Regional Studies, Regional Science

ISSN: (Print) 2168-1376 (Online) Journal homepage: http://www.tandfonline.com/loi/rsrs20

Assessing the spatial impact of policy interventions on real-estate values: an exemplar of the use of the hybrid hedonic/repeat-sales method

Chris Leishman & Craig Watkins

To cite this article: Chris Leishman & Craig Watkins (2017) Assessing the spatial impact of policy interventions on real-estate values: an exemplar of the use of the hybrid hedonic/repeat-sales method, Regional Studies, Regional Science, 4:1, 202-217, DOI: 10.1080/21681376.2017.1360790

To link to this article: https://doi.org/10.1080/21681376.2017.1360790

Published online: 29 Aug 2017.

REGIONAL STUDIES, REGIONAL SCIENCE, 2017
VOL. 4, NO. 1, 202–217
https://doi.org/10.1080/21681376.2017.1360790

OPEN ACCESS

Assessing the spatial impact of policy interventions on real-estate values: an exemplar of the use of the hybrid hedonic/repeat-sales method

Chris Leishman[a] and Craig Watkins[b]

ABSTRACT

This paper sets out to make a contribution to the extensive literature that seeks to develop methods that allow rigorous and robust analysis of the spatial and temporal impacts of public policy interventions on property (real-estate) values. It argues that the hybrid repeat-sales/hedonic method developed in real-estate studies over the last 30 years has considerable, but as yet under-developed, potential as a policy analysis tool. Using data from Glasgow, UK, the empirical analysis illustrates how the technique can be used to understand the spatial spillovers and the dynamic temporal effects of a historic £100 million state-led, area-based, urban-renewal programme, New Life for Urban Scotland. The paper concludes by arguing that, with the rise in the availability of rich geocoded, micro-datasets, this framework is sufficiently flexible to be used to evaluate the real-estate market impacts of a wide range of public policy interventions. Significantly, as the case study demonstrates, the framework overcomes some of the sustained criticisms of the more commonly used hedonic modelling approach. There is, however, still much to do to enhance the technical qualities of the models through further application.

ARTICLE HISTORY
Received 27 April 2017; accepted 25 July 2017

KEYWORDS
House prices; price indices; urban regeneration; policy evaluation

JEL CLASSIFICATIONS
C21, C54, H53, O18, O21, R31

INTRODUCTION

There is an extensive international literature that seeks to understand the spatial and temporal impacts on property (real-estate) values of a wide array of public policy interventions (Adams, Watkins, & White, 2005). The spatial impacts tend to be captured through the use of hedonic models. The hedonic approach, of course, assumes that there are implicit markets for each of the physical, locational and neighbourhood characteristics that determine the value of a dwelling and, using regression analysis, the modelling procedure isolates the contribution of each explanatory variable. Relevant hedonic coefficients have long been interpreted as 'shadow prices' to assess environmental impacts (Freeman, 1979) and, by logical extension, they have also been used increasingly widely to assess the spatial impacts of policy initiatives such as open-space provision, transport system

CONTACT
(Corresponding author) c.a.watkins@sheffield.ac.uk
[a]School of Built Environment, Heriot-Watt University, Riccarton, UK
[b]Urban Studies and Planning, University of Sheffield, Sheffield, UK

investments, changes to planning (e.g., greenbelt) restrictions, and area-based urban renewal policies (Jones & Dunse, 2005; Jun & Kim, 2017; Lai et al., 2007; McConnell & Walls, 2005, respectively).

The temporal impacts of these sorts of public policy interventions are harder to capture within a hedonic framework. To address this weakness, researchers have borrowed from the 'event studies' literature typically used to assess the impact of natural disasters such as earthquakes and floods (Jud & Winkler, 2006). In events studies, hedonic equations are estimated before and after the event with the models tested for parameter stability and, where changes have occurred, the parameters are scrutinized to reveal the extent of the impact of the event. As a variant on this pure approach others, as reviewed in Boyle and Kiel (2001), have sought to capture change over time by including time dummies in their hedonic equations. More recently, some researchers have begun using formal panel regression techniques to examine data that span significant events (Meldrum, 2016).

Despite increasing methodological innovation in the field, the use of hedonic methods for these purposes has been subject to two sustained criticisms. First, the spatial impacts detected tend to lack granularity and often generate estimates that are characterized by steep cliff-edge effects between contiguous areal units (Keskin et al., 2017). Second, as this method of exploring temporal change is very data intensive, most studies tend to cover relatively short time periods and consequently tell us very little about the extent to which changes might be systematized over the long term rather than being evidence of short-term deviations from market equilibrium (Case, Colwell, Leishman, & Watkins, 2006).

This paper seeks to promote the use of a hybrid hedonic/repeat-sales approach (hereafter the 'hybrid' approach) as an alternative method for exploring the spatial and temporal impacts of natural disasters, environmental events and/or policy interventions. The hybrid approach has its roots in the extensive real-estate price index literature where researchers have sought to develop rigorous measures of house prices that control for the variation in dwelling characteristics and quality within the stock of properties transacted in different time periods and in different parts of the market. As discussed above, hedonic methods offer one approach to the development of 'constant quality' house price indices by decomposing the real-estate values into their component parts as a prior step to computing the value of a hypothetical, standard dwelling. Elsewhere, repeat-sales methods are also widely advocated as a robust and reliable alternative to hedonic indices (Costello & Watkins, 2002). The repeat-sales method controls for differences between dwelling types by tracking individual properties as they are sold and resold over a long period of time. The repeat-sales approach acknowledges that the growth in prices will be uneven over time and that averaging growth between sales dates would be misleading. What the regression model does, through the inclusion of a complex set of dummy variables to indicate sales dates, is reveal via the coefficients what the annual average growth rate has been for the price of a hypothetical standard dwelling. In short, the repeat-sales regression equation reveals the average level of appreciation in prices for each of the time periods covered (see Leishman & Watkins, 2002, for an accessible illustration).

The hybrid approach starts with the standard repeat-sales framework and augments it by adding 'hedonic' characteristics. This augmented framework allows us to explore the impact of policy interventions over space and time. To illustrate the use of the method, the paper presents an analysis of the impact of a historic urban regeneration policy, known as New Life in Urban Scotland (Scottish Office, 1988). The study period starts before the introduction of the policy initiative and covers a further period post-intervention, stopping at the point when further changes to the policy landscape and market conditions are likely to have begun to have unmeasured impacts on the model results. In this illustration, although it is possible to extend the framework to capture a wider variety of attributes, we simply augment the repeat sales by adding locational attributes to ensure that spatial difference is captured in a granular manner. Even this relatively restricted form of the model used as a simple illustrative device here allows us to estimate both the way in which an area-based policy has had spillover effects on house prices in different parts of the study area and how the prices impacts have changed over time.

The paper is organized as follows. The next section sketches out the model framework and reviews the way it has been applied in other contexts. The third section describes the policy case study used to exemplify the approach. This includes a brief discussion of the market and policy context within the study area, Castlemilk, a deprived neighbourhood in Glasgow. The fourth section outlines the model results and discusses their interpretation. The results presented are based on four variants on the basic repeat-sales model and they illustrate some of the different ways in which spatial variations in price impacts can be modelled within the framework. The final section offers some brief conclusions about the utility of the method and sets out some challenges for future research.

THE DERIVATION OF THE MODELLING FRAMEWORK

As noted above, the modelling approach adopted in this paper is a based on a hybrid house price index method that combines a repeat-sales model with hedonic real-estate attributes. This modelling approach was established in a paper that analysed the impact of environmental contamination on house prices (Case et al., 2006) and has been subsequently applied to assess the impact of flooding and open space preservation on real-estate markets (Cutter, Fernandez, & Scott, n.d.; Lamond, Proverbs, & Hammond, 2010). The model has its intellectual antecedents in the literature on hybrid real-estate price indices developed over three decades from the early 1980s (Case, Pollakowski, & Wachter, 1991; Case & Quigley, 1991; Englund, Quigley, & Redfearn, 1999; Hill, Carter, Knight, & Sirmans, 1997; Meese & Wallace, 1997; Palmquist, 1982; Quigley, 1995).

The features of the model are best understood by considering the underlying relationship between hedonic methods and repeat-sales approaches. Specifically, as Case et al. (2006) explain, the repeat-sales model can actually be derived from the hedonic approach. To appreciate this, and using Case et al.'s notation (also employed by Cutter et al., n.d.), we should start by describing a hedonic model in the following terms:

$$P_{it} = \gamma X_i^{\alpha_1} e^{\beta_1 Y_i + \tau_1 T_{i1} + \tau_2 T_{i2} \cdots \tau_n T_{in}} \quad \text{(a)}$$

where P_i = the price of property i,

X_i = a prototypical, unchanging attribute of the property,

Y_i = a second, prototypical, unchanging attribute of the property,

$T_{i\Theta}$ = a dummy time variable (with Θ being a discrete indicator of year) such that

$$T_{i\Theta} = \begin{cases} 1, \text{ if } \Theta = t_i \\ 0, \text{ if } \Theta \neq t_i \end{cases}, \text{ and}$$

. t_i = the year of sale of the i_{th} property.

This model, as standard, allows the analyst to compute the implicit price of physical and locational features of the dwelling and, in doing so, isolate the impact of external influences, such as environmental externalities or, of more relevance here, the impact of policy change. The 'before and after' event differences are detected by the inclusion of time dummies in the equation. In order to estimate the model, of course, one of the set of time dummy variables (say,) is omitted from the estimated regression.

Typically, when deriving repeat-sales models, the focus of the researcher has been on meeting the challenges associated with the accurate measurement of price change. Repeat-sales methods are often used when the attribute data required for hedonic analysis are lacking, but data on the value of transactions are extensive. There are two important underlying assumptions to repeat-sales analysis. First, there is an assumption that attributes of individual dwellings remain constant over time and, second, the parameters (or implicit prices) of the attributes also remain unchanged. Thus, if we revisit Case et al.'s hedonic set out above, we are dealing with a dwelling that sells twice, once at year t and once at an earlier year , where the tilde denotes the earlier magnitudes of this and the other variables, and the i subscript denotes the sale pair. The ratio of the two predicted prices is:

$$\frac{P_i}{\tilde{P}_i} = \frac{\gamma X_i^{\alpha_1} e^{\beta_1 Y_i + \tau_1 T_{i1} + \tau_2 T_{i2} + \cdots + \tau_n T_{in}}}{\gamma \tilde{X}_i^{\alpha_1} e^{\beta_1 \tilde{Y}_i + \tau_1 \tilde{T}_{i1} + \tau_2 \tilde{T}_{i2} + \cdots + \tau_n \tilde{T}_{in}}} = e^{\tau_1 (T_{i1} - \tilde{T}_{i1}) + \tau_2 (T_{i2} - \tilde{T}_{i2}) + \cdots + \tau_n (T_{in} - \tilde{T}_{in})} \tag{b}$$

where $X_i = \tilde{X}_i$ and $Y_i = \tilde{Y}_i$.

Equation (b) describes the standard repeat-sales model where the dependent variable is the ratio of prices; the attributes and the implicit prices of the attributes are omitted as they stay constant and cancel each other out; and the time variables in brackets on the right-hand side of the equation take on the value –1 if the first sale occurs during within the period, 1 if the second sale occurs during that period, and 0 if no sale occurs during that period. The dummy variable is no longer dichotomous. In practice, the model tends to be estimated by taking the natural logarithm of both sides, using ordinary least squares.

Both the hedonic and repeat-sales approaches have well-documented limitations. For instance, hedonic models are undermined by identification problems, difficulties in model specification and the challenge of identifying appropriate market boundaries (Malpezzi, 2002). As noted in the introduction, in the specific context of assessing the impact of 'events', such as natural disasters or policy interventions, the hedonic method is poorly equipped to explore the persistence of effects over time, especially where the effects are compounded by changes in house types or market conditions.

There are also several problems associated with use of repeat sales. There is, for example, evidence that repeat sales understate prices because of ageing and depreciation, due to the overrepresentation of more frequently traded starter homes, and as a result of the presence of substandard properties (Case et al., 1991; Clapp & Giacotto, 1992; Clapp, Giacotto, & Tirtiroglu, 1991; Mark & Goldberg, 1984). They also fail to capture the effects of the modification of dwellings, such as house extensions (Case et al., 2006). Conversely, others have found evidence that house price inflation can be overstated by repeat-sales models as a result of the large presence of short-hold properties (Costello, 2002; Steele & Goy, 1997).

Significantly, while hedonic methods capture changing values of parameters, repeat sales are unable to do so. The hybrid method, however, extends the repeat-sales framework in order to introduce this capability. In principle, it should allow repeat-sales models to take account of dwelling modifications providing some attribute measures are available. This can be shown formally by revisiting the model in Equation (b). As illustrated below, where an attribute changes between the sale dates, then the attribute is no longer cancelled out. Thus, this requires that we combine elements of hedonic analysis and repeat-sales analysis into a hybrid model:

$$\frac{P_i}{\tilde{P}_i} = \frac{\gamma X_i^{\alpha_1} e^{\beta_1 Y_i + \tau_1 T_{i1} + \tau_2 T_{i2} + \cdots + \tau_n T_{in}}}{\gamma \tilde{X}_i^{\alpha_1} e^{\beta_1 Y_i + \tau_1 \tilde{T}_{i1} + \tau_2 \tilde{T}_{i2} + \cdots + \tau_n \tilde{T}_{in}}} = \left(\frac{X_i}{\tilde{X}_i} \right)^{\alpha_1} e^{\beta_1 (Y_i - \tilde{Y}_i) + \tau_1 (T_{i1} - \tilde{T}_{i1}) + \tau_2 (T_{i2} - \tilde{T}_{i2}) + \cdots + \tau_n (T_{in} - \tilde{T}_{in})} \tag{c}$$

where $X_i \neq \tilde{X}_i$ and $Y_i \neq \tilde{Y}_i$.

In this formulation, attribute terms are only dropped for the dwelling characteristics that do not change between the sales. A logarithmic transformation yields the traditional repeat-sale analysis plus either the log of the ratio of the attributes (the *X*s in the equation) or the difference in the dwelling characteristics (the *Y*s), for just the attribute measures that change. Case et al. (2006) manipulate the formulation further to show the model where parameters change, rather than attributes, and where both parameters and attributes change. Crucially, this means that analysts can use this framework in numerous different ways. The repeat-sales model can, in theory, be augmented by whatever hedonic parameters prior knowledge or the research puzzle being addressed would lead us to expect to change through time. Thus, at the most sophisticated level, the model both allows the analyst to capture the fixed effect of a hedonic attribute during the study period and, when interacted with space and time, the variation in impacts on different neighbourhoods and in different periods. The attribute specific effects are separate to the general market trend effects.

This first-principles outline of the measurement framework thus provides a basis for the development of an operational model that has been applied to the assessment of the impacts of different market shocks. In the earliest application, Case et al. (2006) sought to examine the impact of Trichloroethylene (TCE) groundwater contamination on real-estate values in Scottsdale, Arizona. The empirical analysis drew on 22,092 repeat sales observed in the study area between 1982 and 1998. They developed several variants on the hybrid model set out above with the most significant of these, the variant that included dynamic data on contamination and took account of geographical location. The model captured the impact of the timing of contamination treatment as well as the effects of the initial event. The results show, unsurprisingly, that the price impacts were greater within the contaminated area than other market segments. Importantly, however, they illustrate that there were some fine-grained distance-decay effects. They also showed that it took more than six years after remediation treatment in 1991 for nominal prices in the most negatively impacted submarket to return to the levels of the early 1980s. Prices in that area, however, had still not quite closed the gap on values in unaffected neighbourhoods that had been comparable in price terms prior to contamination.

Lamond et al. (2010) adapted this approach to explore the impact of severe flooding during autumn 2000 on house prices in 13 locations in the UK. They used repeat-sales data from HM Land Registry from the period between the flood date and December 2006 in their analysis and estimated combined (i.e., based on pooled data from different localities) and location-specific models. They showed that the impact of flood events tended to be temporary and that the effects were highly variable between locations. The research also showed that being located in a designated flood-risk area had no significant impact on value.

In a more recent application, Cutter et al. (n.d.) use the hybrid approach to explore the impacts of the use of a policy to preserve open space for habitat preservation in Riverside, south California. The study draws on 125,424 repeat sales during the 16-year period between 1988 and 2014. In the model, the researchers treat open space habitat designation as being analogous to Case et al.'s contamination remediation treatment. The results show that policy designation has a strong and significant impact on prices and that these impacts vary considerably with distance from the designated area. However, they note, as with the example presented in the next section, that they are unable to disentangle the capitalization effect from a more general time trend in the market and they are unable to isolate unambiguously the preservation policy effects from the influence of other changes to the information set used by buyers and from other policy effects. The lessons from these studies inform the development of and reflections on the model used here.

DATA AND STUDY AREA

Case study

Although this paper seeks to make a methodological rather than substantive policy analysis contribution, we offer, as an exemplar, the selected results of our analysis of the impacts of a historic area-based urban regeneration policy from the UK.

The case study is intended to have some merit in its own right. First, the policy design had been informed by, and is set in the context of, a long history of urban policy experiments in Scotland, dating from and including the Glasgow East Area Renewal initiative established under the Urban Programme in the 1960s (Atkinson & Moon, 1994). As such, the lessons about the wider impacts of area-based policies should be generalizable to some degree. Second, the policy intervention was initiated during a period where property development had, in the UK and elsewhere, come to be viewed as a critical component of local economic development and urban renewal strategies (Healey, Davoudi, O'Toole, Tavsanoglu, & Usher, 1992; Imrie & Thomas, 1993; Rosenburg & Watkins, 1999; Turok, 1992). In that context, property market impacts that contributed to the establishment of sustainable markets were quite explicitly seen as desirable outcomes (Jones & Watkins, 1996). Third, although there has been considerable investment in comprehensive urban policy evaluation (e.g., DETR, 2000; Imrie & Thomas, 1999; Robson et al., 1994; Tyler, Rhodes, Lawless, & Dabinett, 2001) and despite the foregoing comment, this body of work has been criticized for paying insufficient attention to the property market impacts of policy beyond the numbers of new homes developed (Adair et al., 2005).

Against this backdrop, the specifics of the analysis presented here focuses on the Castlemilk Scottish Urban Partnership area in Glasgow. The initiative was established with publication of *New Life for Urban Scotland* (1988), which launched four Scottish Urban Partnerships in Castlemilk (Glasgow), Wester Hailes (Edinburgh), Ferguslie Park (Paisley) and Whitfield (Dundee) (Scottish Office, 1988).

Castlemilk is located to the south-east of Glasgow city centre on the periphery of the city. Its population halved from around 37,000 in 1971 through to 1988, by which time it was characterized by low income levels, high unemployment, low skills and educational attainment. The neighbourhood also suffered from a poor-quality housing stock and few local amenities (see Carley, 1990; and McCrone, 1991, for background information). In 1988, there were only 69 owner-occupied homes in the area (Castlemilk Partnership, 1999). By the time an interim evaluation of the New Life initiative was published in 1995, there was evidence that the process of tenure diversification had begun, assisted by the development of new stock and by sales under the right to buy (a policy that allowed local-authority renters to buy their homes at a discount), and major improvements in the housing stock had been achieved (O'Toole, Snape, & Stewart, 1995). Over £110 million had been spent on new and existing social housing stock, and a further £20 million investment had been secured from the private sector (including a one-third subsidy) for new homes. At that stage, there was evidence of a fragile owner-occupied market becoming established. Importantly, in 1994, central government revealed plans for a new six-year housing investment programme. In terms of creating a new sustainable market, 1995 was to prove the key date for Castlemilk in that the policy commitments made then acted as an important signal to the market that there would be ongoing investment in the neighbourhood.

Given extensive evidence that policy decisions can alter the performance of a number of market segments and that changes in neighbourhood submarkets can be transmitted over space (Jones, Leishman, & Watkins, 2003), the empirical work reported here also examines the housing performance of neighbouring areas. As such, the area studied extends beyond the boundaries of the Castlemilk Partnership and also encompasses the neighbouring Kings Park and Croftfoot areas of Glasgow. This study area is almost exactly matched to the G44 and G45 postcode areas

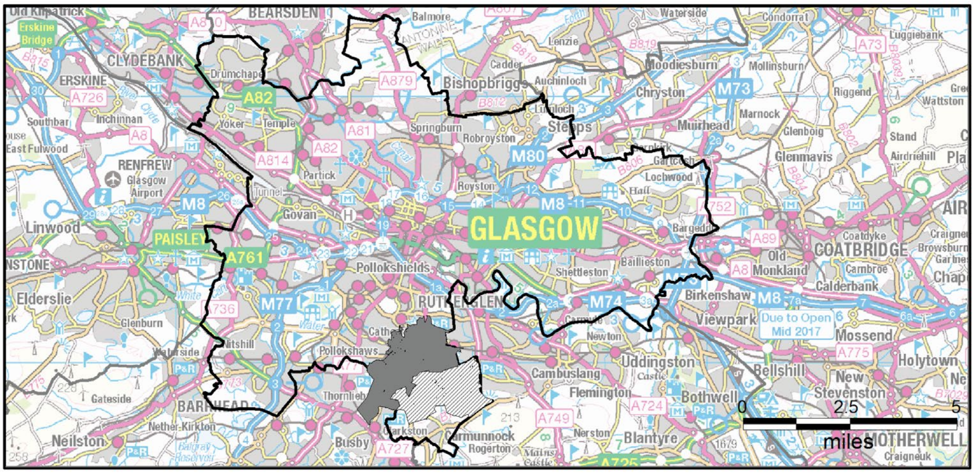

Figure 1. The study area and its context within Glasgow.

(shown in blue and red respectively in Figure 1). The boundaries of G45 are coterminous with the partnership area boundaries.

Data

We use data provided by the Land Value Information Unit (LVIU) based at the University of West of Scotland. The LVIU curates an electronic database of property transactions in Scotland that includes details such as postal address, transaction price and date, and buyer and seller details. Each transaction record has a unique property-specific code permitting instances of repeat sales to be easily identified.

The subset of the LVIU dataset used to estimate the models discussed here includes 4070 paired repeat-sale transactions over 1988–99. There were 111 repeat-sale transactions in the partnership area. As a result, the dataset is clearly, in quantitative terms, dominated by transactions in the established owner-occupied markets in the immediate neighbouring areas of Kings Park and Croftfoot. Preliminary analysis of the transactions data suggests north/south and east/west price gradients exist, with prices rising to the north of Kings Park (away from the partnership area) and falling to the east as the relatively high price area, Kings Park, gives way to Croftfoot.

Towards an operational model that detects policy impacts

Following the formulation presented above in Equation (c), we derive a number of operational models that begin to unpick the impact of the introduction of an area-based urban regeneration initiative on local housing values. The first model, estimated to give a baseline against which to compare other specifications, is a traditional repeat-sale equation:

$$\ln\left(\frac{P_i}{\tilde{P}_i}\right) = \tau_1\left(T_{i1} - \tilde{T}_{i1}\right) + \tau_2\left(T_{i2} - \tilde{T}_{i2}\right) \cdots + \tau_n\left(T_{in} - \tilde{T}_{in}\right) \tag{1}$$

We assume that there is an error term of the usual sort in this and all the other models estimated below. Operationally, the repeat-sales hedonic model is estimated using the natural log of the price relative (the subsequent observed price divided by the prior), and the explanatory variables are time dummies coded −1 for prior sale dates, 1 for subsequent sale dates and 0 otherwise. After estimation, the chronologically ordered coefficients represent the log of the cumulative price index. This is important in relation to our derivation of subsequent models because, having gathered market-wide price trends into the time dummy variables, we can isolate specific effects arising from, in this case, the influence of the regeneration policy.

Model 2 is a simple hybrid where a single hedonic variable is included. This is a 'policy on' variable, and is denoted 'REG' below. This variable, which is the focus of this worked example, is the product of two dummy variables: whether or not the property is located in the area designated as part of the Castlemilk Partnership (see below for further details), and whether or not the second sale occurs after policy intervention in the area. Thus, the REG variable is designed to capture the direct impact of the regeneration expenditure on house prices:

$$\ln\left(\frac{P_i}{\tilde{P}_i}\right) = \tau_1(T_{i1} - \tilde{T}_{i1}) + \tau_2(T_{i2} - \tilde{T}_{i2}) \cdots + \tau_n(T_{in} - \tilde{T}_{in}) + \beta_0 REG_i\left(\varphi_{95,i} - \tilde{\varphi}_{95,i}\right) \quad (2)$$

where

$$\varphi_{95,i} = \left\{\begin{array}{l} 1,\ \text{if second sale occurs in 1995 or thereafter} \\ 0,\ \text{otherwise} \end{array}\right\}$$

$$\tilde{\varphi}_{95,i} = \left\{\begin{array}{l} 1,\ \text{if first sale occurs before 1995} \\ 0,\ \text{otherwise} \end{array}\right\}$$

$$REG_i = \left\{\begin{array}{l} 1,\ \text{property situated in the Partnership area} \\ 0,\ \text{otherwise} \end{array}\right\}$$

In other words, the hedonic variable in model 2 is a dummy that equals 1 if the sales pair is located in the area covered by the urban regeneration policy initiative and the sales pair straddles the date of intervention (i.e., one occurs before and one after). In this instance, as noted above, the key date was 1995. Although the policy initiative was introduced in 1988 and signals the arrival of the first open-market transactions in the area, we have argued that the announcement of the continuation of public sector intervention in 1995 is the most significant policy action in terms of potential market impact. The decision to use 1995 was influenced by the work of Adair et al. (2005), who demonstrate that continued public sector intervention is important in fragile markets and, in line with Jones and Watkins (1996), is required to establish the conditions for a self-sustaining owner-occupied market. Thus, crucially, it is our contention, to be tested, that it is this date that represents the point at which public sector commitment to continuing regeneration would begin to feed through to the market, private housing market activity having already been established by the initial phase of funding in 1988 (O'Toole et al., 1995). Thus, model 2 permits the estimated coefficient on the regeneration dummy variable to indicate whether there has been any post-policy intervention, perhaps more accurately a post-policy continuation announcement, effect on house prices in the designated partnership area.

Model 3 extends the framework by incorporating a time trend that is interacted with the regeneration variable. This allows us to investigate whether the effect dissipates through time or whether, as might be expected, there are cumulative benefits from regeneration policies:

$$\ln\left(\frac{P_i}{\tilde{P}_i}\right) = \tau_1(T_{i1} - \tilde{T}_{i1}) + \tau_2(T_{i2} - \tilde{T}_{i2}) \cdots + \tau_n(T_{in} - \tilde{T}_{in}) + \beta_0 REG_i\left(\varphi_{95,i} - \tilde{\varphi}_{95,i}\right)\partial T_i \quad (3)$$

where

$$\partial T_i = \text{ difference in time between second sale and policy on(second sale year} - 1995)$$

Model 4 combines 'policy on', the linear time trend, and a distance-decay function used. In effect, this means that we are no longer concerned simply with the housing market effects within the partnership area, but we also seek to explore the potential spillover effects in nearby neighbourhoods. As noted above, the dataset is dominated quantitatively by transactions in the neighbouring Kings Park area of south-west Glasgow. Hence, model 4 is as follows:

$$\ln\left(\frac{P_i}{\tilde{P}_i}\right) = \tau_1\left(T_{i1} - \tilde{T}_{i1}\right) + \tau_2\left(T_{i2} - \tilde{T}_{i2}\right) \cdots + \tau_n\left(T_{in} - \tilde{T}_{in}\right) + \beta_0\left(\varphi_{95,i} - \tilde{\varphi}_{95,i}\right)\left(\frac{\partial T_i}{d^2}\right) \quad (4)$$

where

$$\frac{\partial T_i}{d^2} = \text{ linear time trend divided by square of distance (in km) between the property and the central point of the Partnership area}$$

Model 4 is of particular interest in a policy evaluation context since it permits the estimation of the potential spillover effects beyond the targeted area. Intuitively, our expectation is that the effects of regeneration expenditure will diminish with distance, but that there will be a positive impact on house prices in neighbouring areas. The partnership area has an identifiable central point where there is co-location of a local shopping centre, post office, local authority office and leisure facilities. The locational impacts are captured using a straight-line distance measured from this point. Given that we know from other studies that distance-decay functions are rarely linear, we assume an inverse-square relationship. The appropriate form could be an area for further empirical experimentation and future refinement (Case et al., 2006).

RESULTS

Table 1 reports the results of the standard repeat-sales regression estimation, as described in specification (1). Data are available from 1985, although a time dummy is not entered for 1985 and, as with standard practice, the relevant coefficient is assumed to be 0.

Model 2 includes the policy dummy variable describing partnership area transaction pairs in which one transaction occurs before the key policy intervention date, and the other occurs after.

Table 1. Standard repeat-sales regression model.

Variable	Coefficient	*t*-statistic	
1986	–0.055	–0.992	
1987	–0.003	–0.053	
1988	0.071	1.344	
1989	0.216	4.059	***
1990	0.359	6.762	***
1991	0.441	8.277	***
1992	0.386	7.154	***
1993	0.465	8.564	***
1994	0.448	8.188	***
1995	0.427	7.804	***
1996	0.528	9.688	***
1997	0.529	9.595	***
1998	0.538	9.815	***
1999	0.552	10.066	***
Adjusted R^2	0.245		
Standard error	0.445		
F-statistic	95.332	***	

Table 2. 'Policy dummy' model including constant.

Variable	Coefficient	*t*-statistic	
Constant	0.164	4.69	***
y1986	–0.059	–1.077	
y1987	–0.024	–0.44	
y1988	0.026	0.499	
y1989	0.173	3.264	***
y1990	0.302	5.634	***
y1991	0.378	6.967	***
y1992	0.318	5.714	***
y1993	0.39	6.901	***
y1994	0.391	6.792	***
y1995	0.327	5.622	***
y1996	0.421	7.148	***
y1997	0.402	6.633	***
y1998	0.403	6.541	***
y1999	0.417	6.63	***
DIST_E	–0.077	–9.774	***
DIST_N	0.016	1.274	
REG_AFT95	0.534	8.881	***
Adjusted R^2	0.127		
Standard error	0.437		
F-statistic	35.699	***	

Table 3. Policy with a linear time trend and constant.

Variable	Coefficient	*t*-statistic	
Constant	0.173	4.964	***
y1986	–0.058	–1.068	
y1987	–0.024	–0.441	
y1988	0.025	0.483	
y1989	0.171	3.213	***
y1990	0.299	5.56	***
y1991	0.374	6.88	***
y1992	0.311	5.573	***
y1993	0.385	6.796	***
y1994	0.384	6.649	***
y1995	0.328	5.636	***
y1996	0.42	7.103	***
y1997	0.398	6.551	***
y1998	0.394	6.385	***
y1999	0.405	6.428	***
DIST_E	–0.075	–9.46	***
DIST_N	0.012	0.899	
REG_AFT95DT	0.145	7.888	***
Adjusted R^2	0.123		
Standard error	0.438		
F-statistic	34.595	***	

The data used in this study do not encompass sufficiently detailed information to identify minor refurbishment work. However, following Goetzmann and Spiegel (1995), we define the intercept term as the normal (or average) price appreciation following minor improvements or a modest positive market shock. The policy variable is statistically significant and positively signed suggesting that 1995 marks an improvement in housing market performance in the partnership area. As an experiment, we also defined the policy variable using 1990, 1991, 1992, 1993 and 1994 as the policy intervention dates, but none of these variables was found to be statistically significant.

As a further check on the robustness of these results, we re-estimated the model using Stata's xtmixed (multilevel) estimator, defining the higher level as the postcode sector. The transactions belong to 57 postcode sectors across the study area overall. The full results of this estimation are not reported here, but a coefficient of 0.381 and *z*-statistic of 5.80 were obtained with this estimation. This indicates that the statistically significant coefficient reported in Table 2 is robust with respect to the possible issue of bias arising from policy effects having an influence at both the level of the individual dwelling and the study area overall.

Table 3 sets out the results for the third variant of the model. This equation includes a linear time trend and the specification therefore assumes that the benefits of regeneration policy have a cumulative effect. The new policy/time-trend variable is statistically significant, while the coefficient suggests that house prices in the partnership area grew at a rate of around 15% per annum over and above the growth witnessed elsewhere in the study area. The estimated intercept is 0.164, which suggests that unobserved physical improvements between repeat sales of individual dwellings accounts for an increase in value of approximately 16%. This is likely to reflect the tendency for improvements to occur in stock transferred from the local authority to private ownership (Pawson & Watkins, 1998). There is also undoubtedly a gentrification effect, where prices are being driven up by changes in perception about the neighbourhood and by the investment in the local physical environment. As might be expected, the coefficients appear more plausible than those shown in Table 2 (which suggest that prices increased at the flat rate of more than 53% following 1995).

Tables 4a and 4b set out the results of the model 4 estimation. In keeping with the previous analyses, the specification of model 4 above describes 1995 as the 'policy on' date. However, since the model is designed to test for spillover effects on neighbouring Kings Park and Croftfoot rather than just the effects within the partnership area itself, we have a choice of two policy dates: 1988 and 1995. The model is estimated using both alternatives.

The results shown in Table 4a suggest that there were no significant spillover effects resulting from the partnership area status of Castlemilk in 1988. However, it should be noted that the distance-decay parameter of 2 used in the construction of the composite policy/proximity/time-trend variable could be replaced by alternative transformation functions, some of which might

Table 4a. Spillover measured from 1988.

Variable	Coefficient	*t*-statistic	
Constant	0.211	6.076	***
1986	–0.060	–1.089	
1987	–0.029	–0.516	
1988	0.034	0.647	
1989	0.176	3.252	***
1990	0.304	5.549	***
1991	0.382	6.870	***
1992	0.318	5.570	***
1993	0.390	6.709	***
1994	0.370	6.243	***
1995	0.342	5.699	***
1996	0.434	7.142	***
1997	0.419	6.697	***
1998	0.417	6.518	***
1999	0.425	6.527	***
DIST_E	–0.064	–8.012	***
DIST_N	–0.015	–1.181	
AFT88DTD2	–0.0052	–1.124	
Adjusted R^2	0.110		
Standard error	0.441		
F-statistic	30.551	***	

Table 4b. Spillover measured from 1995.

Variable	Coefficient	*t*-statistic	
Constant	0.201	5.766	***
1986	–0.058	–1.055	
1987	–0.022	–0.407	
1988	0.024	0.461	
1989	0.165	3.088	***
1990	0.291	5.385	***
1991	0.368	6.726	***
1992	0.303	5.395	***
1993	0.373	6.541	***
1994	0.356	6.150	***
1995	0.308	5.232	***
1996	0.397	6.643	***
1997	0.375	6.092	***
1998	0.366	5.812	***
Y1999	0.370	5.756	***
DIST_E	–0.073	–8.976	***
DIST_N	0.0007	0.053	
AFT95DTD2	0.014	3.397	***
Adjusted R^2	0.112		
Standard error	0.440		
F-statistic	31.232	***	

yield better results. The results shown in Table 4b, by contrast, identify a statistically significant, though weak, spillover effect resulting from the 1995 policy measures. The magnitude of the coefficient on the composite spillover effect variable implies a gradual shift in the house price gradient beginning in 1995. Specifically, the house-price growth rate begins to increase by 14% per annum at a distance of 1 kilometre from the centre of the partnership area relative to house prices elsewhere in the study area.

Overview of the results

The findings based on the model estimations offer some promising signs. The significance of the policy dummy variable suggests that the 1995 measures are associated with a step change in private housing investment performance after the announcement of continued public sector commitment to area renewal. This may be suggestive of evidence of the reduction in the 'stigma' effect attached to problem estates (Dean & Hastings, 2000). Meanwhile, the policy dummy/time-trend interaction variable allow us to estimate the cumulative or annual effect as approximately 15%.

Model 4 provides some preliminary insights with respect to the issue of spillover effects. The 1988 policy measures seem not to be associated with spillover effects (i.e., taking the Kings Park, Croftfoot and Castlemilk areas as a whole), suggesting that the early interventions had little impact beyond the target area. The analysis reveals that the spatial structure of the house price gradient does not shift until much later. Significantly, there is clear evidence of a shift after the 1995 announcement of further policy measures.

The spillover effect model requires further development, but the preliminary results suggest that the spillover effect (1) increases cumulatively over time and (2) is more pronounced further away from the partnership area. The latter suggestion is interesting as well as intuitively appealing – it suggests that the relatively higher priced parts of the area slightly further from Castlemilk responded more strongly than the relatively low priced parts of the area nearby Castlemilk. The distributional impact of these benefits has potentially interesting implications for debates about the winners and losers from public sector investment and are potentially relevant to discussions about local tax policies.

CONCLUSIONS

In recent years, the UK government has commissioned several large-scale evaluations of its urban regeneration programme. Although these evaluations have sought to consider the impact of regeneration activity on a range of economic and social indicators, the analysis of the effects on property values has been perfunctory. Typically, the property element of the studies has been restricted to a simple count of new homes or new development. Given that the rationale for many regeneration initiatives is to improve 'investability' (Begg, 2002) and to revive failing property markets, the failure to explore the change in property values is striking.

The research reported in this paper sought to address this gap. Using a hybrid hedonic and repeat-sales model, the empirical research examined the impact of the introduction of the New Life for Urban Scotland urban regeneration initiative on house prices in Castlemilk, the focus for the policy initiative, and neighbouring parts of the Glasgow housing market. The analysis is based on an examination of housing transactions drawn from between 1985 and 1999, a period covering sales occurring before, during and after the injection of regeneration funding.

Although this paper analyses the substantive impacts of urban policy interventions on house prices, we contend that the methodological implications are arguably more important than the results of the analysis. The paper has sought to demonstrate successfully the usefulness of hybrid hedonic and repeat-sale models as a means of assessing policy impacts. The most important element of the methodology used here is that it brings location variables into repeat-sale models and offers a way of capturing spatial effects. This is particularly significant in the presence of urban revitalization polices where the parameters on location variables can change profoundly over time. It can also be used to assess the myriad of different events that transform the spatial house price surface. Although we have not done so here, and it does limit the reliability of the substantive policy findings, the method can also be adapted via the inclusion of dwelling attributes to control for physical modifications to the house price stock.

Importantly, the framework also allows analysts to measure the temporal effects of exogenous shocks to the housing system. In our example, we have been able to show that urban renewal policies have cumulative impacts on house prices and that the most significant effects only emerge over a longer time period. The framework has been used to illustrate the absence of systemic effects of flooding and to model the dynamic increase and subsequent dissipation of the effects of environmental contamination. There are many more potential public policy impacts that could be evaluated using this approach.

Despite the intuitive simplicity of the framework and what we hope is evidence of its potential utility, given the increasing availability of high-quality micro-datasets, there are some challenges for the research community. The example used in this paper is limited in several ways. First, given data limitations, our model might be seen as repeat sales plus rather a more extensive hybrid of the sort developed by Englund et al. (1999). There would be some real benefits to be had in terms of improving explanatory power and the robustness of the coefficients from the development and testing of models that have more fully specified hedonic features. On a related point, better data will also allow researchers to address some of the technical challenges presented by spatial heteroskedasticity and spatial autocorrelation.In conclusion, we would encourage researchers to pause before adding to the vast hedonic house-price literature and instead to consider contributing to the development of a body of applied research that uses hybrid index methods to detect the impact of public policy interventions and market shocks.

ACKNOWLEDGMENTS

The authors would like to thank Peter Collwell for his contribution to developing the framework used. We would also like to thank the reviewers for their comments. Any errors are the responsibility of the authors.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

FUNDING

This work was supported by The Royal Institution of Chartered Surveyors (RICS) Education Trust.

ORCID

Chris Leishman http://orcid.org/0000-0002-7853-5035
Craig Watkins http://orcid.org/0000-0002-1249-9473

REFERENCES

Adair, A. S., Berry, J. N., McGreal, W. S., Poon, J., Hutchison, N. E., Watkins, C., & Gibb, K. (2005). Investment performance in urban regeneration areas. *Journal of Property Investment and Finance, 23*, 7–21.

Adams, D., Watkins, C., & White, M. (2005). *Planning, public policy and property markets*. Oxford: Blackwells.

Atkinson, R., & Moon, G. (1994). *Urban policy in Britain*. London: Macmillan.

Begg, I. (2002). Investability; The key to competitive regions and cities. *Regional Studies, 36*, 187–200.

Boyle, M., & Kiel, K. (2001). A survey of house price hedonic studies of the impact of environmental externalities. *Journal of Real Estate Literature, 9*, 117–144.

Carley, M. (1990). *Housing and neighbourhood renewal: Britain's new urban challenge*. London: PSI.

Case, B., Colwell, P., Leishman, C., & Watkins, C. (2006). Estimating the impact of environmental contamination on house prices: A hybrid approach. *Real Estate Economics, 34*, 77–108. ISSN 1080-8620.

Case, B., Pollakowski, H. O., & Wachter, S. M. (1991) On choosing among house price index methodologies. *Journal of the American Real Estate and Urban Economics Association, 19*, 286–307.

Case, B., & Quigley, J. M. (1991). The dynamics of real estate prices. *Review of Economics and Statistics, 83*, 50–58.

Castlemilk Partnership. (1999). Castlemilk regeneration enters a new chapter. *Press Release*, Castlemilk Partnership, June.

Clapp, J. M., & Giacotto, C. (1992). Estimating price indices for residential property: A comparison of repeat sales and assessed value methods. *Journal of the American Statistical Association, 87*, 300–306.

Clapp, J. M., Giacotto, C., & Tirtiroglu, D. (1991). Housing price indices based on all transactions compared to repeat subsamples. *AREUEA Journal, 19*, 270–285.

Costello, G. (2002). Pricing size effects in housing markets. *Journal of Property Research, 17*, 203–220.

Costello, G., & Watkins, C. (2002). Towards a system of local house price indices. *Housing Studies, 17*, 857–873. ISSN 0267-3037.

Cutter, W. B., Fernandez, L., & Scott, T. (n.d.). *Dynamic analysis of open space value with a preservation policy*. unpublished manuscript. April 2017. Retrieved from https://www.researchgate.net/profile/Bowman_Cutter/publication/228984881_Dynamic_Analysis_Of_Open_Space_Value_With_A_Preservation_Policy/links/0deec52bca98a5c8c9000000.pdf

Dean, J., & Hastings, A. (2000). *Challenging images: Housing estates, stigma and regeneration*. Bristol: Policy Press.

DETR. (2000). *City challenge: Final national evaluation*. London: DETR.

Englund, P., Quigley, J. M., & Redfearn, C. L. (1999). The choice of methodology for computing housing price indexes: Comparisons of temporal aggregation and sample definition. *Journal of Real Estate Finance and Economics, 19*, 91–112.

Freeman, A. M. (1979). Hedonic prices, property values and measuring environmental benefits: A survey of the issues. *Scandinavian Journal of Economics, 81*, 154–173.

Goetzmann, W. N., & Spiegel, M. (1995). Non-Temporal components of residential real estate appreciation. *Review of Economics and Statistics, 77*, 199–206.

Healey, P., Davoudi, S., O'Toole, M., Tavsanoglu, S., & Usher, D. (1992). *Rebuilding the city - property-led urban regeneration*. London: E & FN Spon.

Hill, R., Carter, J., Knight, R., & Sirmans, C. F. (1997). Estimating capital asset prices. *Review of Economics and Statistics, 79*, 226–233.

Imrie, R., & Thomas, H. (1993). The limits of property-led regeneration. *Environment and Planning C, 11*, 87–102.

Imrie, R., & Thomas, H. (1999). *British urban policy: An evaluation of UDCs*. London: Sage.

Jones, C., & Dunse, N. (2005). UK roads policy, accessibility and industrial property rents. In D. Adams, C. Watkins, & M. White (Eds.), *Planning, Public Policy and Property Markets* (Chap. 7, pp. 128–147). Oxford: Blackwells.

Jones, C., Leishman, C., & Watkins, C. (2003). Structural change in urban housing markets. *Environment and Planning A, 35*, 1315–1326.

Jones, C., & Watkins, C. (1996). Urban regeneration and sustainable markets. *Urban Studies, 33*, 1129–1140.

Jud, G. D., & Winkler, D. T. (2006). The announcement effect of an airport expansion on housing prices. *Journal of Real Estate Finance and Economics, 33*, 91–103.

Jun, M. J., & Kim, H. J. (2017). Measuring the effect of greenbelt proximity on apartment rents in Seoul. *Cities, 62*, 10–22.

Keskin, B., Dunning, R., & Watkins, C. (in press). Modelling the impact of earthquake activity on real estate values: A multi-level approach. *Journal of European Real Estate Research, 10*.

Lai, L. W. C., Chau, K. W., Yiu, E. C. Y., Wong, K. S. K., Wong, W. S., & Chan, P. Y. L. (2007). Measuring and interpreting the effects of a public sector-led urban renewal project on housing prices – an empirical study of a comprehensive development area zone developed upon 'taking' in Hong Kong. *Environment and Planning B, 34*, 524–538.

Lamond, J., Proverbs, D., & Hammond, F. (2010). The impact of flooding on the price of residential property: A transactional analysis of the UK market. *Housing Studies, 25*, 335–356.

Leishman, C., & Watkins, C. (2002). Estimating repeat sales house price indices for British cities. *Journal of Property Investment and Finance, 20*, 36–58.

Malpezzi, S. (2002). Hedonic pricing models: A selective and applied review. In A. O'Sullivan & K. Gibb (Eds.), *Housing economics and public policy* (Chap. 5, pp. 66–89). Oxford: Blackwells.

Mark, & Goldberg. (1984). Alternative house price indices: An evaluation. *Journal of the American Real Estate and Urban Economics Association, 12*, 30–49.

McConnell, V., & Walls, M. (2005). *The value of open space: Evidence from studies of non-market benefits*. Washington, DC: Resources for the Future.

McCrone, G. (1991). Urban renewal: The Scottish experience. *Urban Studies, 28*, 919–938.

Meese, R. A., & Wallace, N. E. (1997). The construction of residential housing price indices: A comparison of repeat-sales, hedonic regression, and hybrid approaches. *Journal of Real Estate Finance and Economics, 14*, 51–73.

Meldrum, J. R. (2016). Floodplain price impacts by property type in Boulder County, Colorado: Condominium versus standalone properties. *Environmental and Resource Economics, 64*, 725–750.

O'Toole, M., Snape, D., & Stewart, M. (1995). *Interim evaluation of the Castlemilk partnership*. Edinburgh: Scottish Office.

Palmquist, R. B. (1982). Measuring environmental effects on property values without hedonic regressions. *Journal of Urban Economics, 11*, 333–347.

Pawson, H., & Watkins, C. (1998). The position and role of former public sector homes in the owner occupied sector: New evidence from the Scottish housing market. *Urban Studies, 35*, 1291–1309.

Quigley, J. M. (1995). A simple hybrid model for estimating real-estate price indexes. *Journal of Housing Economics, 4*(1), 1–12.

Robson, B. Bradford M., Deas, I., Hall E., Harrison, E., Parkinson, M., … Robinson, F. (1994). *Accessing the impact of urban policy*. London: Inner City Research Programme, HMSO.

Rosenburg, L., & Watkins, C. (1999). Longitudinal monitoring of housing renewal in the urban core: Reflections on the experience of Glasgow's Merchant City. *Urban Studies, 36*, 1973–1996.

Scottish Office. (1988). *New life for urban Scotland*. Edinburgh: Scottish Office.

Steele, M., & Goy, R. (1997). Short holds, the distribution of first and second sales, and bias in the repeat-sales price index. *Journal of Real Estate Finance and Economics, 14*, 133–154.

Turok, I. (1992). Property-led urban regeneration: Panacea or placebo? *Environment and Planning A, 26*, 177–198.

Tyler, P., Rhodes, J., Lawless, P., & Dabinett, G. (2001). *A review of the evidence base for regeneration policy and practice*. London: DETR.