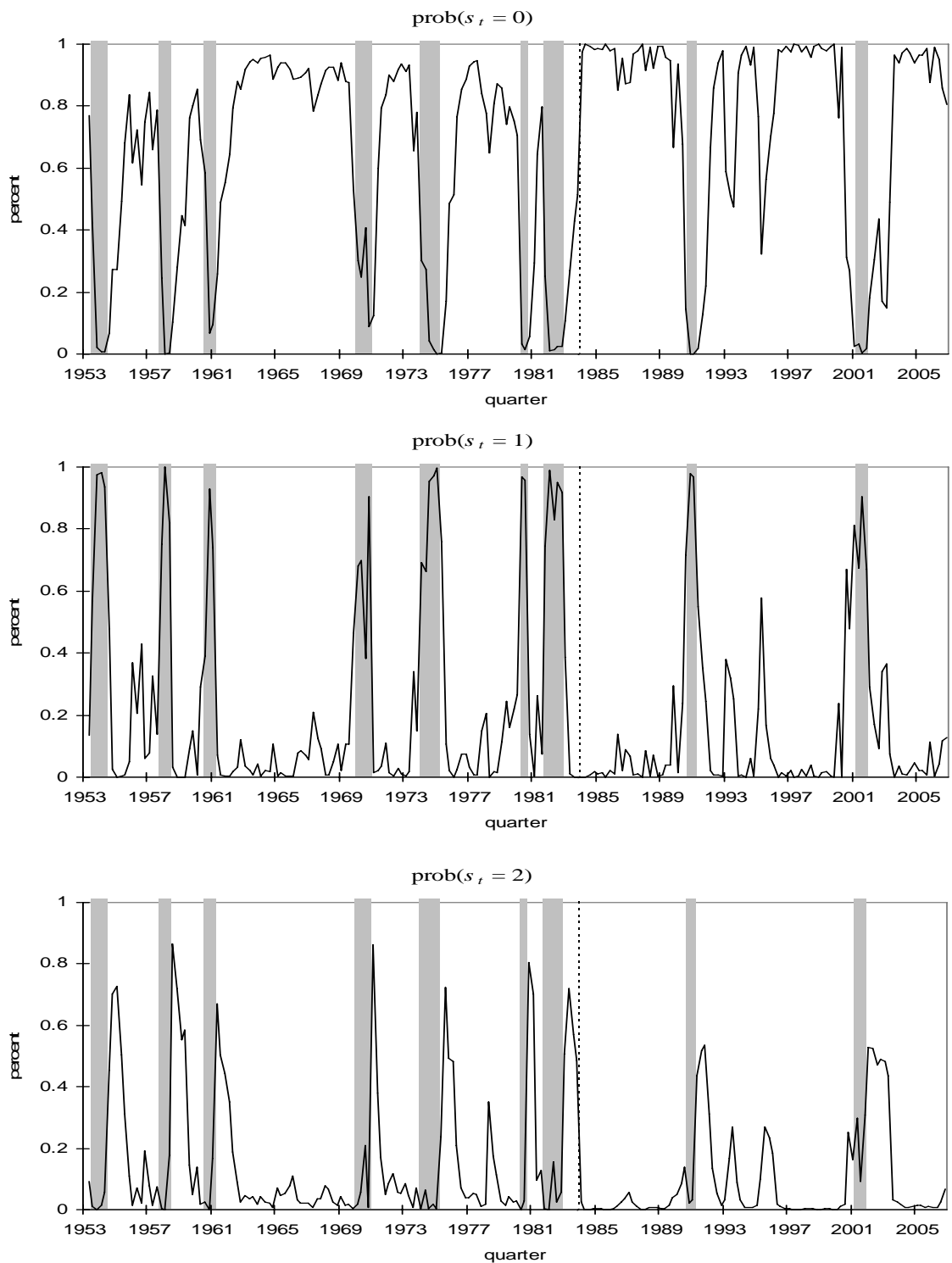
prob($s_t = 0$)

prob($s_t = 1$)

prob($s_t = 2$)

Note: Shaded areas correspond to recessions as documented by the NBER. The vertical discontinuous line refers to 1984.1.

Figure 7: Estimated GDP growth rates
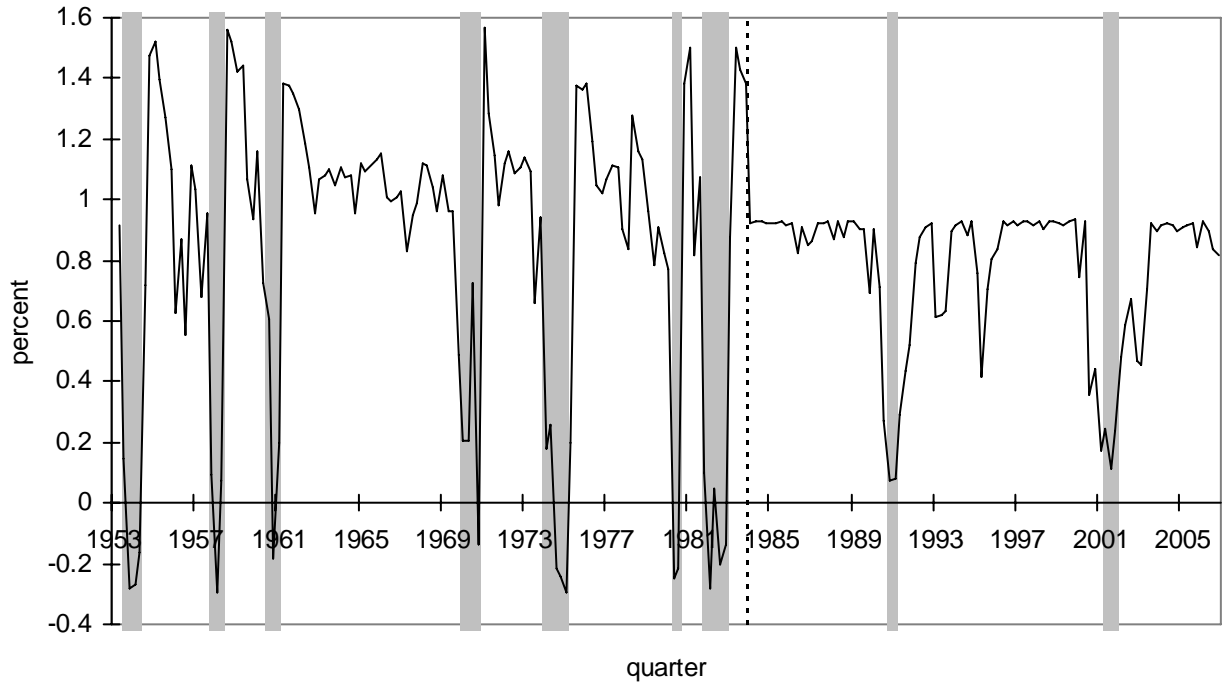
Note: Shaded areas correspond to recessions as documented by the NBER. The vertical discontinuous line refers to 1984.1.

Figure 8: Average contribution of sales to GDP growth
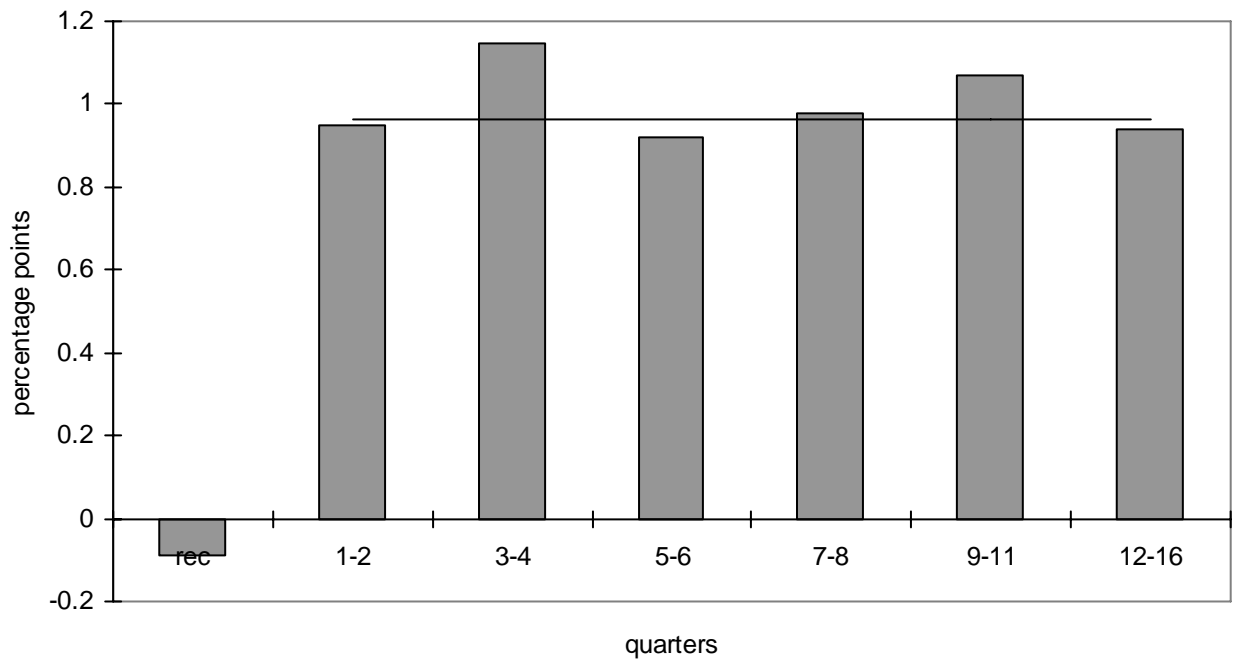
Note: Average contribution of sales to GDP growth for recessions and for several quarters in expansions.

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Figure 9: Average contribution of inventories to GDP growth
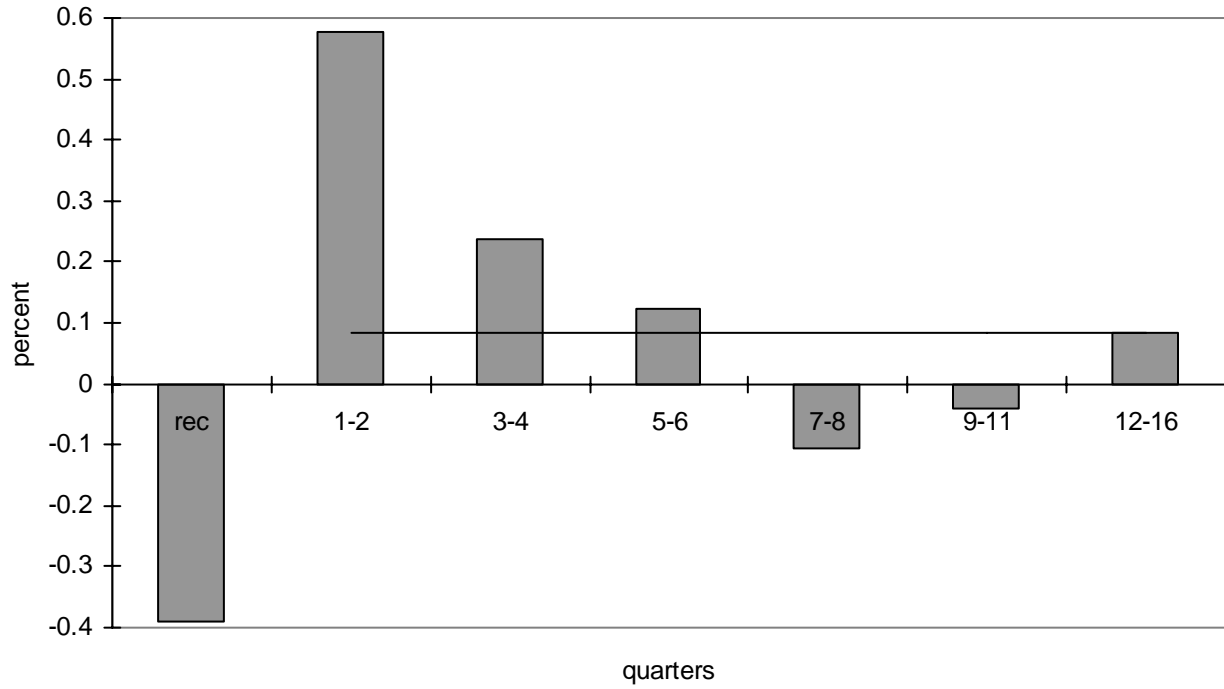
Note: Average contribution of inventories to GDP growth for recessions and for different quarters in expansions.

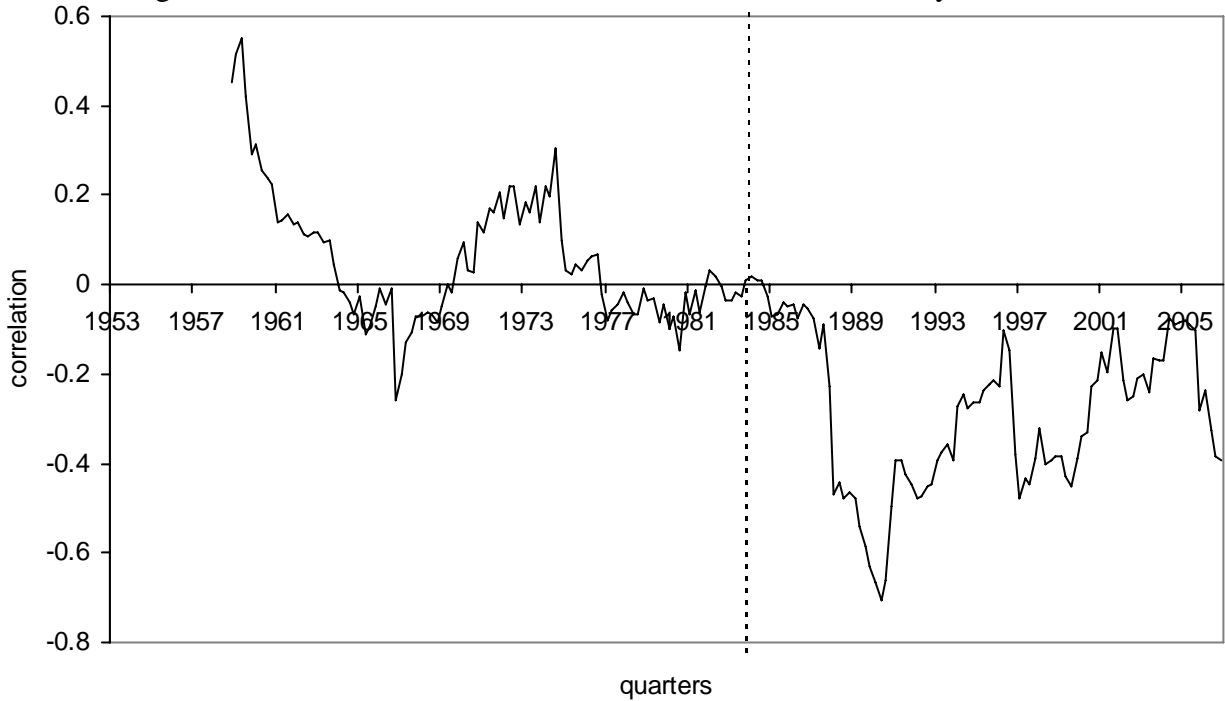# Figure 10: Filtered probabilities for the growth rate of sales
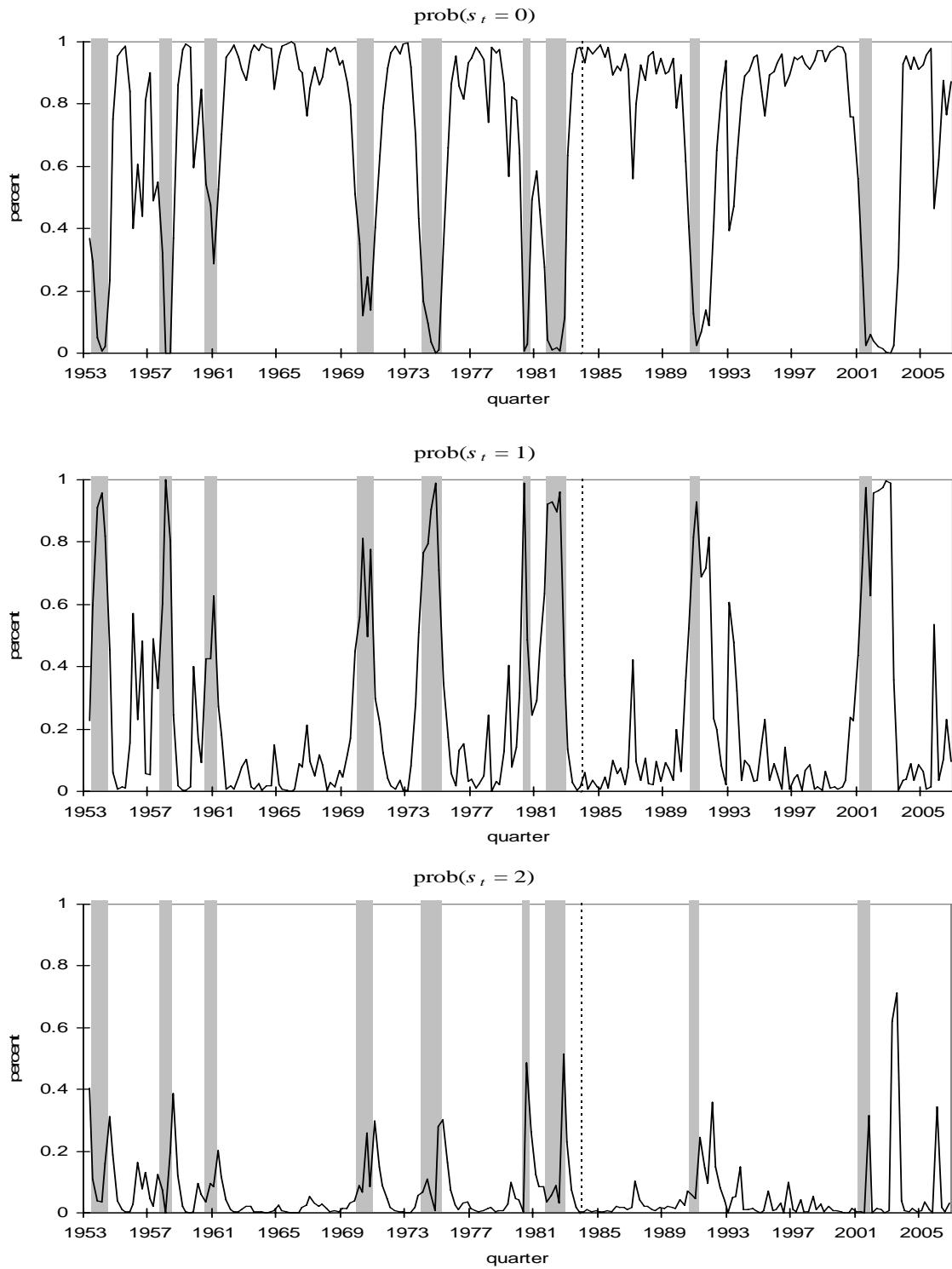
prob($s_t = 0$)

prob($s_t = 1$)

prob($s_t = 2$)

Note: Shaded areas correspond to recessions as documented by the NBER. The vertical discontinuous line refers to 1984.1.

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Figure 11: Variances of GDP growth rates and contributions of sales
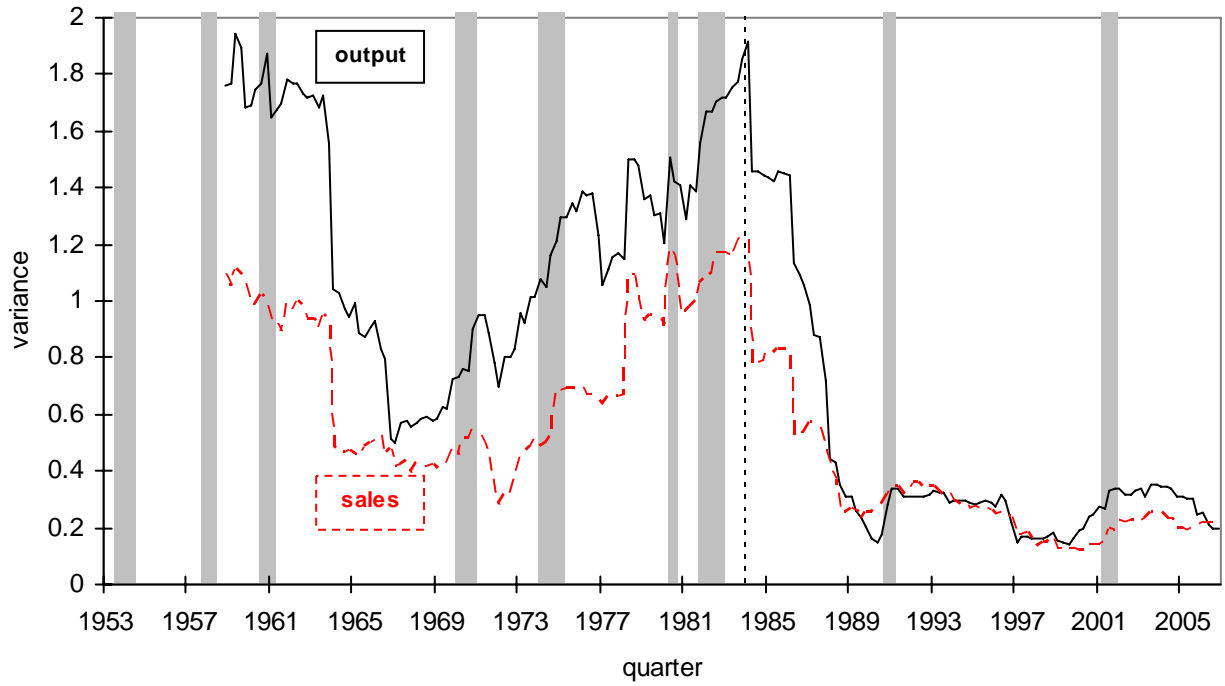
Note: Shaded areas correspond to recessions as documented by the NBER. The vertical discontinuous line refers to 1984.1.

Figure 12: Correlations between contributions of sales and inventory investment

Note: Shaded areas correspond to recessions as documented by the NBER. The vertical discontinuous line refers to 1984.1.