International Journal of Economic Policy Studies
https://doi.org/10.1007/s42495-024-00147-x

RESEARCH ARTICLE

Additional neighborhood effects following renovation of historical heritage: an empirical investigation of the case of Himeji Castle

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Received: 2 February 2024 / Accepted: 21 October 2024

Abstract
Historical buildings require periodic renovation to ensure that their historical value is preserved for future generations. In this study, we use the renovation project conducted at Himeji Castle over about 5 and a half years from 2009 as a case study to analyze the impact of the renovation on the neighboring areas. As shown by the changes in land price trends, it was found that the renovation project had the effect of accelerating the upward trend in land price during the renovation period. In some areas, however, this acceleration effect was shown to diminish after the completion of the project. Nevertheless, the short-term increase in land price during this period was found to be sustained even after the completion of the project. We consider this price increase to be a neighborhood effect created by the renovation.

Keywords Neighborhood effects · Renovation · Historical heritage · Hedonic approach

Introduction

Many researchers have produced a variety of studies on the value of cultural heritage [18, 19, 25, 36]. For example, these studies were synthesized by Vecco [38], who classified the value of cultural heritage into cultural, economic, communication, and ecological categories. Among these, total economic value is divided into use and nonuse values, while use value is further divided into direct and indirect use values,

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Published online: 11 November 2024

and nonuse value is further divided into existence and bequest values. However, the actual overall value of cultural heritage is not decomposed according to these classifications, but rather, represents the characteristics of each aspect of value.

Considering historical buildings as cultural heritage, it is difficult to move them geographically and they are generally not owned by individuals; hence, it is rare for them to be bought and sold, and it is difficult to determine their value directly through market transactions. Historical buildings are considered to have intrinsic value in their existence as cultural heritage, tourism to historical buildings is itself an economic activity, and economic benefits are generated through consumption related to the scenery in the surrounding area. Among the complex values of cultural heritage, this study defines the economic effects that historical buildings have on the surrounding area as “neighborhood effects” and attempts to evaluate them monetarily. Of course, we cannot directly observe the causal mechanism itself, but as Coulson and Leichenko [7], Noonan [27], and van Duijn et al. [37] point out, it is feasible to use external or “neighborhood” effects to measure the economic value generated in the vicinity of historical buildings or assess changes in the economic valuation of the area’s environment. Therefore, this paper attempts to consider how these neighborhood effects are linked to the overall value of historical buildings, and to explore changes in the overall value of historical buildings by evaluating their neighborhood effects. In addition, renovating historically neglected cultural heritage buildings and improving the landscape, especially when developing them as tourist attractions, not only enhances the nonuse value of the historical site, but also envisions improved local environments and regional economic benefits. Considering the renovation of historical heritage sites that have already been developed as tourist destinations, particularly those designated as World Heritage Sites or national treasures, where renovation and maintenance by national or local authorities are expected, the cost burden on local residents is likely to be low and the historical site as a tourist attraction is expected to be maintained perpetually. When such a historical heritage site undergoes renovation, which economic consequences of the renovation can be regarded as “neighborhood” effects? This is the main question the present paper aims to answer.

Most historical buildings in Japan are predominantly wooden. Among the 21 properties recognized as World Heritage Sites, for instance, 10 include wooden buildings [43]. Considering the 230 properties registered as national treasures, 227 are wooden buildings [42]. Characterized by hot, humid summers and cold, dry winters, Japan’s climate ages these buildings, requiring periodic renovation for maintenance. The life-span of wooden buildings depends on various factors, such as the quality at the time of construction, maintenance practices, and environmental conditions. In Japan, the life-span of wooden buildings is estimated to be around 50 years. Hence, many historical wooden buildings require regular renovation to preserve their historical value.

The renovation of historical buildings presents a delicate balancing act between preserving their irreplaceable cultural heritage and ensuring minimal disruption to the surrounding community. While such endeavors undoubtedly contribute to the sustainability of these architectural treasures, they can also introduce temporary problems that must be carefully addressed. On the positive side, renovations play a vital role in safeguarding the historical integrity of these structures to ensure that they continue to serve as testaments to the past for generations to come. Moreover, enhancements to the exteriors and interiors of these landmarks can attract increased tourism, bringing economic benefits to the surrounding area through increased spending on accommodation, dining, and souvenirs. However, these renovation projects can also bring temporary setbacks. The temporary closure of historical buildings to the public during renovation periods can lead to a decline in tourism revenue, potentially affecting local businesses that rely on visitor traffic. Additionally, construction activities and renovation-related noise can disrupt the tranquility of the neighborhood, potentially impacting residents' daily lives and commutes.

In the case of large-scale renovations that span several years, the impact on the surrounding community can be particularly significant. The prolonged presence of construction sites and the associated disruptions can strain community relations and hinder economic activities. This is especially true in densely populated urban areas, where space is limited and resources are shared. Given these considerations, it is crucial to approach historical building renovations with a holistic perspective that balances the preservation of historical heritage with the well-being of the surrounding community. Careful planning and mitigation strategies are essential to minimize disruptions and maximize the overall benefits of these projects. Engaging with the community throughout the renovation process is paramount to addressing concerns, fostering a sense of shared ownership, and ensuring that the benefits of the renovation are distributed equitably, including providing regular updates, addressing feedback promptly, and exploring opportunities for community involvement in the renovation process. Furthermore, employing sustainable renovation practices can significantly reduce the environmental impact of these projects by promoting long-term sustainability for both the historical buildings and the surrounding community. By carefully considering these factors and implementing comprehensive mitigation strategies, we can ensure that renovations of historical buildings not only preserve their historical value, but also contribute to the vitality, well-being, and sustainable development of the communities they serve.

After receiving the above explanations regarding the renovation of these historical buildings, it is important to reiterate the following three points. First, renovations are often carried out by public organizations such as the government, and the financial burden on local residents is minimal. Second, during the renovation period, a decrease in the number of tourists and disruptions to local residents' economic activities and daily lives are inevitable. Third, it is expected that the renovation will enhance the sustainability of the historical building and increase its economic value. Given the fact that many historical buildings in Japan are wooden structures and require repeated renovations at regular intervals to maintain sustainability, the economic value of historical buildings is closely related to changes in the neighborhood effects. Therefore, understanding how the economic value of historical buildings changes before, during, and after renovation, which is the main research question of this paper, is important. The analysis conducted in this paper provides valuable insights for evaluating the economic effects of renovations carried out with public funds such as taxes. This study aims to examine the economic impact of a large-scale renovation conducted at Himeji Castle as an example.

The remainder of the paper is structured as follows. Sections "Related studies and the approach in this paper" and "Himeji Castle" survey the related works and explain the historical background of Himeji Castle and its renovation, respectively. In Section "Data", we explain the data used in this paper. In Section "Model", we introduce the model for empirical research and explain the partial adjustment mechanism, kinked trend specification, and model selection procedure. We explain the estimation results in Section "Empirical results". Finally, Section "Discussion" provides policy implications and some discussions for future work.

Related studies and the approach in this paper

Of course, many studies have been conducted on cultural, historical, and industrial heritages. For example, Wang et al. [39] and Zhang et al. [41] focus on spatial distribution and its influencing factors, Lam et al. [20] discuss the effectiveness and advancement of heritage revitalization, and Bertacchini and Frontuto [4] and Wang et al. [40] investigate the economic or reuse value of industrial heritage sites. When considering the preservation of historical buildings as public policy, as indicated by Mossetto [24] and Benhamou [3], we consider various preservation costs. Rizzo and Throsby [29] emphasized that conducting a cost–benefit analysis is crucial. However, while costs refer to the expenses for policy implementation, benefits involve measuring the economic value of historical buildings. If historical buildings are traded in the market, as suggested by Coulson and Leichenko [7], it might be necessary to distinguish between the internal effect, which is the change in the value of the historical building itself during renovation, and the external effect, which is the change in the benefits that occur to those other than the owner as a result of the renovation. This approach is one of the most useful methods to evaluate the renovation of heritage sites if we can observe the market values of the site itself. However, in the case of Japan, historical buildings such as Himeji Castle, the focus of this study, are typically owned by the government or local authorities, and therefore not traded in the market. In most cases, there is no official evaluation of the heritage site itself. Then, we cannot observe changes of the heritage value following the renovation, so we cannot take a cost–benefit approach.

Evaluating the value of nontraded historical buildings has led researchers to employ various methods, such as the travel cost method, which is based on visitor expenses, the contingent valuation method (CVM) or the choice experiment (CE) method, which is based on a questionnaire survey of people, and the hedonic approach, which is based on regression analysis with several characteristics about the land or property as explanatory variables. These methods are discussed by Frey and Oberholzer-Gee [11] and Snowball [33].

The travel cost approach uses the observed numbers of the tourists to the heritage site. For example, Jimura [15] focuses on the effect of the designation of a World Heritage Site. When we take the travel cost approach to evaluate the renovation of heritage sites, we need not only the number of tourists, but also their travel costs. Usually, the renovation of historical buildings may restrict their use, which reduces the number of tourist visits, so it is difficult to consider this reduction as a decrease in the economic value of the heritage. Additionally, when the site is closed, it is difficult to survey the tourists.

Survey methods based on questionnaires, such as the CVM or CE method, might offer insights, especially if conducted before and after the renovation. However, with the extended duration of projects such as Himeji Castle (over 5 years), it seems difficult to evaluate the fluctuations of the economic value of historic buildings during the renovation period. In this paper, we focus on changes in the values of heritage not only before and after, but also during the renovation, so it is not practical to take this approach.

Therefore, the hedonic approach emerges as the remaining viable evaluation method. Previous researchers (e.g., [27]) have predominantly employed the hedonic approach. To be precise, evaluating the value of historical buildings that are not traded in the market poses difficulties within this framework. However, as Coulson and Leichenko [7], Noonan [27], and van Duijn et al. [37] point out, it is feasible to use external or "neighborhood" effects to measure the economic value generated in the vicinity of historical buildings or assess changes in the economic valuation of the area's environment. The hedonic approach, which analyzes factors influencing economic value as manifested in changes in land prices, provides a method for exploring these aspects. While alternative methods exist, such as analyzing population or housing growth [22], or changes in the composition of the population or gentrification [7], these require longer-term observations. The hedonic approach for property values seems more suitable for an analysis of the additional neighborhood effects of historical site renovation.

Analyses of the economic effects of the preservation of historical buildings that focus on changes in property values or land prices have shown variable results. For example, Noonan [26] use historical landmarks in Chicago as a case study, Coulson and Leichenko [7] and Leichenko et al. [21] use historical destinations in Texas as a case study, and Ahlfeldt and Maennig [1] use Berlin as a case study to show that the neighborhood effects of historical buildings are positive, and that proximity increases the value of residential property. By contrast, Shipley [32] and Noonan and Krupka [28] point out that designation as a historical area has a negative impact on property values because new regulations are introduced, and the supply of new land is restricted. Recently, many studies have taken this approach. For example, Kee and Chau [16, 17] investigate the effects of reuse and conservation of heritage, Franco and Macdonald [10] investigate the relationship between property values and the distance to the cultural heritage site, Dell'Anna [8] investigates the relationship between residential housing values and industrial heritage, Liu and Liu [23] investigate the relationship between housing prices and religious heritage, and Jayantha and Yung [14] investigate rental prices and historical buildings.

While various studies have examined the impact of the preservation of historical buildings and the establishment of historical areas on real estate values in the respective and neighboring areas, there is a notable research gap in the literature analyzing the short-term events of renovation projects that temporarily restrict the use of historical heritage sites already under preservation. Because time and repeated renovations are necessary to maintain the historical value of wooden structures, understanding the additional neighborhood effects of such renovations are important and inevitable for governments, local authorities, and residents in neighboring areas.

Himeji Castle

Using data from various websites (e.g., https://www.himejicastle.jp/en/, https://www.japan.travel/en/spot/1030/), in this section, we summarize the history and characteristics of Himeji Castle in Himeji city, Hyogo Prefecture. Registered as Japan's first World Heritage Site in 1993 (e.g., [6]), Himeji Castle is considered the epitome of wooden castle architecture, embodying both the internal and external features of the seventeenth century. Constructed in 1580 by Hideyoshi Hashiba (Toyotomi Hideyoshi), Himeji Castle served as a strategic stronghold during the Warring States period of Japanese history (approx. 1467–1568). After the Battle of Sekigahara in 1600, Himeji Castle underwent renovations by the lord of Himeji, Terumasa Ikeda, transforming it into an iconic five-story, seven-layer, white plastered keep. Throughout the seventeenth, eighteenth, and nineteenth centuries, successive castle lords conducted repairs, which contributed to its preservation.

All 83 buildings and 107 hectares of land constituting the assets of Himeji Castle are currently designated as national treasures, important cultural heritage, or special historical sites under the Cultural Properties Protection Law, ensuring their protection. Additionally, a 143-hectare buffer zone was designated, and development in this area regulated by the Himeji City Urban Landscape Ordinance established in 1987. With the enactment of the 2004 Landscape Act, amendments to the 1988 Urban Landscape Formation Basic Plan and the establishment of the Himeji City Landscape Guidelines were made in 2007, followed by further revisions to the Himeji City Urban Landscape Ordinance in 2008. In response to these guidelines, any project along the roads offering views of Himeji Castle and projects around the castle exceeding a certain scale require notification to Himeji city municipal government, which also ensures that proposed construction plans harmonize with the historical environmental features of Himeji Castle. Although most of the buildings and land that constitute the assets are government-owned, the remaining land is owned by Hyogo Prefecture, Himeji city, and private enterprises. Designated as the management organization under the Cultural Properties Protection Law, Himeji city established the Himeji Castle Management Office, which oversees the maintenance and management of Himeji Castle based on the 1964 Himeji Castle Management Ordinance and the Special Historic Site Himeji Castle Preservation Management Plan, which was created in 1986 and last revised in 2008 [45–49].

Concerning repairs in the twentieth century, Himeji Castle underwent major repairs in the Meiji (1910–1911) and Showa (1956–1964) eras at intervals of approximately 50 years. About 45 years on from the Showa-era repairs, significant renovation work called the Heisei Restoration project began on October 9, 2009. Spanning about 5 years, the Heisei Restoration project involved a workforce of about 15,000 craftsmen, with a total construction cost of approximately 2.4 billion yen. Of this, Himeji city provided around 1 billion yen, with the remainder funded by the national government. Tourism was affected during the renovation period, as access was restricted to parts of the castle tour route, and the interior of the keep was temporarily closed to the public. However, a facility called "Tenku-no-Shirasagi" (White Heron in the Sky) was established in the temporary roofed area from March 26, 2011, to January 15, 2014 [53]. During this period, there were 1,843,406 visitors to Tenku-no-Shirasagi, and the number of visitors to Himeji Castle increased from 2011 to 2014 (Fig. 1), which helped prevent a decline in tourism during the renovation [50]. After the renovation work was completed, the number of visitors sharply increased, after which, in 2019, they gradually decreased to pre-renovation levels. The decline shown in Fig. 1 from 2020 onward is attributed to the impact of the COVID-19 pandemic, which is outside the analytical period of this study. As for the research on the value of Himeji Castel, although it is important as both a cultural heritage site and a tourist destination, little research has been conducted on its economic value. An exception is Deloitte's [44] estimate of the value of existence based on a questionnaire (approximately 1.8 trillion yen). Teranishi and Yoshida [35] also conducted some academic research on cross-cultural understanding.

Data

To conduct an empirical analysis of the neighborhood effects that are the subject of this paper, it is necessary to know the land prices in the vicinity of Himeji Castle. If possible, it would be ideal to obtain the transaction prices of real estate in the vicinity of Himeji Castle and analyze the changes in transaction prices before, during, and after the renovation. However, it was difficult to obtain specific real estate transaction prices because it was difficult to obtain the

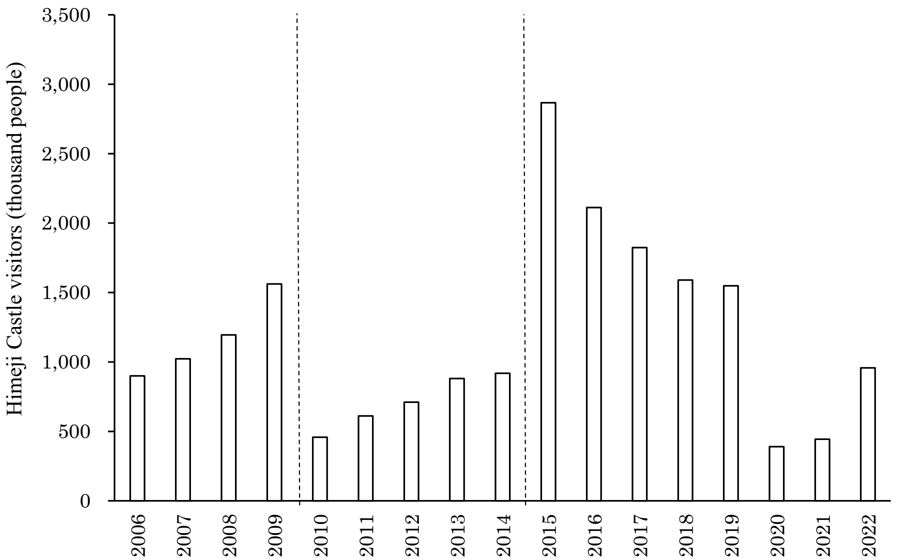

Fig. 1 Number of visitors to Himeji Castle

transaction prices of specific real estate. In addition, it is rare for the same land to be bought and sold continuously, and thus difficult to observe how land prices have changed over time from the actual transactions.

As will be described later, this study assumes that the additional neighborhood effects closely related to the renovation differ depending on the location within the vicinity of Himeji Castle, and it is expected to be difficult to obtain or construct continuous data. For these reasons, the present study uses officially announced land price data for the same locations, which are evaluated continuously. However, the Ministry of Land, Infrastructure, Transport, and Tourism's (MLIT) Land Price Public Announcement is obtained using a nationwide survey and there are not many locations in the vicinity of Himeji Castle that are surveyed continuously. In addition to these MLIT data, this study also analyzes the land price data from the Prefectural Land Price Survey [52].

The Land Price Public Announcement involves the MLIT's Land Appraisal Committee, which conducts an annual nationwide survey of standard land prices on January 1 and officially announces the standard land prices in March every year. On the one hand, the Prefectural Land Price Survey is the price per square meter for vacant land, excluding characteristics such as construction costs. On the other hand, the Prefectural Land Price Survey represents the standard prices of selected benchmark land chosen by the prefectural governor on July 1 every year. These are the prices per square meter of residential land determined by reviewing and adjusting the results appraised by real estate appraisers. Both land prices serve as benchmarks for calculating indicators for general land transactions. Because data from before the start of the renovation of Himeji Castle were also required, there were only seven locations in the vicinity of Himeji Castle that met the conditions of being surveyed since 1997 and continuously surveyed until 2019 before the macroeconomic shock of the COVID-19 pandemic occurred.

The investigation of land price data in the vicinity of Himeji Castle focuses on seven points designated by the Himeji City Landscape Guidelines using data from 1997 to 2019. In this region covered by the guidelines, certain regulations on construction activities are imposed to ensure the formation of a good landscape, as it is an area influenced by the protection of the historical and cultural heritage of Himeji Castle. Specifically, Land Price Public Announcement data are used for five points (i.e., Bozu-machi, Ekimae-cho, Gofuku-machi, Nishinikai-machi, and Soushahon-machi), while Prefectural Land Price Survey data are used for two points (i.e., Shirogane-machi and Sakamoto-machi). The survey period is from 1997 to 2019, when the land price survey data for all seven points are available, also considering the impact of the COVID-19 pandemic. However, data for Sakamoto-machi are only available until 2017. The definitions of the variables and summary statistics used in this study are presented in Table 1. The geographical relationship between the seven points and Himeji Castle is shown in Fig. 2, which shows the geographical relationship with Himeji Castle, JR Himeji Station, which is the closest railway station, and Otemae Street, which connects the station and Himeji Castle.

Table 1 Data definitions and sources

Variable	Definition	Source
Price		
Soushahon-machi	Point at 172 Soushahon-machi	Land Price Public Announcement by Ministry of Land, Infrastructure, Transport and Tourism
Shirogane-machi	Point at 43 Shirogane-machi	Prefectural Land Price Survey by Hyogo Prefecture
Ekimae-cho	Point at 252 Ekimae-cho	Land Price Public Announcement by Ministry of Land, Infrastructure, Transport and Tourism
Gofuku-machi	Point at 32 Gofuku-machi	Land Price Public Announcement by Ministry of Land, Infrastructure, Transport and Tourism
Sakamoto-machi	Point at 96-3 Sakamoto-machi	Prefectural Land Price Survey by Hyogo Prefecture
Nishinikai-machi	Point at 22 Nishinikai-machi	Land Price Public Announcement by Ministry of Land, Infrastructure, Transport and Tourism
Bozu-machi	Point at 66-3 Bozu-machi	Land Price Public Announcement by Ministry of Land, Infrastructure, Transport and Tourism
NPrice	National average land price	Land Price Public Announcement by Ministry of Land, Infrastructure, Transport and Tourism
PPrice	Prefectural average land price: Hyogo Prefecture	Prefectural Land Price Survey by Hyogo Prefecture

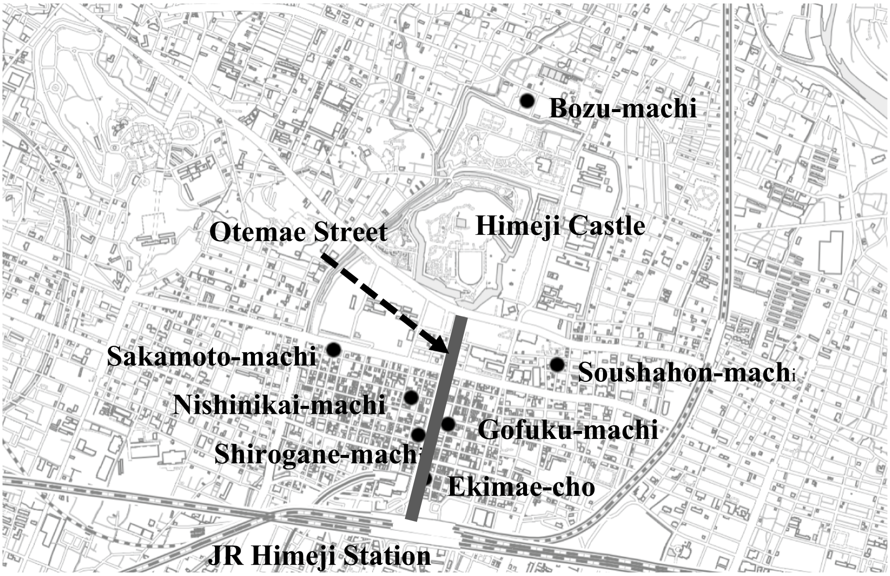

Fig. 2 Himeji Castle area map and analysis points

Model

Reason we do not adopt the difference-in-differences method

Before explaining the model that we adopted in this research, we should discuss the reason why we do not use the difference-in-differences (DID) method, which is often used in recent empirical analyses to investigate the effects of some kinds of policy changes, as described by Angrist and Pischke [2]. There are three reasons for this. First, the present study allows for the possibility that the formation of land prices in the seven locations and the impact of Himeji Castle renovation differ in each location. This assumption makes it difficult to compare the regions where policy effects do and do not occur. We control other variables in a cross-sectional direction because the regions where policy effects do and do not occur differ. The results of empirical analysis described later may have been affected by policies other than the renovation of Himeji Castle, even in neighboring areas. It is difficult to compare land price fluctuations. Therefore, in this study, by modeling the movement of land prices before and after the renovation work period of Himeji Castle, we consider the correlation with the renovation and the changes in land price trends as a sign of the neighborhood effect. Second, unlike cases where the DID method is easy to apply, our target is the price changes not only before and after, but also during the renovation, because it took about 5 years. The long renovation period makes it difficult to use the DID method. Additionally, we understand that changes in land prices during the renovation period make it even more difficult to apply the DID method. Third, in the time-series comparison, the number of observations is not sufficient to test the structural change, which includes the change in the slope of the trend before, during, and after the renovation. Hence, we select a model that can also examine whether the slope of the trend before and after the renovation is the same. The question of whether the slope of the trend before and after the renovation provides useful information about the parallel trend problem assumed by the DID method. However, we do not find suitable places where there is no discontinuity before and after the renovation period with the same slope of trend to test the causal effect using the DID method. The trends of land prices fluctuations are all different even at the seven points we picked, so the DID method is not applicable.

Partial adjustment

This paper analyzes data assessed by public institutions, which are often determined by revising past land price evaluations in consideration of actual transaction prices and the surrounding environment. Hence, land prices may be partially influenced by past land price appraisals rather than actual transaction prices. In this paper, therefore, it is assumed that there is a time lag in the impact of renovation work on land prices, and a partial adjustment model is employed to model the determination of land prices. Denoting the land price at point i and time t as Price_{it}, it is assumed to be determined as:

$$\mathrm{Price}_{it} - \mathrm{Price}_{i,t-1} = \left(1 - \theta_i\right) * \left(\mathrm{Price}^*_{it} - \mathrm{Price}_{i,t-1}\right)$$

where $(1 - \theta)$ represents the adjustment speed, and when $\theta = 0$, the adjustment is 100%, indicating no lag in adjustment. Price^*_{it} is assumed to be the ideal land price at the point when the adjustment is complete, given by:

$$\mathrm{Price}^*_{it} = (\text{trend term})_{it} + \sum_{k=1}^{K} \eta_{ki} x_{kit}$$

Substituting the determination formula for Price^*_{it} into the partial adjustment model and adding an error term, the estimation equation is:

$$\mathrm{Price}_{it} = \theta_i * \mathrm{Price}_{i,t-1} + \left(1 - \theta_i\right) * \left\{ (\text{trend term})_{it} + \sum_{k=1}^{K} \eta_{ki} x_{kit} \right\} + \epsilon_{it}. \quad (1)$$

We assume that the error term is an independent and identically distributed process with its expectation equal to zero. The explanatory variables include the trend term mentioned later and the average land prices for Japan (NPrice_t) and Hyogo Prefecture (PPrice_t):

$$\sum_{k=1}^{K} \eta_{ki} x_{kit} = \eta_1 * \mathrm{NPrice}_t + \eta_2 * \mathrm{PPrice}_t \quad (2)$$

as these are expected to be linked to the average land prices in Himeji city. Table 2 presents the summary statistics for each survey point and explanatory variables, which are calculated using 1997–2019 data. Because the lagged dependent variables

Table 2 Summary statistics

	Mean	Standard deviation	Minimum	Maximum
Price				
Soushahon-machi	132,950	40,350	108,000	243,000
Shirogane-machi	692,500	369,960	450,000	1,700,000
Ekimae-cho	1,320,500	658,820	845,000	3,020,000
Gofuku-machi	814,000	606,530	420,000	2,430,000
Sakamoto-machi	189,000	80,211	135,000	400,000
Nishinikai-machi	226,360	148,230	133,000	635,000
Bozu-machi	118,970	31,254	98,200	188,000
NPrice	122,600	17,177	101,700	165,700
PPrice	145,630	30,039	122,200	222,500

Measured in yen per square meter

were adopted as explanatory variables, the period used for the estimation was from 1997 to 2019.

At this stage of the explanation about the model, strictly speaking, the model estimated in this paper is not the hedonic approach used in the estimation of Rosen's [31] wage function or Roback's [30] rent function. These models decompose wages and land prices into individual or location attributes, while the model in the present paper attempts to explain land price changes solely by trend terms and their linkages with national and Hyogo land prices. Moreover, many studies employing the hedonic approach use cross-sectional data and assume that wages and land prices at the time of analysis are determined by equilibrium prices. By contrast, the present paper assumes that land prices at each time point are not equilibrium prices, but rather, in the process of adjustment toward equilibrium prices. Hence, this paper employs a partial adjustment model. In other words, the ideal price introduced in this paper, Price^*_{it}, can be considered as the equilibrium price at which the supply and demand for land are balanced, reflecting the environment at that point, after the adjustment period has ended.

Kinked trend specification

The trend term considered in this study is somewhat complex and involves three regimes: (1) the trend before the renovation; (2) the trend during the renovation; and (3) the trend after the renovation. To avoid complexity, this subsection and Appendix 1 explain the trends at the ith point without adding subscript i. The trend term in each regime is given by:

$$\begin{array}{lll} \text{Regime 1}: & (\text{trend term})_t = \alpha_1 + \beta_1 * \text{Trend}(t) & \text{for} \quad t = 1, \ldots, t_1 - 1 \\ \text{Regime 2}: & (\text{trend term})_t = \alpha_2 + \beta_2 * \text{Trend}(t) & \text{for} \quad t = t_1, \ldots, t_2 - 1 \\ \text{Regime 3} & (\text{trend term})_t = \alpha_3 + \beta_3 * \text{Trend}(t) & \text{for} \quad t = t_2 \ldots, T \end{array}$$

Here, Trend(t) represents the trend at time t and for (trend term)$_t$, subscripts i are omitted for simplicity. The points of regime switching are denoted as t_1 and t_2. For a continuous transition of the trend at these two points, the following conditions must be satisfied:

$$\alpha_2 = \alpha_1 - \left(\beta_2 - \beta_1\right) * \text{Trend}\left(t_1\right) \& \alpha_3 = \alpha_2 - \left(\beta_3 - \beta_2\right) * \text{Trend}\left(t_2\right).$$

When the regimes change at the points t_1 and t_2 and the trend has gaps at times t_1 and t_2, we introduce the parameters δ_1 and δ_2 for the gaps at t_1 and t_2. Then, the constant terms, α_2 and α_3, are determined as follows:

$$\alpha_2 = \alpha_1 - \left(\beta_2 - \beta_1\right) * \text{Trend}\left(\text{t}_1\right) + \delta_1$$

and

$$\alpha_3 = \alpha_1 - \left(\beta_2 - \beta_1\right) * \text{Trend}\left(\text{t}_1\right) - \left(\beta_3 - \beta_2\right) * \text{Trend}\left(\text{t}_2\right) + \delta_1 + \delta_2$$

If δ_1 is positive, it indicates a positive jump in the trend term at time t_1, whereas a negative δ_1 implies a negative jump. Similarly, δ_2 indicates the direction of the jump in the trend term at time t_2. These values being zero means that the trend term remains continuous at the regime change points. To examine the change in the slope of the trend term between Regimes 1 and 3, considering a gap γ_2, the following relationship holds:

$$\beta_3 = \beta_1 + \gamma_2.$$

Additionally, the difference in slope between Regimes 1 and 2 ($\beta_2 - \beta_1$), denoted as γ_1, indicates an increase (decrease) in the slope of the trend when γ_1 is positive (negative). To assess the change in the slope of the trend from Regimes 2 to 3, a comparison between γ_1 and γ_2 is necessary.

The changes in the trend term as described above can be expressed in a unified equation using two dummy variables, D_{1t} and D_{2t}:

$$\text{D}_{1t} = \begin{cases} 1 \text{ for } t = t_1, \dots, \text{T} \\ 0 \text{ for otherwise} \end{cases},$$

$$\text{D}_2 = \begin{cases} 1 \text{ for } t = t_2, \dots, \text{T} \\ 0 \text{ for otherwise} \end{cases},$$

representing the three regimes:

$$(\text{trend term})_t = \alpha_1 + \beta_1 \text{Trend}(t) + \delta_1 \text{D}_{1t} + \delta_2 \text{D}_{2t}$$

$$+\gamma_1 \left\{ \text{D}_{1t} * \left(\text{Trend}(t) - \text{Trend}\left(t_1\right)\right) - \text{D}_{2t} * \left(\text{Trend}(t) - \text{Trend}\left(t_2\right)\right) \right\}$$

$$+\gamma_2 \text{D}_{2t} * \left(\text{Trend}(t) - \text{Trend}\left(t_2\right)\right) \quad \text{for} \quad t = 1 \dots, \text{T} \tag{3}$$

The details of the derivation of this equation are explained in Appendix 1. In the subsequent estimation of the actual model in the following sections, t_1 is set as the start of Regime 2, corresponding to the beginning of the renovation in 2010, and t_2 is set as the start of Regime 3, which is the year after the completion of the renovation in 2015. By substituting the expression for the trend term in Eq. (3) into the expression for explanatory variables in Eq. (2), along with the partial adjustment model estimation equation (i.e., Eq. (1)), the estimation equation is completed. The parameters to be estimated are α_1, β_1, δ_1, δ_2, γ_1, γ_2, η_1, η_2, and θ. In addition, in this paper, Trend(t) is the year of the Western calendar.

Estimation and model selection procedures

The land prices at each location and the average land prices for Hyogo Prefecture and Japan were logarithmically transformed, and the formula discussed in the above subsections was estimated. As Eqs. (2) and (3) were substituted into Eq. (1) for the trend term ((trend term)$_t$), the estimated model became nonlinear. In this study, nonlinear least squares were used to estimate each parameter for each individual location. This is explained in detail later when considering the analysis results, but this is because we considered the possibility that each of the seven locations received different amounts of neighborhood effects from Himeji Castle. For example, we believe that there are differences in how the neighborhood effect occurs during and after renovations, such as locations that are strongly affected by the effects of the changes in the scenery of the castle and those that are likely to be visited by many tourists.

The estimation was performed using gretl statistical software. Because not all the estimated parameters were statistically significant when all candidate variables were adopted as explanatory variables, model selection was conducted by setting some coefficients of explanatory variables to zero. Specifically, starting with the coefficient with the smallest absolute t-value, one coefficient at a time was set to zero in sequence. The model with the minimum Akaike information criterion (AIC) was selected. Table 3 presents the estimation results for the selected model. In particular, the coefficients of determination for all locations were very high. Considering serial correlation, which was assessed using Durbin's t statistic,[1] no evidence of serial correlation was observed in the error term. Therefore, the estimation results of the selected model, minimizing the AIC, were deemed reasonably reliable. Based on these results, the evolution of land prices at individual locations are discussed. For readers interested in our estimation results before the model selection, these are provided in Appendix 2.

[1] Durbin [9] originally proposed this test as a t-type test version of the Breusch–Godfrey test by Breusch [5] and Godfrey [13] for first-order autocorrelation instead of the F-type test.

Table 3 Estimation results

Parameter	Soushahon-machi	Shirogane-machi	Ekimae-cho	Gofuku-machi	Sakamoto-machi	Nishinikai-machi	Bozu-machi
α_1		−3.79466	−8.32752*	−17.5316**	−4.08035**	−16.0752**	−4.08086
		(2.637840)	(3.756840)	(1.793550)	(1.132390)	(1.100510)	(2.184320)
β_{1i}	−0.0239812**	−0.0308766**			−0.024571**		0.0164175**
	(0.002469)	(0.007176)			(0.006974)		(0.005085)
δ_{1i}	0.0522628**				0.0540436*		
	(0.017064)				(0.024562)		
δ_{2i}	−0.0268115						
	(0.022068)						
γ_{1i}	0.0431157**	0.0500934**	0.0389871**	0.0119691**	0.0395129**	0.043406**	
	(0.005529)	(0.009274)	(0.017814)	(0.007501)	(0.007753)	(0.008416)	
γ_{2i}	0.0207252**	0.0923465**	0.185681**				
	(0.005682)	(0.016980)	(0.033592)				
η_{1i}		−0.755915	−1.06412	−0.483552			−0.849128*
		(0.413061)	(0.849137)	(0.392482)			(0.397684)
η_{2i}	1.00526**	2.20687**	2.91334**	3.07016**	1.3735**	2.36191**	2.14145**
	(0.002410)	(0.245914)	(0.545697)	(0.270343)	(0.090050)	(0.093197)	(0.314927)
θ_i	0.181412	0.339079**	0.594291**	0.624712**	0.322711*	0.665003**	0.700062**
	(0.126543)	(0.087971)	(0.040409)	(0.023815)	(0.112911)	(0.025879)	(0.040783)
Uncentered R^2	0.99794	0.99849	0.99695	0.9990	0.99817	0.99877	0.99619
Log-likelihood	67.3429	59.7862	52.4769	57.9797	56.119	57.857	62.553
AIC	−120.685	−105.572	−92.953	−105.959	−104.594	−107.715	−115.107
Durbin's *t*-test	−0.252	−1.457	0.691	−0.213	−0.356	−0.616	1.732
Number of samples	22	22	22	22	20	22	22

Standard errors in parentheses. * and ** mean statistically significant at 5% and 1%, respectively

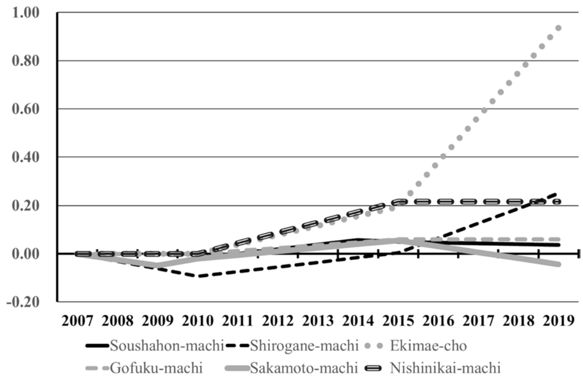

Fig. 3 Estimated trend terms (adjusted as started at 0.0 in 2007)

Empirical results

Before examining the estimation results, particularly for the trend term, a comparison of the estimation results was made for each point. The estimated results for the partial adjustment term θ, which is the term that adjusts the land price with lags, were statistically significant and nonzero for all locations except one, suggesting that the determination of land prices involves lagged variables, and that the adjustment speed varies by point. Moreover, for each point, there is a part that is linked to the average land price of Hyogo Prefecture and, in some locations, to the average land price nationwide, as a correction term for the effect of the average land price of Hyogo Prefecture. This indicates that, in addition to the trend term, there is a part that is synchronized with the movement of land prices at the prefectural or national level.

Regarding the change in the trend term, Fig. 3 shows the adjusted changes in the trend terms, which are the sum of the constant term and the trend obtained from the estimation results in Table 3, adjusted to zero in 2007. Because the model's estimation results are for the logarithmically transformed land prices at each point, the fact that the trend term is a straight line indicates that the rate of change in land prices during this period is constant. Comparing the estimation results for each point, Soushahon-machi and Sakamoto-machi had nonzero estimated values for δ_{1i} or δ_{2i}, especially in both areas, with δ_{1i} statistically significantly positive. This result suggests that the trend term jumped in the positive direction when the renovation began in these regions. In Soushahon-machi, it seems that the trend term statistically insignificantly jumped in the negative direction when the renovation ended. Judging from Fig. 3, however, this discontinuity does not appear to be large. Except for these two locations, the estimation results suggest that the trend term transitioned continuously without a jump. As for the slope of the trend term, γ_{1i} was statistically significantly estimated to be positive for all points except Bozu-machi, indicating that the trend of increases in the land price significantly intensified after the start of the renovation in these regions. Moreover, comparing γ_{1i} and γ_{2i}, even in areas where γ_{2i} was set to zero, such as in Soushahon-machi, the trend returned to the level before the renovation in Gofuku-machi, Sakamoto-machi, and Nishinikai-machi, indicating that the trend did not decrease before the renovation, but did so after the renovation in Soushahon-machi. Regarding the land price level, because the trend before the renovation was negative in Sakamoto-machi, the portion of the trend term after the renovation is below the level before the renovation. However, in other points, the increase in the land price due to the upward slope of the trend was maintained after the renovation. This is an additional neighborhood effect of renovation (see Fig. 4).

By contrast, for Shirogane-machi and Ekimae-cho, the slope of the trend increased further after the renovation. This rise in the land price, which did not disappear even after the renovation, is an additional neighborhood effect brought about by the renovation. The fact that this change appeared as a change in the slope of the trend can be interpreted as gradually realized during the renovation period. The change in the trend term suggests that in locations such as Shirogane-machi and Ekimae-cho, facing Otemae Street, which is the route from JR Himeji Station to Himeji Castle, there was a continuous increase in land prices even after the renovation ended, reflecting the continuous influx of tourists to Himeji Castle. However, the significant change in the trend of land prices in Ekimae-cho may be influenced by the development of a new commercial facility called “Kyasutei 21” on the north side of JR Himeji Station, which is the nearest railway station to Himeji Castle, coinciding with its renovation. According to a local newspaper, “In the fiscal year 2016, sales increased by 4.5% compared to the previous fiscal year … and the number of visitors increased by 2.7%” [51]. On the one hand, this indicates that the redevelopment project in the vicinity of the station attracted many people and may have influenced the significant increase in the land price trend in Ekimae-cho, but this aspect cannot be conclusively identified. On the other hand, in areas where the trend term returned to the original state (see Fig. 5), although the number of tourists to Himeji

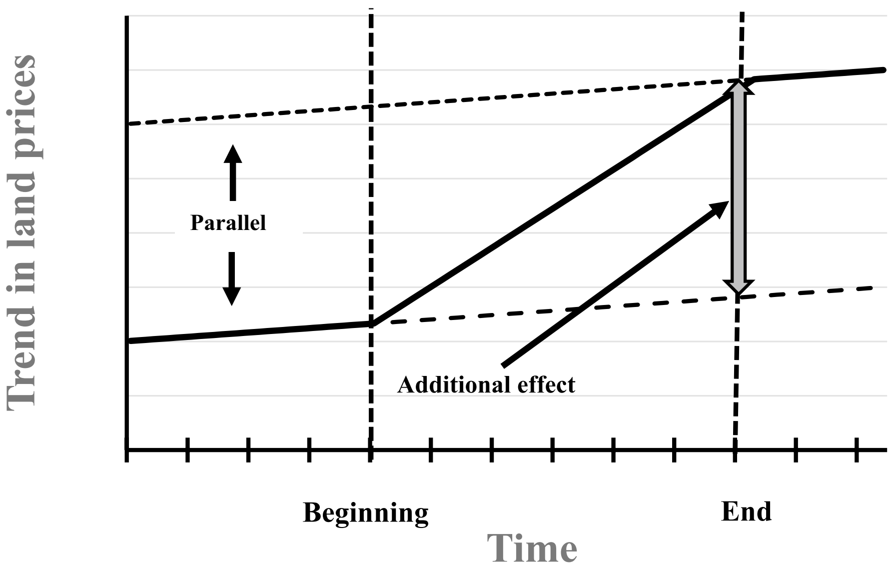

Fig. 4 Additional neighborhood effect

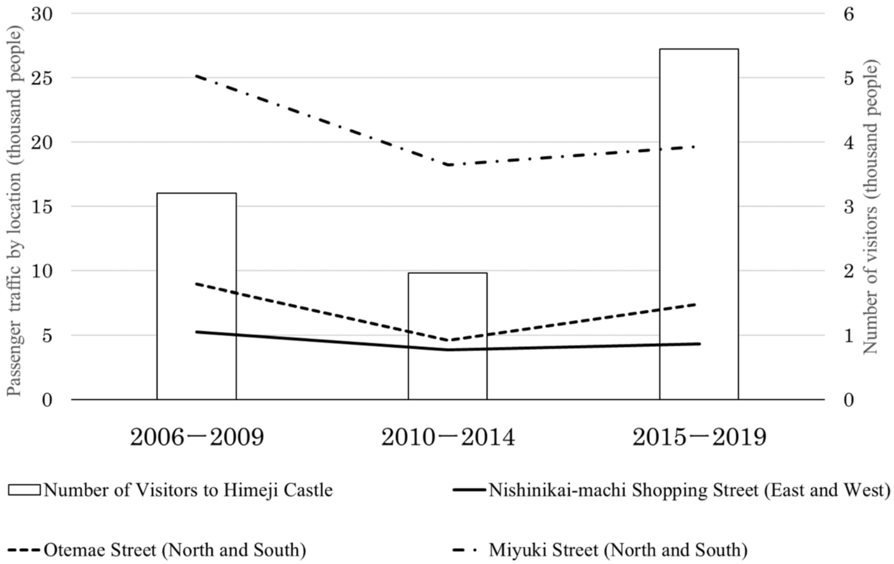

Fig. 5 Comparison of pedestrian traffic around Himeji Castle and number of visitors

Castle increased after the renovation, the land price may reflect that the pedestrian traffic around Himeji Castle has not recovered fully.

Bozu-machi (Fig. 2) was expected to be a location not significantly affected by the movement of tourists from JR Himeji Station to Himeji Castle when viewed from tourists' pedestrian route. As expected, the estimation results for Bozu-machi suggested that the land price at this location was not affected by the changes before and after the renovation of Himeji Castle, but rather, determined through synchronization with the average land prices in Hyogo Prefecture and nationwide.

Discussion

This study delves into the intricate relationship between the renovation of Himeji Castle and surrounding land prices. By employing a sophisticated analysis of land value trend changes, we aimed to shed light on the location-specific impacts of historical building renovations on neighboring areas. We now consider the correlation between the trend changes in land prices and the renovation as apparently causal relationships. Our findings unveil a fascinating tapestry of effects, far removed from a uniform impact across the surrounding regions. Instead, the renovation of Himeji Castle has triggered a diverse spectrum of consequences, intricately intertwined with the location of each area relative to the castle and the unique characteristics of the respective regions. Along the JR Himeji Station–Himeji Castle route, a prominent tourist corridor, land prices experienced a clear upward trajectory following the completion of the renovation project. In these major areas frequented by visitors, the renovation's positive influence on land prices is undeniable. In stark contrast, areas off the tourist route exhibited a temporary land value surge coinciding with the renovation's commencement, only to witness a decline or even disappearance of this upward trend upon completion. However, the results intriguingly suggest a sustained temporary land price increase exceeding the pre-renovation pattern. This rise is attributed to the renovation's neighborhood effects, manifesting as a gradual change in the slope of the trend that emerged during the renovation period. Areas beyond Himeji Castle from the station remained largely unaffected by the renovation, with no significant impact on land prices.

The implications of these findings extend beyond the confines of Himeji Castle, offering valuable insights for future renovations of heritage sites across Japan. First, our study highlights the crucial role of location in determining the neighborhood effects of historical building renovations. Even within close proximity, the impact can vary significantly, underscoring the need for prior zoning investigations to assess the neighborhood effects of each unique project. Second, the gradual emergence of neighborhood effects challenges the assumption of immediate manifestation. Our findings suggest that additional neighborhood effects may take time to materialize, gradually unfolding as the renovation progresses. These gradual changes in the land prices occurred after adjustment for the partial adjustment process. In other words, these changes in the land price occurred persistently. Third, the kinked trend analysis method employed in this study proved to be an effective tool for measuring additional neighborhood effects from historical building renovations. The method used in this paper is expected to be useful for cases where historical buildings have been damaged by disasters, such as earthquakes. For example, the tower at Kumamoto Castle, a historical building located in Kumamoto city, experienced severe damage to the point of collapse from the 2016 Kumamoto Earthquake and is currently being repaired. Fujihara et al. [12] and Takeda and Inaba [34] analyzed the impact of the earthquake damage. By measuring the neighborhood effect of repairing such damage, we can measure whether the value of the damaged historic building has returned to its original value compared with before the disaster, or whether it has become more valuable. This may be a possible analytical method.

Despite these significant contributions, a few limitations remain to be addressed in future research. The construction of the Tenku-no-Shirasagi facility between March 26, 2011, and January 15, 2014, may have influenced the number of visitors to the historical site, potentially confounding the isolated impact of the renovation. In addition, the concurrent redevelopment of the north side of JR Himeji Station complicates the separation of the castle's specific impact on surrounding land prices. Further research is warranted to isolate fully the effects of the castle renovation and the Tenku-no-Shirasagi facility and provide a more comprehensive understanding of the relationship between historical building renovations and neighboring land prices.

Finally, this study relied on land price data from surveys by national and local governments, and the limited number of survey points prevented a detailed examination of changes in land prices in the vicinity of Himeji Castle. The availability of actual real estate transaction data could have enabled a more detailed analysis. However, the feasibility of continuously collecting extensive transaction data in the neighboring areas of Himeji Castle remains unclear.

Appendix

Appendix 1 Derivation of the kinked trend term

Three regimes exist and we allow jumps at each regime change point. If we want to investigate whether these regime changes are continuous, some complex restrictions are required between parameters. Then, we explain the restrictions and re-parameterization step-by-step. First, we consider the parameter change at t_1 between Regimes 1 and 2. To clarify the trend change, we re-parameterized $\beta_2 = \beta_1 + \gamma_1$. Then, we can consider the enlarged trend of Regime 1's $(\text{trend term})_t$ at t_1 as follows:

$$(\text{trend term})_{t1} = \alpha_1 + \beta_1 * \text{Trend}(t_1)$$

and the trend of Regime 2's $(\text{trend term})_t$ at t_1:

$$(\text{trend term})_{t1} = \alpha_2 + (\beta_1 + \gamma_1) * \text{Trend}(t_1).$$

If there is no gap between these two trend terms, the following equation holds: $\alpha_1 + \beta_1 * \text{Trend}(t_1) = \alpha_2 + (\beta_1 + \gamma_1) * \text{Trend}(t_1)$.
Then, we can rewrite this equation as:

$$\alpha_2 = \alpha_1 - \gamma_1 * \text{Trend}(t_1).$$

If a gap (or jump) exists between two trend terms, we can introduce parameter δ_1, and the above relationship changes to:

$$\alpha_2 = \alpha_1 - \gamma_1 * \text{Trend}(t_1) + \delta_1$$

and we can rewrite the trend term for Regime 2 with newly introduced parameters as follows:

$$(\text{trend term})_t = \alpha_1 - \gamma_1 * \text{Trend}(t_1) + \delta_1 + (\beta_1 + \gamma_1) * \text{Trend}(t) \text{for} t = t_1, \ldots, t_2 - 1.$$

Furthermore, we can rewrite this equation as:

$$(\text{trend term})_t = \alpha_1 + \beta_1 * \text{Trend}(t) + \delta_1 + \gamma_1 * \{\text{Trend}(t) - \text{Trend}(t_1)\}$$

$$\text{for} t = t_1, \ldots, t_2 - 1.$$

When we write the trend terms of Regimes 1 and 2 as a single equation, we introduce a dummy variable:

$$D_{1t} = \begin{cases} 1 \text{ for } t = t_1, \ldots, t_2 - 1 \\ 0 \text{ for otherwise} \end{cases},$$

And write the trend term as:

$$(\text{trend term})_t = \alpha_1 + \beta_1 * \text{Trend}(t) + \delta_1 D_{1t} + \gamma_1 * D_{1t} * \left(\text{Trend}(t) - \text{Trend}\left(t_1\right)\right) \text{ for } t = 1, \ldots, t_2 - 1.$$

When γ_1 is not zero, to test whether δ_1 is not zero is a simple case for testing regression discontinuity when the linear relationship is assumed before and after the regime changes [2].

Next, we consider the change between Regimes 2 and 3. In this change, we first introduce a re-parameterization: $\beta_3 = \beta_1 + \gamma_2$. A parameter change occurs at t_2 between Regimes 2 and 3. Using the re-parametrized Regime 2 trend term, we can consider the enlarged trend of Regime 2's $(\text{trend term})_t$ at t_2 as follows:

$$(\text{trend term})_{t2} = \alpha_1 + \beta_1 * \text{Trend}\left(t_2\right) + \delta_1 + \gamma_1 * \left\{\text{Trend}\left(t_2\right) - \text{Trend}\left(t_1\right)\right\}$$

and the trend of Regime 3's $(\text{trend term})_t$ at t_2:

$$(\text{trend term})_{t2} = \alpha_3 + \left(\beta_1 + \gamma_2\right) * \text{Trend}\left(t_2\right)$$

If no gap exists between these two trend terms, the following equation holds:

$$\alpha_1 + \beta_1 * \text{Trend}\left(t_2\right) + \delta_1 + \gamma_1 * \left\{\text{Trend}\left(t_2\right) - \text{Trend}\left(t_1\right)\right\} = \alpha_3 + \left(\beta_1 + \gamma_2\right) * \text{Trend}\left(t_2\right).$$

Then, we can rewrite this equation as:

$$\alpha_3 = \alpha_1 + \beta_1 * \text{Trend}\left(t_2\right) + \delta_1 + \gamma_1 * \left\{\text{Trend}\left(t_2\right) - \text{Trend}\left(t_1\right)\right\} - \left(\beta_1 + \gamma_2\right) * \text{Trend}\left(t_2\right)$$

If a gap (or jump) exists between the two trend terms, we can introduce parameter δ_2, and the above relationship changes to:

$$\alpha_3 = \alpha_1 + \beta_1 * \text{Trend}\left(t_2\right) + \delta_1 + \gamma_1 * \left\{\text{Trend}\left(t_2\right) - \text{Trend}\left(t_1\right)\right\} - \left(\beta_1 + \gamma_2\right) * \text{Trend}\left(t_2\right) + \delta_2$$

and substituting the above relationship into α_3, we can rewrite the trend term for Regime 3 with newly introduced parameters as follows:

$$(\text{trend term})_t = \alpha_1 + \beta_1 * \text{Trend}\left(t_2\right) + \delta_1 + \gamma_1 * \left\{\text{Trend}\left(t_2\right) - \text{Trend}\left(t_1\right)\right\} + \delta_2 - \left(\beta_1 + \gamma_2\right) * \text{Trend}\left(t_2\right) + \left(\beta_1 + \gamma_2\right) * \text{Trend}(t) \text{for} t = t_2, \ldots, \text{T}.$$

This equation can be rewritten as follows:

$$(\text{trend term})_t = \alpha_1 + \delta_1 + \delta_2 + \beta_1 * \text{Trend}(t) + \gamma_1 * \left\{\text{Trend}\left(t_2\right) - \text{Trend}\left(t_1\right)\right\} + \gamma_2 * \left\{\text{Trend}(t) - \text{Trend}\left(t_2\right)\right\} \text{for} t = t_2, \ldots, \text{T}.$$

When we write the trend terms of Regimes 1–3 as a single equation, we additionally introduce a dummy variable:

$$D_{2t} = \begin{cases} 1 \text{ for } t = t_2 \ldots, \text{T} \\ 0 \text{ for otherwise} \end{cases},$$

And modify the dummy variable as:

$$D_{1t} = \begin{cases} 1 \text{ for } t = t_1, \ldots, T \\ 0 \text{ for otherwise} \end{cases},$$

And combine the following two equations:

$$(\text{trend term})_t = \alpha_1 + \beta_1 * \text{Trend}(t) + \delta_1 D_{1t} + \gamma_1 * D_{1t} * \left(\text{Trend}(t) - \text{Trend}\left(t_1\right)\right)$$

$$\text{for } t = 1, \ldots, t_2 - 1$$

and:

$$(\text{trend term})_t = \alpha_1 + \delta_1 + \delta_2 + \beta_1 * \text{Trend}(t) + \gamma_1 * \left\{\text{Trend}\left(t_2\right) - \text{Trend}\left(t_1\right)\right\}$$

$$+\gamma_2 * \left\{\text{Trend}(t) - \text{Trend}\left(t_2\right)\right\} \text{for} t = t_2, \ldots, T.$$

Finally, we can write the trend term as follows:

$$\begin{aligned}(\text{trend term})_t = \alpha_1 + \beta_1 \text{Trend}(t) + \delta_1 D_{1t} + \delta_2 D_{2t} + \gamma_1 \{D_{1t} * \left(\text{Trend}(t) - \text{Trend}\left(t_1\right)\right) - D_{2t} \\ * \left(\text{Trend}(t) - \text{Trend}\left(t_2\right)\right)\} + \gamma_2 D_{2t} * \left(\text{Trend}(t) - \text{Trend}\left(t_2\right)\right) \quad \text{for} \quad t = 1 \ldots, T\end{aligned}$$

where the combination of the following two terms:

$$\gamma_1 * D_{1t} * \left(\text{Trend}(t) - \text{Trend}\left(t_1\right)\right) \text{ for } t = 1, \ldots, t_2 - 1$$

and

$$\gamma_1 * \left\{\text{Trend}\left(t_2\right) - \text{Trend}\left(t_1\right)\right\} \text{for} t = t_2, \ldots, T$$

are

$$\begin{aligned}\gamma_1 * D_{1t} * \left(\text{Trend}(t) - \text{Trend}\left(t_1\right)\right) - \gamma_1 * D_{2t} * \left(\text{Trend}(t) - \text{Trend}\left(t_1\right)\right) \\ + \gamma_1 D_{2t} * \left\{\text{Trend}\left(t_2\right) - \text{Trend}\left(t_1\right)\right\} \text{for} t = 1, \ldots, T\end{aligned}$$

becomes

$$\gamma_1 \left[D_{1t} * \left(\text{Trend}(t) - \text{Trend}\left(t_1\right)\right) - D_{2t} * \left(\text{Trend}(t) - \text{Trend}\left(t_2\right)\right)\right] \text{for} t = 1, \ldots, T.$$

Appendix 2 Full model estimation results

Table 4 provides the full model estimation results before variable selection.

Table 4 Estimation results before variable selection (full model)

Parameter	Soushahon-machi	Shirogane-machi	Ekimae-cho	Gofuku-machi	Sakamoto-machi	Nishinikai-machi	Bozu-machi
α_1	0.335732	−3.83967	−8.44815	−14.7945*	−2.74110	−9.12804	−9.53974
	(1.70465)	(2.62733)	(7.74718)	(5.97581)	(2.08378)	(5.34092)	(9.22213)
β_{1i}	−0.0197957*	−0.0373268**	0.0152555	−0.0110255	−0.0307442**	−0.0253896	0.0362227
	(0.00711)	(0.00889)	(0.03484)	(0.02516)	(0.00763)	(0.02629)	(0.03717)
δ_{1i}	0.032828	0.0387968	−0.120648	−0.0089666	0.0648706	0.0474481	−0.0668313
	(0.02871)	(0.03882)	(0.12564)	(0.08471)	(0.03069)	(0.07714)	(0.10873)
δ_{2i}	−0.0250765	−0.00493095	−0.0664137	−0.0314855	−0.0153461	−0.0327886	−0.0579469
	(0.02632)	(0.03828)	(0.10264)	(0.07331)	(0.03016)	(0.06784)	(0.09669)
γ_{1i}	0.0375824**	0.0547653**	0.0440326	0.0266936	0.0423795**	0.0475735	0.0070526
	(0.00853)	(0.01223)	(0.03335)	(0.02715)	(0.01020)	(0.02699)	(0.03399)
γ_{2i}	0.0223826	0.0927027**	0.196592**	0.0175212	0.0262812	0.0637442	−0.0307608
	(0.01169)	(0.01627)	(0.04066)	(0.03700)	(0.02277)	(0.03248)	(0.05181)
η_{1i}	−0.243627	−0.512528	−1.62583	−0.622322	−0.101229	−0.628283	−0.578478
	(0.32144)	(0.47806)	(1.26849)	(0.91847)	(0.39253)	(0.86030)	(1.17687)
η_{2i}	1.21421**	1.97538**	3.46684**	2.98708**	1.36621**	2.42016**	2.31764*
	(0.22331)	(0.32703)	(1.02806)	(0.70645)	(0.26438)	(0.68744)	(1.05200)
θ_i	0.248567	0.284786*	0.625872**	0.590124**	0.219882	0.591164**	0.743852**
	(0.16540)	(0.10778)	(0.10292)	(0.07765)	(0.15193)	(0.10391)	(0.08713)
Uncentered R^2	0.99811	0.99859	0.99730	0.9991	0.9986	0.9990	0.9965
Log-likelihood	68.2794	60.5474	53.808	58.484	59.475	60.267	63.492
AIC	−118.558	−103.095	−89.616	−98.969	−100.951	−102.534	−108.985
Number of samples	22	22	22	22	20	22	22

Standard errors in parentheses. * and ** mean statistically significant at 5% and 1%, respectively

Acknowledgements We are grateful for the valuable comments from the editor and the two anonymous referees. With their comments, we have improved the paper more accurately and added detailed explanations.

Funding Open Access funding provided by Osaka University.

Data availability We are not allowed to provide the data, but most of the data are public and thus can be found on websites listed in our Data section.

Declarations

Conflict of interest There are no potential conflicts of interest in this research.

Research involving human participants and/or animals This research did not involve human participants or animals.

Informed consent The analysis did not require informed consent from any participants.

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