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Constructing Building Price Index Using Administrative Data

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Improving the accuracy of deflators is crucial for measuring real GDP and growth rates. However, construction prices are often difficult to measure. This study uses the stratification and hedonic methods to estimate price indices. The estimated indices are based on the actual transaction prices of buildings (contract prices) obtained from the Statistics on Building Starts survey information from the administrative sector in Japan. Compared with the construction cost deflator (CCD), calculated by compounding input costs, the estimated output price indices show higher rates of increase during the economic expansion phase after 2013. This suggests that the profit surge in the construction sector observed in that period is not fully reflected in the CCD. Furthermore, the difference between the two "output-type" indices obtained by stratification and hedonic methods shrinks when the estimation methods are precisely configured.

Key words: Building price index; stratification method; hedonic method; Japan; administrative data.

1. Introduction

Improving the accuracy of deflators (price indices) is crucial for correctly measuring real GDP and growth rates. However, price indices often deviate from deflators that meet the System of National Accounts (SNA) international standards (Eurostat et al. 2009) due to difficult access to price information and technical limitations in indexing. This issue is particularly evident in the construction industry, as the contribution of construction investment in a country's GDP is typically large. Hence, improving the accuracy of construction price indices is fundamental for statistical departments in various countries. For example, the Japanese Statistics Commission, the command post for statistics, together with the ministries and agencies that prepare statistics, has been working on reforms required by the government's Council on Economic and Fiscal Policy and the Council for the Promotion of Statistical Reform. The "Basic Plan for the Development of Official Statistics" (the 3rd Basic Plan), approved by the Cabinet in March 2018, states that "from the perspective of improving the accuracy of real values (omission), research and empirical studies for the use of market-based prices for

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construction and retail services (margins) will be promoted." The report recognizes that improving the accuracy of the deflator (price index) in realizing nominal values will substantially improve the accuracy of GDP estimates.

In Japan, the Statistics Commission, the command post for statistics, together with the ministries and agencies that prepare statistics, has been working on reforms required by the government's Council on Economic and Fiscal Policy and the Council for the Promotion of Statistical Reform. The "Basic Plan for the Development of Official Statistics" (the 3rd Basic Plan), approved by the Cabinet in March 2018, states that "from the perspective of improving the accuracy of real values (omission), research and empirical studies for the use of market-based prices for construction and retail services (margins) will be promoted." The report recognizes that improving the accuracy of the deflator (price index) in realizing nominal values will substantially improve the accuracy of GDP estimates.

In Japan, there is no output-type construction price index based on actual transaction prices (contract prices) of buildings and civil engineering structures. The SNA's deflator uses "input-cost" prices as an alternative price index based on the intermediate input and labor costs required for construction activities. However, the resulting construction deflator does not reflect changes in the profit margins of the construction sector, possibly causing errors in the real value of construction investment.

In this context, there is a need to develop an output-type construction price index. In our survey of previous studies, we could not find any that focused on estimation methods for output-based construction price indexes. We believe that this is due to the following reasons: (1) buildings are made-to-order and thus highly heterogeneous, making quality adjustment extremely difficult; and (2) strong data constraints make empirical research difficult as seen in the papers such as Diewert and Shimizu (2015, 2017, 2022), where they apply the Builders Model to the construction price index by separating land and buildings from property prices.

Some countries have adopted output-type construction price indices that directly measure output prices (contract prices), namely actual transaction prices of buildings and civil engineering structures, instead of the conventional input-cost price indices. Statistical authorities in Canada, Germany, the U.S., and the UK have already developed output price indexes, some of which are used as price indexes for the construction industry in GDP statistics (see, for example, Office for National Statistics 2018).

In this study, we attempt to create an output-type building price index directly measuring output prices by using large-scale administrative data from the Statistics on Building Starts, based on the Notification of Building Construction that must be submitted in Japan when constructing a building. To the best of our knowledge, this is the first study to construct a price index using these data. We propose a new approach that utilizes large-scale information collected by administrative agencies. This approach may be considered entirely novel, not only in Japan but also in other countries.

The remainder of this article is organized as follows. Section 2 summarizes the limits of the current input-cost construction price indices and provides an overview of three common approaches to creating output-type construction price indices. Section 3 provides an overview of the administrative data obtained from the Statistics of Construction Starts, explaining how the stratification and hedonic methods are used to create the proposed price index. Section 4 reports the estimation results of the output-type building price indices obtained through the stratification and hedonic methods, comparing them with the input-cost construction cost deflator (CCD). Additional analyses and results are then proposed and discussed. Section 5 summarizes the study's findings and outlines the remaining issues for future research.

2. Output-Type Construction Price Indices

2.1. *Factors of the Use of Input-Cost Price Indices in the Construction Sector*

The SNA calculates real amounts by dividing nominal amounts, such as the production value, by a delator (see Cabinet Office (2022) for detailed instructions on how to create an index in the case of Japan). A deflator is a price index calculated by continuously surveying the prices of goods and services with constant quality through repeated transactions, indexing the prices of each product, so that the base point is equal to 100, and weighing the price indices of individual products using weights corresponding to the transaction amounts. In Japan's SNA, the Consumer Price Index (CPI) produced by the Statistics Bureau of the Ministry of Internal Affairs and Communications; the Corporate Goods Price Index (CGPI) and the Services Producer Price Index (SPPI) produced by the Bank of Japan; and the Agricultural Price Index produced by the Ministry of Agriculture, Forestry and Fisheries are typically used. See Cabinet Office (2022) for detailed instructions on how to create an index.

However, in the construction sector, there is no market transaction price-based construction price index. In the case of goods and services covered by the CPI and the CGPI and SPPI, goods and services of the same quality are exchanged repeatedly; hence, a constant-quality price index may be created by continuously examining price trends. In contrast, buildings and civil engineering structures are custom-made products, and those of the same quality are not traded repeatedly. Therefore, it is not possible to continuously survey the market transaction prices (contract prices) of buildings and civil engineering structures of the same quality.

The SNA has developed an alternative, input-cost construction price index based on the input costs of buildings and civil engineering structures and used it as a deflator. The Bank of Japan's CGPI and the SPPI are employed for the materials used for assessing construction activities (intermediate inputs), and the Ministry of Health, Labor, and Welfare's (MHLW) Monthly Labor Survey is used to derive per capita wages in the construction industry, used for assessing labor costs (compensation of employees). In addition, the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) produces the CCD, one of Japan's most used input-cost construction price indices. Although we omit the details here and want readers to see MLIT (2021) for detailed information in Japanese and MLIT (n.d.a.) for general information in English, CCDs are made in a similar way to the SNA construction deflator except that they are based on Laspeyres formula. They are made of piling up input costs, material costs from CGPI, SPPI and wages from MHLW's Monthly Labor Survey, but profits of construction firms are not incorporated.

2.2. *Factors Causing Bias in the Input-cost Construction Price Index*

The current input-cost construction price indices, such as the SNA construction deflator, have two major limitations.

First, these indices only cover the intermediate inputs and compensation of employees. Intermediate inputs and compensation of employees accounted for 90% of the output of construction in 2019. The profit generated by construction activities (operating surplus and mixed income), fixed capital depletion, and taxes (taxes imposed on "produced and imported goods" minus "subsidies"), which accounted for the remaining 10%, were not covered. The profit share of the construction sector, which is not covered, often causes errors in the "input cost" price index as it fluctuates significantly compared to input costs due to changes in the environment in which construction companies receive orders. Price changes due to a variation in the profit of the construction industry, not considered by the current input-cost construction price index, are assumed to be equal to those of intermediate inputs and compensation of employees. If these price changes are different, the resulting price index is substantially biased, as the coverage of the input-cost price index changes over time.

Second, the Monthly Labor Survey only reports the average per capita wages of construction workers, used as price data to assess labor costs; hence, it does not consider changes in the quality of labor, such as age, length of service, education, and employment status. Compensation of employees' accounts for more than 30% of the construction industry's output (35% in 2019). As Fukao et al. (2017) point out, its impact is significant and likely to influence changes in building quality. For instance, according to the Japan Industrial Productivity (JIP) Database 2021, the quality of labor in the construction industry (the average of building and civil engineering) has improved by 12% from 1994 to 2018. Moreover, JILPT (2020) estimates that the rate of increase in simple average wages and average wages with fixed attributes in the construction industry from the MHLW's "Basic Survey on Wage Structure" shows a 13% increase from 1994 to 2019 due to improvements in the quality of work (The gap is 13% over 25 years).

2.3. *How to Create An Output-Type Construction Price Index*

To overcome insufficient coverage of the price indices and wage data with no fixed quality, it is necessary to create a price index based on market transaction prices, namely, an output-type index reflecting the output prices of buildings and civil engineering structures. OECD (1997) introduces the following six methods to construct a price index: (1) Model price method, (2) Quoted prices method, (3) List prices method, (4) Matched models method, (5) Stratification method, and (6) Hedonic method. Among these, the methods typically adopted in most countries are (1) the model price approach, (5) the per square meter (stratified) approach, and (6) the econometric (hedonic) approach. In this section, we summarize their characteristics. Furthermore, for house price indexes, Hill (2013) and Silver (2011) provide a comprehensive overview of quality-fixing methods, and Hill et al. (2018) compared the differences to price indexes by several methods, including the Stratification method (Mixed adjustment approach), the hedonic approach, and others.

2.3.1. Model Price Method

The model price method is a compiling method in which "models" of typical buildings and civil engineering structures are obtained by adding up the hypothetical prices of construction materials, labor, machinery, and equipment for each component, and adding the assumed profit of the construction company. This method has been used in the U.S., Canada and Germany, among others. In Japan, this method has been adopted for some items in the CGPI and the SPPI; however, it has not yet been adopted for the CCD and the SNA deflator.

For example, in the U.S., the U.S. Bureau of Labor Statistics purchases data on past construction projects from construction cost estimating companies, selecting representative construction projects for each region (Northeast, Midwest, South, and West) to construct a "building model." The construction contract price is calculated by adding all the "assemblies" required to obtain the building model and all the "components" required for the assemblies. Furthermore, the U.S. BLS, together with experts (construction cost estimating companies), periodically reviews the building models to ensure that they are representative. Every month, when each contractor responds to the survey, they are asked to check in advance the factors affecting the determination of bid prices so that realistic prices are investigated. In addition, the collected prices are verified to ensure that they do not deviate from the actual prices, and cases in which the margin ratio fluctuates significantly due to changes in the content of the work (price changes due to quality changes) are discarded. In Canada, Statistics Canada designates a representative newly constructed building and asks construction companies the price change of each production factor from the previous quarter. In Germany, the Federal Statistical Office of Germany directly obtains the unit price of constructions, equivalent to the output price, from the surveyed companies.

However, this method has some limitations. First, the price indices may not reflect the transaction prices traded in actual markets if some of the production factors in the building or construction models are not representative. Second, as the modeled prices are not actual transaction prices, they may not accurately reflect the market situation. Third, the cost of producing these statistics is generally high since it is often necessary to hire experts for designing a standard model. Fourth, the burden on construction companies reporting hypothetical estimated prices is also high, which can lead to difficulty of Statistics bureaus to collect markup rate data. The last and not the least, quality adjustment of labor costs and estimation of user costs also involve difficulties in terms of data collection and analysis. In this regard, the U.S. BLS (U.S. Bureau of Labor Statistics), together with experts (construction cost estimating companies), periodically reviews the building models to ensure that they are representative. Every month, when each contractor responds to the survey, they are asked to check in advance the factors affecting the determination of bid prices so that realistic prices are investigated. In addition, the collected prices are verified to ensure that they do not deviate from the actual prices, and cases in which the margin ratio fluctuates significantly due to changes in the content of the work (price changes due to quality changes) are discarded.

2.3.2. Stratification Method

This method stratifies price data into multiple attributes, which have a large impact on prices (use, structure, construction method, building method, and region, among others), creating a price index based on the average price for each subdivided stratum. In this method, buildings and civil engineering structures with different qualities are regarded as having the same quality for price data belonging to the same stratum. This approach is commonly employed in existing price indices (See Eurostat et al. (2013) for further information).

In the stratification method, once the subdivision rules have been determined, the burden of producing price indices remains constant as that of tabulating ordinary statistical surveys, and price indices may be produced with a small workload. The degree of homogeneity of the price index increases with the availability of attribute data. In addition, unlike the model pricing approach, this method does not require extensive expertise in building and civil engineering. However, increasing the number of attributes used for subdivision reduces the number of observations in the same stratum, often resulting in no price data in many strata (empty strata), generating bias and noise.

2.3.3. Hedonic Method

This approach estimates the price of a product by considering it as an aggregate of the values of various performances and functions (a bundle of attributes) and using regression analysis. The commodity price is expressed as an equation consisting of a bundle of attributes, and this equation is called a "hedonic function." The regression analysis employs the collected price and attribute data, controlling for the effects of various attributes, and then creating a price index based on the estimated time-series dummies.

Among the construction-related deflators currently used for GDP statistics, only the U.S. uses the hedonic method. In the U.S., this approach is based on data from the Survey of Construction, a survey conducted by the U.S. Bureau of the Census on housing, including actual construction costs and data on the location, layout, and construction method of the housing sector.

In the hedonic method, it is easier to increase the degree of homogeneity compared to the stratification method because empty data can be handled by specifying dummy variables precisely. However, this approach requires knowledge of econometrics to estimate the hedonic function, and the estimation requires many attribute variables. When attributes are not available or are measured in an incorrect way, the model may be subject to omitted variable or other misspecification issues, which could lead to endogeneity problems. Furthermore, it is necessary to periodically re-estimate the hedonic function, increasing the burden of producing price indices. We outline the advantages and disadvantages of the hedonic method in the estimation of price indexes here. Advantages include: (1) As well as having a basis in economic theory and index theory, the theoretical biases of the hedonic method are clear, and (2) Since it makes it possible to control for the many characteristics of building, it enables the sorting of data into specialized indexes by purpose. Disadvantages include: (1) Since it is necessary to collect many characteristics, information-gathering costs are high, (2) In cases where it is not possible to collect important characteristics for determining property prices, one faces the problem of omitted variable bias, (3) In cases of strong heterogeneity, it may not be possible to control for quality. For further information on estimating price indices using the hedonic method, see Eurostat et al. (2013), Benedetti et al. (2022), for example.

3. Estimation of Output-Type Construction Price Indices Using the Administrative Data

3.1. Data

We construct an output-type construction price index for housing and non-housing buildings using the stratification and hedonic methods. Individual data from the Statistics of Building Starts are used as the source material (see Table 1 for attribute items available in the Statistics).

In Japan, the Building Standard Law requires the owner to submit a Notification of Construction Work to the prefectural governor when constructing a building. The MLIT compiles the Notification of Construction Work and publishes the Statistics on Building Starts. These statistics comprise all building investments. The administrative data used in this study

Table 1. *List of attribute items in the statistics of the building starts questionnaire.*

Number	Item name	Sign and description
1	Year of survey	2005–2020
2	Survey month	01–12
3	Prefectural Number	01 to 47, Hokkaido to Okinawa
4	City, Town and Village Code	XXX
5	Intra-municipal serial number	XXXX
6	Scheduled construction period	01–99 (months)
7	The builder	1: country, 2: prefecture, 3: municipality, 4: company, 5: non-company organization, 6: individual
8	Structure	1: Wooden structure, 2: Steel-framed reinforced concrete structure, 3: Reinforced concrete structure, 4: Steel structure, 5: Concrete block structure, 6: Others
9	Building use	In addition to the classification based on the Standard Industrial Classification, classification is based on the use of offices and stores.
10	Construction type	1: New construction, 2: Extension, 3: Reconstruction
11	Capital stock classification	1: 10 million yen or less, 2: Over 10 million yen to 30 million yen or less, 3: Over 30 million yen to 100 million yen or less, 4: Over 100 million yen to 1 billion yen or less, 5: Over 1 billion yen (Only when the architect is "4: Company")
12	City planning classification	1:Urbanized area, 2:Urbanized control area, 3:Undefined urban planning area, 4:Quasi-urban planning area, 5:Under urban planning area and quasi-urban planning area
13	Building classification	1 to 9: Enter a series of numbers when there are two or more buildings in one construction report. The same number should be entered for the same building, and "9" should be entered for all buildings above "9"
14	Small number	If there are two or more houses in one building with different use relationships, enter the series number.
15	Number of floors above ground in new construction	01-99 (only when the construction type is "1: New Construction")
16	Number of basement floors in new construction	1 to 9 (only if the construction type is "1: New Construction")
17	Site area of new construction	m^2 (only if the construction type is "1: New Construction")
18	Total floor area	(As there is no obligation to report building work if the area is less than 10 m^2) it takes a value of 11 m^2 or more
19	Construction contract expenses	10,000 yen
20	Versatile or not	If 1, it indicates a multi-use building
21	Number of housing units to be removed	XXX
22	Relationship of use of retired housing	1: Owner-occupied house, 2: Rental house, 3: Salary housing
23	Building method	1: Conventional construction method, 2: Prefabricated construction method, 3: Frame wall construction method

Table 1. Continued

Number	Item name	Sign and description
24	Construction type	1: Newly established, 2: Other
25	Funds for new housing	1:Privately financed housing, 2:Public housing, 3:JHF housing, 4:Urban Renaissance Agency housing, 5:Others (only if the construction type is “1: New construction”)
26	Type of housing	1: Dedicated housing, 2: Conjoined housing, 3: Other housing
27	Building (e.g., house)	1: Single-family houses, 2: Row houses, 3: Apartment houses
28	Usage restrictions, limitations	1: Owner-occupied house, 2: Rental house, 3: Salaried house, 4: Condominium house
29	Number of housing units	XXXX
30	Total floor area of the house	m^2

Note: Variables 1 to 20 are used to describe both housing and non-housing buildings while those from 21 to 30 are only used for housing buildings.
Source: Compiled based on survey sheets from the MLIT’s Building Starts statistics.

cover 7.92 million cases from January 2005 to December 2020 (an average of approximately 500,000 cases per year). A large amount of information on building prices and attributes may be obtained from the administrative data (see Online Supplemental Data, Appendix 1 for details). We use the unit price per floor area of the construction contract expenses (construction contract expenses/total floor area) as the price information of the buildings. The unit price per floor area (#19 / #18 in the Table 2) is one of the most important indicators in the dataset. It shows wide range of variations based on the type of structures and characteristics of the buildings. Wood structure and Non-Housing S buildings show relatively cheap average price of 14.10–16.26 ten k. yen compared with the high price of 26 ten k. of Non-housing RC, 22.10 of Housing S and 20.99 of Housing RC. The standard deviation of prices stands at the highest in Non-Housing RC which implies large heterogeneity among buildings.

It should be noted that the construction contract expenses in the Statistics on Building Starts is the value at the time the notification of construction work is submitted, not the actual amount of construction expenses at the time of completion, nor is it converted to a progress basis. However, contracting practice observed in construction companies in Japan is rather different from those in other countries. In Japan, so called general construction companies give one stop services to customers, and changes in construction schedule or plan have less impact compared with those in other countries. According to the statistics by the MLIT, deviations in unit price per floor area of completed buildings from contracted prices remain at 2–3%, which means construction expenses at the time of completion don’t substantially deviate from those at the contract stage unlike other countries. That information is available at MLIT (n.d.b) but only published in Japanese.

3.2. *Overview of the Stratification Method*

The stratification method involves the following four steps:

1. The data are divided into strata based on the attributes expected to affect the quality of a building, such as the structure of the building, construction method, and venue. Hence,

Table 2. Descriptive statistics on the numeric data from building starts.

	Housing·W					Non-Housing·W				
	Min	Max	Avg	Med	Sd	Min	Max	Avg	Med	Sd
#19 (ten k. yen)	5	0.9 bn.	1,997	1,800	1,044.03	2	2.8 bn.	2,524	1,432.5	4,922.85
#18 (m^2)	11	2,993	124	111	56.49	11	14,001	174	104	246.96
#19 / #18	0.10	88.48	16.26	15.71	4.16	0.03	206.68	14.38	14.18	6.72
#15 (N. floor)	1	7	2	2	0.39	1	5	1	1	0.49
#16 (N. floor)	1	7	1	1	0.11	1	3	1	1	0.11
#6 (month)	1	98	4	4	1.24	1	72	3	3	1.98
#17 (m^2)	12	1.49 mm.	227	180	907.68	11	3.49 mm.	992	355	18,694
#29 (unit)	1	64	1	1	1.38	-	-	-	-	-

	Housing·RC					Non-Housing·RC				
	Min	Max	Avg	Med	Sd	Min	Max	Avg	Med	Sd
#19 (ten k. yen)	26	104 bn.	20,206	8,000	85,146	2	65.8 bn.	37,873	9,000	136,694
#18 (m^2)	11	0.20 mm.	1,016	403	3,214.03	11	0.25 mm.	1,672	408	5,951.73
#19 / #18	0.10	355.63	20.99	19.53	8.43	0.11	365.59	25.91	22.86	14.87
#15 (N. floor)	1	60	4	3	3.50	1	42	3	2	2.21
#16 (N. floor)	1	8	1	1	0.30	1	8	1	1	0.47
#6 (month)	1	93	8	7	3.82	1	99	8	7	5.29
#17 (m^2)	15	1.75 mm.	551	306	5,057.25	9	9.95 mm.	4,984	849	82,317
#29 (unit)	1	1,634	15	7	30.63	-	-	-	-	-

Table 2. *(Continued)*

	Housing·S					Non-Housing·S				
	Min	Max	Avg	Med	Sd	Min	Max	Avg	Med	Sd
#19 (ten k. yen)	5	80 bn.	3,784	3,000	13,072	1	300 bn.	11,605	2,500	112,314
#18 (m^2)	11	0.24 mm.	182	132	425.10	11	0.58 mm.	765	194	4,001.90
#19 / #18	0.12	240.04	22.10	21.37	5.81	0.001	459.39	14.10	11.90	10.37
#15 (N. floor)	1	54	2	2	0.62	1	54	2	1	1.21
#16 (N. floor)	1	4	1	1	0.18	1	8	1	1	0.52
#6 (month)	1	73	3	3	1.26	1	99	4	3	2.98
#17 (m^2)	12	39,338	273	210	241.82	4	9.24 mm.	2,441	626	36,612
#29 (unit)	1	1,493	2	1	4.36	-	-	-	-	-

Note 1: Min = minimum, max = maximum, ave = average, med = median, sd = standard deviation, k. = thousand, mm. = million, bn. = billion

Note 2: Variable # in each row corresponds to that of Table 1.

Note 3: #19 / #18 means the unit price per floor area of the construction expenses (construction contract expenses divided by total floor area).

Note 4: The descriptive statistics of #16 is calculated only for buildings that have basement floors.

Source: Compiled based on microdata of the MLIT's Building Starts statistics.

the quality of the buildings within the same group is differentiated even though group members have similar characteristics.

2. The total amount of contract construction expenses, as well as the total floor area of a property, are calculated for the buildings included in the same group. Then, the unit price per floor area is obtained by dividing total expenses by the total floor area. This unit price represents the building price of the group.
3. The value of the unit price is transformed so that the index considers the average in FY 2011 as 100 following the base year of the CCD. In this article, we denote Japanese Fiscal Year (from April to next March) as FY and Calendar Year as CY unless otherwise noted. The index is constructed for every stratum. In this article, we denote Japanese Fiscal Year (from April to next March) as FY and Calendar Year as CY unless otherwise noted.
4. Finally, the indexed unit prices are aggregated by taking a weighted average based on the FY 2011 value of the total contract construction costs of each group. That is, the price index calculated in this method is a fixed-standard Laspeyres index. As described later, the output-type indices estimated in this study are compared with the input-cost indices, the MLIT's CCD. CCD undergoes major revisions about every five years, so indices in the figures are constructed based on the link coefficients for FY2005–FY2011 and FY2011–FY2015. All the indices are rebased so that FY 2011 = 100 just for comparison. We estimated geometric mean-based indices as well as transaction numbers-based indices in the following sections.

The index obtained after the above four steps, becomes the final output building price index. In this study, we classify buildings into two categories: housing and non-housing buildings, which greatly differ in quality, and adopt quarterly aggregates. We do this because the available attribute items are different for housing and non-housing properties, and the percentage of empty strata can be greatly improved by using quarterly aggregation instead of monthly aggregation. In addition, for empty strata, we examine the following five typically used imputation methods: (1) the last observed price data, (2) the price data of the same period in the previous year, (3) the average price of non-empty strata, (4) the average quarter-on-quarter growth rate of non-empty strata, and (5) the average year-on-year growth rate of non-empty strata. The results are omitted here for the sake of brevity. For details, please contact the authors. Regarding "private rents" in the CPI, the index is created by supplementing the rents for the most recent month horizontally for rented houses that became vacant due to renters moving out, thus becoming missing values. We replaced empty strata with the last observed value because this approach results in the smallest fluctuations in the estimated price index. (If you want to know the details, please contact the authors). This is the same method adopted in "private rents" in the Japanese CPI, the index is created by supplementing the rents for the most recent month horizontally for rented houses that became vacant due to renters moving out, thus becoming missing values.

For stratification, items that greatly affect the quality of the building and have an impact on the unit price of the building should be selected. Specifically, for housing buildings, the "construction method" (prefabricated and two-by-four, among others), "construction method" (single-family house and apartment house, among others), "structure" (wooden and reinforced concrete, among others), "prefecture (region)," and "use relationship" (owner-occupied and rental house, among others) are selected. In the case of non-housing buildings, “building use” (e.g., industry of the company that built the building), “structure,” and “prefecture” (region) are used (Table 3).

3.3. Overview of the Hedonic Method

The dependent variable of the hedonic function is the unit price per floor area of the estimated construction expenses (construction contract expenses/total floor area). In this study, we use the logarithmically transformed value, in line with Diewert (2003). We adopt a rolling estimation method, in which the estimation is performed with the window length of 12 months. This is a widely accepted method for estimating housing price indices by the Eurostat et al. (2013), Hill et al. (2022) and Shimizu et al. (2010), for example. The method has the advantage of reflecting time-series changes in parameters and has been adopted in the official statistics in many countries including Japan. The rolling window hedonic method is used in the “Official Property Price Index” published by Statistics Office in many countries. All available attribute items are used as explanatory variables, and a one-sided log-linear hedonic function is employed, as follows: The estimation period ranges from January 2005 to December 2020, 181 times the rolling estimation in a 12-month window frame; all of the variables are found to be statistically significant at the 10% level of significance throughout the whole period.

$$\log p_i = \alpha + \sum_{j=1}^{n} \beta_j x_{i,j} + \sum_{k=2}^{m} \delta_k d_{i,k} + \sum_{t=2}^{\tau} \gamma_t TD_{i,t} + u_i, \tag{1}$$

Table 3. Attribute items in the stratification method.

	Attribute (specification) item	Contents
Housing	Building method	Prefabricated, two-by-four, other (conventional construction method)
	Building (e.g., house)	Single-family houses, row houses, and apartment buildings
	Structure	Wooden construction, steel-framed reinforced concrete construction, reinforced concrete construction, steel construction, and concrete block construction, among others
	Administrative divisions of Japan	47 Prefectures
	Usage restrictions, limitations	Owner-occupied houses, rental houses, salaried housing, and condominiums
Non-housing	Versatile or not	Multi-purpose buildings, among others
	Purpose	Standard Industrial Classification (Middle Classification)
	Structure	Wooden construction, steel-framed reinforced concrete construction, reinforced concrete construction, steel construction, and concrete block construction, among others
	Administrative divisions of Japan	47 Prefectures

p_i: unit price per square meter of building i;
α: constant term;
$x_{i,j}$: jth attribute of building i (numerical value);
β_j: parameter of numerical data;
$d_{i,k}$: kth attribute of building i (dummy);
δ_k: parameter of the dummy variable;
$TD_{i,t}$: survey month t of building i (time dummy);
γ_t: time dummy parameters (representing quality-adjusted prices);
u_i: error term.

The estimation period ranges from January 2005 to December 2020, 181 times the rolling estimation in a 12-month window frame; all of the variables are found to be statistically significant at the 10% level of significance throughout the whole period, to say the estimation results first.

It is difficult to assume a linear relationship between the qualities of buildings due to the wide distribution of the number of stories. Therefore, in addition to setting multiple dummy variables in a nonparametric manner, a piecewise linear function is also introduced like did in Diewert and Shimizu (2015, 2016, 2017). This function divides the number of floors into multiple categories and assumes linear relationships within each category. The use of piecewise linear functions allows us to consider cases in which the impact of increasing the number of floors from a one-story building to a two-story building is different from the impact of increasing the number of floors from a 20-story building to a 21-story building. For example, in the case in which the number of floors is divided into three categories, we obtain:

$$\begin{aligned} f_S(S_i) \equiv {} & D_{S,i1}\lambda_1 S_i + D_{S,i2}[\lambda_1 S_1 + \lambda_2(S_i - S_1)] + D_{S,i3}[\lambda_1 S_1 + \lambda_2(S_2 - S_1) \\ & + \lambda_3(S_i - S_2)], \end{aligned} \tag{2}$$

where S_i is the building i's number of stories above ground (S_1, S_2 are the maximum number of stories in Category 1 and Category 2, respectively), $D_{S,i}$ is a dummy variable that takes a value of 1 if the number of stories above ground falls into each category, and λ is the coefficient through which each story category affects the unit price per total floor area.

In cases in which a dummy variable is not continuously observed throughout the rolling window, an adjustment is made to redefine it into a “wider range of dummy variables” integrated with other items. This adjustment is made since the inclusion or exclusion of these explanatory variables (depending on the point in time of the estimation) may lead to significant changes in the estimated values of the coefficients. For example, the dummy variable representing Aomori Prefecture is redefined into a regional dummy for the Tohoku region, and the usage dummies are redefined by industry instead of dividing them by use, such as warehouses and stores. Although indices are estimated based on the monthly basis, we use quarterly series by taking simple average to them. For further details of the Hedonic estimation, please see Online Supplemental Data, Appendix 2.

4. Estimation Results of the Output-Type Building Price Index

4.1. Output-type Building Price Index and CCD

This section compares the output-type building price indices estimated by the stratification and hedonic methods with the CCD, an input-cost index. We evaluate the estimation results focusing on six categories, namely wood-frame, reinforced concrete (RC), and steel-frame (S) construction for housing and non-housing buildings, respectively, which account for a large share of the total building stock.

The estimation period ranges from the first quarter of 2005 to the fourth quarter of 2020. It includes an expansionary phase, approximately until 2007, a sharp recessionary phase triggered by the Lehman shock in 2008–2009, and a long expansionary phase from the fall of 2012 to the fall of 2018. From autumn 2012 onward, construction investment has raised substantially, and the construction sector's profits have increased markedly due to an improvement in the order environment. In addition to these factors, the recession caused by the spread of COVID-19 and the subsequent rise in housing demand have caused lumber prices to start rising from approximately July 2020, leading to a "wood shock." The Bank of Japan's CGPI confirms that the impact of rising import prices for materials has become more significant since the beginning of 2021, but the impact has not been as pronounced during the analysis period (until the end of 2020). In terms of prices, the sharp rise in resource prices up to approximately 2008 has increased the prices of construction materials, followed by a decline in material prices in 2009, and a gradual rise in prices since 2013. In addition, the recession caused by the spread of COVID-19 and the subsequent rise in housing demand have caused lumber prices to start rising from approximately July 2020, leading to a "wood shock." The Bank of Japan's CGPI confirms that the impact of rising import prices for materials has become more significant since the beginning of 2021, but the impact has not been as pronounced during the analysis period (until the end of 2020). These phenomena reflect substantial price changes, such as increases in labor costs due to the persistent labor shortage in the construction sector and rises in the profits of construction companies. Hence, we evaluate changes in the construction price index that reflect such variations in the economic conditions. The estimated indices are compared with the CCD (Figure 1).

In comparing those indices, we need to be careful about possible influences caused by differences in the methodologies. For the CCD, since it is impossible for us to reconstruct the indicator, we referred to the Paasche-check results published by the data source. CCD is a Laspeyres index based on the weights derived from the Input-Output Table and it undergoes major changes in the methodological standards almost every five years. In the sample period of this paper, it has three different standard years, that is, FY2005, FY2011 and FY2015. We estimated the Fisher indices from the Paasche-check results conducted at the time of standard revisions and checked their deviations from the Laspeyres indices. The estimated biases are about 0.2 point to 0.5 point, so differences in calculation methods can be negligible when evaluating the movements of CCD.

Considering the discussion in De Haan (2004), the hedonic price indices (the quality-adjusted Jevons index) are interpreted as the stratification method based on geometric mean stratum. We conducted the Stratification estimation based on the geometric mean with three

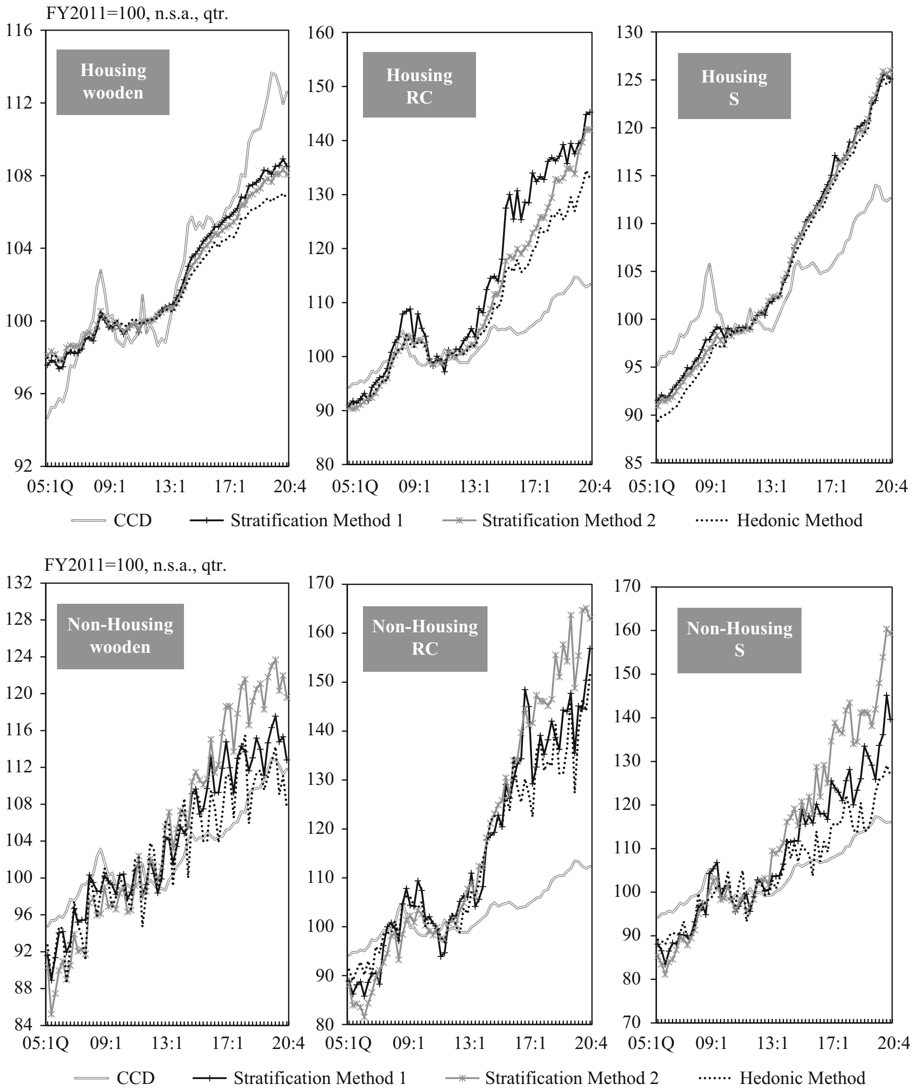

Fig. 1. Output-type building price index.

Note 1: Quarterly indices for Hedonic Method are obtained by simple average of monthly indices.

Note 2: Stratification Method 1 is based on the transaction value weights, and Method 2 is on transaction numbers weights.

Source: MLIT, CCD; calculations by the authors.

base years of FY2005, FY2011, and FY2015. These indices are then connected by using link coefficients like we did in the CCD. Moreover, we considered two different types of weights to aggregate each stratum; the transaction value weights (Stratification Method 1) and transaction numbers weights (Stratification Method 2). The former is compatible with the CCD and the latter is to make comparison with the Hedonic estimation. Eurostat et al. (2013) recommend the following for the choice of weights, in the case of the house price index: “A price index which is required to measure the wealth associated with the ownership of residential property should be stock-weighted. A price index which is required for measuring the real output of the residential real estate industry should be sales-weighted". Diewert (2003) mentions weights for price indexes using the hedonic method.

The output-type construction price indices obtained by the stratification and hedonic methods show a larger increase than the input-cost CCD for all series except for housing and wood construction (housing and RC construction, housing and S construction, non-housing and wood construction, non-housing and RC construction, and non-housing and S construction). In many cases, the gap between the CCD and the output-type construction price index was almost negligible until 2012, but from 2013 onward, the gap has gradually increased. In the economic expansion phase, since 2013, the true construction prices captured by the output-type construction price index are higher than those captured by the existing input-cost price indices (the CCD and SNA's index). The results suggest that the estimated output-type construction price index may effectively overcome the measurement difficulties outlined in this study.

In the late 2000s, the timing of the increase in the indices based on both the stratification and hedonic methods, especially for housing and RC construction, lags behind the increase in the CCD, and the fluctuation is modest. This result indicates that construction companies cannot immediately pass on changes in materials and labor costs reflected in the CCD to building owners in a competitive environment; hence, they negotiate prices over time and reflect them in their contract prices.

Finally, comparing the indices obtained by the stratification method with those generated by the hedonic method, we find that in some cases, they show approximately the same increase (housing/S and non-housing/RC); however, a certain gap is observed between the price index obtained using the stratification method (non-housing/wooden) and that obtained by the hedonic method. The former increases more than the latter, and the gap between the two is, at times, large (housing/RC, non-housing/wooden, and non-housing/S) (Table 4).

As described above, among the six series of output-type indices, the gap between the two indices is large for three series: housing/RC construction, non-housing/wood construction, and non-housing/S construction. This discrepancy may be due to inappropriate selection of attributes for stratification and subdivision in the stratification

Table 4. Discrepancies between the stratification method, hedonic method, and CCD – housing/non-housing and structure.

Housing/ Non-housing	Structure	Stratification versus CCD	Hedonic versus CCD	Stratification versus Hedonic
Housing	wooden	medium gap	medium gap	medium gap
	reinforced concrete construction	**large gap**	**large gap**	**large gap**
	steel construction	medium gap	medium gap	small gap
Non-housing	wooden	**large gap**	medium gap	**large gap**
	reinforced concrete construction	**large gap**	**large gap**	small gap
	steel construction	**large gap**	medium gap	**large gap**

method and insufficient quality adjustment, among others. In addition, the hedonic method may suffer from misspecification bias, such as omitted variable bias since RC high rise condominium and non-housing buildings are likely to be insufficient quality adjustments due to a lack of attributes because of their heterogeneity. As for misspecification bias, please see Ekeland et al. (2004) and Heckman et al. (2010) for further information. In the next subsection, we further discuss this point.

4.2. Evaluation of Output-Type Building Price Index: Increasing Variability

Among the three series in which substantial gaps are observed, for housing/RC and non-housing/S constructions, the unit price per total floor area of the construction contract expenses has been increasing in recent years (Figure 2). Although only the graph for housing/RC is shown, the same trend is confirmed for non-housing/S.

This result indicates that the variation in the quality of buildings has been large in housing/RC and non-housing/S. This phenomenon may be due to an increase in the number of high-rise condominiums such as tower apartments and the larger variation in buildings constructed with steel frames owing to the recent improvement in construction technology.

To adjust for the effects of these increased variations, in the stratification method, the elements detailed in Table 5 are added as items for subdivision and stratification, and the stratification items are further subdivided to improve the degree of homogeneity of attributes.

In addition, in the hedonic method, we divide the data by setting a total floor area as a threshold to estimate the function for each data point. Referring to the distribution of the number of observations, we estimate the cases divided into three categories for housing

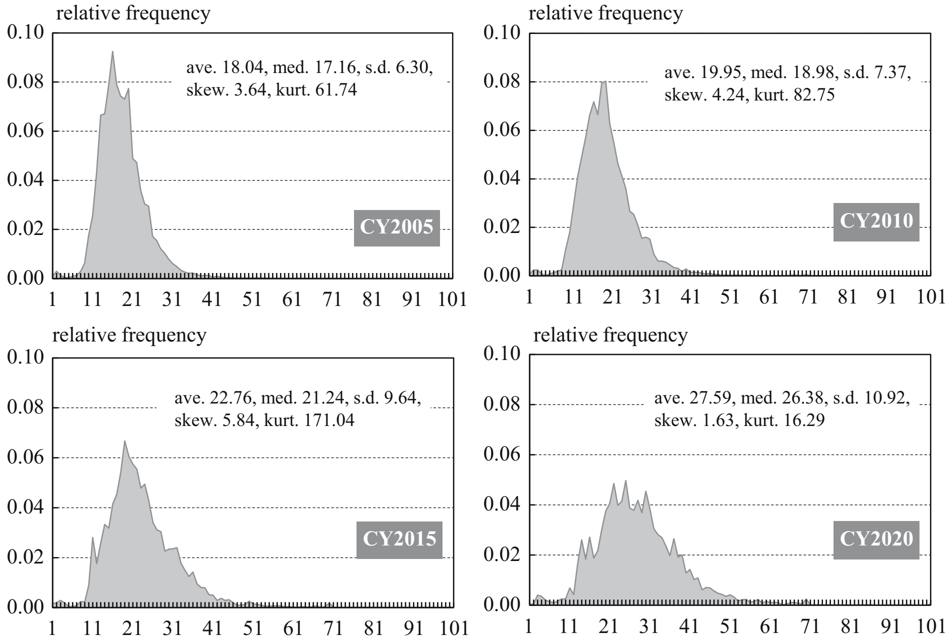

Fig. 2. Distribution of unit price per square meter in housing RC construction.

Note: The unit of x-axis is 10,000 yen except the last bin which shows over one million.

Source: MLIT and calculations by the authors.

Table 5. Additional items in the stratification method.

Housing/non-housing	Baseline	Addition of stratification and subdivision items
Housing	Building method, construction method, structure, prefecture, and use relationship	Baseline; Builder, capitalization category, city planning category, basement, retired housing, funds for new housing, use (building with housing industrial use)
Non-housing	Multi-use or not, use, structure, and prefecture	Baseline; Architect, capitalization category, city planning category, underground

and RC structures: total floor area of 200 m^2 or less, over 200 m^2 to 800 m^2, and over 800 m^2; for non-housing and S structures: total floor area of 100 m^2 or less, over 100 m^2 to 300 m^2, and over 300 m^2. By dividing the sample by the size of the buildings, differences in the coefficients of the explanatory variables in the hedonic estimation may be considered, preventing small buildings, which have a small share in the value of the construction contract expenses but a high share in the sample size, from having excessive influence.

Figure 3 compares the indices obtained by the stratification method with the addition of subdivision and stratification items and the indices obtained by the hedonic method with sample division by total floor area. Comparing Figure 3 with Figure 1, we show that the difference between stratification and hedonic indices is much smaller than that obtained before dividing the sample for both housing/RC and non-housing/S.

The degree of homogeneity in the stratification method is improved by increasing the number of items to be subdivided and stratified, enhancing the accuracy of the index. In addition, by dividing the sample addressed by the hedonic method, the price trends of

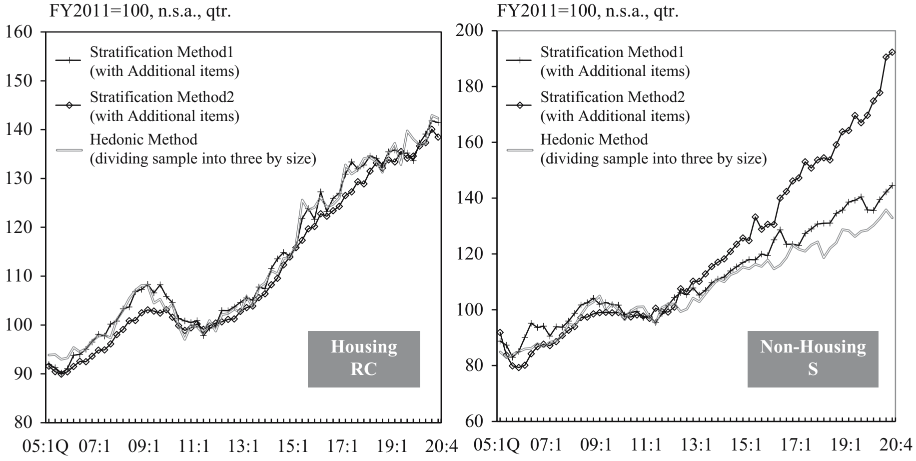

Fig. 3. Stratification, hedonic method: Additional estimation index 1.

Note 1: Quarterly indices for Hedonic Method are obtained by simple average of monthly indices.

Note 2: Stratification Method 1 is based on the transaction value weights, and Method 2 is on transaction numbers weights.

Source: MLIT and calculations by the authors.

buildings with a high rate of price increase and a large scale, such as tower condominiums, are reflected by a more appropriate weight, narrowing the gap between the two methods. However, it should be noted that the stratification method undergoes large fluctuations depending on the choice of aggregation weights. It implies immanent instabilities in the stratification method, and the Hedonic method is superior in terms of quality adjustment.

4.3. Effect of Seasonality on Non-Housing and Wooden Structures

Among the three series in which index gaps are observed, the non-housing and wood-frame series show large quarterly fluctuations in both indices, suggesting that seasonality is likely observed (Figure 1). By addressing the number of observations for each month for warehouses in agriculture, forestry and fisheries industry (corresponds to 314 classification number of types of dwellings, industries, and use) and stores in food services industry (classification number: 532), which have a large share in the non-housing/wooden category (Figure 4, right), we observe seasonal fluctuations with a peak in June. The seasonal changes in the composition of non-housing/wooden buildings may affect the estimated indices because the unit price per square meter for seasonally built constructions such as beachside houses and small cottages used for storing harvests is significantly lower than for other buildings.

Based on these characteristics, in the stratification method, the index is created by adding stratification items in the same way as in the two series described in the previous subsection. In the hedonic function, "use of buildings" dummy variables, such as "office," "store" and so on are added in addition to the industry of the building owner company, and the interaction term between the industrial/usage dummy and the time dummy is employed to capture seasonal changes in the composition of buildings within each industry and use category (Figure 4, left). The results show that the gap between the index obtained by the stratification method with the addition of stratification items and the hedonic index with

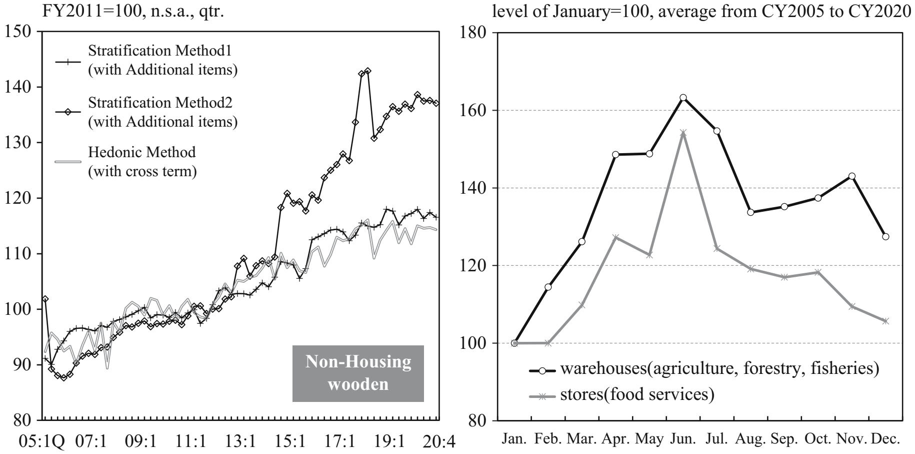

Fig. 4. Left: stratification, hedonic method; Additional estimation index 2. Right: number of observations for use/application categories applicable to non-housing/wooden.

Note 1: Quarterly indices for Hedonic Method are obtained by simple average of monthly indices.

Note 2: Stratification Method 1 is based on the transaction value weights, and Method 2 is on transaction numbers weights.

Source: MLIT and calculations by the authors.

the addition of the cross term is reduced. In addition to the increase in the degree of quality adjustment in the stratification method, the effect of seasonal variation is removed by adding the cross term in the hedonic method; thus, the fluctuation in the index is smaller than that shown in Figure 1. The index is thus considered more appropriate.

5. Conclusion

This study builds an output-type building price index using large-scale administrative data from the Statistics of Building Starts, using the stratification and hedonic methods.

By considering changes in the six series of indices for housing and non-housing buildings categorized by the structure type, we obtain an output-type building price index with a reasonable level of accuracy. Except for housing/wooden, during the sample period, all series (housing/RC, housing/S, non-housing/wooden, non-housing/RC, and non-housing/S) have increased at a higher rate than the CCD, the input-cost price index, and currently official statistics. This trend has been particularly eminent recently, especially since 2013. The output-type building price indices obtained by the stratification and hedonic methods reflect that profits in the construction sector have been increasing due to the recent improvements in the environment for construction orders. As such, the output-type building price index provides valuable information.

We confirm that the current input-cost price indices may not be sufficient to improve the accuracy of real construction investment in Japan and accurately reflect the activities of the construction sector. A new, highly accurate output-type construction price index may better serve this scope.

The hedonic method allows a higher degree of homogeneity or quality adjustment. Although the stratification method requires relatively small compiling costs, the estimated indices have shown some fluctuations especially in non-housing structures where the number of samples is limited, and those buildings are supposed to have larger heterogeneity than housing buildings. Chain linked stratification indices have shown chain drift while the hedonic method indices have been relatively stable for the sample periods used in this research, which supports the findings of Ivancic et al. (2011).

This study's results indicate that the indices obtained by the stratification and hedonic methods for the three series of housing/wooden, housing/S, and non-housing/RC show approximately the same level of increase. However, for the three series of housing/RC construction, non-housing/wooden construction, and non-housing/S construction, a certain discrepancy is observed between the two indices. These gaps may be reduced by refining the estimation. The stratification method may be used to create an output-type building price index at a low cost. However, as seen in the estimated indices, it is also true that the degree of quality adjustment in the stratification method might be limited, and we must carefully check its specifications when adopting this method.

Despite its methodological contribution, the current study has some limitations. First, the proposed price index does not reflect improvements in the quality of labor, which are expected to have a significant impact in the medium to long term. The attribute items of the Statistics of Building Starts used do not reflect improvements in building quality associated with increased quality of labor due to data limitations. Second, the construction contract expenses of a building provided by the Statistics of Building Starts are estimated at the time when construction began and not at the time of completion; hence, they do not reflect design changes after the construction start. The method for converting the price index into an accrual-based index to match the SNA standards for estimating construction investment is also worth further investigation. While our research has shown benefits of using the administrative data, most of them are not generally available in the electric format in Japan. Construction documents, which are abundant in a building's attribute information, are to be submitted to the local authorities as papers while the Statistics of Building Starts are available in the digital form since they are surveyed in the different questionnaire which is usually to be filled in by extracting only small fraction of the Construction documents. In addition to further verification of the estimation method, the above issues should be examined in the future.

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