How can we estimate the quality deterioration with time in the rental service of office buildings in Japanese Services Producer Price Index?

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Abstract

The Research and Statistics Department of the Bank of Japan, which compiles the Services Producer Price Index (SPPI), has adjusted quality for deterioration with time in office buildings since the beginning of 2010. This quality adjustment has been applied for the Items in Subgroup "Office space rental" with a view to excluding the aging bias of offices. In the Japanese SPPI, the impact of the quality adjustment in Subgroup "Office space rental" accounts for around 0.7 percent per year on average.

This paper explains the specific method used to adjust for quality changes caused by age-related depreciation of office buildings. Different depreciation rates are applied to the three components of office buildings, namely the building frame, attached equipment, and land. The impact of renovation investment on the depreciation rates has also been taken into account.

This groundbreaking method facilitates estimation of the non-linear change in the pace of quality deterioration not only with age, but also with changes in land prices.

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1. Outline of the price index for "Office space rental": Pricing method and Quality adjustments

1.1 Outline of the Subgroup "Office space rental"

The Research and Statistics Department of the Bank of Japan, which compiles the Services Producer Price Index (SPPI), measures price changes for renting office buildings in the Subgroup "Office space rental." The Subgroup of "Office space rental" accounts for 4.4 percent of the overall index.

The number of sample prices is around 300 (as of January 2010). The SPPI follows approximately 3,500 prices altogether, so the sample size for the Subgroup "Office space rental" is relatively larger than other Subgroups.

On the whole, there is wide variation in office rents by region in Japan, so the index for "Office space rental" in the SPPI is based on four geographic pricing areas. Four separate Items are thus published, namely "Office space rental (Tokyo area),""Office space rental (Osaka area),""Office space rental (Nagoya area)," and "Office space rental (Other areas)."

1.2. Pricing method for "Office space rental"

The index of "Office space rental" in the SPPI has two main characteristics. First, it follows the actual rent paid by renters. Second, it covers all tenants, including both new and renewed contracts. This makes it superior to other rent surveys conducted by private research institutions in terms of coverage. In general, such surveys cover only advertised list prices for new tenants. The SPPI might thus be considered a more accurate reflection of overall trends.

When compiling the index, the average rent per square meter for a sample office has been followed. The average rent is calculated by dividing total income from a sample office by total floor area in operation.

1.3. What kinds of quality adjustments are required for "Office space rental"?

The quality of renting office buildings is determined by various factors. Among others, four factors have a great influence on rent.

The first is "location," that is, where buildings are located. Important factors in this regard may include city, neighborhood, and time taken to reach nearby railway stations on foot.

The second is "size," measured by floor space. The third is "features of attached equipment." Various facilities such as elevators, air-conditioning systems, and security systems have an effect on service quality. The fourth is "age," or the length of time elapsed since a building was initially constructed.

In order to compile the index for "Office space rental" in the SPPI, the rent for a specified office building has been surveyed continuously. This means that two factors —"location" and "size"— are completely fixed over time. In addition, the "features of attached equipment," such as types and numbers, remain unchanged. As a result, three factors—"location," "size," and "features of attached equipment"—can be viewed as constants.

For "age," however, it is necessary to consider "aging bias." The quality of a building frame and attached equipment deteriorates as they age and become outdated. The quality of the associated rental services gradually declines as a result. Since we follow the rent of a specified office building, this possibly causes aging bias in the price index.

In order to compile an appropriate fixed-quality price index, it is important to adjust for quality changes caused by depreciation of offices with time.

1.4. Bank of Japan’s approach

The Bank of Japan has developed a method for estimating depreciation rates to adjust for aging bias in the index. The outline of the method is as follows:

(1) Estimate depreciation rates for offices of different ages

(2) Survey the age of each sample office

(3) Apply different depreciation rates to individual sample offices according to age

These procedures facilitate estimation of overall depreciation rates. The method has been adopted for the SPPI since January 2010.

There is some precedent in the United States with regard to rental service of residential structures, with indexes for rent and rental equivalence of residential dwellings in the CPI having been adjusted for quality bias with age. However, "commercial real estate" tends to be much more variable in quality, making adjustment a much more difficult process.

To our knowledge, ours is the first attempt to adjust for quality changes in the rental service of office buildings. This paper explains the underlying concept and practical method.

2. Why is it difficult to measure the depreciation rate for office buildings?

2.1. Simple approach: Hedonic quality adjustment

In order to measure the quality deterioration with age for offices, the so-called "Hedonic method" is a simple and reasonable approach. For example, based on a Hedonic regression model, it is possible to analyze the relationship between office rent and various characteristics (such as age, location, scale, and facilities), and then estimate the regression coefficient of age (=aging effects). With the regression coefficient of age (among others) derived by regression analysis, the depreciation rates can be measured.

In practice, in the United States, Hedonic quality adjustments have been applied for the rent samples in the CPI Housing Survey, following the formula listed below.

$$\ln rent_{i,t} = \alpha_t + \gamma_1 age_{i,t} + \gamma_2 age_{i,t}^2 + \beta X_{i,t} + u_{i,t}$$

The survey follows more than 20,000 prices, using Census samples and housing micro data.

2.2. Difficulties associated with Hedonic quality adjustments

So, is it possible to use the Hedonic method to adjust for quality changes of office renting service? This appears difficult for the following three reasons.

First, in general, office buildings have more varieties of quality than residential structures. The quality of offices varies widely, so more attribute variables must be used. In order to estimate the relationship between office rent and price-determining characteristics precisely, the sample size must number at least a few thousand. In practice, however, it is difficult to collect such a huge amount of data continuously. As mentioned above, the Subgroup "Office space rental" has greater coverage than other Subgroups, but still only covers around 300 prices.

Second, it is necessary to estimate regression models with high frequency, because the regression coefficient of age is likely to change over time. In fact, the U.S. CPI carries out regressions once a year. The results show that the regression coefficient of age has changed with time.

Third, the regression function of the Hedonic approach is so complicated that it cannot be expressed as simple function forms such as linear and logarithmic. For the most part, existing studies were based on the assumption that "depreciation proceeds at a fixed rate." In other words, they assumed that the quality of office renting services declines in an exponential manner (with the dependent variable linear and independent variable logarithmic). However, some statistical tests revealed this assumption not to be suitable, this implies that the function is so complicated.

For the above reasons, it is difficult to use the Hedonic method to adjust for quality changes in office renting service. It is thus necessary to find some alternative.

3. The methodology for the calculation of depreciation rates developed by Bank of Japan: Basic concept

3.1. The methodology for the estimation of depreciation rates developed by Bank of Japan: Basic concept

The SPPI has estimated the rate of quality deterioration of office renting service under the following two assumptions.

The first assumption is that the office rent is the sum of the rental fee for land, building frame and attached equipment (such as elevators, light fixtures, air-conditioning equipment, and security systems). The second is that the quality of rental service of office buildings is proportional to the total asset value of land, frame, and attached equipment.

Based on these assumptions, the decrease in the quality that office renting service provides can be regarded as equivalent to the total decrease in the total asset value of office building (capital depletion).

$$\textit{Depreciation rate for offices} = \frac{\begin{array}{c}\textit{the decrease in the asset value}\\ \textit{(structure and attached equipment)}\end{array}}{\begin{array}{c}\textit{the asset value of office building}\\ \textit{(structure, attached equipment and land)}\end{array}}$$

In order to calculate depreciation rates of office buildings, we assume the (hypothetical) standard office building for every location, which is composed of land, building frame and attached equipment (such as elevators, light fixtures, air conditioning equipment, security systems and so on). Second, we set the initial asset value for the standard office building for every location, by estimating expenses for obtaining land, frame and attached equipment, at the time of construction. Third, we measure the depreciation due to aging and the asset value year by year, based on the assumption that the values of the frame and attached equipment depreciate every year at a fixed rate.

In addition, we take into account the impact of renovation investment on asset value of the standard office building. As the office building gets older, renovations are undertaken in order to prolong service life. Renovation investment usually enhances asset value and must therefore be reflected in some form of quality adjustment.

Depreciation rates for office buildings can then be estimated using the above formula.

3.2. Advantages of the asset value approach

The asset value approach would appear to have the following five advantages.

First, it helps to represent complicated depreciation, corresponding to actual situations. That is, by regarding depreciation as the sum of value changes of three assets; land, building frame and attached equipment, the approach can describe the complicated depreciation profile as something variable with age, by just using fixed depreciation rates of land, building frame and attached equipment.

Second, external data (the rate of capital depletion = declining-balance rate <fixed rate>) are available as depreciation rates for frame and attached equipment. For example, the declining-balance rates used to estimate net stocks of *SNA (National Accounts of Japan*) are available, as well as those derived from related literature. As such, it is not necessary to estimate depreciation rates from scratch. This also means that the asset value approach can be applied to other services besides the rental service of office buildings.

Third, it incorporates value changes due to renovation investment. As years go by, the asset value declines at a slower pace due to renovation investment. Our approach makes it possible to reflect such value changes.

Fourth, it is possible to cope with quality variability across offices by area or location by adjusting for the proportions of land and attached equipment within the total asset, which are influenced by (i) land prices and (ii) differences in floor space by area (resulting from regulations on height or floor-area ratio of building). For example, in Tokyo, where land prices are relatively high, land accounts for a relatively high proportion of total asset value. The proportions of value accounted for by frame and attached equipment—both of which depreciate with time—are comparably small. As a result, the depreciation rates in Tokyo are relatively low.

Fifth, it reflects time series variations in depreciation rates. In the strong economy when land prices are soaring, the depreciation rate becomes lower. Conversely, in the weak economy when land prices are declining, the rate becomes higher.

To summarize, the greatest advantage of the asset value approach is that it reflects the effect of land prices on depreciation rates, by adjusting the proportions of land, frame, and equipment, with each depreciation rate (land, frame and equipment) fixed. In other words, by using the structural parameters such as depreciation rates of three assets and by changing the proportion ratios of three assets, we can estimate the complicated depreciation pattern more precisely. On the other hand, in the case of the Hedonic method, variation in land prices depending on location and economic conditions makes the regression coefficient of age comparatively volatile when estimating regression models.

4. The methodology for the calculation of depreciation rates developed by Bank of Japan: Practical method

4.1. Depreciation rates for building frame

In order to implement the aforementioned asset-value approach, it is necessary to set the depreciation rates for building frame and equipment, both of which deteriorate in quality over time.

Firstly, the depreciation rate for building frame is assumed to be 5.0% per year based on *Saita and Higo[2010]*[4], the first and (to date) only relevant study in Japan. Under

[4] It is difficult to measure depreciation rates for offices for the following three reasons. First, it is difficult to collect a sufficient number of selling prices for offices. Second, it is more difficult to collect data related to a lot of attributes that determine the quality of offices. Third, the quality of buildings varies widely and individual transactions differ considerably. Depreciation rates thus vary widely and are difficult to estimate appropriately.

this assumption, the value of frame deteriorates to 10% of the initial value after 45 years, which indicates that the average service life of building frame equals 45 years unless renovation investment is made.

In Japan, the declining-balance rate applied for non-residential structures in *National Accounts* is 5.98%, a bit higher than our estimation of the depreciation rate. Behind it, it can be presumed that samples in *National Accounts* cover buildings with shorter service lives than offices.

In the United States, the declining-balance rate (Office buildings-Private nonresidential structures) is 2.47% per year, according to the BEA depreciation estimates (*Hulten and Wykoff [1981]*). So our estimated depreciation rate is approximately twice that of the U.S. This indicates that the service life of offices in Japan is shorter than that in the U.S., which can perhaps be attributed to Japan's strict building construction standards which builders have to meet to prevent big earthquake damages. Additionally, the impact of renovation improvement is not considered in the U.S.

It thus seems appropriate to set the depreciation rate at 5.0% per year.

4.2. Depreciation rates for attached equipment

Office buildings are generally equipped with machinery-related facilities. For example, electrical wiring systems, air-conditioning equipment, elevators, multilevel parking lots, sanitary equipment (water supply, gas and draining systems) and security systems are often installed in office buildings. On the whole, the service life of machinery is shorter

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Faced with those problems, *Saita and Higo[2010]* took the following measures. First, they used data on office rents instead of sale prices. In the office building market, the sales transactions of office buildings rarely occur, while there are a lot of rental transactions of them. So, they collected a lot of rental fee transaction data.

Second, they considered the quality differences due to attached equipment or location to the greatest extent possible, by incorporating many attribute variables that correlate with office rent fee and age, in order to avoid the bias of coefficient of age in the estimating hedonic functions.

Third, they adjusted for the bias caused by retirements. In light of the fact that end-of-life offices are demolished with time, they estimated the survival probability profile data for each age of office buildings derived from the survey research for office buildings in Tokyo conducted by the architecture professionals. By using survival and non-survival probability profiles of office buildings, they estimated rent in order not to underestimate depreciation.

Fourth, they considered the impact of land and equipment on office rent. Usually, rental fees include rent for land as well as for building frame. So, they estimated the depreciation for frame itself, distinguishing from land and equipment.

Fifth, they considered the impact of renovation investment which is needed to maintain performance. In general, when renovations are conducted, the rent rises due to an increase in utility. So they adjusted for the quality changes due to renovation.

than that of building frame, meaning that the depreciation rate for attached equipment is larger than that for frame.

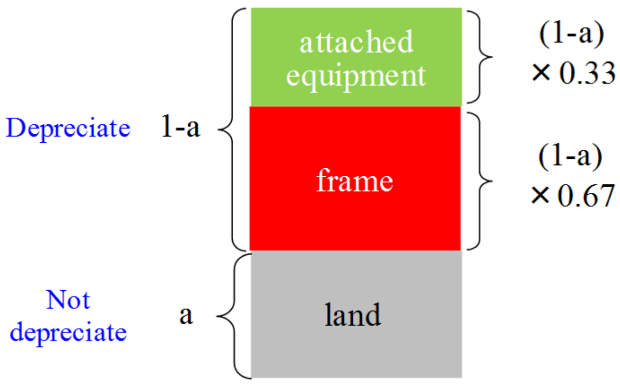
The depreciation rate for attached equipment is assumed to be 14.2% per year referring to the manual by "Japan Facility Management Association," which explains the life-cycle cost for building management and estimates the average life of attached equipment at 15 years. With the average service life of 15 years, the depreciation rate is calculated presuming that the value of attached equipment declines to 10 % of its initial value 15 years after construction.

4.3. Proportions of land, frame and attached equipment

In order to employ the "asset value approach," it is necessary to set the proportions of land, building frame and attached equipment accounting for the total asset value of the standard office building by location. As stated before, these three portions determine the value of office (Figure 1).

First, estimate the proportion of land (a) at the timing of construction by location, using official land prices from "Land Market Value Publication" and official statistics related to construction expenses of buildings from "*Construction Starts*", which are published by Ministry of Land, Infrastructure, Transport and Tourism. Next, fix the ratio of frame and attached equipment to be 67 to 33, referring to the literature by "Japan Facility Management Association."

(Figure 1) Proportions of the asset value of offices



4.4. Differences in depreciation rates due to the proportion of land

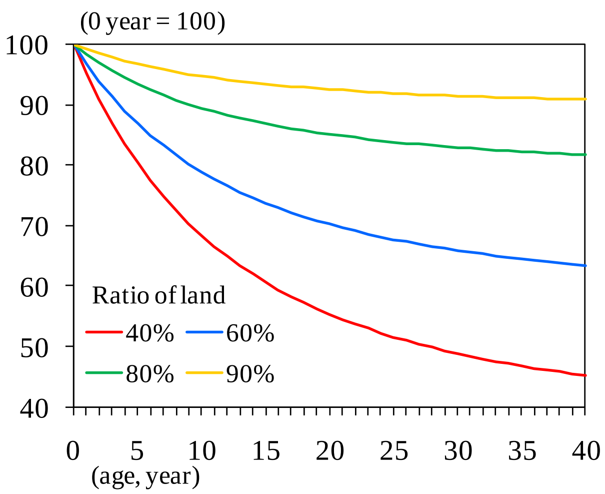
This chapter examines the case that does not take renovation investment into account. We first take a look at the value of offices and depreciation rates.

Individual series show office values for each location with different ratios of land value to total asset value (Figure 2-1). Each value when newly built is set to be 100. In each case, office value declines with the passage of time. 40 years after construction, land accounts for almost the entire asset value.

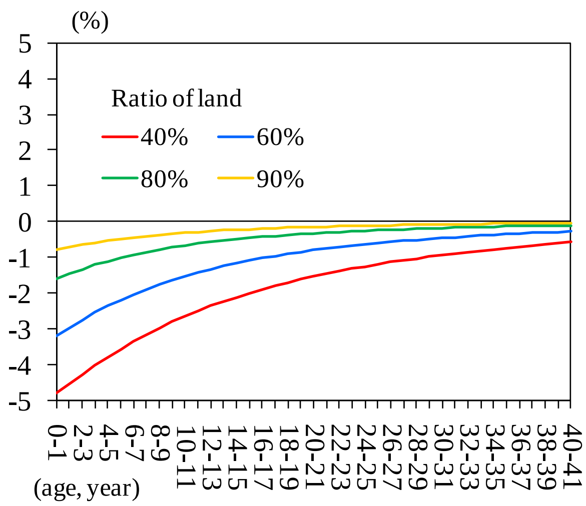
The aggregated depreciation rate for the total asset is smaller than that for frame (5.0%) and for equipment (14.2%) because the land value remains unchanged. In addition, the depreciation rates have a propensity to diminish gradually over time. That is because the ratio of land value in the total asset value increases with time, while the ratios of frame value and attached equipment value to total value decrease.

We next examine the impact of the ratio of land on the total asset value and aggregated depreciation rates. It is clear that as the proportion of land is smaller, the office value declines more and the depreciation rate becomes larger (Figure 2-2). This is because the proportions of frame and attached equipment that deteriorate with time account for a higher percentage of the total asset value.

(Figure 2-1) Value of offices



(Figure 2-2) Depreciation rates



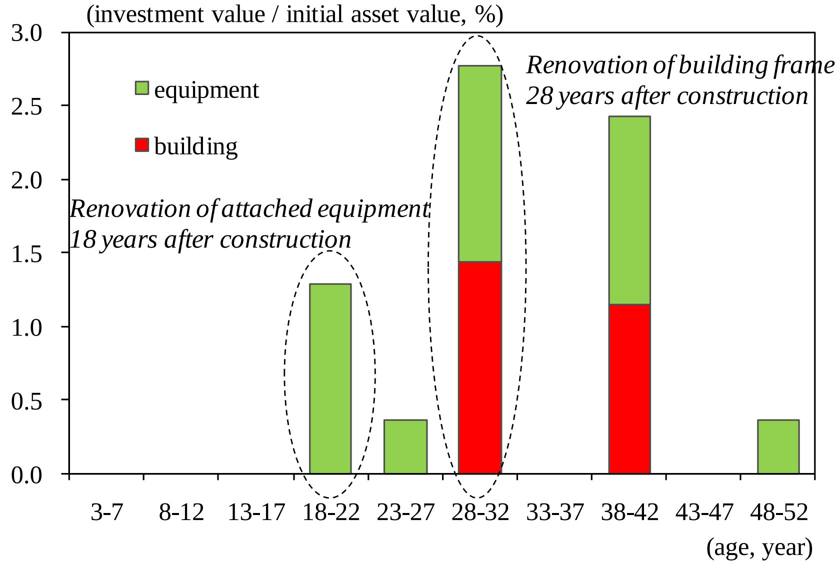
4.5. Assumed patterns of renovation investment

The case in the previous chapter premises that building frame and attached equipment deteriorate and lose value with the passage of time. In practice, however, office buildings are renovated by exchanging end-of-life equipment to prolong the service life. Therefore, the pace of decrease in value slows down.

The SPPI has estimated the average renovation investment patterns for offices according to age beforehand, referring to surveys of office owners by Ministry of Land, Infrastructure, Transport and Tourism. Under the assumption that renovations are conducted according to those patterns, the value and net depreciation rates for offices can then be estimated.

More specifically, we assume that, on average, (1) renovations for attached equipment are conducted 18 years after construction and (2) renovations for frame are conducted 28 years after construction (Figure 3).

(Figure 3) Average patterns of renovation investment



5. Depreciation rates in the SPPI

5.1. Depreciation rates for different age

This chapter looks at the characteristics of depreciation rates applied for four Items; Tokyo area, Osaka area, Nagoya area and Other areas, in the "Office space rental" under the above assumptions. In order to estimate the total depreciation rate for each area, we calculate the average values of depreciation rates of standard office buildings for each location by age. Next, we multiply the depreciation rate for each area by age based on the distribution of sample offices by age.

Total depreciation rates for each area

= *Σ(Depreciation rate per year for each area by age)×(distribution of sample offices by age for each area)*

In all areas, depreciation rates diminish with time. This is because the value of building frame and attached equipment declines at an early stage, whereas the land value remains unchanged which in turn accounts for a greater proportion of total value.

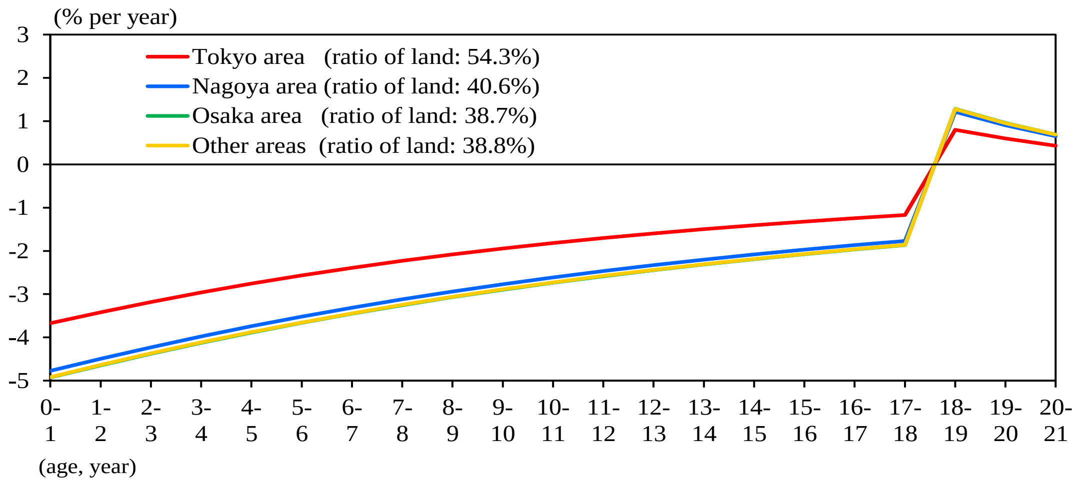
In addition, we find that net depreciation rates have turned positive due to renovation investment 18 years after construction.

Looking at depreciation rates for different ages, each level differs depending on area. This is mainly attributable to differences in the ratio of land value to total value.

For example, in 2013 the land ratio was 54.3% in Tokyo area, 40.6% in Nagoya Area, 38.7% in Osaka area, and 38.8% in Other areas. Land clearly accounts for a higher proportion of total asset value in Tokyo.

Given these estimated ratios, the depreciation rate in Tokyo with higher land prices is lower than in other areas each year. On the other hand, the rates are relatively high in Nagoya area, Osaka area, and Other areas, where land accounts for a small share of total asset value (Figure 4).

(Figure 4) Depreciation rates for different age

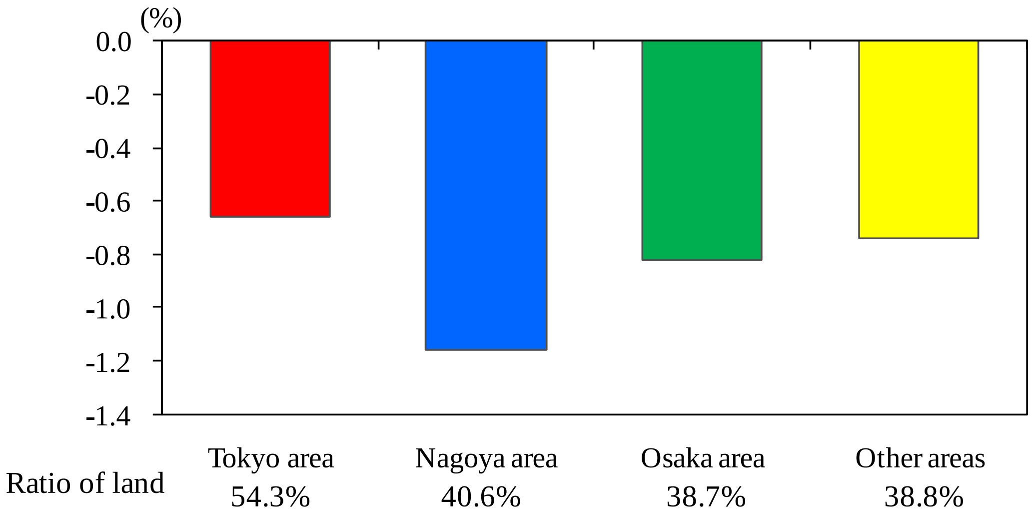


5.2. Differences in depreciation rates by area

According to the estimation above, the annual depreciation rates to be reflected for the index in 2015 are -0.66% (Tokyo area), -1.16% (Nagoya area), -0.82% (Osaka), and -0.74% (Other areas) . These translate into an average overall depreciation rate of 0.71% per year (Figure 5).

The depreciation rate is small in Tokyo area with high proportion of land. As for Nagoya area, Osaka area and other areas, the rates differ because of the distribution of offices by age, although the proportion of land in each area is almost the same.

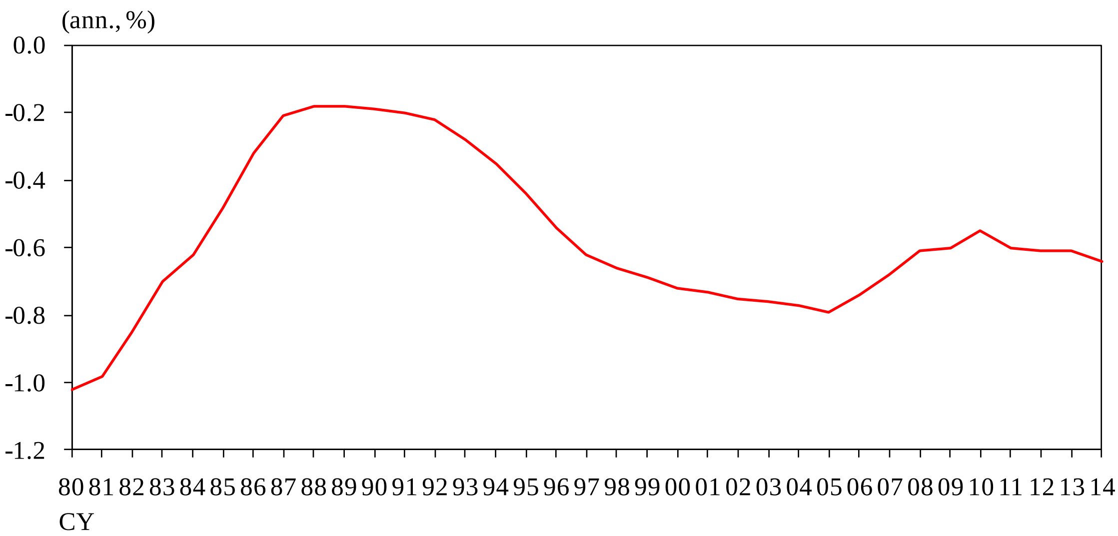
(Figure 5) Depreciation rates for different areas



5.3. Time-series variation of depreciation rate

As mentioned in chapter 3, the changes in land prices have a great impact on depreciation rates. Take the Tokyo area for example (Figure 6). The estimated time-series variation of depreciation rate shows that when land prices were soaring (in the late 1980s), the depreciation rate decreased to 0.2% per year. In turn, when land price were falling (in the mid 2000s), the rate increased to 0.7% per year. It is thus evident that changes in land prices cause great variance in depreciation rates.

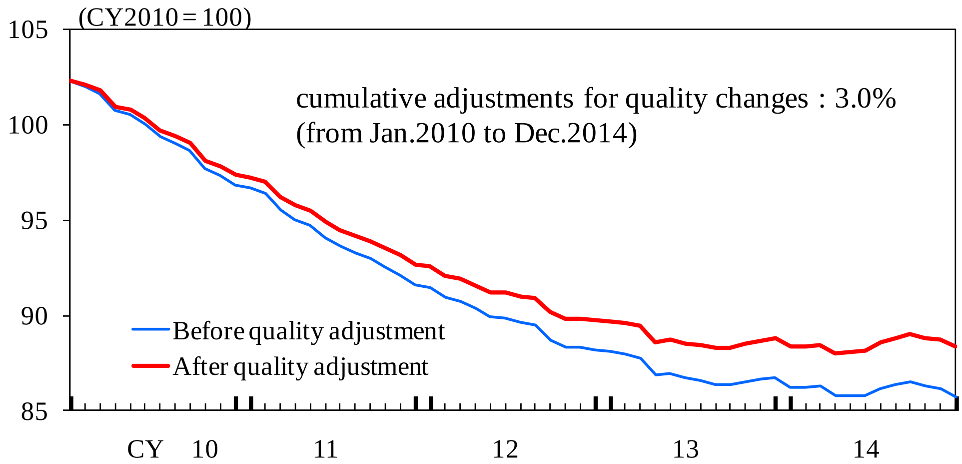
(Figure 6) Depreciation rate of Tokyo area



5.4. Impact on the price index due to depreciation

Finally, we focus on the impact of depreciation on the SPPI. As for the index of Tokyo area, for instance, the cumulative adjustments for quality changes amount to 3.0% over five years (from January 2010 to December 2014) (Figure 7). The quality bias due to depreciation accumulates monotonically over time, so the index level before quality adjustment for each Item in the Subgroup "Office space rental" has been skewed downward by the bias to a significant extent in the long run.

(Figure 7) Example: Tokyo area



6. Conclusion

This paper has explained the concrete method "Asset value approach" used to adjust for the quality deterioration with time in office renting service in the Services Producer Price Index (SPPI) of Japan.

As this paper shows, in order to calculate the depreciation rates of office buildings, firstly we assume the (hypothetical) standard office building composed of land, building frame and attached equipment. Secondly, we set the initial asset value for the standard office building by location, by estimating expenses for obtaining land, frame and attached equipment, at the time of construction. Thirdly, we measure the aggregated depreciation rates due to aging and the total asset value year by year, based on the assumption that the values of the frame and attached equipment depreciate every year at a different fixed rate. And we also take into account the impact of renovation investment on the depreciation rates.

This groundbreaking method facilitates estimation of the non-linear complicated change pattern in the pace of quality deterioration not only with age, but also with changes in land prices. In more detail, it can show the effect of land prices on depreciation rates, by adjusting for the proportions of land, frame, and equipment, with each different depreciation rate (land, frame and equipment) fixed.

The Bank of Japan has used this method for adjusting for aging bias in rental service of office buildings since the beginning of 2010. The impact of the quality adjustment accounts for around 0.7 percent per year on average.

7. Remaining issues

The method is groundbreaking in that it gives solutions to some challenges such as restricted data sources. However, the following issues remain for further research.

The first point pertains to the validity of the assumption that the depreciation rates for building frame and attached equipment are constant. In reality, these depreciation rates are likely to change with time. In particular, there is a possibility that the service life of frame has lengthened due to stricter quake-resistance standards imposed after the Great East Japan Earthquake. However, the life of equipment might also shorten due to widespread use of IT facilities. In response to those changes, it is necessary to consider how often the depreciation rates should be recalculated. In this regard, it might be worth considering whether declining-balance rates from other sources, such as those used in *National Accounts*, would be acceptable substitutes.

Second, it is necessary to expand data sources to estimate average patterns for renovation investment. At this point, average patterns are based on the surveys with office owners by Ministry of Land, Infrastructure, Transport and Tourism as stated in Chapter 4.5, with more detailed data required to enhance estimate precision.

Third, it is worth examining the possibility of adopting the method for other Items ("Sales space rental," "Hotel rental," "Warehouse space rental," and "Parking space rental") in the Subgroup "Real estate rental." However, this would require attention as to how to figure out the distribution of buildings by age and average renovation patterns.

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