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Abstract

Private consumption has been resilient on the whole, although relatively weak developments have been seen for a prolonged time, ever since the consumption tax hike in April 2014. Various factors have been pointed out as attributable to such weakness. Among these factors, we focus on the effect of the temporary policy measures to promote purchasing environmentally friendly durable goods since 2009 and the consumption tax hike in 2014.

This paper employs spectrum analysis for investigating the impact of replacement cycles for durable goods consumption. It is concluded that both medium-term cycles, including replacement cycles of digital appliances, and long-term cycles, including replacement cycles of passenger-cars and household appliances, exerted large adverse effects on durable goods consumption after the consumption tax hike in 2014. Looking at the period after 2016, however, the medium-term cycle is generating positive effects again, while the long-term cycle still works as the downward pressure on durable goods consumption. This analysis suggests that the downward pressure from replacement cycles of durable goods has started to decrease gradually.

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* This paper applies the spectrum analysis technique used in Box 3 of "Outlook for Economic Activity and Prices (Outlook Report)" released in July 2016 to the analysis on durable goods consumption. The authors would like to thank Toshitaka Sekine, Koji Nakamura, Hibiki Ichiue, Takuji Kawamoto, Ichiro Muto, Sohei Kaihatsu, Maiko Koga, Naoya Kato, Yoshiyuki Kurachi, Ko Miura and the staff of the Bank of Japan for their helpful comments. Any errors or omissions are the responsibility of the authors. The views expressed herein are those of the authors alone and do not necessarily reflect those of the Bank of Japan.

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1. Introduction

Private consumption has been resilient on the whole, although relatively weak developments have been seen for a prolonged time since the consumption tax hike in April 2014. Various factors have been pointed out as attributable to such weakness, including the front-loaded increase and subsequent decline in demand for durable goods prior to and after the temporary policy measures to promote purchasing durable goods and the consumption tax hike, a decline in real disposable income due to the consumption tax hike and the rise in food prices, a negative wealth effect due to a decline in stock prices, bad weather, and anxiety over the social security system, including pensions.

Since 2009, there have been several factors which promote purchases of durable goods, such as temporary policy measures to promote replacement of durable goods, the ending of analog TV broadcasting, and the consumption tax hike. These factors helped to create subsequent decline in demand for durable goods after the front-loaded increase. Although these facts are well known, there are few empirical studies focusing on the quantitative impact of these factors. This paper demonstrates an empirical analysis on the impact of replacement cycles for durable goods consumption. There are many works that attempt to decompose business cycle into multiple cycles with different periods from the old times, such as Schumpeter (1939)[1]. In this paper, spectrum analysis—a widely used method in the literature—is applied to durable goods consumption.

The remainder of the paper is organized as follows. Section 2 gives an overview of the developments in private consumption, especially durable goods consumption in recent years. Section 3 summarizes the framework of spectral analysis. Section 4 shows the results of spectral analysis on durable goods consumption and discusses the impact of some policy measures after 2009 and the consumption tax hike in 2014. Finally, Section 5 concludes and touches on a few remaining issues.

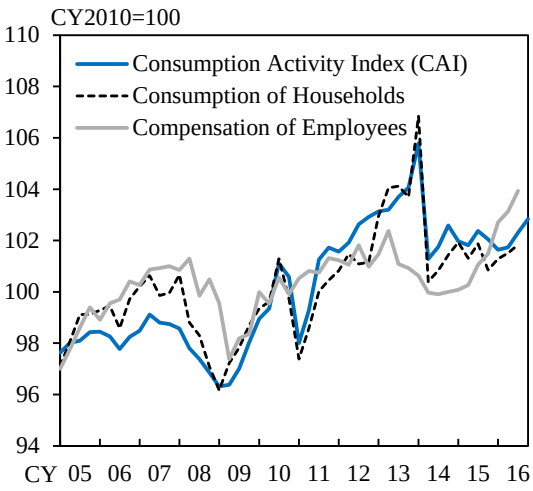
[1] Schumpeter (1939) explains multiple-cycle theory, which suggests that business cycles are composed of multiple cycles with different periods, including the Kondratieff cycle (50 years), the Juglar cycle (10 years) and the Kitchin cycle (40 months).

2. Private Consumption and Durable Goods Consumption in Recent Years

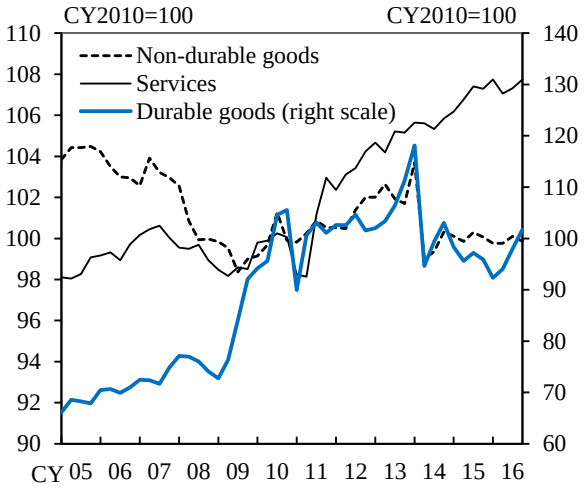
Private consumption has been resilient on the whole, although relatively weak developments have been seen for a prolonged time since the consumption tax hike in April 2014 (Chart 1). Developments in private consumption by components through recent years show a relative weakness in durable and non-durable (including semi-durable) goods. Various factors have been pointed out as attributable to such weakness, including the front-loaded increase and subsequent decline in demand for durable goods prior to and after the temporary policy measures and the consumption tax hike, a decline in real disposable income due to the consumption tax hike and the rise in food prices, a negative wealth effect due in part to a decline in stock prices, bad weather, and anxiety over the social security system, including pensions.

Chart 1. Private Consumption in Recent Years

(1) Private consumption



(2) Components of the CAI



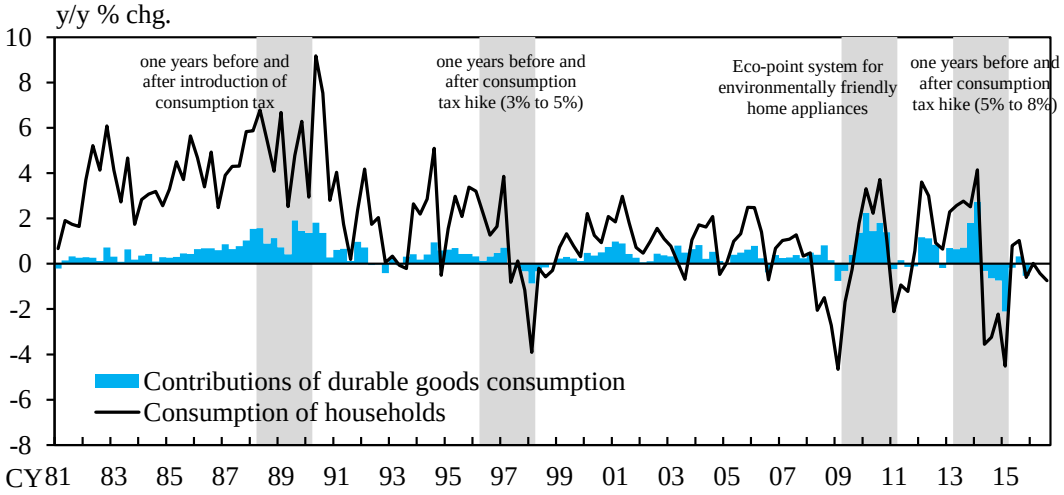
Note: Figures for the Consumption Activity Index in (1) exclude inbound tourism consumption and include outbound tourism consumption. Consumption of households excludes imputed rent. All figures are real values.

Sources: Cabinet Office, "National Accounts"; Bank of Japan, "Consumption Activity Index."

Since the Lehman shock in the fall 2008, the impact of volatile developments of durable goods consumption on overall private consumption has become larger (Chart 2). Some factors have been pointed out as attributable to such volatile developments, including the front-loaded increase and subsequent decline in demand for durable goods prior to and after (a) the temporary policy measures for replacement of old appliances and cars

to environmentally friendly ones, (b) replacement of analog TV sets to digital ones against the background of the ending of analog broadcasting in July 2011 and (c) the consumption tax hike in April 2014 (Chart 3, Appendix Chart 1).

Chart 2. Private Consumption with the Contribution of Durable Goods Consumption



Note: Consumption of households excludes imputed rent. Data from 2016/Q1 to Q3 are obtained by extending durable goods consumption and private consumption using the quarter-on-quarter rates of changes in the Consumption Activity Index. All figures are real values.
Sources: Cabinet Office, "National Accounts"; Bank of Japan, "Consumption Activity Index."

Chart 3. Policy Measures and Other Factors Surrounding Durable Goods Consumption

	Items	Periods for application/purchases
A. Policy measures for replacement to environmentally friendly durable goods[2]		
Eco-point system for environmentally friendly home appliances	TV sets Air-conditioners Refrigerators	May 2009 – Mar. 2011
Subsidy for environmentally friendly cars	Passenger-cars	June 2009 – Sept. 2010 Apr. 2012 – Sept. 2012
Tax break for environmentally friendly cars	Passenger-cars	Apr. 2009 –
B. Ending of analog broadcasting	TV sets	July 2011
C. Consumption tax hike (5% to 8%)[3]	All goods	Apr. 2014

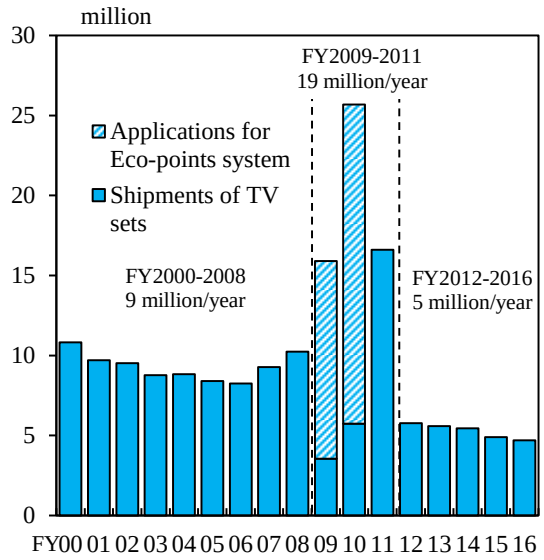
[2] For details of the policy measures, see Appendix Chart 1.

[3] As of April 2014, it was planned to hike the consumption tax from 8% to 10% in October 2015. This might have caused the further front-loaded increase in demand for durable goods prior to the

With regards to shipments of TV sets, the average between 2009 and 2011 increased to more than double the average between 2000 and 2008.The average between 2012 and 2016 decreased to about one-quarter of the average between 2009 and 2011 (Chart 4). In the survey of reasons for replacements of TV sets, “not working” was normally the highest in the past (Chart 5). However, the ratios for “(replacement to) Items with higher quality” and “others” including replacement to digital TV sets due to temporary policy measures and the ending of analog broadcasting have clearly increased during 2009 and 2011.

These facts show that one of the factors behind volatile the developments of durable goods consumption in recent years is the front-loaded increase and subsequent decline in demand prior to and after the temporary policy measures since 2009 and the consumption tax hike in 2014. This paper will quantitatively show changes in purchasing behavior affected by these factors and the subsequent impact on private consumption.

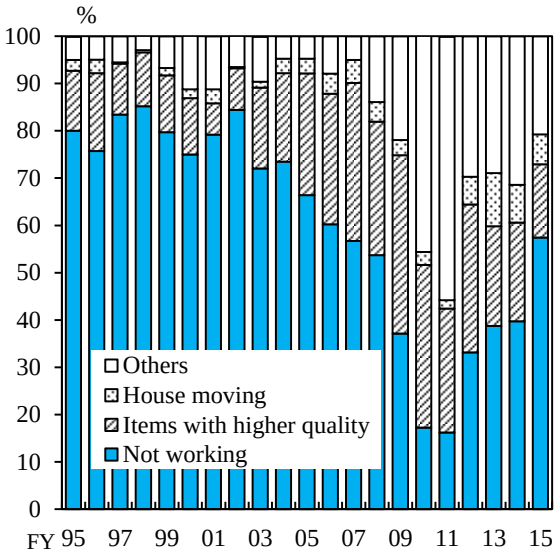
Chart 4. Domestic Shipments of TV Sets



Note: Figure for FY2016 is annualized from April-November Figures.

Sources: JEITA; METI.

Chart 5. Reasons for Replacement of TV



Source: Cabinet Office, “Consumer Confidence Survey.”

consumption tax hike in April 2014.

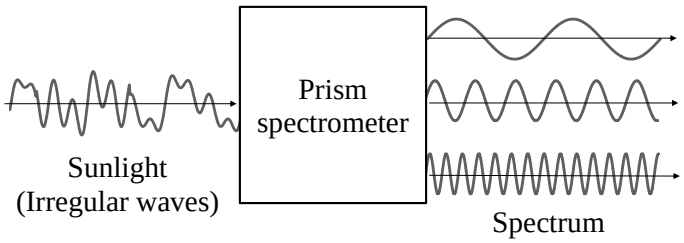
3. Framework of Spectrum Analysis

There are many works that explain developments of the economy by focusing on cyclical fluctuations, such as Schumpeter (1939). Various studies have been made to extract, in particular, cyclical components of macro-economic time-series data such as GDP. For extracting cyclical components, some studies use various specific methods like the "production function approach," "time-series approach" and so on. The "time-series approach" is widely used for analysis, because this approach requires only target data itself. The popular methods of "time-series approach" are Hodrick-Prescott (1980) filter and the band-pass filter method, such as the Baxter and King (1999) filter, which is based on the idea of spectrum analysis.

This paper applies the spectrum analysis method, which extracts multiple cyclical components to capture cyclical fluctuations of consumption of durable goods with different replacement cycles. The spectrum analysis has the following features: (a) converting a time-series data to a weighted sum of various frequency cycles in mathematical expression, and (b) extracting specific frequency cycles from time-series data.

To understand the framework of spectrum analysis of time-series data, the prism spectrometer works as a good analogy (Chart 6). When white sunlight enters a prism spectrometer, it is divided into a rainbow of colors. This phenomenon is the result of decomposing sunlight, which is an aggregate of waves of various frequencies, into rays of light with different frequencies by a prism spectrometer. In the same way, spectrum analysis decomposes time-series data into multiple cyclical components with various frequencies.

Chart 6. Prism Spectrometer



Source: Hino (1977)

One mathematical technique used for spectrum analysis is the Fourier transform. The Fourier transform is a mathematical technique for representing time-series data as the weighted sum of sine and cosine waves. This technique is generally used in the field of electrical engineering.

Specific steps of spectrum analysis are as follows:

(a) Representing time-series data as the weighted sum of sine and cosine waves (Fourier series).

(b) Decomposing the Fourier series into frequency components by the Fourier transform.

(c) The component with the cycle to be extracted is left unchanged, and the other components are replaced with zeros.

(d) Recomposing the time-series data by the inverse Fourier transform.

The band-pass filter, which is a method of applying the Fourier transform, is frequently used in the fields of electrical engineering. In economics, the Baxter and King (1999) filter and the Christiano and Fitzgerald (2003) filter are the most popular among band-pass filters. Both filters have advantages and disadvantages for economic analysis. The filtered series using the BK filter will not be revised by re-estimation with the latest data added to time-series data, because this filter is based on calculation of centered moving average. On the other hand, the CF filtered series will be ex-post revised by re-estimation given the arrival of further data on subsequent quarters. The BK filter is not able to estimate filtered figures for certain periods at the beginning and end of time-series data. However, the CF filter is able to estimate the end-point figures[4]. Taking these advantages and disadvantages into account, the CF filter is chosen in this paper, because the main focus of this paper is an investigation for recent developments in durable goods consumption.

[4] The end-point problem of filtering methods, which means large estimation errors of filtered figures for certain periods at the beginning and end of a time-series data, is pointed out in various literature. For details, see Urasawa and Seitani (2008) and Yamasawa (2009).

Chart 7. Features of BK Filter and CF Filter

	Advantages	Disadvantages
BK filter	Filtered series will NOT be revised by re-estimation given the arrival of further data on subsequent quarters.	End-point figures are NOT able to be estimated.
CF filter	End-point figures are able to be estimated.	Filtered series will be ex-post revised by re-estimation given the arrival of further data on subsequent quarters.

Source: Yamasawa (2009).

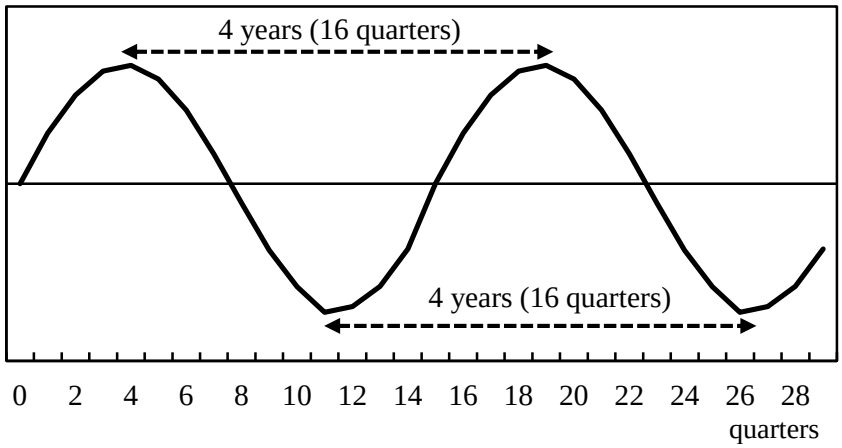
4. Spectrum Analysis on Durable Goods Consumption

This section shows the quantitative result of spectrum analysis with a band-pass filter (Christiano and Fitzgerald filter) on durable goods consumption.

4-1. Period of cycle to extract

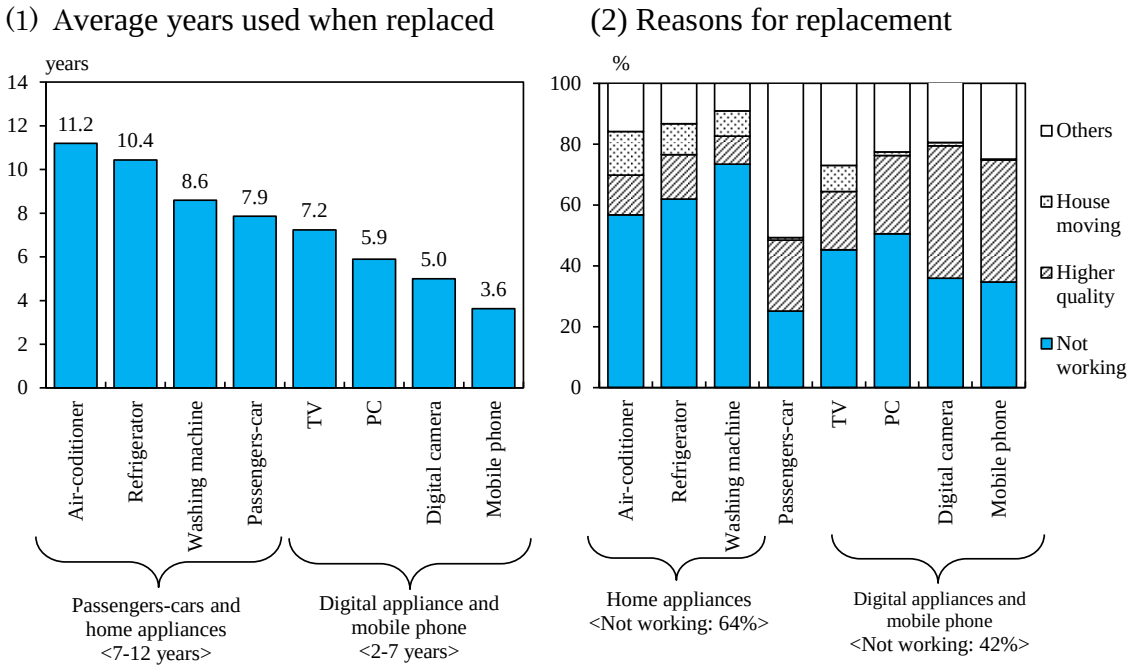
The Christiano and Fitzgerald filter requires specifying a range for a given cycle's period, which is extracted. The period of cycle means the time to form one complete cycle (Chart 8). In this paper, the range of period of the extracted cycle is set for capturing the replacement cycles of consumer durable goods, taking into account the average length of consumer replacement cycles. This is based on the assumption that the peak of replacement demand for a good will come again in line with the average length of replacement cycle of the good.

Chart 8. Period of Cycle (ex. 4 years)



With regards to the average length of replacement cycle for consumer durable goods, cycles for digital appliances including TV sets, digital cameras, personal computers, mobile phones are relatively short (about 5 years), but cycles for passenger-cars and home appliances, including refrigerators, washing machines, and air conditioners, are long (about 10 years). In the consumer survey of reasons for replacements, the reasons given are quite different. "Not working" is the most popular reason for home appliances, but many respondents replace digital appliances for other reasons[5] (Chart 9). These facts suggest that purchasing behavior is different between durable goods with short replacement cycles and long ones.

Chart 9. Consumer Survey for Replacements of Durable Goods



Note: Figures are averages between FY2013 and 2015.
Source: Cabinet Office, "Consumer Confidence Survey."

[5] The average length of replacement cycle for passenger cars is long, but the survey of reasons for replacements of passenger cars shows that reasons other than "Not working" are primary factors. This fact suggests that many consumers sell their cars in the secondhand-market before they fail.

In this paper, the business cycle is defined as a cycle with less than 12-year periods[6]. For the analysis on consumer durable goods, the medium-term (2 to 7 years) cycle and the long-term (7 to 12 years) cycle are extracted. The medium-term cycle includes the replacement cycle of digital appliances (including TV sets, mobile phones, and so on) and the long-term includes the cycle of passenger cars and general home appliances (including refrigerators, air-conditioners, and so on). The amplitudes of extracted cycles are allowed to fluctuate over time in the spectrum analysis, thus, the spectrum analysis is able to extract complex cycles composed of time-varying amplitudes and periods.

In addition, the short-term cycle of less than two years is also extracted. This cycle shows short-term fluctuations including statistical noises, the effects of bad weather, and other temporary factors. And the trend component is defined as the residual component after extracting the three cycles. Finally, durable goods consumption is divided into three cyclical components and the trend.

4-2. Results of frequency analysis on durable goods consumption

4-2-1. Overview of the result

In this spectrum analysis, the quarterly durable goods consumption series (seasonal adjusted) is decomposed by band-pass filter (Christiano and Fitzgerald filter) to four components; (a) the short-term cycle of less than two years, (b) the medium-term cycle of 2-7 years, (c) the long-term cycle of 7-12 years and (d) the trend components of more than 12 years[7]. Chart 10 shows the results.

Chart 11 shows the contributions of medium- and long-term cycles to quarterly changes of durable goods consumption. From 2009 to 2010, the medium- and long-term cycles worked as drivers of powerful growth of durable goods consumption. Increases in

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[6] Burns and Mitchell (1946) suggested that "in duration business cycles vary from more than one year to 10 or 12 years." Howrey (1968) finds little evidence for the existence a business cycle longer than about 10 years. Based on these studies, the following works mostly define the maximum period of business cycle as less than 10-12 years.

[7] As suggested by Christiano and Fitzgerald (2003), linear trends are removed from raw data prior to applying the filter. The additional trial for spectrum analysis using a logarithm of durable goods consumption supports the results in this paper.

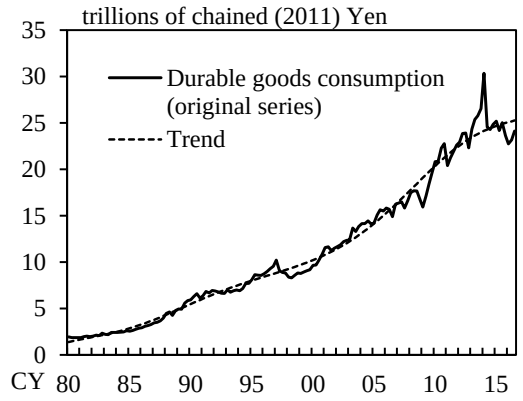
demand resulted from the temporary policy measures for replacement and the ending of analog TV broadcasting listed in Chart 3. In 2011, there was a decline following the front-loaded increase.

The medium-term cycle accelerated growth again from 2013 to 2014/Q1. This is the front-loaded increase in demand prior to the consumption tax hike in April 2014. After the consumption tax hike, both medium- and long-term cycles exerted adverse effects. This means the subsequent decline in demand after the temporary policy measures and the consumption tax hike. From the beginning of 2016, the medium-term cycle has risen again, although the long-term cycle has exerted downward pressure. Thereafter, it is likely that the downward pressure on durable goods consumption has started to decrease gradually.

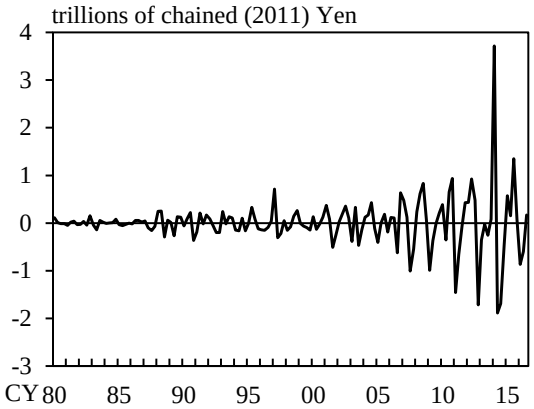
It is concluded that the front-loaded increase in demand for durable goods prior to the temporary policy measures since 2009 and the consumption tax hike in 2014 caused an adverse impact on durable goods consumption in subsequent periods.

Chart 10. Results of Spectrum Analysis on Durable Goods Consumption

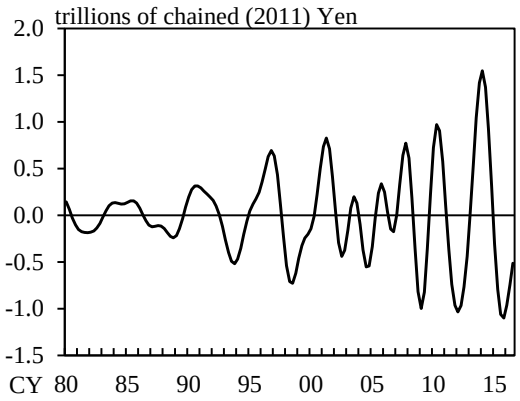
(1) Original series and trend component



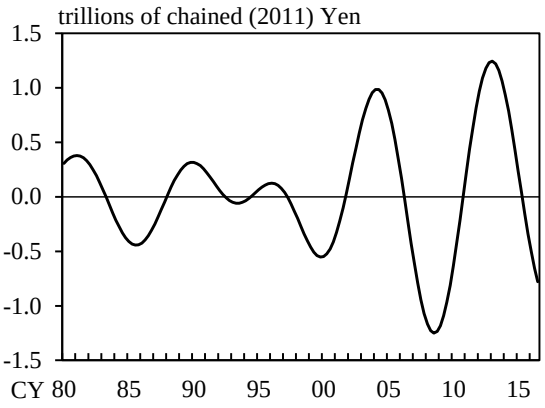
(2) Short-term cycle of less than 2 years



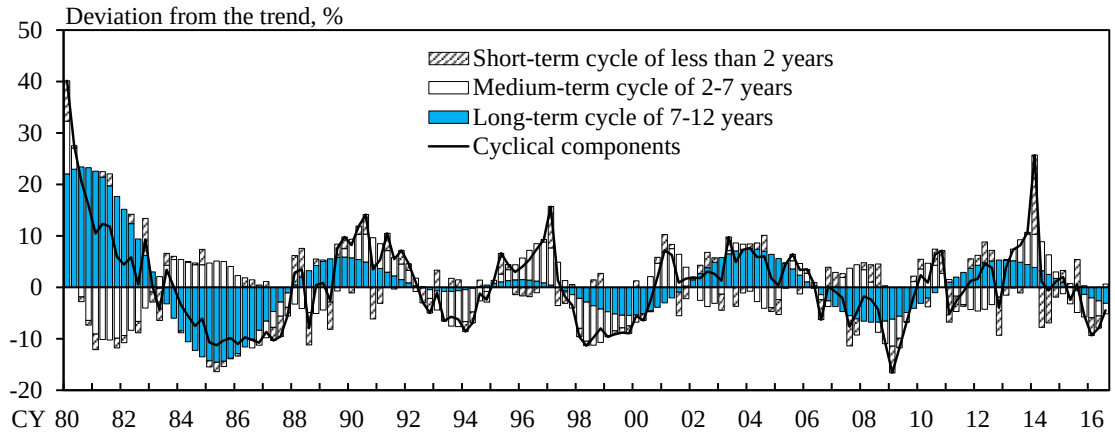
(3) Medium-term cycle of 2-7 years



(4) Long-term cycle of 7-12 years



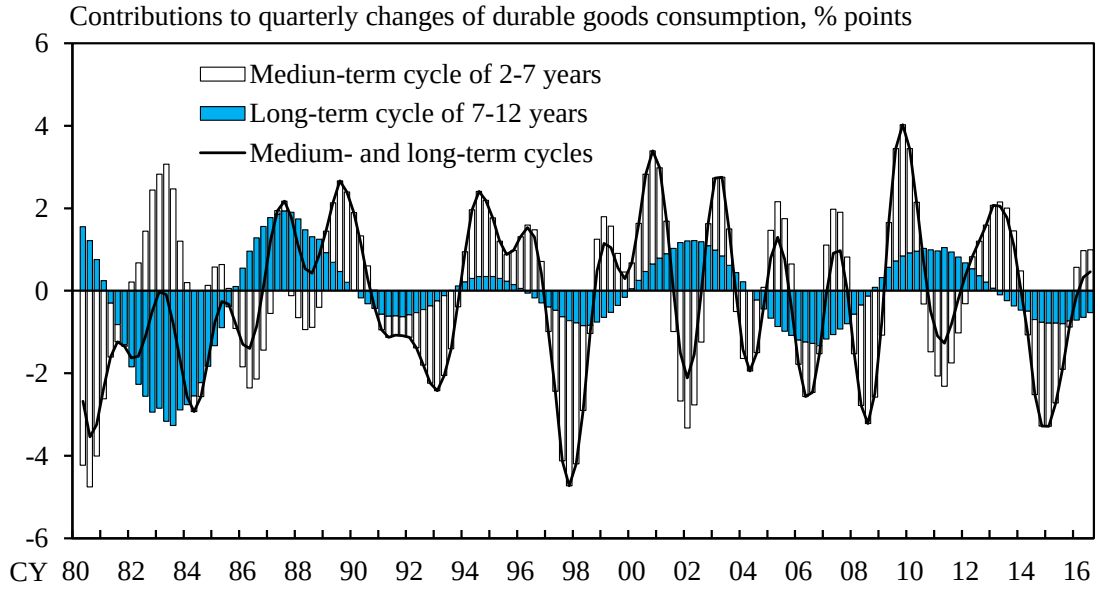
(5) Decomposition of business cycle for durable goods consumption



Notes: 1. Data from 2016/Q1 to Q3 are obtained by extending durable goods consumption using the quarter-on-quarter rates of changes in the Consumption Activity Index (durable goods). Cyclical components are extracted using the Christiano-Fitzgerald filter.

2. The trend component is calculated by subtracting cyclical components from the original series.

Chart 11. Contributions of Medium- and Long-term Cycles
to Durable Goods Consumption



4-2-2. Fluctuation factors for each cycle

This section discusses some fluctuation factors for each cycle of durable goods consumption. In practice, we apply spectrum analysis to underlying factors (including stock price, consumer confidence and household income) in the same way we do to durable goods consumption and compare the cyclical components between durable goods and the factors to investigate their relationships[8].

(a) Short-term cycle of less than two years

Short-term cycle of less than two years shows short-term fluctuations including statistical noises, the effects of bad weather and other temporary factors[9]. It is clear, in particular, that the short-term cycle includes fluctuations of the front-loaded increase and subsequent decline prior to and after the consumption tax hike. The short-term cycle pushed up durable goods consumption by 14% at 2014/Q1 and pushed it down by -18 % at 2014/Q2.

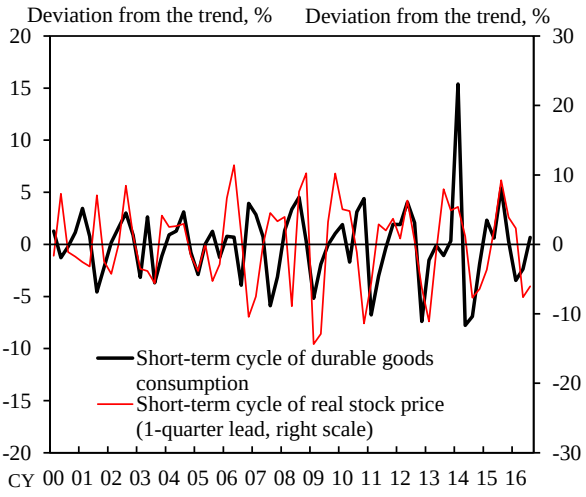
[8] In these analyses, we define the period of business cycle as less than 12 years. This is longer than the average period of Japan's business economy cycle of 4-5 years as defined by the Cabinet Office.

[9] For details of the effect of bad weather on private consumption, see Box 4 of "Outlook for Economic Activity and Prices (Outlook Report)" released in April 2016.

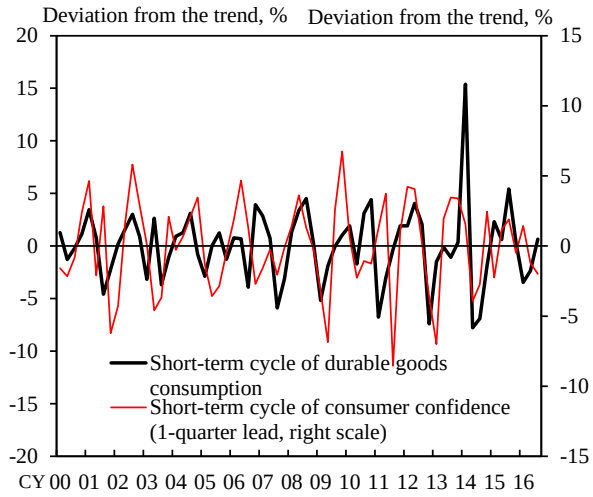
And it is likely that fluctuations of volatile stock price and consumer confidence affect the short-term cycle. Chart 12 shows the short-term cycles of durable goods consumption, real stock price, and consumer confidence. The periods and phase of three cycles are mostly matched. This implies that the short-term fluctuation of durable goods consumption is affected to a certain degree by stock price and consumer confidence.

Chart 12. Short-term Cycle of Durable Goods Consumption, Stock Price and Consumer Confidence

(1) Durable goods and stock price



(2) Durable goods and consumer confidence



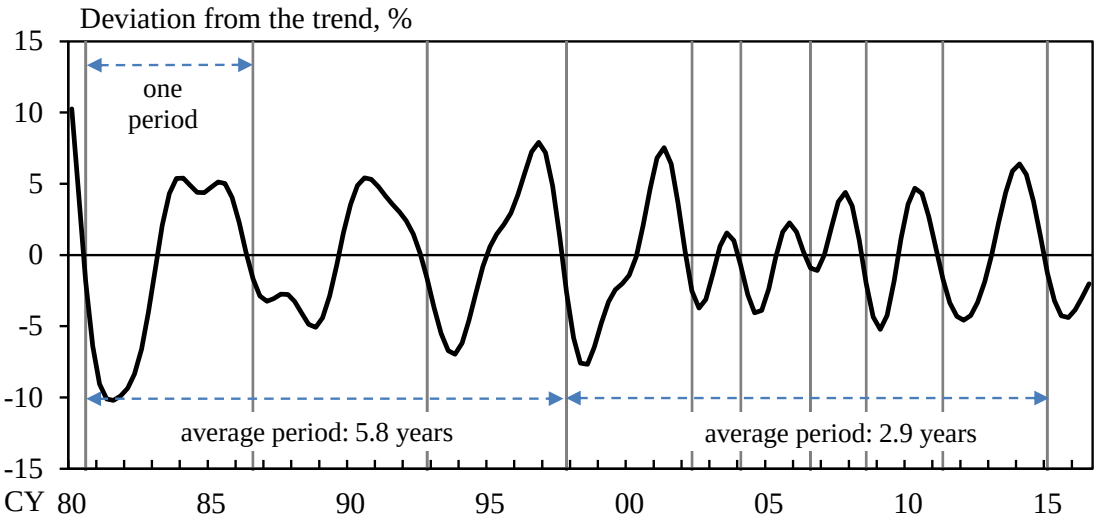
Notes 1: Real stock price is obtained by deflating nominal stock price by the CPI.
2: Figures for consumer confidence are based on the "Consumer Confidence Survey."

(b) Medium-term cycle of 2-7 years

(b-1) Replacement cycle of digital appliances

The medium-term cycle of durable goods consumption includes the replacement cycles of digital appliances, mobile phones, and so on. From a somewhat longer-term perspective, the periods of cycle since 2000 have become shorter in comparison with the periods before 2000 (Chart 13). There are two factors behind this change. First, it is pointed out that mobile phones, which have a short replacement cycle, have been purchased more than other digital appliances. Second, the various factors that promoted durable goods consumption since 2009 have shortened the replacement cycle temporally.

Chart 13. Periods of Medium-term Cycle for Durable Goods Consumption



From 2009 to 2010, the medium-term cycle increased quarterly changes of durable goods consumption due to increases of demand resulting from the temporary policy measures for replacement and from the end of analog TV broadcasting. In 2011, the cycle pushed downward due to the decline following the front-loaded increase. The cycle rose again from 2013 to 2014/Q1 due to the front-loaded increase in demand prior to the consumption tax hike in April 2014. After the consumption tax hike, the medium-term cycle exerted adverse effects. This means the subsequent decline in demand after the temporary policy measures and the consumption tax hike. From the beginning of 2016, the medium-term cycle has risen again.

(b-2) Factors other than replacement cycle

Not only the replacement cycle but also household income affect the medium-term cycle of durable goods consumption. Until 2009, the periods and phases of medium-term cycles of durable goods consumption and household income are mostly matched (Chart 14). However, after 2010, both cycles began deviating from one another. This implies that there were purchasing behaviors not in line with income due to various factors listed in Chart 3.

The medium-term cycle is also affected by stock price and consumer confidence, as is

the short-term cycle. It is considered that the medium-term cycle of stock price depends on medium-term developments of profitability and dividends. And the medium-term cycle of consumer confidence is affected by medium–term developments in the employment and income situations. The periods and phases of three cycles are mostly matched before 2014 (Chart 15). However, the cycles of durable goods consumption and stock price began deviating from one another after 2014. This suggests that purchasing behavior is not in line with stock price due to various factors listed in Chart 3. These suggest the large impact of the front-loaded increase by various factors in demand for consumer durable goods.

Chart 14. Medium-term Cycles of Durable Goods Consumption and Household Income

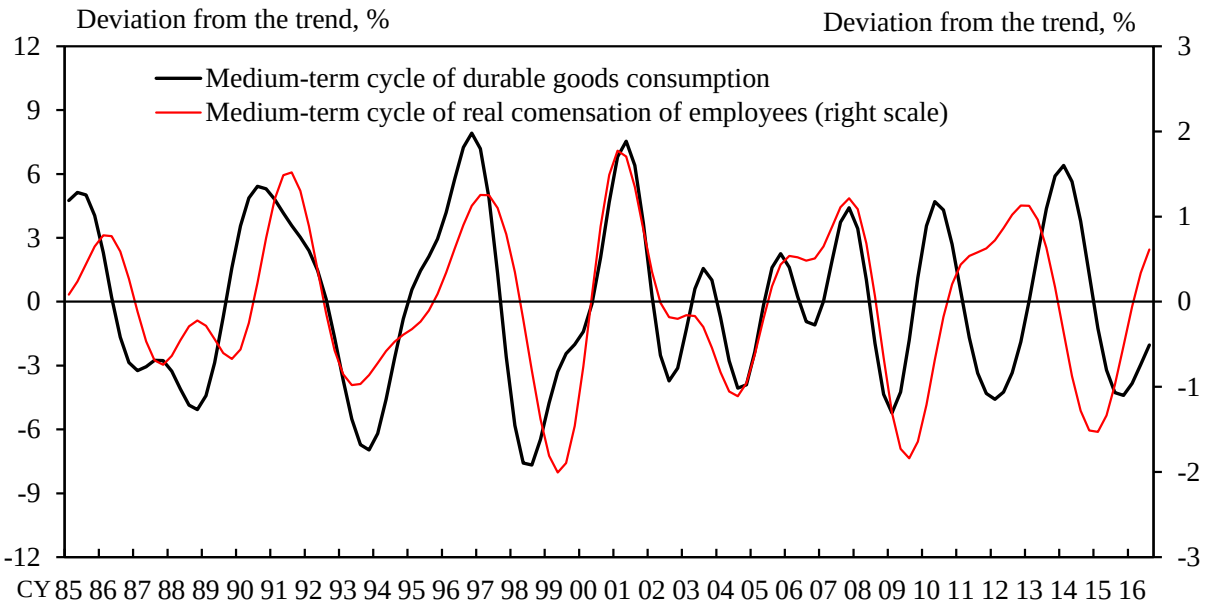
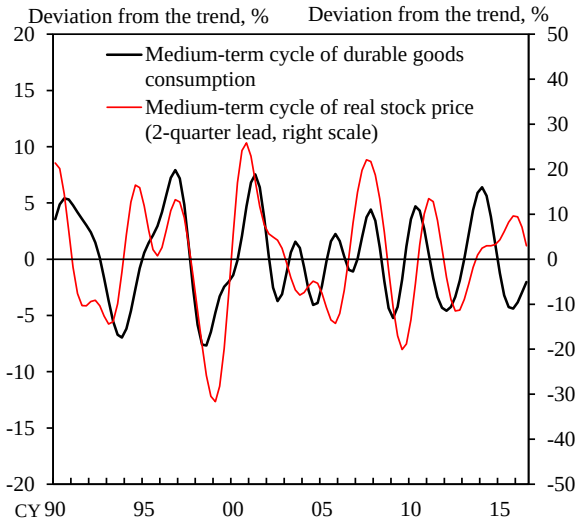
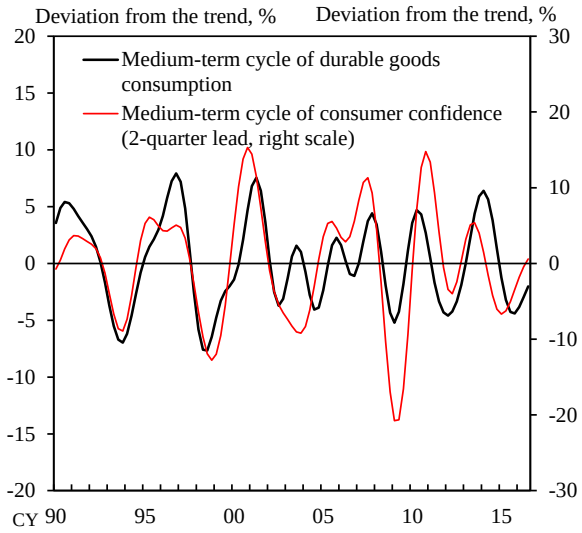


Chart 15. Medium-term Cycles of Durable Goods Consumption, Stock Price and Consumer Confidence

(1) Durable goods and stock price



(2) Durable goods and consumer confidence



(c) Long-term cycle of 7-12 years

(c-1) Replacement cycle of digital appliances

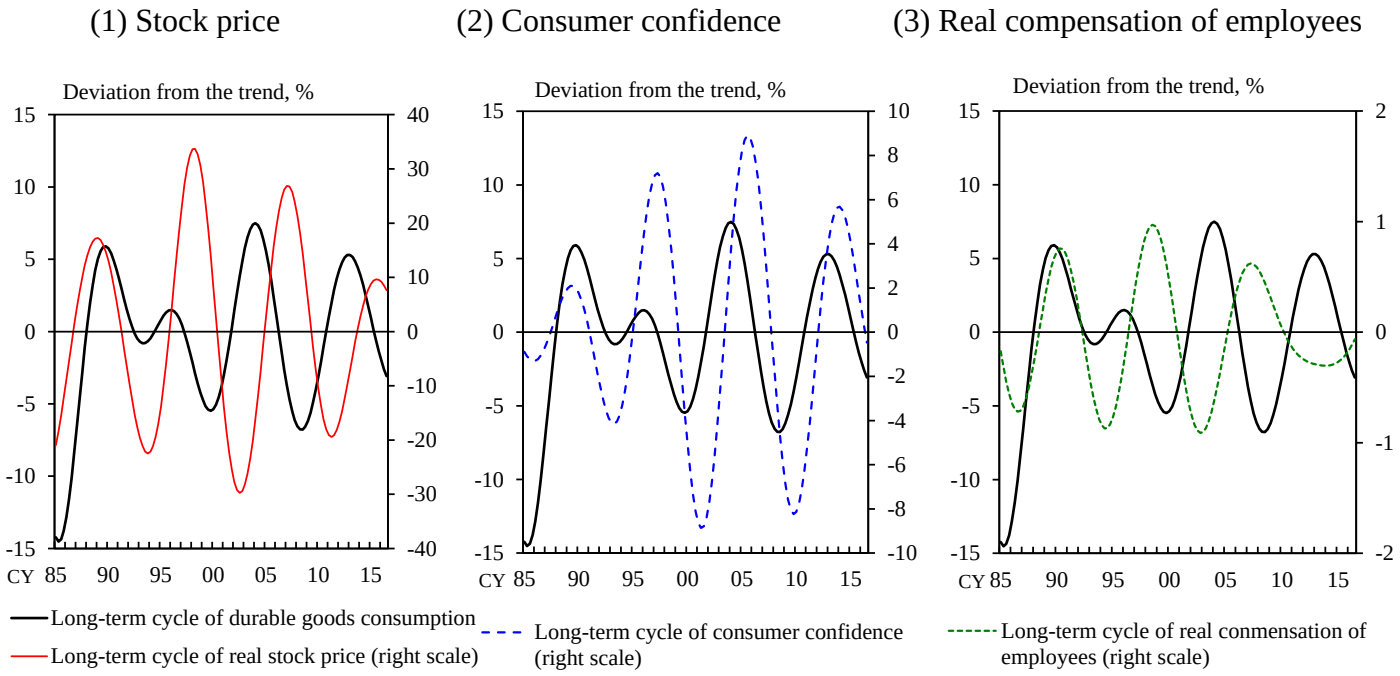
The long-term cycle of durable goods consumption includes the replacement cycles of passenger cars and home appliances such as refrigerators, air-conditioners, and washing-machines. Looking at the recent developments of the long-term cycle, the cycle worked as a driver of quarterly growth of durable goods consumption from 2009 to 2012 (Chart 11). There is almost no difference between the periods of cycle before and after 2009. This suggests that the positive effect of the medium-term cycle from 2009 to 2012 develops in line with usual replacement cycle. The result is that both medium- and long-term cycles pushed up durable goods consumption from 2009 to 2010. After around 2013, the long-term cycle began pushing down. From April 2014 to 2015, there was downward pressure from both medium- and long-term cycles. This caused relatively weak developments of durable goods consumption after April 2014.

(c-2) Factors other than replacement cycle

Factors other than replacement cycle could affect the long-term cycle of durable goods

consumption. To test this hypothesis, the long-term cycle of durable goods consumption is compared with long-term cycles of stock price, consumer confidence, and household income (Chart 16). Looking at this chart, there are no interrelations between durable goods consumption and other factors after the mid-1990s. This fact suggests that purchasing behavior for consumer durable goods with long replacement cycles are mostly determined by their replacement cycles. In addition, this conclusion is supported by the results of the survey for replacement reasons; it shows the tendency for prolonged use of general home appliances (Chart 9(2)).

Chart 16. Long-term Cycle of Durable Goods Consumption, Stock Price, Consumer Confidence and Household Income

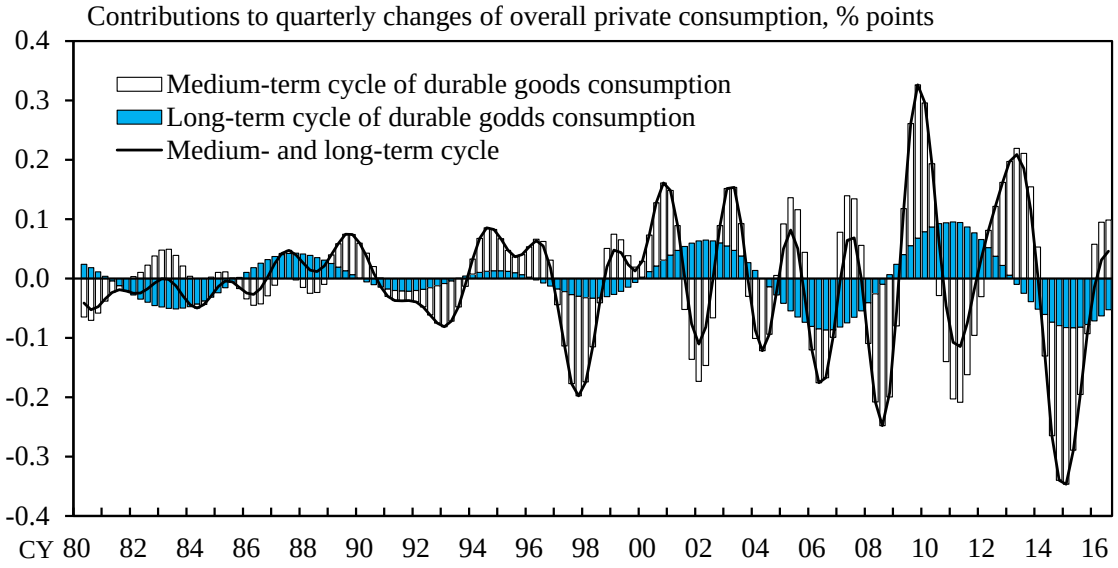


4-3. Effects on private consumption by durable goods consumption in recent years

As shown in the previous sections, it is observed that various factors, including policy measures and a consumption tax hike, in recent years have affected durable goods consumption. Chart 17 shows the impact of medium- and long-term cycles of durable goods consumption to quarterly changes in overall private consumption. There are certain contributions in recent years; around +0.3 percentage points during 2009-2010;

less than -0.1 percentage points in 2012; less than 0.2 percentage points prior to the consumption tax hike (from 2013 to 2014/Q1); more than -0.4% percentage points from 2014/Q2 to 2015.

Chart 17. Contributions of Medium- and Long-term Cycles of Durable Goods Consumption to Overall Private Consumption

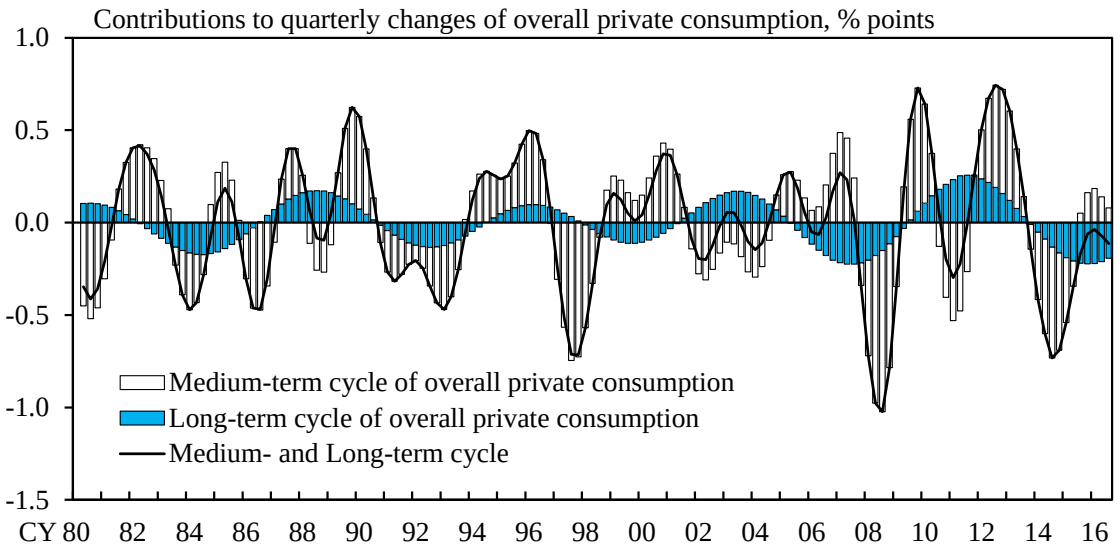


Note: Up to 2015/Q4, private consumption expenditure is consumption of households (excluding imputed rent) from the SNA. Data from 2016/Q1 to Q3 are obtained by extending private consumption expenditure using the quarter-on-quarter rate of change in the Consumption Activity Index (adjusting travel balance).

To investigate the effects on overall private consumption in a straightforward manner, overall private consumption is decomposed by spectrum analysis (Chart 18 and Appendix Chart 5)[10]. Looking at the result, it is clear that medium- and long-term cycles have a negative impact on overall private consumption. This suggests that the result of frequency analysis for durable goods consumption is robust.

[10] Yamasawa (2009) suggests the improvement method to avoid the endpoint problem of spectrum analysis. According to this method, the data for 2016/Q4-2018/Q1 is substituted with economists' forecasts of real private consumption (ESP forecasts).

Chart 18. Medium- and Long-term Cycles of Overall Private Consumption



Note: Cyclical components are extracted using the Christiano-Fitzgerald filter. Up to 2015/Q4, private consumption expenditure is consumption of households (excluding imputed rent) from the SNA. Data from 2016/Q1 to Q3 are obtained by extending private consumption expenditure using the quarter-on-quarter rate of change in the Consumption Activity Index (adjusting travel balance). Data from 2016/Q4 to 2018/Q1 are substituted with forecasts by economists as of Dec. 2016.

5. Conclusion and Remaining Issues

To investigate the background behind relatively weak private consumption since the consumption tax hike in April 2014, we employ spectrum analysis for durable goods consumption. In this spectrum analysis, durable goods consumption series is decomposed by a band-pass filter to four components: (a) the short-term cycle of less than two years, (b) the medium-term cycle of 2-7 years, which includes replacement cycles of digital appliances, (c) the long-term cycle of 7-12 years and (d) the trend components of more than 12 years. The obtained results suggest that both medium- and long-term cycles exerted large adverse effects on durable goods consumption after the consumption tax hike. It is concluded that the front-loaded increase in demand for durable goods prior to the temporary policy measures since 2009 and the consumption tax hike in 2014 caused an adverse impact on durable goods consumption in subsequent years. However, the medium-term cycle began rising again in early 2016. Thereafter, it

is likely that the downward pressure from replacement cycles of durable goods will decrease gradually.

This paper leaves some issues for future study, since our sole focus here is durable goods consumption. However, non-durable (including semi-durable) goods consumption is also relatively weak (Chart 1). Investigating the background of weakness of non-durable goods consumption is an important remaining issue. Moreover, technical issues remain, too. As discussed earlier, one should bear in mind that it is difficult to estimate filtered series in real time. Filtered series by Christiano and Fitzgerald filter applied in this paper will be ex-post revised by re-estimation given the arrival of further data on subsequent quarters[11]. It would be useful to re-estimate after additional accumulation of data to check our conclusions.

[11] In Appendix Chart 6, we represent a real-time estimate exercise against final estimates for spectrum analysis on durable goods consumption. In comparison with these estimates of (a) full sample (1980/Q1 – 2016/Q3), (b) data set as of 2010 (1980/Q1 - 2010/Q4) and (c) data set as of 2013 (1980/Q1 - 2013/Q4), it is clear that periods and phases of cycles are almost matched, although the amplitudes are different. This exercise supports the conclusion in this paper.

Appendix Chart 1. Policy Measures for Replacement to Eco-friendly Durable Goods

1. Eco-points System for Environmentally Friendly Home Appliances

Period for purchases	May 2009– March 2011
Overview	➢ Subsidy in the form of "eco-points" for purchases of energy-efficient digital terrestrial TV sets, air-conditioners, and refrigerators. ➢ "Eco-points" are exchangeable for eco-friendly goods, vouchers, and so on. ➢ The amount of eco-points provided differs according to the size of the items. (Ex. Digital terrestrial TV sets up until Dec. 2010) Over 46 inch 36,000 points / set 42, 40 inch 23,000 points / set 37 inch 17,000 points / set ➢ Total amount of registered eco-points: 639.5 billion points (= 639.5 billion yen)

2. Subsidy for Environmentally Friendly Cars

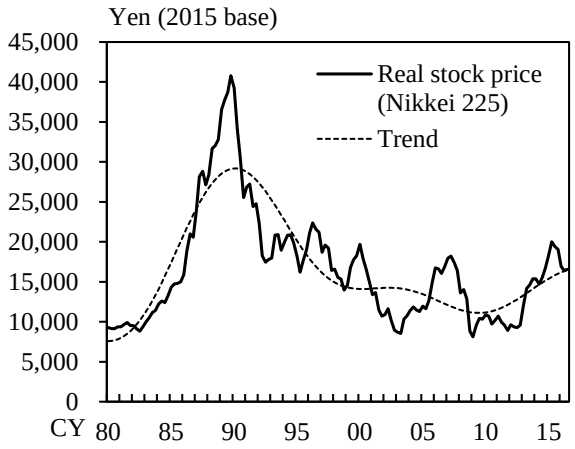
Periods for applications	(a) June 2009– September 2010 (b) April – September 2012
Overview	➢ (a) Scrap incentives and (b) provide a subsidy for purchasing energy-efficient cars. ➢ (a) Standard car (with scrapping): 250,000 yen / unit, standard car (without scrapping): 100,000 yen, small car (with scrapping): 125,000 yen / unit, small car (without scrapping): 50 ,000 yen (b) Standard car: 100,000 yen / unit, small car: 70,000 yen per unit ➢ Budget (for passenger cars): (a) about 580 billion yen, (b) about 270 billion yen

3. Tax Break for Environmentally Friendly Cars

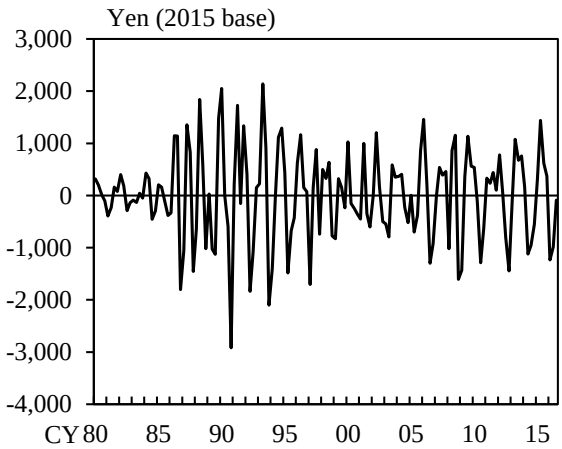
Period for purchases	April 2009 –
Overview	➢ Exemption or break of automobile acquisition tax and motor vehicle tax for purchasing of energy-efficient cars

Appendix Chart 2. Results of Spectrum Analysis on Real Stock Price

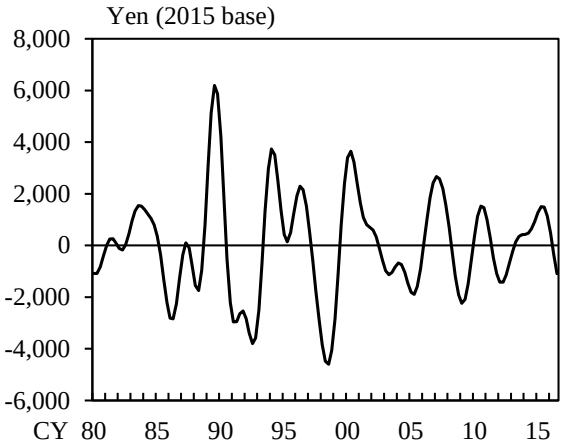
(1) Original series and trend component



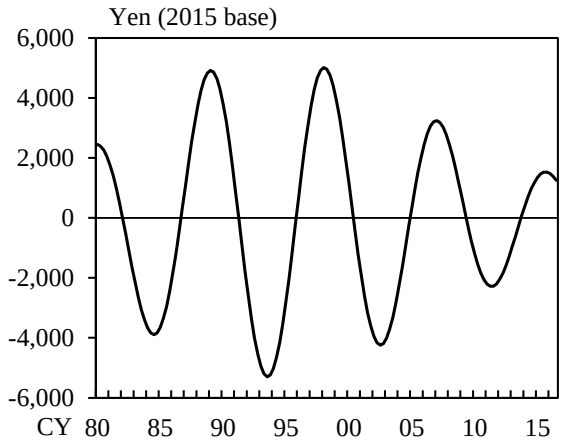
(2) Short-term cycle of less than 2 years



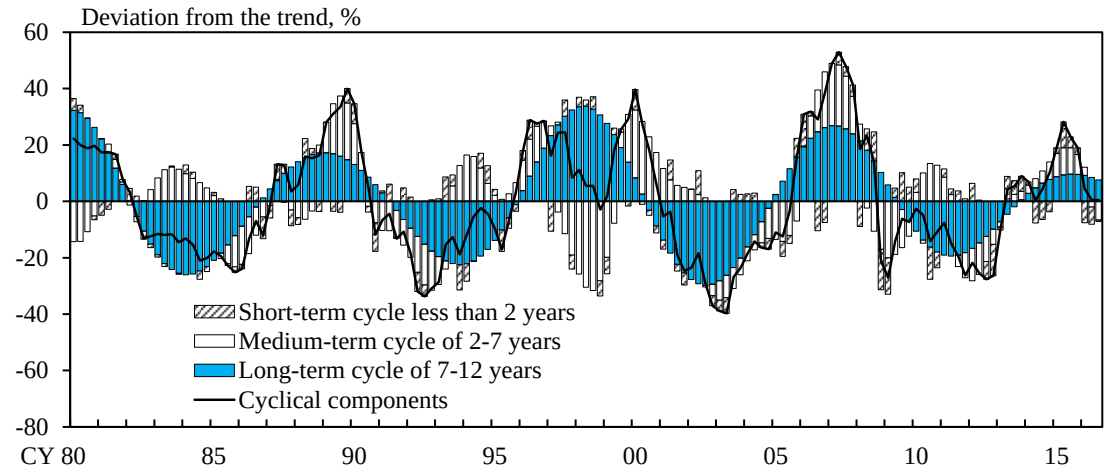
(3) Medium-term cycle of 2-7 years



(4) Long-term cycle of 7-12 years



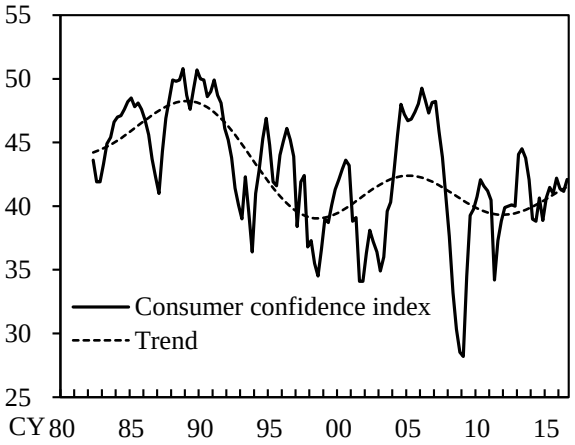
(5) Decomposition of business cycle for real stock price



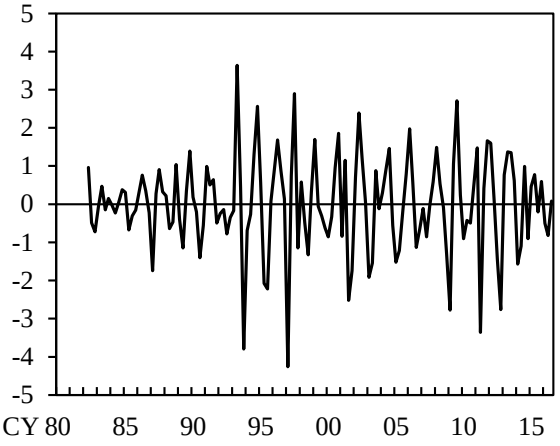
Note: Real stock price is obtained by deflating nominal stock price by the CPI.

Appendix Chart 3. Results of Spectrum Analysis on Consumer Confidence

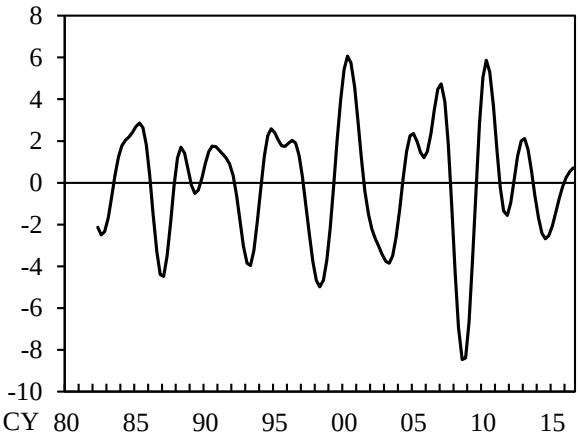
(1) Original series and trend component



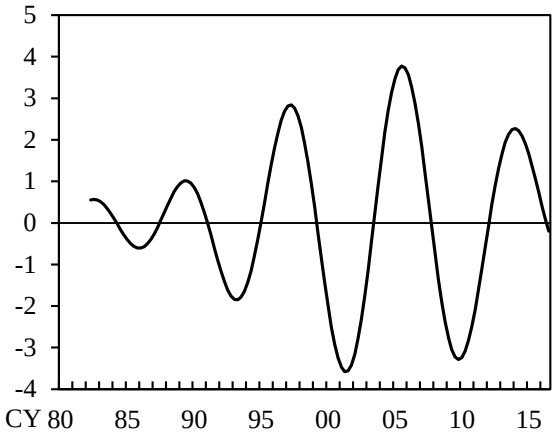
(2) Short-term cycle of less than 2 years



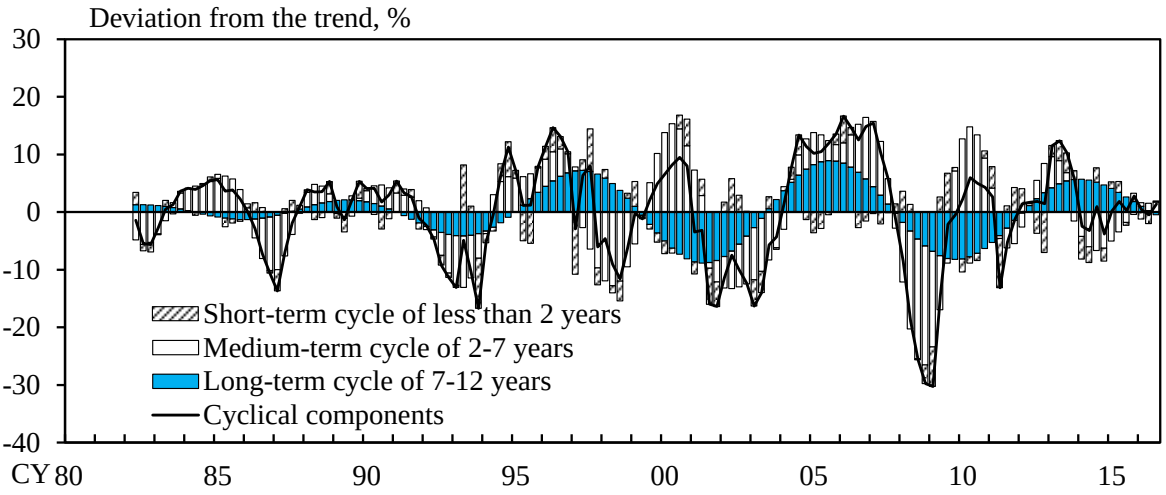
(3) Medium-term cycle of 2-7 years



(4) Long-term cycle of 7-12 years



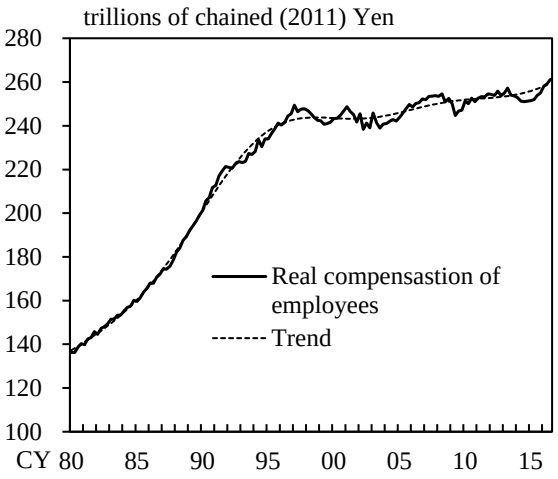
(5) Decomposition of business cycle for consumer confidence



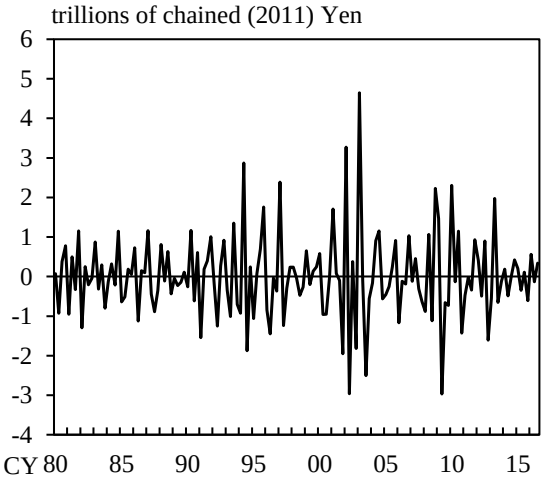
Note: Consumer confidence is Consumer Confidence Index by the Cabinet office (seasonally adjusted).

Appendix Chart 4. Results of Spectrum Analysis on Real Compensation of Employees

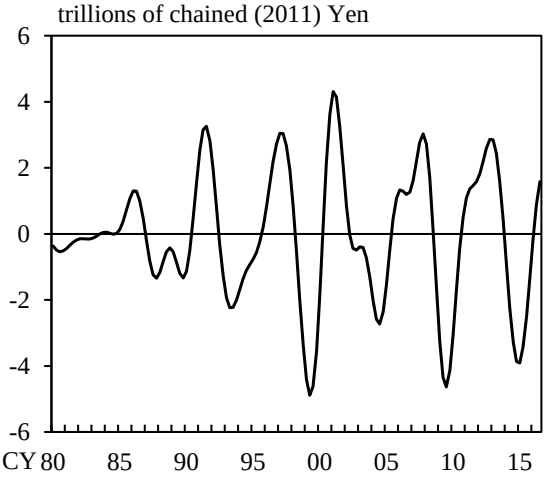
(1) Original series and trend component



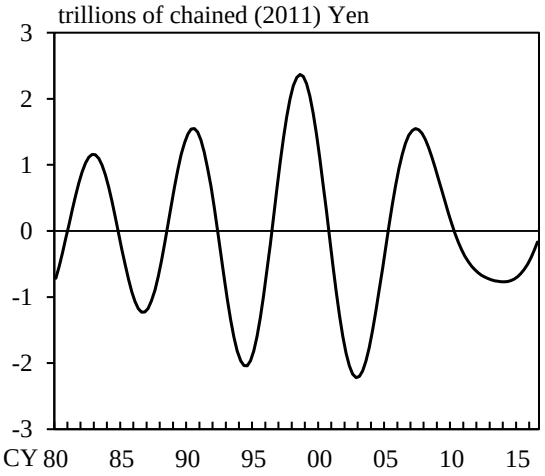
(2) Short-term cycle of less than 2 years



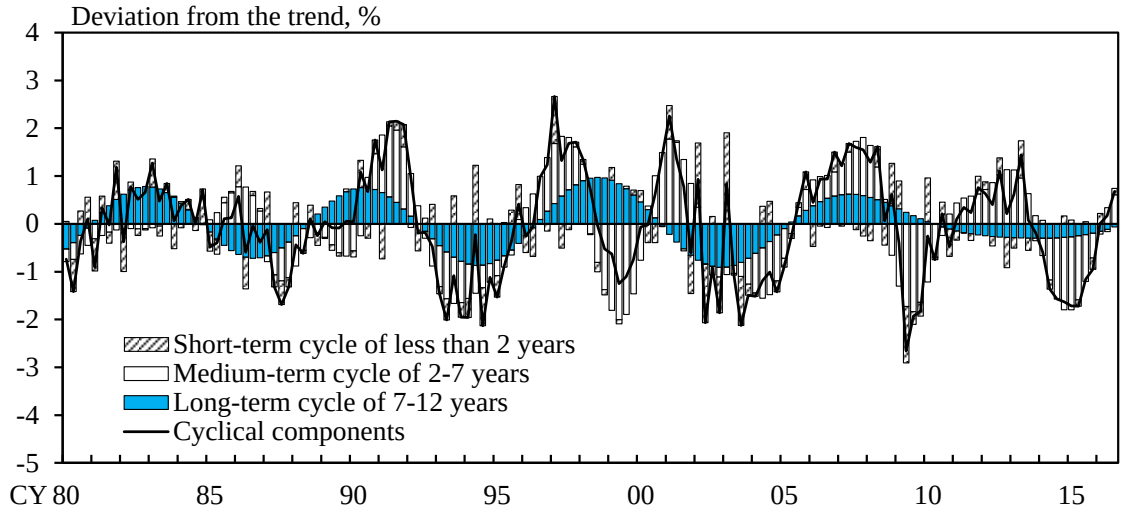
(3) Medium-term cycle of 2-7 years



(4) Long-term cycle of 7-12 years

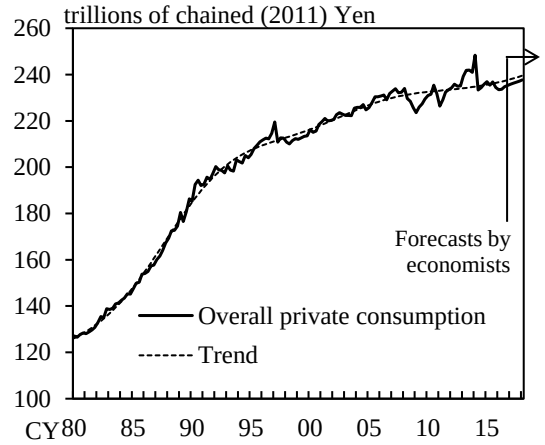


(5) Decomposition of business cycle for compensation of employees

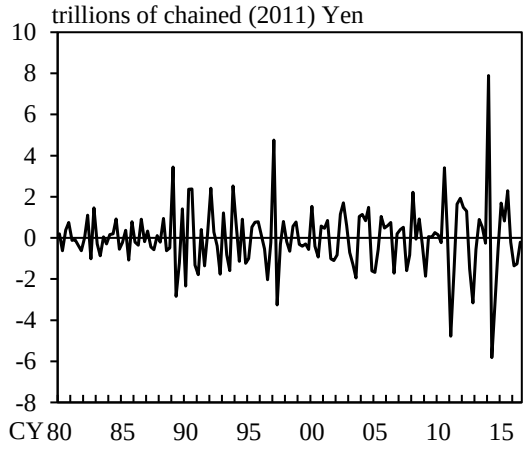


Appendix Chart 5. Results of Spectrum Analysis on Overall Private Consumption

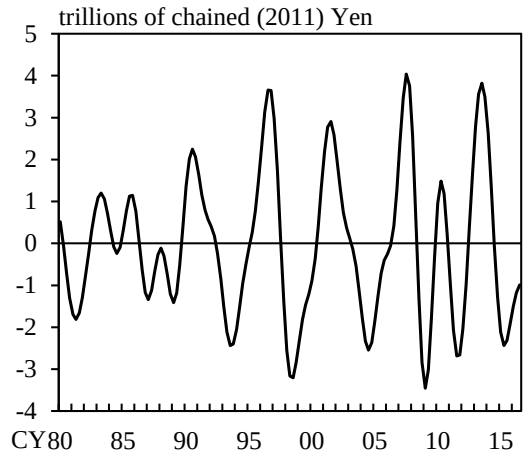
(1) Original series and trend component



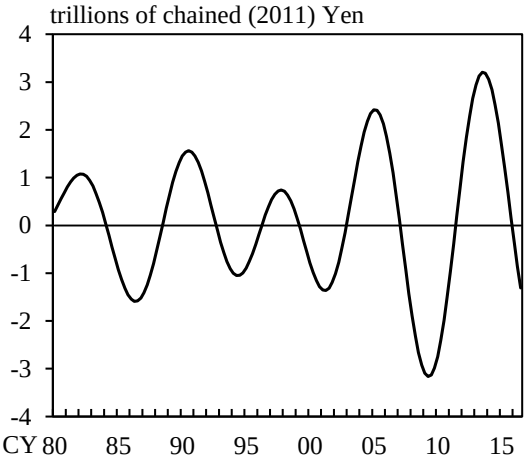
(2) Short-term cycle of less than 2 years



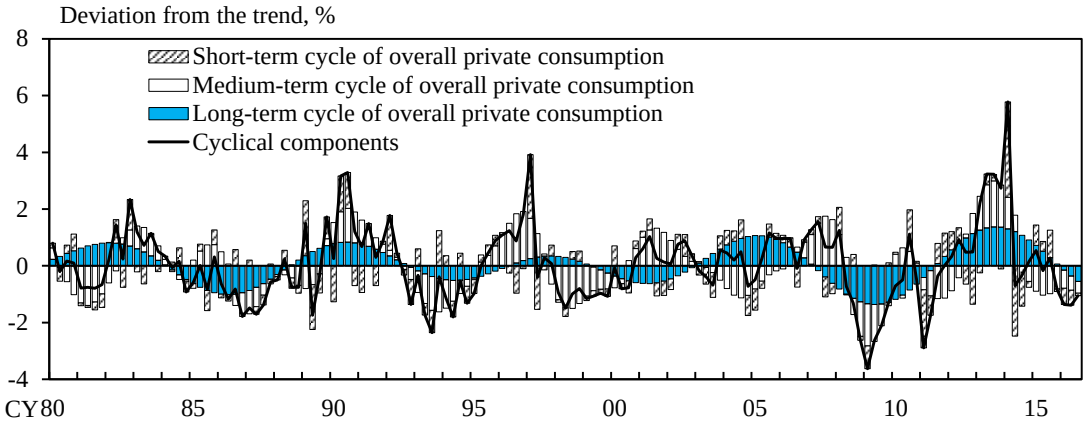
(3) Medium-term cycle of 2-7 years



(4) Long-term cycle of 7-12 years



(5) Decomposition of business cycle for overall private consumption

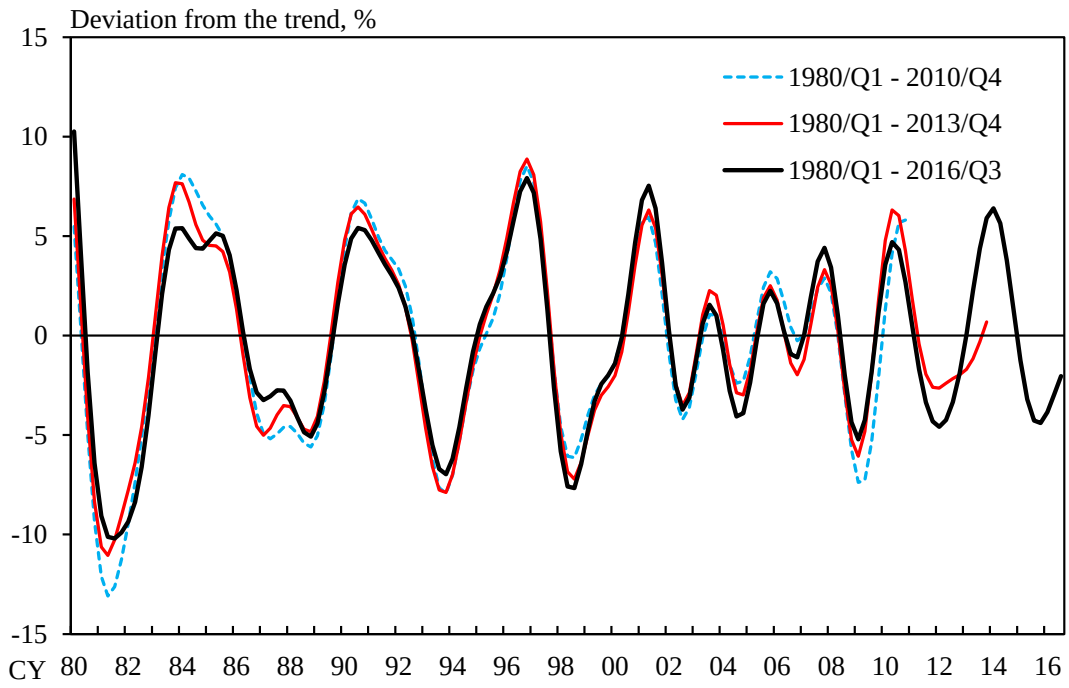


Note: Up to 2015/Q4, private consumption expenditure is consumption of households (excluding imputed rent) from the SNA. Data from 2016/Q1 to Q3 are obtained by extending private consumption expenditure using the quarter-on-quarter rate of change in the Consumption Activity Index (adjusting travel balance). Data from 2016/Q4 to 2018/Q1 are substituted with forecasts by economists as of Dec. 2016.

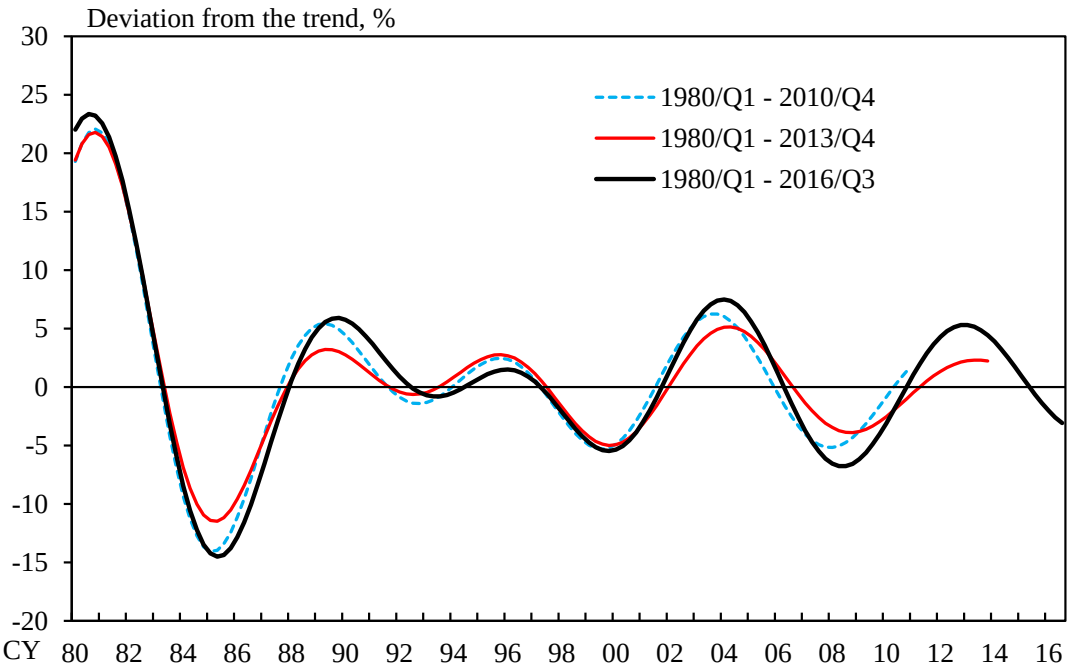
Appendix Chart 6. Spectrum Analysis Based on Real-time Data

<Durable Goods Consumption>

(1) Medium-term cycle of 2-7 years



(2) Long-term cycle of 7-12 years



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