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Structural Change and Business Cycle Fluctuations in Japan: Revisiting the Stylized Facts

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Abstract

The Japanese economy has experienced massive structural changes since the end of the 1990s, including a decline in the working-age population, a decade of deflation, an increase in the number of non-regular workers, which has almost doubled since the early 1990s, contributing to a large reduction in wage costs, and rapid advances in globalization. What are the implications of such changes for Japan's business cycle dynamics? This paper analyzes the stylized facts of Japanese business cycle fluctuations under structural change.

The results, based on traditional frequency domain analysis using more than 60 quarterly macroeconomic time series, provide robust findings. Among the most interesting ones is that scheduled hours worked play an increasingly important role as a buffer for labor input, suggesting that Japanese firms tend to adjust their labor input through hours worked, owing, in part, to the increasing number of non-regular workers, which allows firms to adjust labor input in a relatively flexible manner while keeping the number of employees unchanged. The increased role of hours worked is confirmed by an analysis based on a time-varying parameter structural vector autoregression (TVP-VAR) model taking the time-varying nature of the underlying structure of the economy into account. Meanwhile, in other areas such as private consumption and investment, wages, deflators and prices, and financial market indicators, the basic nature of business cycle fluctuations has remained broadly unchanged, implying that structural change does not necessarily affect the cyclical regularities in all macroeconomic time series.

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1. Introduction

Apart from the question why economies grow, which is the focus of growth theory, a key issue in macroeconomics is why economic activity fluctuates – that is, why there are business cycles. Understanding the source and nature of business cycle characteristics is important not only from an academic perspective, but also from a policy-making perspective in order to gauge the overall state of the economy and to devise effective economic policies.

Advances in economic theory and empirical techniques have substantially increased our understanding of business cycles, so that a range of basic business cycle characteristics – or "stylized facts" – that to a degree can be regarded as universal and constant over time have been identified. At the same time, however, it is also easily conceivable that if there are substantial changes in the underlying structure of the economy, the characteristics of business cycles may also change as a result.

Figures 1 and 2 show the cyclical component and the trend component of developments in Japan's real gross domestic product (GDP) from the mid-1980s onward. The figures indicate that whereas business cycles, which are represented by the cyclical component of real GDP, fluctuate with some regularity within a certain range, the overall trend of the economy displays a decline in the slope around the mid-1990s. Given this change in the trend growth rate of the economy against the background of a host of structural changes, the question naturally arises whether any changes in business cycle developments can be observed.

The aim of this study is to examine this question in detail. To this end, the study starts by dividing the period from 1980 onward into two subperiods – with the period up to 2000 regarded as the period before and the period from 2000 onward as the period after substantial structural change – and investigating and comparing the characteristics of business cycles before and after this year. The analysis shows that particularly notable changes can be observed in the way firms adjust labor input. Therefore, in the next step, a time-varying parameter structural vector autoregression (TVP-VAR) model taking the time-varying nature of the underlying structure of the economy into account is estimated in order to examine these changes in the way labor input is adjusted more detail.

In the literature on business cycles studies, there was an active debate before the global financial crisis on the so-called "Great Moderation" referring to the decline in output volatility observed from the 1980s onward in the United States (see, e.g., Kim and Nelson (1999), McConnell and Perez-Quiros (2000), Chauvet and Potter (2001), Stock and

Watson (2002)).[1] The literature has offered various explanations for this stabilization of the macro-economy, focusing primarily on changes in economic structure, improved macro-economic policies, and the absence of major economic shocks. For example, Kim and Nelson (1999) argue that the volatility of economic shocks has declined and that differences between growth rates during booms and busts were also smaller than in the past, while McConnell and Perez-Quiros (2000) argue that the volatility of durable goods production including inventories has decreased. Meanwhile, Stock and Watson (2002) cited improved economic policies as well as the absence of negative economic shocks such as productivity and commodity price shocks. While the "Great Moderation" had been regarded as a permanent phenomenon, following the global financial crisis, the focus of the debate appears to have shifted to the role of structural issues as exemplified by the "secular stagnation" hypothesis by Summers (2014).

This study investigates developments in Japan's business cycles under structural change, including the impact of economic shocks such as the global financial crisis, based on the conventional approach of frequency domain analysis. Employing more than 60 macroeconomic time series that, in addition to GDP demand components, include a wide range of areas such as aggregate employment, wages, deflators and prices, interest rates and stock prices, money, exchange rates, and overseas economies, the analysis seeks to identify in which areas changes in business cycle characteristics can or cannot be observed. Although business cycle characteristics, as mentioned above, to a degree can be regarded as universal, the results indicate that they are not immutable. Specifically, notable changes can be observed in hours worked and employment, while in other areas business cycle characteristics do not show substantial changes despite structural changes in the economy.

Given these findings, in order to examine the causes and implications of changes in business cycle characteristics where they are observed, a TVP-VAR model is developed, allowing the analysis of business cycle trends in a robust manner. While TVP-VAR models have been mainly used in the field of monetary policy analysis, they also lend themselves to the analysis of business cycle dynamics.

The remainder of this study is organized as follows. Section 2 attempts to identify the point in time at which to split the observation period into a period before and a period after structural change. Section 3 then outlines the frequency domain analysis employed in this study. Next, Section 4 empirically examines the business cycle characteristics before and after the structural change and investigates changes in these characteristics. In

[1] General interest in the topic also increased, triggered by the then-Federal Reserve Chairman Bernanke's speech on "The Great Moderation" in 2004. Meanwhile, Blanchard and Simon (2001), for example, report that the decline in output and inflation volatility could be observed not only in the United States but other advanced economies as well.

addition, Section 5 focuses on the mechanism through which firms adjust their labor input, which is where especially notable change can be observed, and presents analyses using the TVP-VAR model. Finally, Section 6 concludes.

2. Examination of economic structural change

While structural change tends to be a gradual process consisting of a variety of overlapping developments, for the purpose of the analysis here it is useful to divide the observation period from 1980 to 2016 into two subperiods in order to elicit the impact of structural changes on the business cycle. This means that it is necessary to identify a point in time at which to split the observation period. The approach taken here is to test for parameter stability, and for simplicity the period before the point in time thus identified will be referred to as the period before structural change, and the period after that point in time as the period after structural change.

A basic assumption of time-series analysis is that the structure of the data is constant over time; however, this assumption sometimes is unrealistic. Taking Japan's GDP as an example, if changes in the environment such as the demographic structure or economic relations with the rest of the world affect the way that economic variables interact with each other, such changes are likely to give rise to changes in the data generation process as well. Moreover, when there are major shocks such as the rise of Japan's bubble economy during the second half of the 1980s and its subsequent collapse, the Asian financial crisis (in the late 1990s), or the global financial crisis triggered by the Lehman shock (in the late 2000s), it is possible that such shocks – even if the shocks themselves may be only temporary – affect the data generation process later down the road.

As mentioned, such structural change does not occur overnight but generally develops over a certain period of time, so that it would not make sense to assume that there exists a specific point in time in which there is a structural break. Rather, it makes more sense to regard structural change as a cumulative process, in which changes build up over time. Therefore, the approach taken in this study is to run the sequential CUSUM test to examine when a statistically significant change in the structure of the data generation process in the model can be observed in order to divide our observation period into two subperiods. Specifically, the estimation is conducted by simply regressing the real GDP data shown in Figure 2 on a deterministic linear trend.

The CUSUM test result indicates that the cumulative sum of forecast errors began to diverge from a value of 0 (which indicates that the prediction is unbiased and that the model explains the data well) around the mid-1990s and starts to deviate from the 95 percent confidence interval in 1998, so that the null hypothesis that there is no change in the structure of the model is rejected (Figure 3).[2]

The findings suggest that Japan's economy experienced substantial structural change in the late 1990s, so that in the analysis below the observation period will be divided into two subperiod in order to investigate changes in business cycle characteristics. Specifically, the period will be split at the first quarter of 1999, which represents the beginning of Japan's 13th postwar business cycle, with the period from the start of the observation period in 1980Q1 to 1999Q1 referred to as the "period before 2000" for convenience and the period from 1999Q1 to 2016Q3, the end of the observation period, referred to as the "period from 2000."

In facts, Japan's economy has experienced various structural changes since the end of the 1990s: on the supply side, the working age population has started to decline reflecting the aging and shrinking of Japan's population; on the demand side, a chronic lack of demand has led to persistent deflation and zero interest rates; in terms of economic structure, the transformation toward a service-based economy has continued, while in the labor market wages have fallen and non-regular employment has increased; meanwhile, in the corporate sector saving has increased, and looking abroad, globalization has continued to advanced. Given these myriad changes, let us now turn to examining how the characteristics of business cycles have changed.

3. Frequency domain analysis framework

To empirically characterize the business cycle fluctuations based on the observable macroeconomic time series, the conventional approach is applied, using a band-pass filter (BP filter) following Stock and Watson (1999).[3]

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[2] This result is also consistent with the non-linear trend observed in Figure 2. Furthermore, rolling regressions based on the model mentioned above to examine changes in the parameter over time show that from the mid-1990s onward the parameter value more or less halved in size.

[3] Starting with Beveridge and Nelson (1981), various methods of extracting the cyclical component from time-series data, including filtering methods, have been proposed; however, none of these methods can provide a definite answer in terms of decomposing an observed variable into trend and cycle. For example, regarding the widely used Hodrick-Prescott (HP) filter, King and Rebelo (1993) point out that while the HP filter can render stationary any non-stationary process up to the fourth order, results with desirable properties can only be obtained when applying it to integrated processes up to the second order; moreover, Cogley and Nason (1995), among other things, point out that while time-series of many macroeconomic variables are integrated at the first order, applying the HP filter to such processes is equivalent to detrending a random walk process, so that applying the HP filter to a difference stationary process can generate spurious cyclicality. Further, Hamilton (2017) recently again highlighted the limitations of the use of the HP filter, reiterating the points above, and as an alternative for extracting the cyclical component proposed using the forecast errors from regression models.

The frequency domain analysis used in this study also cannot escape from the distorting effect of using approximate filters on the pre-filtered series of the time series data, and when using a filter, it is essential not only to understand its limitations and but also to check the validity of the results obtained, including the economic interpretation. Therefore, to check the results obtained used the BP filter, their consistency with the conventional understanding of business cycles,

3.1 BP Filter

The BP filter is a technique that makes it possible to extract nonlinear trends. Specifically, it retains the cyclical component of each series within a specific band of frequency, and removes other components. It can therefore be used to decompose a series into its low, high, and intermediate frequency components, which are regarded as the trend, irregular, and business cycle components, respectively, in order to distinguish between the business cycle component and other components. Denoting the series before filtering by y_t and the series obtained by applying the BP filter to y_t by x_t yields the following relationship:

$$x_t = B(L)y_t,$$

where the BP filter, $B(L)$, is an ideal moving average with symmetric weights and can be represented as follows:

$$B(L) = \sum_{k=-\infty}^{\infty} B_k L^k$$

where L is the lag operator and $B_k = B_{-k}$ for all k. The BP filter can then be represented by the frequency response function based on the Fourier Transform:

$$B(e^{-i\lambda}) = B_0 + B_1 e^{-i\lambda} + B_2 e^{-i2\lambda} +, \quad , + B_k e^{-ik\lambda},$$

where $e^{-i\lambda} = \cos\lambda - i\sin\lambda$. Finally, a component belonging to the desired frequency band can be extracted employing the following frequency response function, which takes a value of 1 for frequencies to be extracted and 0 otherwise:

$$B(e^{-i\lambda}) = \begin{cases} 1 \quad if\ \lambda \in \{(\underline{\lambda}, \overline{\lambda}) \cup (-\underline{\lambda}, -\overline{\lambda})\}, & \lambda \in [-\pi, \pi] \\ 0 \quad & otherwise \end{cases}$$

including the cyclical regularities of macroeconomic series, is examined. Moreover, the robustness of the results for hours worked and employment, for which notable changes in business cycle characteristics are found, is checked using an alternative approach based on a TVP-VAR model.

where $\underline{\lambda}$ is the low cut frequency and $\overline{\lambda}$ is the high cut frequency.

When using the BP filter, it is necessary to arbitrarily set the length of the cycle of the cyclical component to be extracted. Following previous studies, for the analysis here, the cyclical component in the range from 6 to 32 quarters is extracted from each macroeconomic time series, and the cyclical component of real GDP is defined as the business cycle.[4]

3.2 Data description and statistics

In order to characterize the business cycle fluctuations based on the macroeconomic time series, several conventional statistics are employed: the standard deviation, the first order auto-correlation of the cyclical component of each series (x_t), and six orders of cross-correlation of the cyclical component of each series with the cyclical component of real GDP (gdp_{t+k}, where k represents the k quarter lag or lead of real GDP). The standard deviation and the cross-correlation of each series with real GDP measure the size of the variation in each series and the strength of its correlation with the cyclical component of real output respectively, assuming that series x_t is procyclical if its cross-correlation is positive and countercyclical if its cross-correlation is negative; moreover, series x_t is said to lag real GDP if its maximum correlation lags real GDP observations.

Turning to the data used for the analysis, more than 60 quarterly macroeconomic time series spanning a wide range of fields will be examined. As mentioned, the data will be split into the period before 2000 and the period from 2000 onward to investigate the business cycle characteristics during each of the periods and compare them.[5]

4. Business cycle characteristics and changes therein

4. 1 Business cycle characteristics before 2000

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[4] For the analysis of business cycles using the BP filter, Baxter and King (1999) and Christiano and Fitzgerald (2003) respectively propose what are called the Baxter-King Filter (BK Filter) and the Cristiano-Fitzgerald Filter (CF Filter). Since the BP filter is constructed on the premise of infinite data, in practice some sort of approximation is needed. The BK filter therefore imposes the restrictions that the weights of the filter are symmetrical and sum to zero, limiting the number of terms of the moving average (generally, 12 period lags and leads are used), while in the case of the CF filter, filtering is applied to all data from the beginning to the end of the observation period, adjusting the weights at the end of the observation period. In this study, the BK filter (with a 12 period lag and lead) is used for examining business cycle characteristics.

[5] For the analysis, all variables except for rates of change, ratios, interest rates, etc., are expressed in logarithm and then filtered. Regarding the GDP data, as of September 2017, data based on the Benchmark Year Revision of 2011 have been released only going back to 1994, so that in this study, values based on the Benchmark Year 2005, which are available back to 1980, are used. However, as shown in Figure 1, the cyclical component of real GDP is roughly the same based on both benchmark years.

In order to examine changes in business cycle characteristics under economic structural change, this section starts by outlining business cycle characteristics before 2000 (i.e., the period before structural changes). Table 1 shows the statistics for the cyclical component of each series before 2000. Regarding the demand components of GDP, the results are essentially in line with those reported by Urasawa (2008), who examined business cycle characteristics up to early 2000. They can be summarized as follows:

- The most stable GDP component is private consumption. On the other hand, investment, exports, and imports are the most volatile components. As regards cyclicality, except for government expenditure, all items are procyclical.
- While private non-residential investment is procyclical with a lag, housing investment is procyclical with a lead. On the other hand, public investment and government consumption are both countercyclical and lag the business cycle.
- Both exports and imports are procyclical; however, while exports are almost coincident with the business cycle, imports lead the business cycle.

Turning to employment, aggregate employment, hours worked, and labor productivity are all procyclical; on the other hand, the unemployment rate – in line with Okun's Law – is countercyclical and strongly correlated with the business cycle; furthermore, it lags the economy. Looking at the cyclical volatility, all of the variables fluctuate less than output.

Examining employment in more detail shows that the number of employed persons, the number of employees, and the regular employment index are all procyclical and lag the business cycle. This result likely reflects the traditional pattern of labor input adjustment in Japan whereby in the early stages of an upswing or downswing, it is not the number of employees but hours worked that are adjusted. That is, when the economy is recovering or entering a recession, labor input is first adjusted through an increase or decrease of hours worked, while the number of employees is adjusted only when necessary, so that employment is affected only with a lag.

Looking at hours worked in more detail indicates that nonscheduled hours worked are procyclical with a lead, and very volatile. As mentioned earlier, this can interpreted as reflecting the particular way in which labor input is adjusted in Japan; that is, in the transitional phase of the business cycle when firms start to adjust output levels, they adjust labor input by first adjusting nonscheduled hours worked. In other words, in the past, nonscheduled hours worked played an important role as a buffer to adjust labor input; moreover, the timing of changes in nonscheduled hours worked and the amplitude of such changes provided important signals for forecasting the future course of the business cycle.[6] However, as will be discussed later, from 2000 onward, this traditional adjustment mechanism where nonscheduled hours worked acted as a buffer has changed.

Turning to wages, reflecting the effect of nonscheduled earnings and bonuses, these are basically procyclical and lag the business cycle. Scheduled earnings are relatively stable and no clear relationship with the business cycle can be observed; on the other hand, nonscheduled earnings, reflecting developments in nonscheduled hours worked, show relatively large fluctuations and are procyclical and lead the business cycle.

Next, inflation has a lower cyclical volatility than output, is procyclical, and lags the business cycle. Meanwhile, the level of money is procyclical and lags the business cycle, while the money growth rate tends to be countercyclical and lags the business cycle. Finally, with regard to stock prices, the Nikkei Stock Average and the TOPIX both are procyclical with a lead and are most volatile.[7]

4.2 Changes in business cycle characteristics

The previous section described the characteristics of business cycles in Japan in the period before 2000. This section turns to the period since 2000, examining business cycle characteristics in the wake of the structural changes Japan experienced in the late 1990s and comparing them with the business cycle characteristics before 2000.

Table 2 presents the same statistics as Table 1, but for the period since 2000, while Figure 4 provides a visual comparison of the cross-correlation coefficient for selected macroeconomic time series vis-à-vis the business cycle before and since 2000. Looking at the direction and strength of the correlation, as well as whether a variable leads or lags the economy, particularly notable changes – much more substantial changes than in other areas – can be observed in relation to hours worked and employment. On the other hand, in areas other than hours worked and employment, changes are generally relatively minor, and patterns for GDP expenditure components such as consumption and investment, as well as wages, inflation, and developments in financial markets generally speaking are similar to those before 2000.

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[6] In fact, until the 6th Revision of the Indexes of Business Conditions in July 1987, nonscheduled hours worked were used as a leading indicator in the Indexes of Business Conditions, provided by the Cabinet Office.

[7] An additional variable representing market trends is the VIX index, which, however, is available only for the period since 2000. The correlation coefficient of this variable and business conditions is highest at time k=2, when it is -0.71, indicating that the VIX index is countercyclical and leads business conditions.

Taking a closer look at those variables for which changes in business cycle characteristics *can* be observed, and starting with GDP expenditure components, reveals the following:

- While the direction and strength of the cyclicality in private residential investment remains unchanged, it no longer leads the economy. A likely explanation is that before 2000 changes in housing investment, in response to asset prices such as stocks, led the economy as a whole, but the change in the market environment such as the consistent fall in house prices since the early 1990s seems to have changed this. In addition, especially since the late 1990s, institutional factors are also likely to have played a role, given that the promotion of housing construction has served as a pillar of stimulus measures through, for example, the expansion of tax measures to promote house purchases.

- As for imports and exports, an increase in the correlation with the business cycle can be observed. In addition, the correlation between the business cycle in Japan and global GDP has increased, reflecting the fact that as a result of further advances in globalization, economic ties among countries around the world have continued to strengthen, which appears to result in a stronger impact on developments in Japan's domestic economy.

Turning to aggregate employment, the link between the unemployment rate and business conditions remains largely unchanged. However, this is not the case for total employed and employees: whereas the strength of the correlation with the business cycle at the peak, as well as the timing of the peak of about 2-3 quarters behind the business cycle are generally unchanged, in both cases the correlation coefficient for longer lags has fallen (for k=-6, it has fallen from around 0.5 to around 0). This implies that, both in expansionary and recessionary phases, the correlation between the economy and employment disappears after about one-and-a-half years, meaning that the responsiveness of employment to changes in economic activity have weakened.[8]

Further, looking at the link between business cycles and scheduled hours worked shows a notable increase in the correlation between the two, suggesting that scheduled hours

[8] With regard to the regular employment index, a downward shift in the cross-correlation coefficient in the period since 2000 can be observed. Dividing the regular employment index for the period since 2000 into part-time workers and full-time workers shows that the business cycle characteristics of the number of full-time workers are generally the same as those of regular employees overall, while the number of part-time workers shows hardly any correlation with business conditions (the six-period lag and lead correlation coefficients are both around 0 to 0.1).

worked play an increasingly important role as a buffer to adjust labor input. In order to examine the reasons for these changes, changes in the labor supply on a man-hour basis (year-on-year change) are decomposed into changes in employment and hours worked. The results, shown in Figure 5, indicate that in the period since 2000, changes in hours worked (in particular immediately after the outbreak of the global financial crisis) have played a larger role in adjustments of labor input – not only during periods in which labor input decreased, but also when it increased – than in the period before 2000. It should be noted that hours worked in Japan have fallen consistently, and a major reason for this, especially since the mid-1990s, is the decline in scheduled hours worked due to the increase in part-time employment. It seems that the increased role of adjustments in hours worked largely reflects the increase in part-time workers, whose hours worked can be adjusted more flexibly. In fact, the increased responsiveness of scheduled hours worked to business conditions can also be gleaned from the "Survey on Labor Economy Trends." Looking at what means firms employed in practice to adjust labor input shows that the share of firms that did so through the adjustment of holidays, switching of days off, etc., increased from 2000 to 2016.[9] It is likely that such changes in the way that firms adjust the hours worked not only of part-time workers but also of full-time workers are responsible for the greater responsiveness of scheduled hours worked to changes in business conditions.[10]

In sum, the results regarding the link between business conditions on the one hand and employment and hours worked on the other suggest that the way in which firms adjust labor input has changed and that the role of adjustments in hours worked, and particularly in scheduled hours worked, has increased. To further examine these results, the next section presents additional analyses based on a TVP-VAR model.

Before that, however, let us look at the results for some of the other variables. For instance, some change, although relatively minor, can be observed with regard to the effective job-openings-to-applicants ratio and the number of new job offers: whereas the former used to be coincident with the business cycle, it is now lagging; on the other hand, the latter used to lead the business cycle, but now is coincident. Next, let us examine the

[9] The survey, conducted by the Ministry of Health, Labour and Welfare, suggests that among firms that adjusted employment, the share of firms that did so through by adjusting holiday, switching days off, etc., increased by 7 percentage points between 2000 and 2016 and the share that did so through transfers increased by 4 percentage points. On the other hand, the shares of firms that adjusted employment by reducing or stopping mid-career hiring (-5 percentage points), restricting overtime (-4 percentage points), or stopping or reducing contract renewals of part-time workers (-2 percentage points) all decreased.

[10] Dividing changes in scheduled hours worked into changes in the number of days worked and scheduled hours worked per day shows that trends in scheduled hours worked essentially reflect those in the number of days worked. This suggests that firms increasingly adjust scheduled hours worked mainly through days worked, reflecting the increased use of non-regular employees, whose number of days worked is more flexible. This trend is consistent with the result of the survey by the Ministry of Health, Labour and Welfare mentioned above.

separation rate, which is the percentage of workers leaving their job (due to resignation or dismissal) in regular employment. Job separation can be distinguished into involuntary and voluntary job separation. Involuntary job separation (through dismissals) is likely to decline during an economic recovery and increase during a recession; conversely, voluntary job separation (e.g., through resignations to change jobs) is likely to increase during an economic recovery and decline during a recession, so that the two act in opposite directions. The results in Figure 4 indicate that whereas before 2000, the two largely offset each other, in the period since 2000, the correlation of the job separation rate with the business cycle increased and the job separation rate is countercyclical now. Another variable is the fill rate, which is the ratio of the number of persons starting a new job to the number of new job openings. In general, growth in new job openings will accelerate increase more than the number of persons starting a new job when the employment situation improves, so that the fill rate is countercyclical. The figure shows that there has been no major change in this pattern.

A final point regarding aggregate employment concerns the ratio of part-time workers (the share of part-time workers in all employees). One of the major structural changes is that this ratio has been increasing as a trend regardless of developments in business conditions, and Figure 4 indicates that, compared to the period before 2000, the correlation of the ratio of part-time workers with business conditions has weakened as a result.

Turning to wages, the results indicate that the correlation of scheduled earnings with the business cycle – reflecting the changes in scheduled hours worked – has increased, so that the correlation of total cash earnings with the business cycle has also increased. The increase in wage flexibility through changes in employment forms such as the increased use of part-time workers potentially is also responsible for the increased correlation with the business cycle. Finally, the correlation of inflation with the business cycle, especially in terms of the GDP deflator, has declined, in part reflecting the fact that whereas the economy fluctuated considerably within a short period of time through external shocks such as the global financial crisis, prices were not that strongly affected by such external shocks.

5. Analysis of changes in business cycle characteristics using a TVP-VAR model

The previous section investigated business cycle characteristics based on frequency domain analysis and, by comparing these characteristics during the two subperiods, examined the impact of structural change on the characteristics of business cycles in Japan.

The investigation showed that particularly notable changes can be observed in the link between business conditions on the one hand and employment and hours worked on the other. To check the robustness of these findings and examine them in more detail, this section presents an analysis of changes in the way labor input is adjusted in Japan using a TVP-VAR model.

While VAR models have been widely used for the empirical analysis of the relationships among macroeconomic time series for quite some time, more recently the use of TVP-VAR models, which explicitly take into account the time-varying nature of the underlying structure of the economy, has gained ground. In the frequency domain analysis presented in the previous section, in which observations were divided into two subperiods, the averages for each of the two periods were examined and compared. However, using a TVP-VAR model, it is possible to examine how the relationships among variables changed as the economy underwent structural change, without any *a priori* assumptions regarding the timing that structural change occurred.

Since Primiceri's (2005) seminal study in the field,[11] it is common to incorporate stochastic volatility into the VAR model with time-varying coefficients. Following previous studies, this study employs the Markov Chain Monte Carlo (MCMC) method in the context of Bayesian inference for estimation.

5.1 Structure of the model

Consider the following VAR (p) model, with a p^{th} order lag, assuming time-varying parameters and stochastic volatility:

$$Y_t = B_{1,t}Y_{t-1} + \cdots + B_{p,t}Y_{t-p} + u_t,$$

where Y_t is a $(k \times 1)$ vector consisting of k observed variables, $B_{i,t}$ is a $(k \times k)$ matrix of time-varying coefficients $(i = 1, \cdots, p)$, and u_t is a $(k \times 1)$ vector of structural shocks, which are assumed to follow a normal distribution with mean 0 and time-varying covariance matrix Ω_t. Then decompose u_t as follows:

$$u_t = A_t^{-1} \Sigma_t \varepsilon_t,$$

where

[11] Del Negro and Primiceri (2015) added a modification to part of the estimation algorithm of the time-varying parameter model in Primiceri (2005).

$$A_t = \begin{bmatrix} 1 & 0 & \cdots & 0 \\ a_{21,t} & 1 & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ a_{k1,t} & \cdots & a_{kk-1,t} & 1 \end{bmatrix},$$

$$\Sigma_t = \begin{bmatrix} \sigma_{1,t} & 0 & \cdots & 0 \\ 0 & \ddots & \ddots & \vdots \\ \vdots & \ddots & \ddots & 0 \\ 0 & \cdots & 0 & \sigma_{k,t} \end{bmatrix},$$

$$\varepsilon_t \sim N(0, \quad I_k),$$

where $A_t \ \Omega_t A_t' = \Sigma_t \Sigma_t'$. Moreover, $a_{ij,t}$ is the time-varying simultaneous response of variable i to structural shocks to variable j, while $\sigma_{i,t}^2$ represents the time-varying variance of structural shocks. Further, defining β_t as a $(k^2 p \times 1)$ vector representing the elements in each row of $B_{i,t}$, a_t as a vector of the lower-triangular elements of A_t, and h_t as a vector of diagonal elements of Σ_t (where $h_{i,t} = log\sigma_{i,t}^2$), β_t, a_t, h_t show the time-varying parameters of the model, which, following previous studies, are assumed to follow a random walk process as follows:[12]

$$\beta_{t+1} = \beta_t + u_{\beta,t},$$

$$a_{t+1} = a_t + u_{a,t},$$

$$h_{t+1} = h_t + u_{h,t},$$

$$\begin{bmatrix} \varepsilon_t \\ u_{\beta,t} \\ u_{a,t} \\ u_{h,t} \end{bmatrix} \sim N\left(0, \quad \begin{bmatrix} I & O & O & O \\ O & \Sigma_\beta & O & O \\ O & O & \Sigma_a & O \\ O & O & O & \Sigma_h \end{bmatrix}\right),$$

where I is a $(k \times k)$ identity matrix.

[12] A random walk is suitable for the purpose of capturing non-recursive changes, since it can take into account not only temporary but also permanent shifts in parameters following a non-stationary process.

The model defined in this manner allows the variance of structural shocks to evolve over time following a random walk. The stochastic volatility assumption makes the estimation difficult because the likelihood function becomes intractable, requiring Bayesian inference based on the MCMC method.

5.2 Bayesian estimation of the model

The estimation procedure of the model using the MCMC method employed in this study follows Nakajima (2011). Specifically, given the observed data (y), the random sample from the posterior distribution of $\pi(\beta, a, h, \omega|y)$, consisting of the time varying parameters β_t, a_t, h_t and the covariance matrix ($\omega = (\sum_\beta, \sum_a, \sum_h)$), can be obtained by sampling recursively the conditional distribution where the most recent values of the conditioning parameters are used in the simulation, following the MCMC algorithm.

Because β and a can be represented by a linear state space model, they are sampled using the simulation smoother proposed by de Jong and Shephard (1995) to obtain the random sample from the conditional posterior distribution. On the other hand, since h cannot be expressed by a linear state space model, h is sampled using the multi-move sampler by Shephard and Pitt (1997) and Watanabe and Omori (2004).

5.3 Data and settings

Next, based on the analytical framework outlined above, this section examines changes in the mechanism of labor input adjustment in the Japanese economy. The TVP-VAR model used in this study is based on three time series (seasonally adjusted, quarterly values) consisting of real GDP (GDP), scheduled hours worked (HRS), and the number of employees (EMP). For the estimation, data from 1980Q1 to 2016Q3 is employed using log differences. The identification of structural shocks is achieved through the conventional recursive approach assuming that the time ordering of variables is GDP, HRS, and EMP, based on the pattern of labor adjustment by firms observed in practice. (However, even if the time ordering of variables were GDP, EMP, HRS, the results would remain essentially unchanged.)

The following priors are assumed for the covariance matrix of structural shocks, following Nakajima (2011) as well as others: $\sum_\beta \sim IW(40, 0.01I)$, $w_{ai}^2 \sim IG(2, 0.01I)$, and $w_{hi}^2 \sim IG(2, 0.01I)$, where IW is an inverse Wishart distribution, while IG is an inverse gamma distribution. Moreover, w_{ai}^2 and w_{hi}^2 are the i^{th} diagonal element of $\sum_a$ and $\sum_h$, respectively. Meanwhile, for simplicity, a diagonal matrix is assumed for the covariance matrix. Moreover, again following Nakajima (2011) as well as others, the initial states of the time-varying parameters are set to $\beta_{p+1} \sim N(0,10I)$, $a_{p+1} \sim N(0,10I)$, and $h_{p+1} \sim N(0,100I)$, assuming a sufficiently wide prior distribution. Finally, simulations are based on 50,000 iterations, discarding the first 5,000 for convergence.

5.4 Estimation results

Before discussing the results obtained estimating the model using the MCMC approach, it is first examined whether the generated random sample converges to the posterior distribution. Table 3 reports the posterior mean, the posterior standard deviation, and the 95 percent credible intervals of the selected parameters derived from the MCMC sample (in this case, the i^{th} diagonal components of $\sum_{\beta}$, $\sum_{a}$, and $\sum_{h}$) as well as the convergence diagnostic (CD) following Geweke (1992). Based on the CD statistics, the null hypothesis of convergence to the posterior distribution is not rejected for the parameters at the 5 percent significance level. Table 3 also reports the inefficiency factor, which measures the efficiency of sampling. The largest value for the inefficiency factor is around 150, which is comparable to values in previous studies, where even the largest values are less than 200, indicating that the MCMC algorithm produces posterior draws efficiently and that generating 50,000 samples can be regarded as sufficient for posterior inference.

Based on the estimation results of the model, let us now examine changes in the mechanism through which labor input in Japan's economy is adjusted. Specifically, it is examined how the response of scheduled hours worked and the number of employees to a structural shock in GDP (demand shock) has changed over time since 1980.

Figure 6 shows the estimation results of the TVP-VAR model and a constant parameter VAR model of the cumulative impulse responses of GDP, HRS, and EMP to a demand shock. For the TVP-VAR model, the figure shows the results of the cumulative impulse responses in 1985, 1995, 2005 and 2015 (all in the first quarter), while for the constant parameter VAR model the results for the total period (1980Q1 to 2016Q3) as well as for the subperiod before 2000 and the subperiod since 2000 are shown. The results suggest the following.

First, since 1985, the response of scheduled hours worked to a demand shock has increased over time. This indicates that scheduled hours worked respond more strongly to economic fluctuations caused by a demand shock, which is consistent with the result in the previous section that in the period since 2000 the correlation between the business cycle and scheduled hours worked has increased. Note that this finding is also confirmed by the results of the constant parameter VAR model.

On the other hand, the response of the number of employees to a demand shock gradually increased from 1985 until 2005, but fell substantially in 2015, dropping even below the level in 1985. Similarly, the results of the constant parameter VAR model indicate that the response of the number of employees in the period since 2000 was lower than in the period before 2000, which is consistent with the change in business cycle characteristics seen in the previous section; however, unlike the TVP-VAR model, the constant parameter VAR cannot capture that the response tended to increase until 2005. In other words, a limitation of the constant parameter VAR model based on splitting the observation period is that it cannot identify at what point in time the change occurred; in contrast, with the TVP-VAR model, it is possible to examine such developments in detail.

Therefore, in order to do just that, Figure 7 plots developments in the time-varying simultaneous correlation between the number of employees as well as scheduled hours worked on the one hand and demand shocks on the other. Starting with scheduled hours worked, the figure indicates that the simultaneous correlation coefficient obtained from the TVP-VAR model rose from close to 0 to about 0.1 in the mid-1980s and then remained almost unchanged until the mid-1990s. However, it then started to increase again in the latter half of the 1990s, so that in the early 2000s it exceeded the 95 percent confidence interval of the simultaneous correlation coefficient obtained from the constant parameter VAR model for the period before 2000. It continued to follow an increasing trend until reaching a peak in 2005. After that, it gradually decreased from 0.3 at its peak in 2005 and stood at around 0.2 in 2016. The increased relationship between the economy and scheduled hours worked is confirmed by the gradual increase in the time-varying simultaneous correlation coefficient throughout the period, with relatively large changes observed in the mid-1980s and in 2000.

Next, turning to the number of employees, reflecting the fact that employment, by its nature, tends to lag changes in output, the simultaneous correlation with demand shocks is smaller than that of hours worked, falling within a range of 0 to 0.1 (except in 2005), and has been relatively stable. As a result, no major change can be observed in the simple comparison of the period before 2000 and that since 2000. However, looking at developments since the mid-2000s, a relatively large decline can be observed. In particular, there was a remarkable decline after the outbreak of the global financial crisis, and it is possible that this reflects efforts in various forms to maintain employment, including government policies, in response to the sudden deterioration of the economy.

In sum, the results of the TVP-VAR analysis also indicate that since 2000, the increase in the link between business cycles and scheduled hours worked has gone hand in hand with a decline in the link between business cycles and employment, suggesting that adjustments in hours worked, and particularly scheduled hours worked, in response to changes in business conditions have come to play a larger role.

6. Conclusion

Business cycles fluctuate as a result of various shocks to the economy as well the way that such shocks are transmitted to the economy. Although business cycle characteristics, to some extent can be regarded as universal and constant over time, they can change when there are structural changes in the economy. Against this background, this study presented a number of empirical analyses to examine developments in the business cycle under economic structural change. The major findings can be summarized as follows:

(i) The frequency domain analysis comparing the periods before and since 2000 showed that particularly notable changes in business cycle characteristics can be observed in terms of hours worked and employment, where changes have been much more pronounced than in other areas. On the other hand, in most other areas, no major changes in business cycle characteristics can be observed. For example, patterns in GDP expenditure components such as consumption and investment, as well as wages, prices and financial markets, generally speaking, have remained unchanged from the period before 2000.

(ii) Main areas in which business cycle characteristics have changed since 2000 and the correlation with the business cycle has increased include housing investment and, against the background of further advances in globalization, imports and exports. Turning to employment, where the most pronounced changes were observed, the correlation between the business cycle and the number of employees weakened, while the correlation between the business cycle and hours worked increased. Moreover, whereas before 2000, changes in nonscheduled hours worked led changes in business cycles, this lead disappeared in the period from 2000 onward and the correlation of scheduled hours worked with business cycles increased.

(iii) The likely reason is that as a result of changes in the way firms adjust labor input the responsiveness of scheduled hours worked not only of part-time but also of full-time workers to changes in business conditions has increased. The finding that the role of hours worked in the adjustment of labor input was supported by the results of the TVP-VAR analysis.

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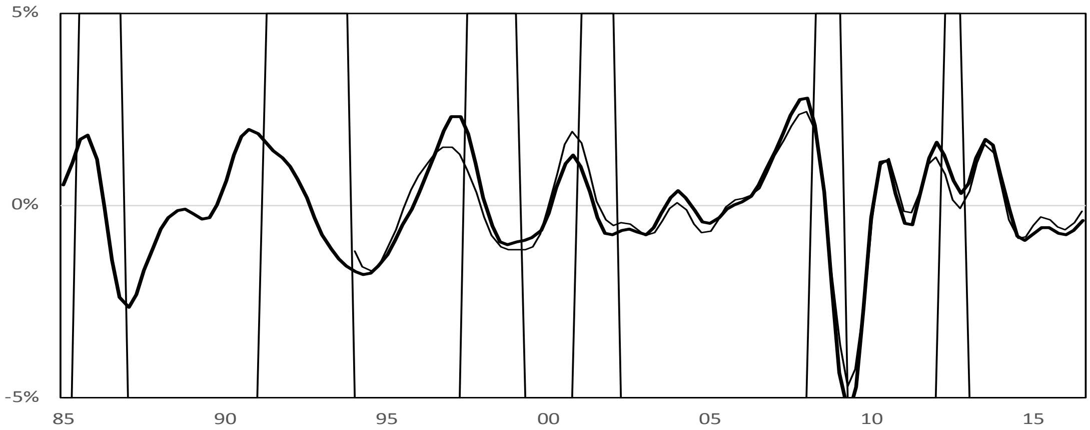
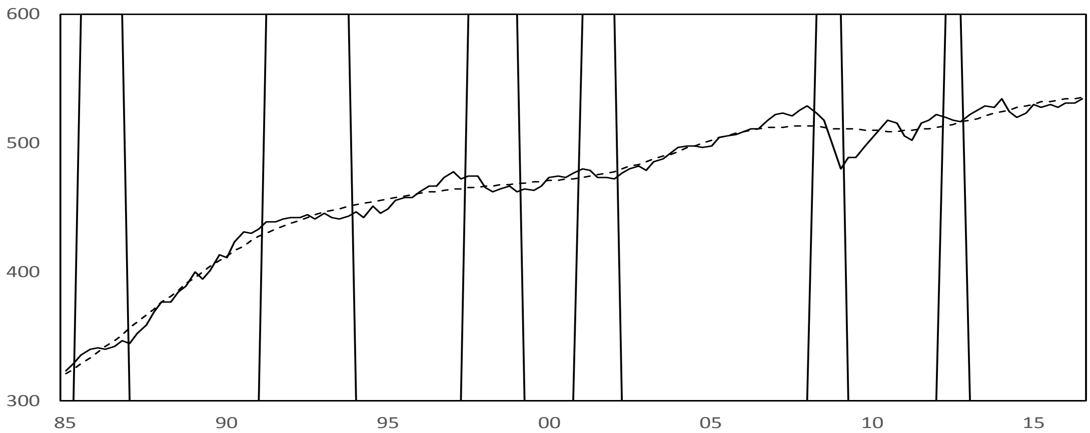
Figure 1: Cyclical component of real GDP



Notes:

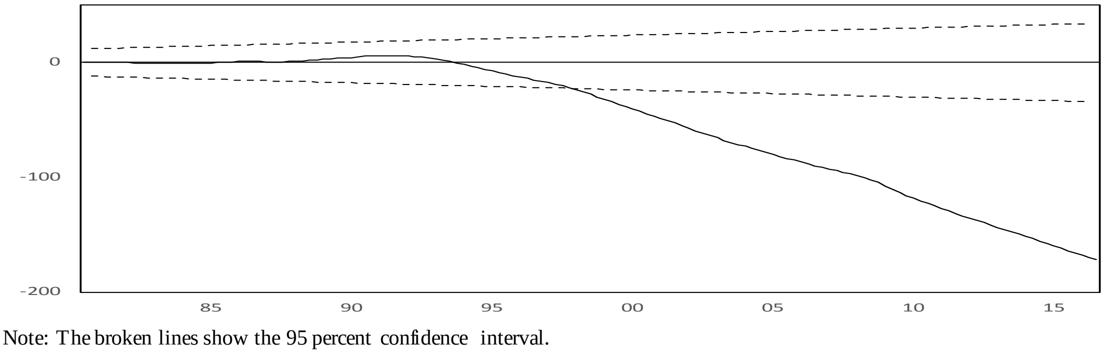
1. The cyclical component of real GDP falling within a range of 6 to 32 quarters is defined as the business cycle. The figure shows the business cycle component obtained using the CF filter.
2. The thick line is based on benchmark year 2005 data, while the thin line is based on benchmark year 2011 data.
3. The vertical lines show the official business cycle peak and trough dates determined by the Cabinet Office (the same applies to Figure 2).

Figure 2: Real GDP and its trend component



Note: The solid line shows real GDP (on a benchmark year 2005 basis, in trillion yen), while the broken line shows the trend component of real GDP obtained using the CF filter.

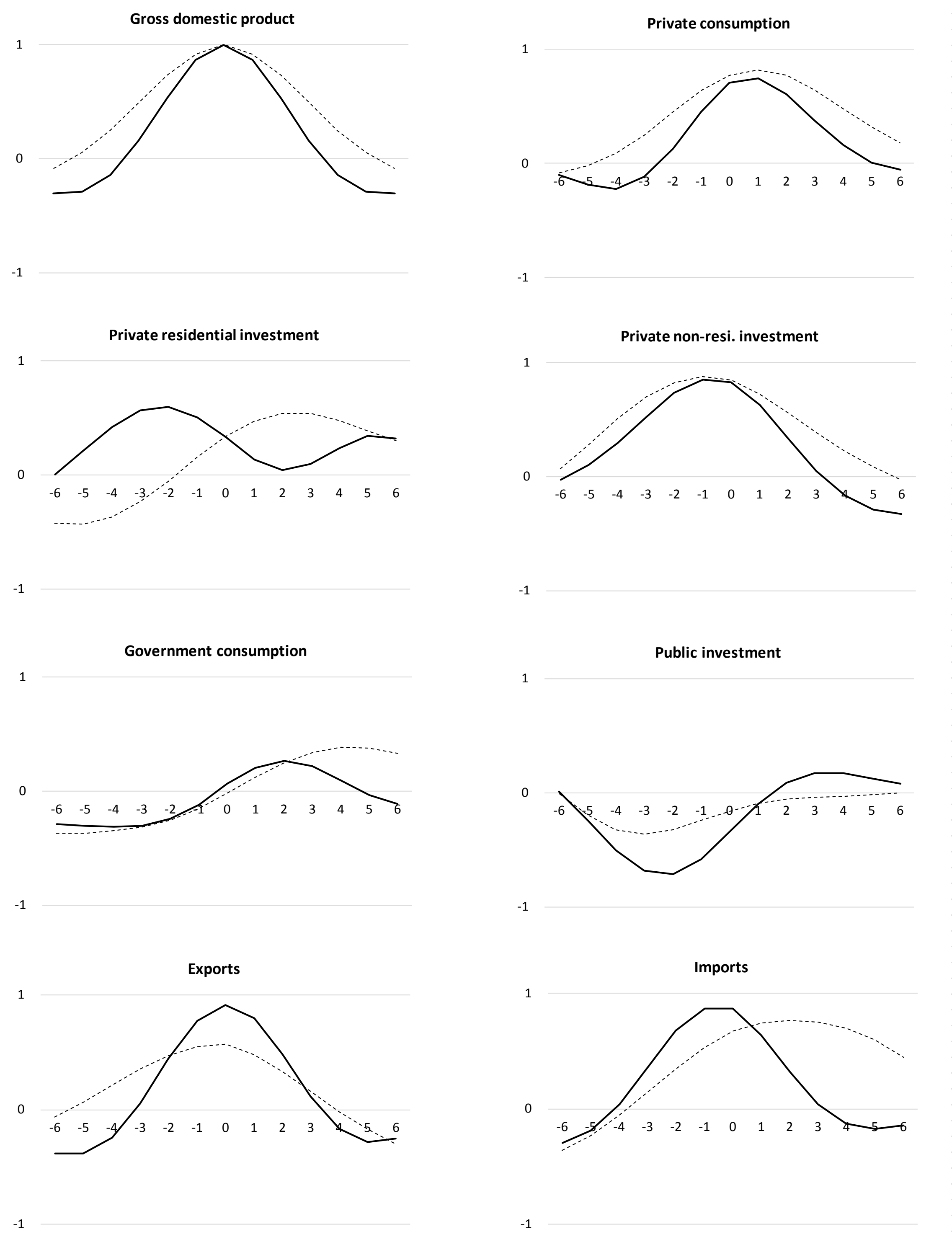
Figure 3: Result of the CUSUM test



Note: The broken lines show the 95 percent confidence interval.

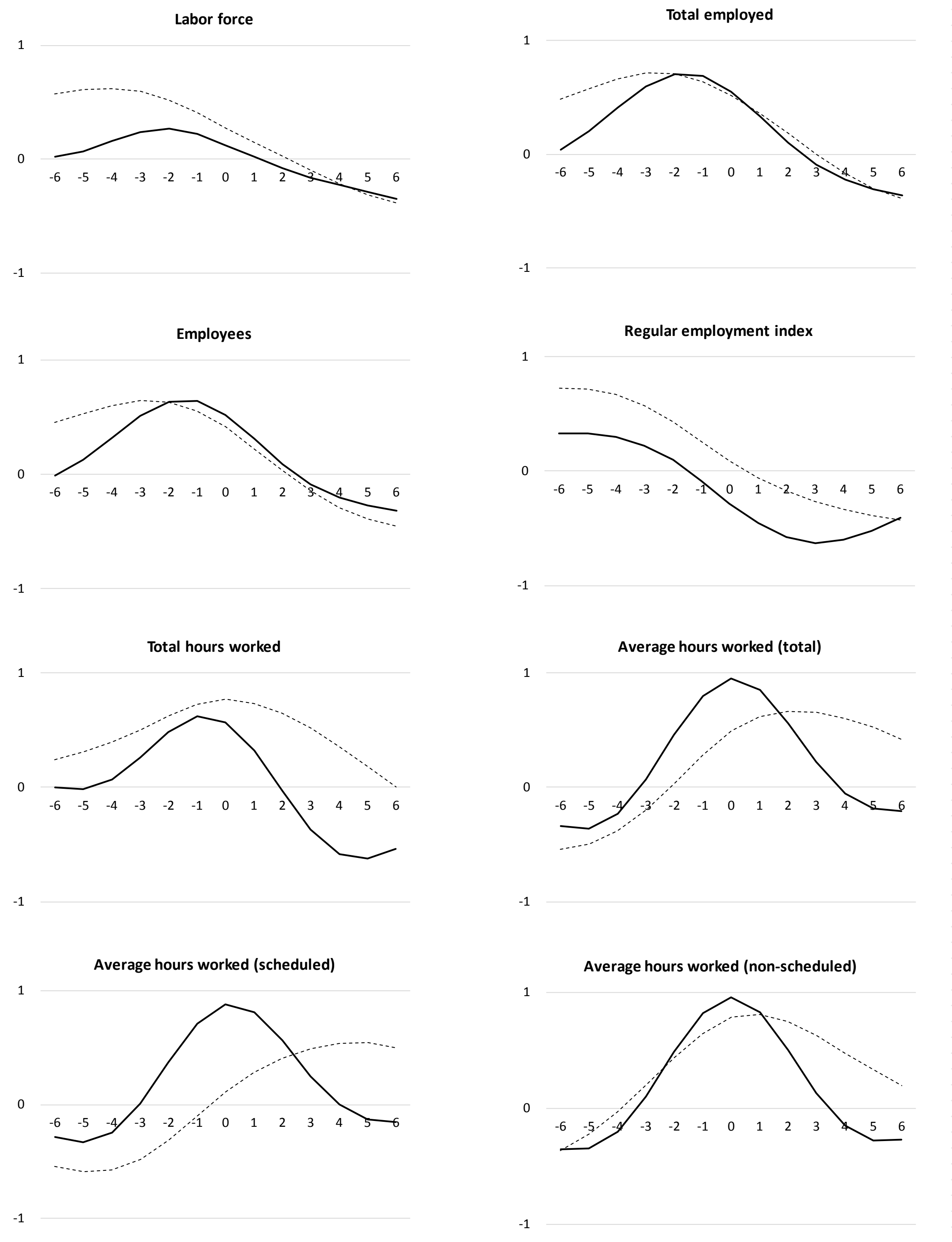
Figure 4: Change in cross-correlation: Comparison of before 2000 and since 2000

(a) GDP components

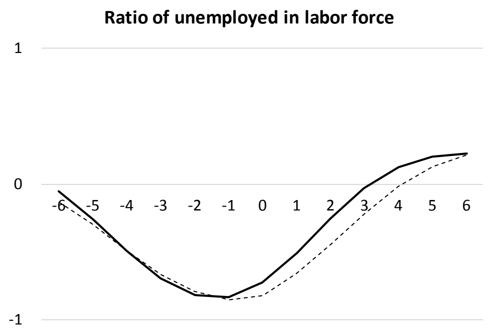


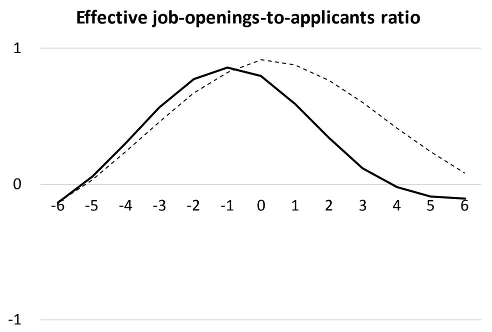
Notes: The charts show the cross-correlation coefficients vis-à-vis GDP presented in Tables 1 and 2. The solid lines represent the period since 2000 (Table 2), while the broken lines represent the period before 2000 (Table 1). (The same applies for panels (b) to (e) below.)

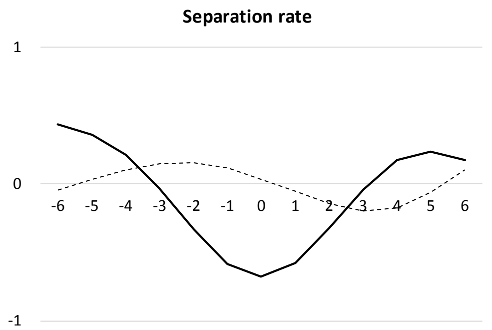
(b) Employment

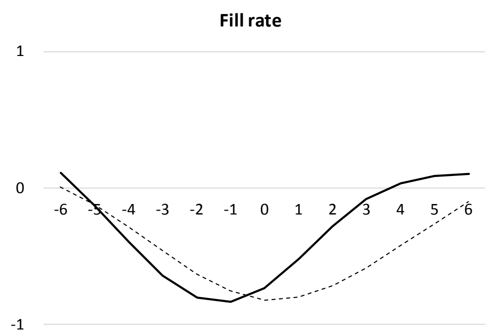


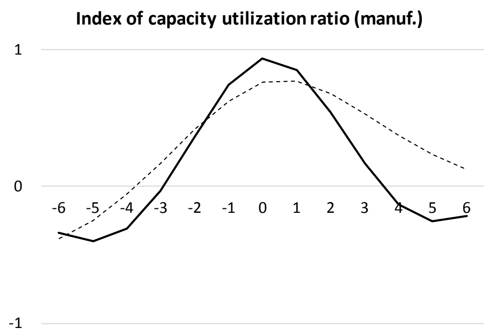
(b) Employment (continued)

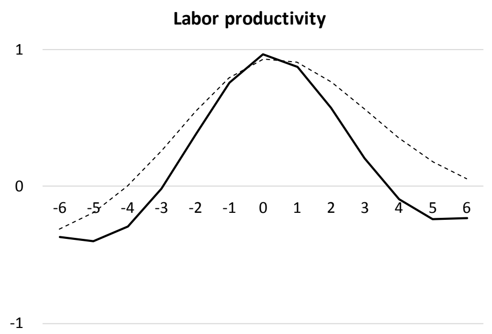




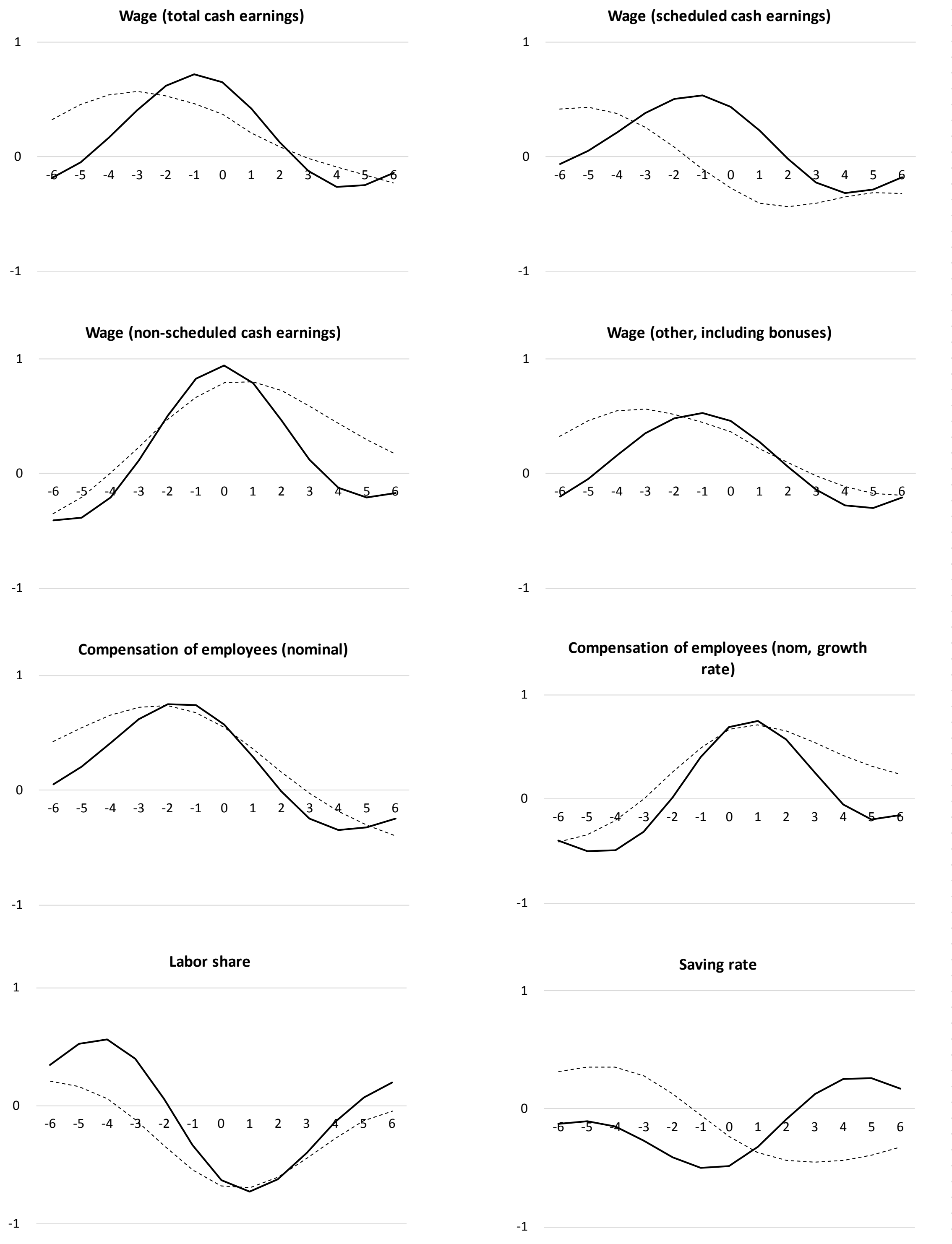




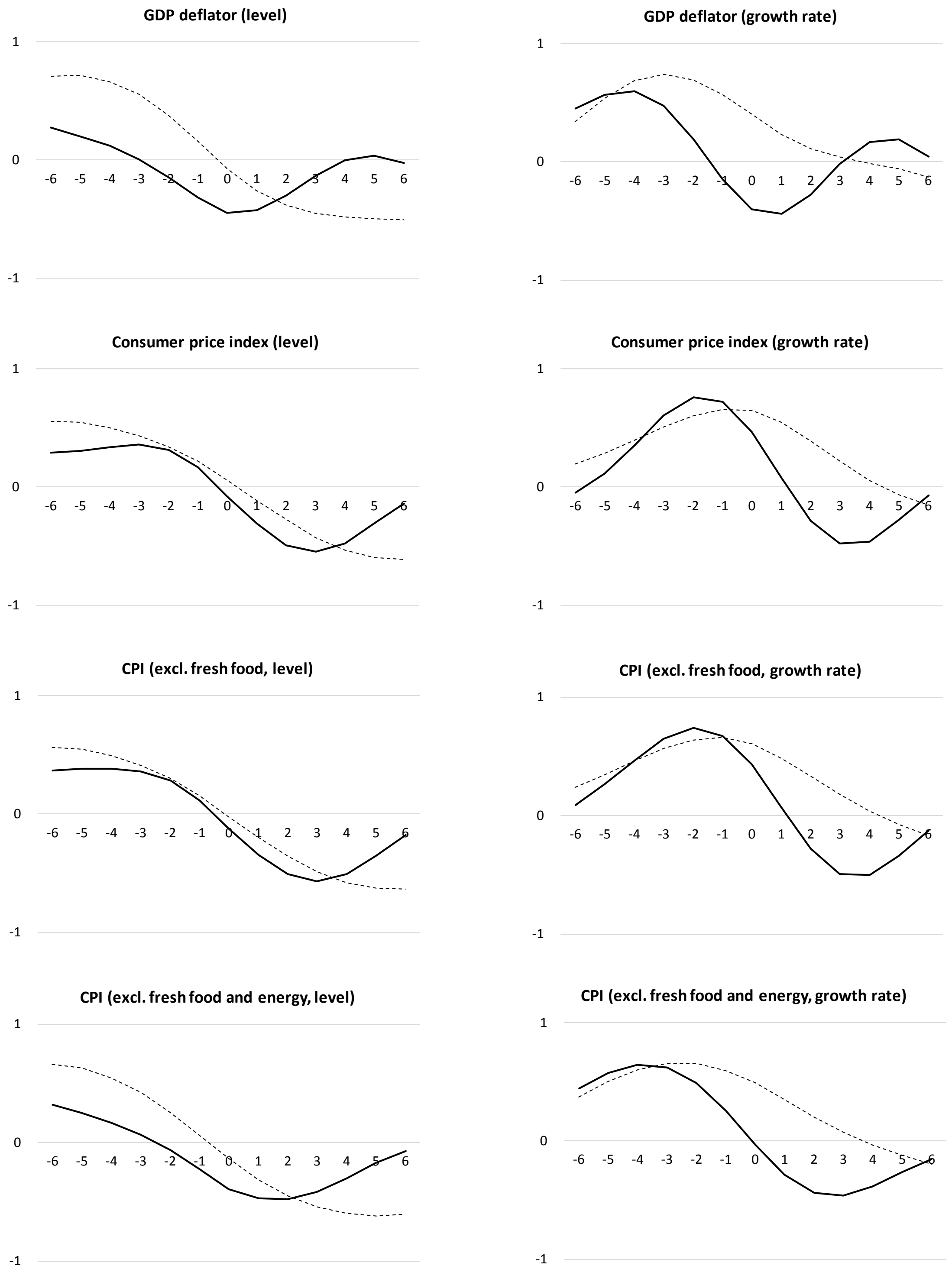




(c) Wages


Wage (total cash earnings)
1
0
-1
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6
Wage (scheduled cash earnings)
1
0
-1
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6
Wage (non-scheduled cash earnings)
1
0
-1
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6
Wage (other, including bonuses)
1
0
-1
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6
Compensation of employees (nominal)
1
0
-1
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6
Compensation of employees (nom, growth rate)
1
0
-1
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6
Labor share
1
0
-1
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6
Saving rate
1
0
-1
-6 -5 -4 -3 -2 -1 0 1 2 3 4 5 6

(d) Deflators and prices



(e) Interest rates, stock prices, money

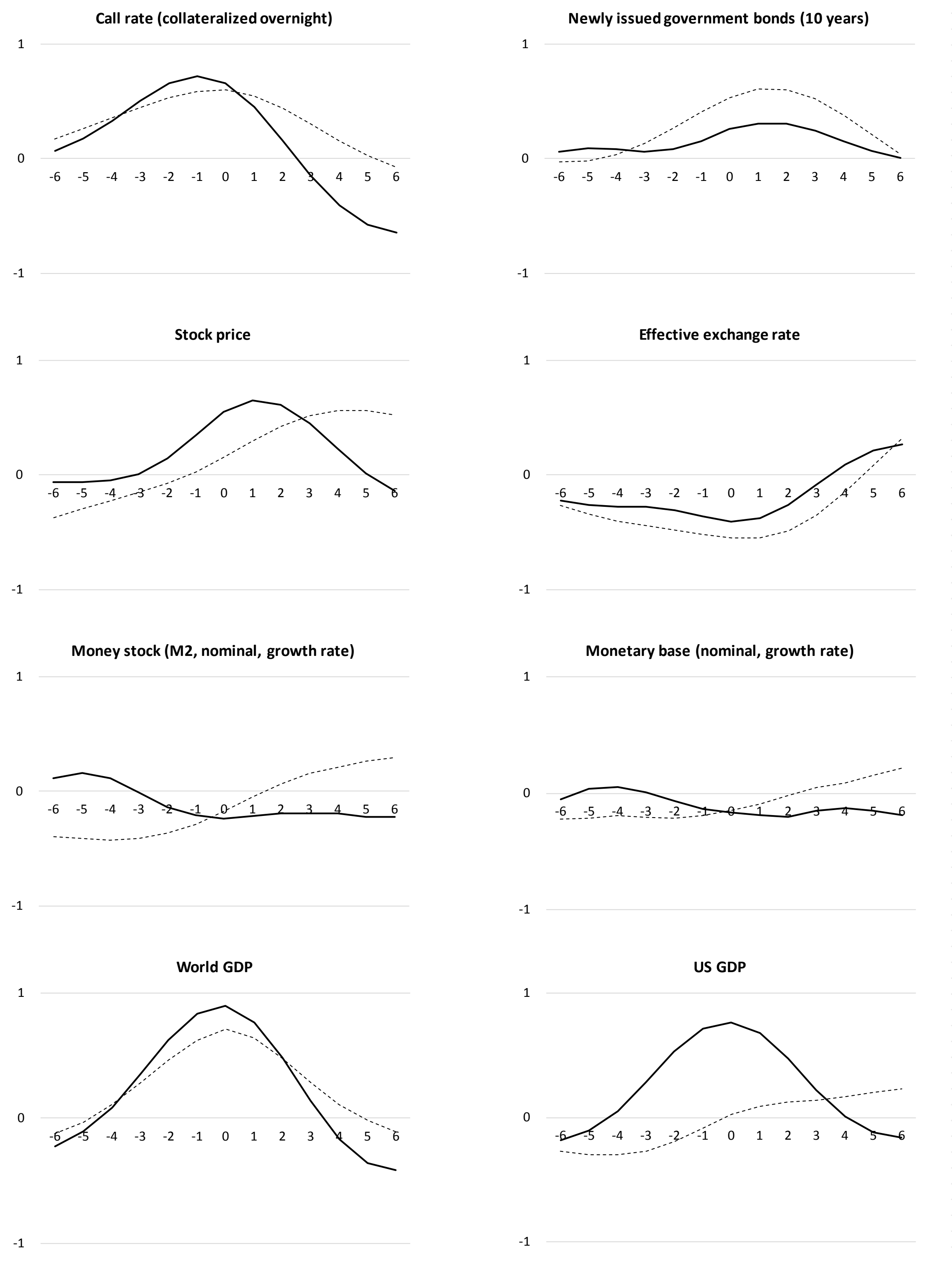
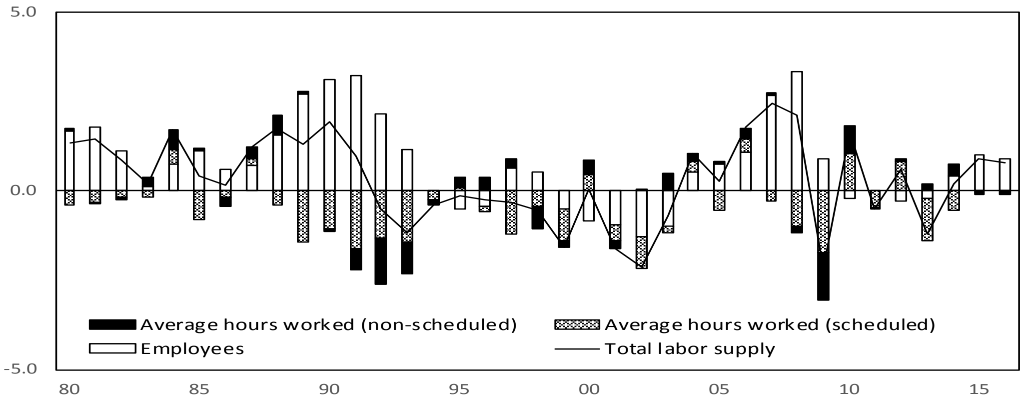
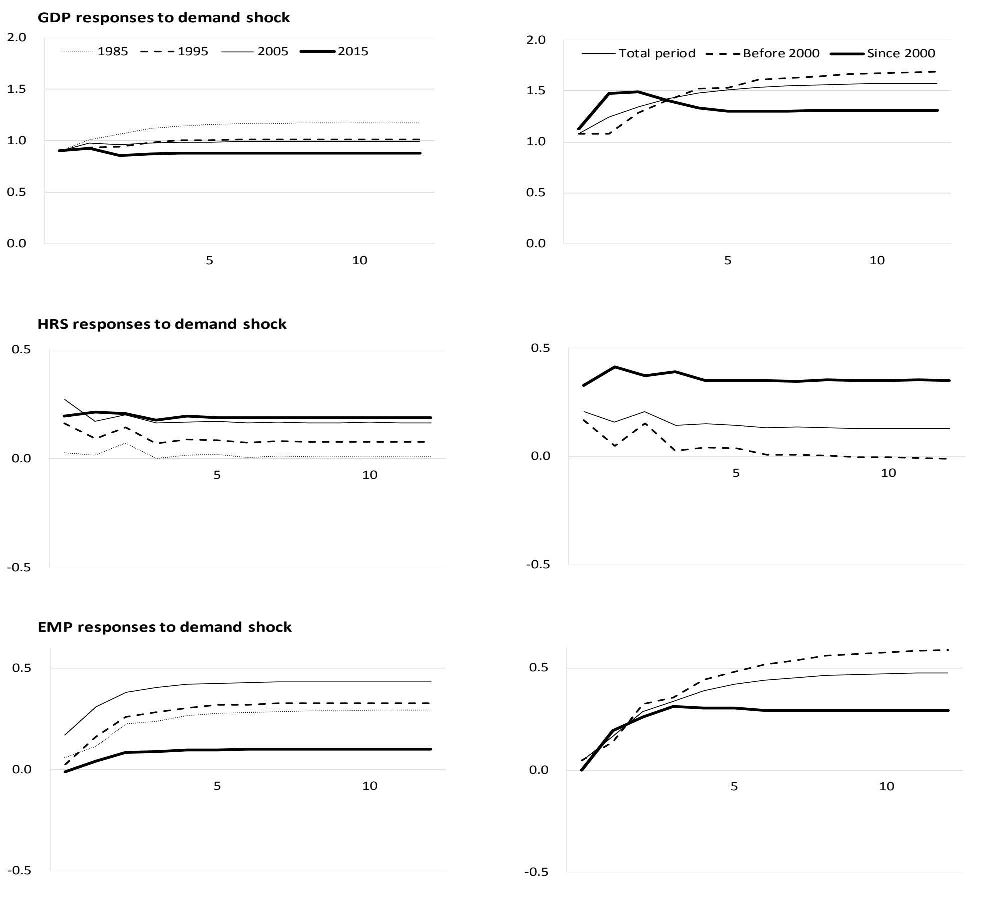


Figure 5: Developments in total labor supply (man hours): Contribution of hours worked and number of employees



Notes: The total labor supply is the number of regular employees multiplied by the hours worked per person. The figure shows the year-on-year rates of change in percent.

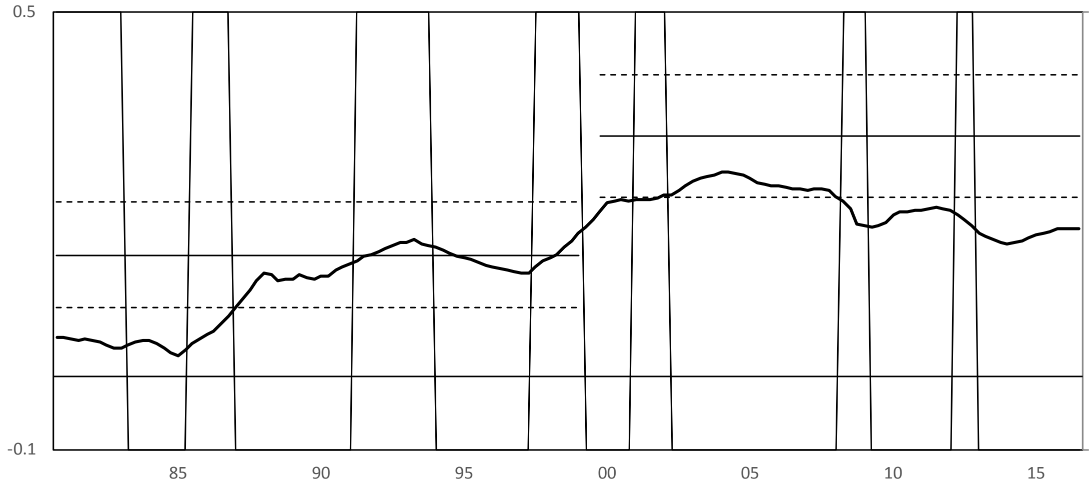
Figure 6: Impulse responses of GDP, scheduled hours worked, and employees to a demand shock: TVP-VAR model (left) and constant VAR model (right)



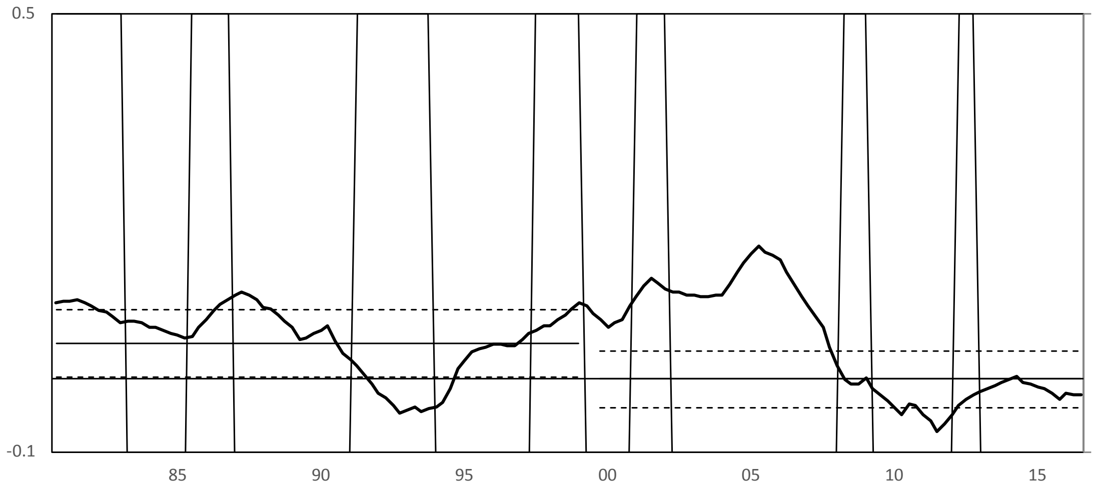
Note: The panels on the left for the TVP-VAR model show the cumulative impulse responses in 1985, 1995, 2005 and 2015 (all in the first quarter), while the panels on the right for the constant VAR model show the responses for the total period (1980Q1 to 2016Q3) as well as for the subperiod before 2000 and the subperiod since 2000 are shown.

Figure 7: Developments in simultaneous correlation coefficients obtained from TVP-VAR model

(a) Simultaneous correlation of scheduled hours worked with demand shocks



(b) Simultaneous correlation of number of employees with demand shocks



Notes:
1. The thick line shows the time-varying coefficient of simultaneous correlation between scheduled hours worked (panel (a)) and the number of employees (panel (b)) and demand shocks obtained from the TVP-VAR model. The thin horizontal lines represent the simultaneous correlation coefficients obtained from the constant parameter model for the period before 2000 and the period since 2000, with the broken lines representing the 95 percent confidence intervals.
2. The vertical lines show the official business cycle troughs and peaks determined by the Cabinet Office.

Table 1: Statistics for cyclical component: Before 2000

Macroeconomic time series	Std. Dev.	Relative Std. Dev.	Auto-correlation	Cross-correlation with GDP (Corr[xt, gdpt+k]) k: -6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
Gross domestic product	1.24%	1.00	0.92	-0.09	0.05	0.25	0.49	0.73	0.92	1.00	0.92	0.73	0.49	0.25	0.05	-0.09
GDP components																
Private consumption	0.80%	0.65	0.91	-0.08	-0.02	0.09	0.25	0.45	0.64	0.78	0.82	0.77	0.65	0.48	0.32	0.18
Private residential investment	6.49%	5.24	0.91	-0.42	-0.43	-0.37	-0.23	-0.05	0.15	0.34	0.47	0.54	0.54	0.48	0.39	0.30
Private non-resi. investment	5.33%	4.31	0.94	0.06	0.28	0.50	0.70	0.83	0.87	0.84	0.72	0.56	0.38	0.22	0.08	-0.03
Change in private inventory (relative to GDP)	0.24%	0.20	0.77	-0.16	-0.04	0.11	0.28	0.43	0.53	0.53	0.39	0.22	0.08	0.00	-0.02	0.00
Government consumption	0.91%	0.74	0.92	-0.37	-0.37	-0.35	-0.31	-0.25	-0.15	-0.02	0.12	0.25	0.34	0.39	0.38	0.33
Public investment	4.20%	3.39	0.84	-0.01	-0.20	-0.33	-0.37	-0.32	-0.24	-0.16	-0.09	-0.06	-0.04	-0.03	-0.02	0.00
Exports	3.58%	2.89	0.90	-0.06	0.06	0.21	0.35	0.47	0.55	0.57	0.48	0.33	0.16	-0.02	-0.17	-0.30
Imports	5.56%	4.49	0.93	-0.36	-0.23	-0.06	0.14	0.35	0.53	0.67	0.74	0.77	0.75	0.70	0.60	0.45
Employment																
Labor force	0.35%	0.29	0.94	0.57	0.61	0.62	0.59	0.52	0.41	0.27	0.15	0.03	-0.10	-0.21	-0.32	-0.39
Total employed	0.45%	0.37	0.95	0.49	0.58	0.66	0.71	0.71	0.64	0.52	0.36	0.18	0.00	-0.17	-0.30	-0.39
Employees	0.59%	0.48	0.96	0.46	0.53	0.60	0.64	0.63	0.55	0.41	0.23	0.03	-0.15	-0.29	-0.39	-0.45
Regular employment index	0.68%	0.55	0.97	0.72	0.72	0.67	0.57	0.43	0.26	0.08	-0.06	-0.17	-0.26	-0.33	-0.39	-0.42
Total hours worked	0.51%	0.41	0.94	0.24	0.31	0.39	0.51	0.63	0.72	0.77	0.74	0.65	0.51	0.35	0.18	0.00
Average hours worked (total)	0.69%	0.56	0.94	-0.54	-0.49	-0.38	-0.20	0.04	0.28	0.50	0.61	0.66	0.66	0.61	0.53	0.42
Average hours worked (scheduled)	0.45%	0.36	0.92	-0.54	-0.59	-0.58	-0.48	-0.31	-0.10	0.12	0.28	0.41	0.49	0.54	0.54	0.50
Average hours worked (non-scheduled)	4.88%	3.94	0.94	-0.37	-0.22	-0.03	0.20	0.44	0.64	0.78	0.81	0.75	0.63	0.48	0.33	0.20
Ratio of unemployed in labor force	0.16%	0.13	0.90	-0.13	-0.30	-0.48	-0.66	-0.79	-0.85	-0.82	-0.66	-0.44	-0.21	-0.01	0.13	0.22
Effective job-openings-to-applicants ratio	13.36%	10.79	0.94	-0.13	0.03	0.24	0.46	0.67	0.83	0.91	0.88	0.76	0.60	0.42	0.24	0.08
New job offers	7.89%	6.37	0.93	-0.28	-0.15	0.03	0.25	0.47	0.67	0.81	0.84	0.78	0.67	0.51	0.35	0.20
Job placement rate	1.46%	1.18	0.93	-0.55	-0.47	-0.31	-0.09	0.16	0.42	0.63	0.74	0.76	0.71	0.61	0.49	0.38
Separation rate	0.04%	0.03	0.81	-0.04	0.04	0.11	0.15	0.16	0.12	0.04	-0.05	-0.14	-0.19	-0.17	-0.06	0.10
Accession rate	0.06%	0.05	0.86	-0.27	-0.16	0.03	0.25	0.46	0.60	0.64	0.59	0.47	0.32	0.21	0.16	0.17
Fill rate	2.01%	1.62	0.95	0.01	-0.12	-0.28	-0.46	-0.63	-0.75	-0.82	-0.80	-0.71	-0.58	-0.42	-0.26	-0.10
Ratio of part-time workers	0.48%	0.39	0.75	-0.33	-0.53	-0.66	-0.69	-0.63	-0.53	-0.41	-0.22	-0.11	-0.06	-0.02	0.03	0.10
Index of capacity utilization ratio (manuf.)	3.28%	2.65	0.90	-0.38	-0.25	-0.06	0.17	0.42	0.63	0.76	0.77	0.68	0.53	0.38	0.24	0.12
Labor productivity	1.08%	0.87	0.90	-0.31	-0.19	0.00	0.26	0.55	0.79	0.93	0.91	0.77	0.56	0.35	0.18	0.06
Wages																
Wage index (total cash earnings, nominal)	0.75%	0.61	0.94	0.26	0.42	0.57	0.70	0.78	0.79	0.70	0.53	0.33	0.12	-0.06	-0.21	-0.32
Wage index (contractual cash earnings, nom)	0.43%	0.34	0.92	0.05	0.17	0.33	0.50	0.64	0.69	0.64	0.50	0.32	0.12	-0.07	-0.23	-0.34
Wage index (total cash earnings, nom, growth rate)	0.25%	0.20	0.82	-0.48	-0.44	-0.35	-0.20	0.03	0.29	0.52	0.64	0.64	0.56	0.45	0.35	0.28
Wage index (total cash earnings, real)	0.78%	0.63	0.93	-0.32	-0.15	0.04	0.23	0.39	0.52	0.60	0.61	0.58	0.54	0.48	0.41	0.32
Wage index (contractual cash earnings, real)	0.74%	0.60	0.94	-0.59	-0.52	-0.39	-0.22	-0.03	0.14	0.29	0.40	0.48	0.53	0.55	0.53	0.49
Wage index (total cash earnings, real, growth rate)	0.26%	0.21	0.83	-0.53	-0.56	-0.52	-0.43	-0.30	-0.15	0.01	0.11	0.18	0.22	0.25	0.27	0.29
Wage (total cash earnings)	1.01%	0.82	0.73	0.33	0.45	0.54	0.57	0.53	0.46	0.37	0.21	0.09	-0.01	-0.09	-0.16	-0.23
Wage (scheduled cash earnings)	0.66%	0.53	0.89	0.42	0.43	0.38	0.26	0.08	-0.11	-0.27	-0.40	-0.44	-0.40	-0.35	-0.31	-0.32
Wage (non-scheduled cash earnings)	4.18%	3.38	0.93	-0.35	-0.20	0.00	0.23	0.47	0.67	0.79	0.80	0.72	0.59	0.44	0.30	0.17
Wage (others, including bonus)	4.30%	3.47	0.63	0.33	0.46	0.54	0.56	0.52	0.45	0.37	0.22	0.09	-0.02	-0.11	-0.17	-0.19
Compensation of employees (nominal)	1.24%	1.00	0.95	0.43	0.54	0.65	0.73	0.74	0.68	0.55	0.36	0.16	-0.03	-0.18	-0.30	-0.39
Compensation of employees (nom, growth rate)	0.37%	0.30	0.87	-0.41	-0.35	-0.21	0.00	0.25	0.49	0.67	0.71	0.65	0.54	0.41	0.31	0.24
Labor share	0.40%	0.32	0.90	0.21	0.17	0.06	-0.12	-0.34	-0.54	-0.68	-0.70	-0.60	-0.45	-0.27	-0.13	-0.04
Saving rate	0.75%	0.61	0.82	0.32	0.35	0.36	0.28	0.13	-0.06	-0.24	-0.37	-0.44	-0.45	-0.44	-0.39	-0.32
Deflators and prices																
GDP deflator (level)	0.66%	0.54	0.95	0.71	0.72	0.67	0.55	0.38	0.16	-0.07	-0.26	-0.38	-0.45	-0.48	-0.49	-0.50
GDP deflator (growth rate)	0.70%	0.57	0.88	0.34	0.54	0.69	0.74	0.70	0.57	0.40	0.23	0.11	0.04	-0.01	-0.06	-0.13
Consumer price index (level)	0.76%	0.61	0.95	0.56	0.55	0.50	0.44	0.34	0.22	0.06	-0.11	-0.28	-0.43	-0.54	-0.60	-0.61
Consumer price index (growth rate)	0.78%	0.63	0.91	0.20	0.29	0.39	0.51	0.61	0.66	0.65	0.55	0.39	0.22	0.06	-0.06	-0.15
CPI (excl. fresh food, level)	0.67%	0.54	0.95	0.57	0.55	0.49	0.41	0.30	0.16	-0.02	-0.20	-0.36	-0.49	-0.58	-0.62	-0.63
CPI (excl. fresh food, growth rate)	0.74%	0.60	0.89	0.24	0.35	0.46	0.57	0.64	0.66	0.61	0.49	0.33	0.18	0.04	-0.07	-0.17
CPI (excl. fresh food and energy, level)	0.68%	0.55	0.95	0.66	0.63	0.55	0.42	0.26	0.06	-0.14	-0.31	-0.45	-0.54	-0.60	-0.62	-0.61
CPI (excl. fresh food and energy, growth rate)	0.70%	0.56	0.89	0.37	0.50	0.60	0.66	0.65	0.59	0.49	0.35	0.20	0.07	-0.03	-0.12	-0.20
Domestic corporate goods price index	1.30%	1.05	0.94	0.18	0.23	0.30	0.38	0.46	0.49	0.47	0.38	0.24	0.07	-0.09	-0.24	-0.36
Domestic corporate goods price index (growth)	0.44%	0.36	0.83	-0.15	-0.18	-0.21	-0.18	-0.08	0.09	0.28	0.43	0.50	0.50	0.44	0.36	0.26
Interest rates and stock price																
Call rate (collateralized overnight)	0.94%	0.76	0.95	0.18	0.26	0.35	0.45	0.53	0.59	0.60	0.55	0.44	0.30	0.16	0.03	-0.08
Tokyo interbank offered rates (3 months)	0.87%	0.70	0.94	0.15	0.22	0.29	0.39	0.48	0.55	0.58	0.55	0.46	0.35	0.22	0.09	-0.01
Newly issued government bonds (10 years)	0.51%	0.42	0.91	-0.03	-0.02	0.03	0.13	0.27	0.41	0.54	0.61	0.61	0.52	0.38	0.21	0.04
Long-term prime lending rate	0.60%	0.48	0.92	0.14	0.20	0.28	0.36	0.43	0.46	0.46	0.43	0.37	0.29	0.18	0.08	-0.02
Interest rate spread	0.54%	0.44	0.90	-0.27	-0.36	-0.44	-0.49	-0.51	-0.48	-0.41	-0.30	-0.17	-0.06	0.02	0.05	0.06
Stock price	11.22%	9.07	0.91	-0.37	-0.30	-0.22	-0.15	-0.08	0.02	0.16	0.30	0.43	0.52	0.57	0.56	0.52
Money and exchange rate																
Money stock (M2, nominal)	1.69%	1.37	0.97	0.33	0.35	0.35	0.35	0.34	0.33	0.31	0.29	0.26	0.22	0.19	0.16	0.12
Money stock (M2, nominal, growth rate)	0.44%	0.35	0.88	-0.39	-0.41	-0.42	-0.41	-0.37	-0.29	-0.17	-0.05	0.06	0.15	0.21	0.27	0.30
Monetary base (nominal)	2.37%	1.91	0.96	0.31	0.34	0.34	0.33	0.31	0.29	0.27	0.26	0.23	0.20	0.18	0.15	0.12
Monetary base (nominal, growth rate)	0.67%	0.55	0.86	-0.22	-0.21	-0.19	-0.20	-0.21	-0.19	-0.15	-0.09	-0.02	0.05	0.09	0.15	0.21
Effective exchange rate	7.51%	6.07	0.93	-0.26	-0.35	-0.40	-0.44	-0.48	-0.52	-0.55	-0.55	-0.49	-0.35	-0.15	0.09	0.32
Overseas economies																
World GDP	0.26%	0.21	0.81	-0.12	-0.03	0.11	0.28	0.47	0.63	0.71	0.64	0.48	0.28	0.11	-0.02	-0.11
US GDP	0.45%	0.36	0.82	-0.27	-0.30	-0.30	-0.27	-0.19	-0.09	0.03	0.09	0.12	0.14	0.17	0.20	0.23
China GDP	0.93%	0.76	0.94	-0.47	-0.54	-0.57	-0.55	-0.49	-0.41	-0.32	-0.27	-0.23	-0.21	-0.18	-0.14	-0.08
EU GDP	0.29%	0.23	0.93	-0.09	0.02	0.16	0.30	0.45	0.57	0.66	0.67	0.63	0.58	0.54	0.50	0.46

Notes: The table reports the cross-correlation of the cyclical component of real GDP and the cyclical component of each of the macroeconomic variables, as well as their standard deviations, etc. The cyclical components were extracted using the BK filter (with 12-period lags and leads).

Table 2: Statistics for cyclical component: Since 2000

Macroeconomic time series	Cross-correlation with GDP (Corr[xt, gdpt+k])															
				k												
	Std. Dev.	Relative Std. Dev.	Auto-correlation	-6	-5	-4	-3	-2	-1	0	1	2	3	4	5	6
Gross domestic product	1.57%	1.00	0.86	-0.31	-0.29	-0.14	0.16	0.54	0.86	1.00	0.86	0.54	0.16	-0.14	-0.29	-0.31
GDP components																
Private consumption	0.85%	0.54	0.82	-0.10	-0.19	-0.22	-0.12	0.13	0.45	0.71	0.75	0.61	0.38	0.16	0.01	-0.06
Private residential investment	5.35%	3.41	0.84	0.01	0.21	0.42	0.56	0.60	0.50	0.34	0.13	0.04	0.09	0.24	0.34	0.32
Private non-resi. investment	4.39%	2.80	0.91	-0.03	0.10	0.29	0.52	0.73	0.85	0.82	0.63	0.34	0.05	-0.17	-0.29	-0.33
Change in private inventory (relative to GDP)	0.37%	0.24	0.82	-0.41	-0.26	0.06	0.45	0.75	0.82	0.63	0.28	-0.07	-0.29	-0.34	-0.27	-0.18
Government consumption	0.71%	0.45	0.90	-0.29	-0.30	-0.31	-0.30	-0.25	-0.12	0.07	0.20	0.26	0.22	0.10	-0.04	-0.11
Public investment	3.61%	2.30	0.83	0.01	-0.24	-0.50	-0.68	-0.71	-0.58	-0.34	-0.10	0.08	0.17	0.17	0.13	0.08
Exports	7.39%	4.71	0.85	-0.38	-0.39	-0.24	0.06	0.44	0.77	0.91	0.79	0.48	0.11	-0.17	-0.28	-0.25
Imports	4.42%	2.82	0.87	-0.29	-0.19	0.04	0.36	0.68	0.87	0.87	0.64	0.32	0.04	-0.13	-0.17	-0.14
Employment																
Labor force	0.26%	0.17	0.94	0.02	0.07	0.16	0.24	0.27	0.23	0.12	0.02	-0.08	-0.16	-0.22	-0.29	-0.35
Total employed	0.45%	0.29	0.94	0.04	0.20	0.41	0.60	0.70	0.69	0.55	0.33	0.10	-0.09	-0.22	-0.30	-0.36
Employees	0.49%	0.31	0.93	-0.01	0.13	0.32	0.51	0.64	0.64	0.52	0.31	0.09	-0.09	-0.21	-0.27	-0.31
Regular employment index	0.79%	0.50	0.96	0.33	0.33	0.30	0.22	0.10	-0.08	-0.29	-0.46	-0.58	-0.63	-0.60	-0.52	-0.41
Total hours worked	0.89%	0.57	0.89	0.00	-0.01	0.07	0.26	0.48	0.62	0.57	0.32	-0.03	-0.37	-0.58	-0.62	-0.54
Average hours worked (total)	0.77%	0.49	0.86	-0.34	-0.36	-0.23	0.07	0.46	0.80	0.95	0.85	0.56	0.22	-0.05	-0.19	-0.21
Average hours worked (scheduled)	0.51%	0.33	0.86	-0.29	-0.33	-0.25	0.01	0.37	0.71	0.88	0.81	0.56	0.25	0.00	-0.13	-0.15
Average hours worked (non-scheduled)	4.29%	2.74	0.85	-0.35	-0.35	-0.20	0.10	0.49	0.82	0.96	0.83	0.51	0.13	-0.15	-0.28	-0.27
Ratio of unemployed in labor force	0.29%	0.19	0.94	-0.05	-0.26	-0.49	-0.69	-0.82	-0.83	-0.72	-0.50	-0.25	-0.02	0.13	0.20	0.23
Effective job-openings-to-applicants ratio	16.02%	10.21	0.93	-0.14	0.06	0.31	0.57	0.77	0.86	0.80	0.59	0.34	0.12	-0.02	-0.09	-0.10
New job offers	8.58%	5.47	0.94	-0.26	-0.10	0.12	0.36	0.59	0.73	0.76	0.67	0.51	0.34	0.21	0.11	0.05
Job placement rate	1.44%	0.92	0.90	-0.26	-0.26	-0.17	0.04	0.34	0.66	0.87	0.87	0.70	0.44	0.18	0.01	-0.07
Separation rate	0.06%	0.04	0.85	0.44	0.36	0.21	-0.03	-0.33	-0.58	-0.68	-0.58	-0.33	-0.03	0.17	0.24	0.17
Accession rate	0.04%	0.02	0.86	0.39	0.31	0.17	0.02	-0.10	-0.12	-0.02	0.10	0.19	0.17	0.03	-0.18	-0.35
Fill rate	2.34%	1.49	0.93	0.11	-0.12	-0.39	-0.64	-0.80	-0.83	-0.73	-0.51	-0.28	-0.08	0.04	0.09	0.10
Ratio of part-time workers	0.48%	0.30	0.85	-0.02	-0.13	-0.24	-0.33	-0.38	-0.36	-0.26	-0.11	0.06	0.19	0.25	0.24	0.18
Index of capacity utilization ratio (manuf.)	6.69%	4.26	0.84	-0.34	-0.40	-0.31	-0.03	0.37	0.74	0.94	0.85	0.54	0.17	-0.13	-0.25	-0.22
Labor productivity	1.38%	0.88	0.85	-0.36	-0.40	-0.29	-0.01	0.39	0.76	0.96	0.88	0.58	0.21	-0.09	-0.23	-0.23
Wages																
Wage index (total cash earnings, nominal)	0.97%	0.62	0.90	-0.18	-0.05	0.16	0.42	0.66	0.78	0.74	0.55	0.28	0.03	-0.13	-0.18	-0.15
Wage index (contractual cash earnings, nom)	0.69%	0.44	0.91	-0.20	-0.12	0.05	0.30	0.57	0.75	0.78	0.65	0.41	0.15	-0.05	-0.16	-0.20
Wage index (total cash earnings, nom, growth rate)	0.42%	0.27	0.78	-0.31	-0.48	-0.59	-0.54	-0.30	0.07	0.43	0.62	0.59	0.37	0.12	-0.04	-0.04
Wage index (total cash earnings, real)	1.01%	0.64	0.92	-0.37	-0.26	-0.07	0.16	0.42	0.64	0.77	0.75	0.61	0.40	0.18	0.02	-0.07
Wage index (contractual cash earnings, real)	0.84%	0.53	0.92	-0.40	-0.34	-0.22	-0.02	0.22	0.48	0.68	0.76	0.72	0.56	0.34	0.12	-0.05
Wage index (total cash earnings, real, growth rate)	0.37%	0.24	0.83	-0.30	-0.49	-0.64	-0.69	-0.58	-0.33	0.02	0.35	0.54	0.55	0.43	0.27	0.15
Wage (total cash earnings)	1.32%	0.84	0.82	-0.18	-0.05	0.16	0.41	0.62	0.72	0.65	0.42	0.13	-0.13	-0.26	-0.24	-0.14
Wage (scheduled cash earnings)	0.71%	0.45	0.85	-0.06	0.06	0.21	0.38	0.51	0.54	0.43	0.23	-0.02	-0.22	-0.32	-0.29	-0.18
Wage (non-scheduled cash earnings)	3.99%	2.54	0.85	-0.41	-0.38	-0.21	0.12	0.51	0.83	0.94	0.79	0.47	0.12	-0.12	-0.21	-0.17
Wage (others, including bonus)	5.43%	3.46	0.72	-0.20	-0.05	0.16	0.35	0.48	0.52	0.46	0.28	0.06	-0.14	-0.28	-0.30	-0.21
Compensation of employees (nominal)	1.10%	0.70	0.92	0.05	0.21	0.41	0.62	0.75	0.74	0.57	0.29	-0.01	-0.24	-0.35	-0.33	-0.25
Compensation of employees (nom, growth rate)	0.45%	0.28	0.81	-0.40	-0.50	-0.49	-0.31	0.02	0.40	0.69	0.75	0.57	0.25	-0.05	-0.20	-0.15
Labor share	0.55%	0.35	0.86	0.34	0.53	0.56	0.40	0.06	-0.33	-0.63	-0.73	-0.63	-0.40	-0.14	0.07	0.20
Saving rate	0.65%	0.42	0.87	-0.12	-0.11	-0.15	-0.27	-0.41	-0.50	-0.48	-0.32	-0.09	0.12	0.25	0.26	0.17
Deflators and prices																
GDP deflator (level)	0.58%	0.37	0.87	0.28	0.20	0.12	0.01	-0.14	-0.31	-0.45	-0.42	-0.30	-0.13	0.00	0.03	-0.02
GDP deflator (growth rate)	0.50%	0.32	0.82	0.45	0.57	0.60	0.47	0.19	-0.15	-0.40	-0.44	-0.27	-0.02	0.17	0.19	0.05
Consumer price index (level)	0.59%	0.38	0.89	0.29	0.31	0.34	0.36	0.31	0.17	-0.07	-0.31	-0.49	-0.55	-0.47	-0.31	-0.14
Consumer price index (growth rate)	0.62%	0.40	0.73	-0.05	0.11	0.35	0.60	0.76	0.72	0.47	0.07	-0.29	-0.48	-0.46	-0.28	-0.07
CPI (excl. fresh food, level)	0.57%	0.36	0.83	0.36	0.38	0.39	0.36	0.28	0.11	-0.12	-0.34	-0.51	-0.57	-0.50	-0.35	-0.17
CPI (excl. fresh food, growth rate)	0.58%	0.37	0.85	0.09	0.26	0.47	0.65	0.74	0.67	0.43	0.07	-0.28	-0.49	-0.50	-0.34	-0.13
CPI (excl. fresh food and energy, level)	0.57%	0.36	0.90	0.32	0.25	0.17	0.07	-0.06	-0.23	-0.40	-0.47	-0.48	-0.42	-0.30	-0.17	-0.07
CPI (excl. fresh food and energy, growth rate)	0.47%	0.30	0.91	0.45	0.57	0.65	0.62	0.49	0.26	-0.03	-0.28	-0.43	-0.46	-0.38	-0.26	-0.15
Domestic corporate goods price index	1.46%	0.93	0.89	0.21	0.36	0.51	0.63	0.68	0.60	0.38	0.05	-0.29	-0.51	-0.57	-0.47	-0.29
Domestic corporate goods price index (growth)	0.66%	0.42	0.78	-0.32	-0.32	-0.25	-0.09	0.18	0.49	0.72	0.72	0.48	0.11	-0.24	-0.39	-0.31
Interest rates and stock price																
Call rate (collateralized overnight)	0.11%	0.07	0.92	0.07	0.18	0.33	0.51	0.66	0.72	0.66	0.45	0.16	-0.15	-0.41	-0.57	-0.64
Tokyo interbank offered rates (3 months)	0.14%	0.09	0.92	0.30	0.38	0.46	0.53	0.55	0.49	0.34	0.13	-0.10	-0.31	-0.48	-0.58	-0.61
Newly issued government bonds (10 years)	0.17%	0.11	0.80	0.06	0.09	0.08	0.06	0.08	0.15	0.26	0.31	0.30	0.24	0.15	0.07	0.01
Long-term prime lending rate	0.19%	0.12	0.87	0.37	0.44	0.47	0.44	0.36	0.26	0.15	0.05	0.00	-0.03	-0.03	-0.05	-0.10
Interest rate spread	0.21%	0.13	0.82	-0.15	-0.17	-0.23	-0.29	-0.29	-0.20	-0.02	0.16	0.30	0.40	0.43	0.43	0.40
Stock price	15.81%	10.08	0.91	-0.06	-0.06	-0.05	0.01	0.15	0.35	0.55	0.65	0.61	0.46	0.23	0.02	-0.14
Money and exchange rate																
Money stock (M2, nominal)	0.48%	0.30	0.90	0.00	0.02	0.02	0.01	0.01	0.03	0.06	0.04	0.03	0.01	0.00	-0.01	0.00
Money stock (M2, nominal, growth rate)	0.17%	0.11	0.79	0.11	0.16	0.12	-0.01	-0.14	-0.21	-0.24	-0.21	-0.19	-0.19	-0.20	-0.22	-0.22
Monetary base (nominal)	7.46%	4.76	0.94	-0.02	0.01	0.01	0.00	-0.01	0.02	0.09	0.09	0.10	0.11	0.12	0.14	0.17
Monetary base (nominal, growth rate)	2.52%	1.60	0.77	-0.06	0.04	0.05	0.00	-0.07	-0.13	-0.16	-0.19	-0.20	-0.15	-0.13	-0.15	-0.18
Effective exchange rate	6.27%	4.00	0.90	-0.22	-0.26	-0.27	-0.28	-0.31	-0.36	-0.41	-0.37	-0.26	-0.09	0.09	0.22	0.27
Overseas economies																
World GDP	0.49%	0.31	0.91	-0.22	-0.11	0.09	0.35	0.62	0.84	0.90	0.77	0.49	0.14	-0.17	-0.36	-0.41
US GDP	0.53%	0.34	0.93	-0.18	-0.10	0.05	0.28	0.53	0.71	0.77	0.68	0.47	0.22	0.01	-0.12	-0.16
China GDP	0.43%	0.28	0.95	-0.06	-0.03	0.03	0.12	0.25	0.38	0.49	0.50	0.39	0.16	-0.12	-0.38	-0.54
EU GDP	0.60%	0.38	0.92	-0.20	-0.04	0.18	0.43	0.67	0.82	0.82	0.67	0.39	0.08	-0.18	-0.35	-0.40

Notes: See Table 1.

Table 3: Selected parameter estimates of the TVP-VAR model

	Mean	Std. Dev.	95% interval		CD	Inefficiency
$(\Sigma_\beta)_1$	**0.016**	0.002	0.013	0.021	**0.38**	**7.53**
$(\Sigma_\beta)_2$	**0.016**	0.002	0.013	0.020	**0.29**	**8.25**
$(\Sigma_\alpha)_1$	**0.050**	0.015	0.029	0.086	**0.84**	**48.12**
$(\Sigma_\alpha)_2$	**0.046**	0.013	0.028	0.077	**0.24**	**37.72**
$(\Sigma_h)_1$	**0.263**	0.078	0.140	0.445	**0.42**	**60.64**
$(\Sigma_h)_2$	**0.254**	0.126	0.069	0.546	**0.50**	**147.11**

Note: The table shows the posterior mean, posterior standard deviation, and 95 percent interval of the i^{th} diagonal elements of $(\Sigma_\beta)_i$, $(\Sigma_\alpha)_i$, and $(\Sigma_h)_i$, as well as the Geweke (1992) convergence diagnostic (CD).