Analysing the Relationship Between Residential Property Prices and Their Determinants: A Semiparametric Geographically Weighted Regression Approach

***Menganalisis Perhubungan antara Harga Hartanah Kediaman dan Penentunya: Suatu Pendekatan Semiparametrik* Geographically Weighted Regression**

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Abstract

This paper analyses the relationship between residential property prices and their determinants, taking account of the local geography. A semiparametric geographically weighted regression (S-GWR) technique is employed to explore this relationship. Selling prices, structural and locational attributes data were collected from the database of the. The Department of Valuation and Services of Malaysia, including selected maps and reports. The outcome of this paper shows a strong geographically varying relationship between residential property prices and their determinants in which the residential property price determinants have a positive impact on prices in some areas but a negative or no impact on others. The magnitude of the effect is also found to be geographically varied; the capitalisation in residential property prices is found to be greater in some areas but less or nil in other parts. The use of S-GWR technique allows such geographically varying relationships to be exposed, hence leading to a better understanding of the relationship between residential property prices and their determinants.

Keywords

House prices, semiparametric geographically weighted regression (S-GWR), Tanjong Malim

Abstrak

Kertas ini menganalisis hubungan antara harga hartanah kediaman dan penentunya, dengan mengambil kira geografi tempatan. Satu teknik semiparametrik geographically weighted regression (S-GWR) digunakan untuk meneroka hubungan ini. Data harga jualan, struktural dan lokasi dikumpulkan dari pangkalan data Jabatan Penilaian dan Perkhidmatan Malaysia, termasuk peta dan laporan dipilih. Hasil daripada kajian ini menunjukkan hubungan yang kuat dari segi kepelbagaian geografi antara harga hartanah kediaman dan penentunya di mana penentu harga hartanah kediaman mempunyai kesan positif ke atas harga di sesetengah kawasan tetapi negatif atau tidak memberi kesan kepada kawasan lain. Magnitud kesan ini juga menunjukkan

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perbezaan dari segi geografi; peningkatan ke atas harga hartanah kediaman didapati lebih besar di beberapa kawasan tetapi kurang atau sifar di bahagian-bahagian lain. Penggunaan teknik S-GWR membolehkan hubungan geografi yang berbeza-beza dapat ditonjolkan, oleh itu membawa kepada pemahaman yang lebih baik tentang hubungan antara harga hartanah kediaman dan penentunya.

Kata kunci

Harga rumah, semiparametrik geographically weighted regression (S-GWR), Tanjong Malim

Introduction

Property price, in particular residential property price, is a great concern of government, real estate developers and the general population. This is due to the fact that housing market and changes in residential property prices can affect the entire economy such as economic growth, inflation, interest rates and the banking sector. From the social perspective, changes in residential property prices, especially rises, can affect social equity and affordability. In most parts of the world today, particularly in big cities, affordability is the biggest housing concern among residents. For instance, a survey carried out by The Guardian in the United Kingdom (UK) in 2014 indicates that affordability is found to be the biggest housing concern among the general population in the UK. Similarly, in Malaysia, issues pertaining to home ownership have been the biggest concern among people over the years, especially for those who reside in more developed region such as in the Klang Valley, Johor Bahru and Penang. In addition, changes in residential property prices can also indicates better/worse accessibility to the central business district (CBD) and amenities, good/poor schools and high/low crime rates in a neighbourhood etc.

An important question to ask is, upon what factors do residential property prices depend? If we asked the economists, they will tell us that the price of residential properties depends on the supply and demand of housing in the market. But when asking real estate practitioners about this question the most likely answer will be "location, location and location", and consequently it becomes the main interest of this paper. This implies that the surrounding area of a unit of residential property is found to be a key factor in determining its prices. For instance, a unit of residential property located in a peaceful neighbourhood is more desirable than the very same property in an area with high crime rates. Based on this reasoning, we expect that the residential property will fetch a better premium when located in the former rather than the latter area. However, it is important to note here that the physical characteristics (structural attributes) of the property itself also play an important role in determining its desirability and price. Therefore, it has been established that a combination of both physical and locational attributes contributes significantly to the formation of residential property prices (see, for example, Powe *et al.*, 1995; Orford, 1999; Dziauddin *et al.*, 2013). This is due to the fact that the selling price of a residential property reflects both structural and locational attributes such as the size of floor area, tenancy, the age of the residential property, proximity to central business district (CBD), schools, rail transit stations, etc. By regressing the transaction prices against physical and locational attributes, one can estimate the contribution of these attributes to residential property prices. The next important question to ask is do structural and locational attributes have similar effects and magnitudes on residential property prices across the geographical area? If not, how varied are they across the geographical area? And do we have a better approach and tool to reveal these geographically varying effects and magnitudes?

The purpose of this paper, therefore, is to analyse the relationship between residential property prices and the attributes that they possess by taking account of the local geography. As these attributes are not directly traded, a number of techniques are available to estimate their effects. The literature has shown that there are two broad categories of non-market techniques: stated preference techniques on the one hand and revealed preference techniques on the other. In the context of this paper, one of the revealed preference techniques is hedonic pricing, which is used to analyse this relationship.

Methodology

The study area

The empirical study was conducted in Tanjong Malim, Perak, Malaysia, which is located approximately 70 kilometres north of Kuala Lumpur and 130 kilometres south of Ipoh via the North-South Expressway, and in recent years a lot of development can be observed particularly after the operationalising of heavy industry such as PROTON (national car maker), vendors for PROTON and the completion of phase one Sultan Azlan Shah Campus (Sultan Idris Education University) in Proton City. Tanjong Malim was chosen because there were enough housing transactions during the period of study (2011) and also a sufficient variation in the locational attributes. It encompasses an area of 949.86 square kilometres and had a population of about 41,693 in 2010. There are three main employers in Tanjong Malim; national car maker PROTON Company (which has a production plant in Tanjong Malim) and its vendors, Sultan Idris Education University (two campuses), and Sultan Azlan Shah Polytechnic.

Tanjong Malim itself is a medium-sized town. It lies on the Perak-Selangor state border, with Bernam River serving as the natural divide, and also at the foot of Titiwangsa range. The main features in the landscape are natural greens and commodity crops such as palm oil and rubber plantations. The buildings in the town are typically no higher than three stories. In most of the housing areas detached, terraced and traditional Malay houses predominate. Thus, the general profile of the town is almost flat. As a newly developed area, residents of Tanjong Malim are served by basic amenities such as local banks, a post office, a district hospital, places of worship, local shops, commuter services, a medium-sized shopping mall, and small-sized fast food restaurants. Furthermore, the only recreational facility available in Tanjong Malim is located ten kilometres away from the main residential areas and it was developed by a private company as part of an integrated township known as Proton City consisting of residential, commercial, institutional as well as industrial areas. For private transport, Tanjong Malim benefits from good arterial road access.

Sampled data and selection of independent variables

House price transactions for 2010 and 2011 were chosen to be the sample for this study. In total, 350 units of residential property selling prices were collected. However, after going through several steps to clean the sample dataset by eliminating the unsuitable data and unavailable data, the study was left with 212 observations across 14 housing estates. The selling price of an individual house and its physical characteristics were collected from the Department of Valuation and Property Services, Malaysia (Teluk Intan, Perak branch).

Variables used in this paper were selected on the basis of their inclusion in previous studies (see, for example, Powe *et al.*, 1995; Orford, 1999; Dziauddin *et al.*, 2013) and most importantly, on the basis of their availability and multicollinearity. According to Laakso (1997 cited by Tyrvainen and Miettinen, 2000), the number and quality of explanatory variables vary considerably from one study to another.

A list of variables for inclusion in the HPM and S-GWR is given in Table 1. It has been argued by Tyrvainen and Miettinen (2000) that in hedonic models multicollinearity between explanatory variables commonly exists. As a result, 'estimating accurate and stable regression coefficients may be difficult' (Tyrvainen & Miettinen, 2000). To handle this problem Tyrvainen and Miettinen suggest that one can omit a highly collinear variable from the model, provided this does not lead to serious specification bias.

Table 1 List of explanatory variables and their expected effects on residential property prices

Explanatory variables (Physical characteristics)	Expected sign*	Explanatory variables (Locational attributes)	Expected sign*
Size of floor area	+	Proximity to town centre	-
Size of lot area	+	Proximity to primary school	-
Bedroom 0 = <3 rooms, 1 = 3 rooms or more	+	Proximity to university	-

+ increasing/- reducing effect on the selling price.

In order to measure the distance to locational attributes from a given residential property, a geographic information system (GIS) was used in this study. GIS was used to organise and manage large spatial datasets (that is, units of residential properties), and, of course, their physical and locational attributes too. Most importantly, GIS was used to position each observation accurately on a local map by using the geographical coordinates. Moreover, the combination of GIS and spatial analysis has been particularly useful in this study in which the distance and proximity was measured accurately by measuring the distance from one point to another using network distance.

The estimation methods

The discussion in this section is focussing on the methods used in this paper, that is by using the S-GWR. The GWR in general, however, is based on a global regression model (a hedonic price model) which is then modified by GWR to calibrate local regression parameters by weighting the distance between one data point and another through the coordinates of data (Fotheringham *et al.,* 1998), and S-GWR is a new version of the GWR technique to analyse geographically varying relationship between a dependent variable and its explanatory variables, which is available in a new version of the GWR software (GWR 4.0) developed by Nakaya *et al.,* (2009). In this framework, one can implement model selection in order to judge which explanatory effects on the dependent variable are globally fixed or geographically varying in generalised linear modelling (GLM) (Nakaya *et al.,* 2009).

The hedonic price model

The general form of a hedonic pricing model can be presented as:

$$P_i = f\ (S, L,) + \varepsilon \qquad (1)$$

where,

P_i = the market price of property i,
S and L = the vectors of structural and locational variables,
ε = a vector of random error terms.

Semiparametric geographically weighted regression (S-GWR) model

As is widely recognised, in estimating residential property prices by means of HPM one of the main problems is that the parameter estimates are normally being applied constantly over the whole geographical area. In other words, the relationships being analysed are assumed to be 'stationary' across the geographical area, although in reality relationships are arguably not stationary and said to exhibit spatial heterogeneity. In response to that, a relatively new spatial econometric technique known as S-GWR, which addresses the issue of spatial heterogeneity, is used in this paper. Fotheringham *et al.,* (1998) have pointed out that this spatial heterogeneity if not carefully handled may cause problems for the interpretation of parameter estimates from a global regression model.

It was argued in the literature that any relationship that is not stationary across a geographical area will not be represented well by a global regression model. Fotheringham *et al.,* (2002) have argued further that failing to address issues related to spatial heterogeneity may cause the estimated parameter produced by a global regression model to mislead locally (Fotheringham *et al.,* 2002). The GWR, on the other hand, has the capability to deal with spatial heterogeneity by taking into account coordinates in the estimated parameter. The standard GWR model can be mathematically expressed at location i in space as follows (Crespo & Grêt-Regamey, 2013):

$$P_i = \beta_0 (u_i, v_i) + \sum_{k=1}^{p} \beta_k (u_i, v_i)\, x_{ik} + \varepsilon_i, \quad i = 1, \ldots, n, \tag{2}$$

where,

P_i	= response variable at point i,
u_i, v_i	= tspatial coordinates of point i,
$\beta_0 (u_i, v_i)$	= location-specific intercept term parameter,
$\beta_k (u_i, v_i)$	= kth location-specific parameter,
p	= number of unknown local parameters to be estimated (excluding the intercept term),
x_{ik}	= kth explanatory variable associated with $\beta_{k,}$
ε_i	= a random component assumed to be independently and identically distributed,
n	= number of observations

Based on equation 2 above, location-specific parameters $\beta_k (u_i, v_i)$ are estimated using weighted least squares and can be expressed as follows (Crespo & Grêt-Regamey, 2013):

$$\beta (u_i, v_i) = [X^T W_i X]^{-1} X^T W_{iy}, \quad i = 1, \ldots, n, \tag{3}$$

where,

$\beta (u_i, v_i)$	= a (p x 1) vector parameter estimates at location i,
X	= an (n x p) matrix of observed explanatory variables,
W_i	= a distance decay (n x n) matrix
y	= an (n x 1) vector of observed response variables,

Note that p and i are as defined in the equation 2 above. Location i is also denoted as the regression point; the point at which parameters are being estimated. As expressed in the equation above, the weighting of an observation is done through a distance decay matrix (W_i) so that observations located near to the point in space are weighted more than observations located further away. As mentioned above, a new version of GWR called S-GWR developed by Nakaya *et al.,* is actually an extension of the previous version of GWR. In this new version the user is enabled to implement model selection through the semiparametric approach. Semiparametric includes partially linear terms of explanatory effects on the dependent variable in the canonical parameter and it can be expressed as follows (Nakaya *et al.,* 2009):

$$P_i = \beta_0 (u_i, v_i) + \sum_{k=1}^{p} \beta_k (u_i, v_i) x_{ik} + \sum_{l=1} \gamma l Z l_i \qquad i = 1, \ldots, n \qquad (4)$$

where Zl_i is lth explanatory variable and γl is its coefficient that is globally fixed across a geographical area. By this geographically weighted calibration and semiparametric approach, continuous and smooth surfaces of local parameter estimates can be mapped over a geographical area and the effects of explanatory variables on the dependent variable can be judged, whether it is globally fixed or geographically varying.

Empirical results

The results of the HPM and S-GWR models using the above specifications are presented below in two stages. The first part shows the results from the hedonic price model and the second part shows the results from the S-GWR model.

The HPM estimation

The next stage of the estimation process using HPM is to choose the functional form which best portrays the relationship between a property's market price and each of the variables describing its characteristics. There were four common functional forms used in HPM: linear, semi-log, double-log and Box–Cox linear (Garrod & Willis, 1992; Cropper *et al.,* 1988). Unfortunately, economic theory does not generally give clear guidelines on how to choose a particular functional form for property attributes (Garrod and Willis, 1992). However, Cropper *et al.,* (1988) suggest that linear, semi-log, double-log and Box–Cox linear perform best, with quadratic forms, including the quadratic Box–Cox, faring relatively badly. Based on the advice given by Cropper *et al.,* (1988), double-log specification was used to measure the relationship between residential property prices and their determinants in this study. The model is regressed on a set of explanatory variables as follows:

$$\ln P_i = \beta_0 + \beta_1 \ln FLRAREA_i + \beta_2 BEDROOMS_i + \beta_3 \ln LOTAREA_i + \beta_4 \ln TOWN_i + \beta_5 \ln PRIMARYSCH_i + \beta_6 \ln UNIVERSITY_i + \varepsilon \qquad (5)$$

where i is the subscript denoting each property; P_i is the price of property i in Malaysian ringgit (RM); ln is natural logarithm; FLRAREA is the floor area of the property in square metre; LOTAREA is the size of lot area of the property in square metre; BEDROOMS is 1 if property has 3 or more bedrooms, 0 otherwise). TOWN, PRIMARYSCH and UNIVERSITY are Tanjong Malim town, primary school and university, respectively. These continuous explanatory variables are all measured in metres. Finally, $\beta_0,\ldots,\beta_6$ denotes a set of parameters to be estimated associated with the explanatory variables (including the intercept term), and ε denotes standard error of the estimation, which is assumed to be independently and identically distributed. The descriptive statistics of the model's variables are shown in Table 2.

Table 2 Descriptive statistics of the model's variables

Variable	Type[a]	Description	Units	Min	Max	Mean
Dependent variable						
SELLING	C	Residential property price transactions	Malaysian ringgit (RM)	38000	550000	137221.09
Explanatory variable						
Physical characteristics						
FLRAREA	C	Size of floor area	Square metre	46.50	233.74	106.19
LOTAREA	C	Size of lot area	Square metre	55.60	709.00	176.19
BEDROOMS	C	Number of bedroom	Dummy (0 or 1)	0	1	0
Location variables						
TOWN	C	Proximity to central business district	Metre	50	709	4249.68
PRIMARYSCH	C	Proximity to primary school	Metre	20	9900	2085.67
UNIVERSITY	C	Proximity to university	Metre	850	9800	3543.09

[a]C = continuous

Table 3 shows the results for the HPM together with geographical variability tests of local coefficients procedure for S-GWR model. In general, the model fits the data reasonably well and explained 83 per cent of the variation in the dependent variable. Within the final model most of the explanatory variables that influenced residential property prices are significant at the 1 per cent level and have the anticipated positive and negative signs, except for the town centre variable (TOWN). As this is a double-log functional form, the interpretation of the estimated coefficients relates to their elasticity effect on price. In other words, a one square-metre/number/metre change in x (explanatory variables) will cause a b per cent change in y (dependent variable).

Table 3 Global regression statistics and ANOVA table

	Estimate of (β)	Standardised coefficients (β)	p-value for the HPM	Geographical variability tests of local coefficients*
Constant	6.86			-20.91
FLRAREA	0.58	0.53	0.00	-4.59
BEDROOMS	0.29	0.28	0.00	NA
LOTAREA	0.25	0.22	0.00	NA
TOWN	0.08	0.15	0.00	-10.27
PRIMARYSCH	-0.07	-0.16	0.00	-6.81
UNIVERSITY	0.09	0.12	0.00	-166.11

Notes: Goodness of fit: adjusted R^2 = 0.83 (HPM); adjusted R2 = 0.85 (S-GWR). AICc = -51.14 (HPM); AICc = -64.97 (S-GWR)
* = negative value indicates that these variables vary across the geographical area
NA = BEDROOMS and LOTAREA variables were classified as global and therefore were not included in the geographical variability test

Among the physical characteristics of the property, significant contribution is shown by the variable size of the property, measured by the floor area (FLRAREA). For every square-metre increase in floor area, the expected selling price of a residential property increases by 0.58 per cent or RM749 of the mean price of the property. The magnitude of the effect of floor area was expected, since floor area is always associated with the size of the property – this is consistent with most of the HPM literature.

Among the locational attributes of explanatory variables, the parameter estimates for proximity to the university (UNIVERSITY) is the most statistically significany. The model suggests that for every metre away from the university a residential property price experience increases by 0.09 per cent. This equates to RM3.48 at the mean. This result is also unexpected since we would expect that residential property prices decrease for every metre away from the university.

Calibration of the HPM: S-GWR estimation

As highlighted in the literature, the main contribution of the GWR technique is the ability to explore the spatial variation of explanatory variables in the model. Thus, the coefficients of explanatory variables may vary significantly across a geographical area. The analysis using S-GWR software in this paper presents two diagnostic types of information: the information for the HPM and S-GWR model – including general information on the model and an ANOVA (it can be used to test the null hypothesis that the S-GWR model shows no improvement over the HPM).

In this analysis, the local model benefits from a higher adjusted coefficient of determination (adjusted R^2) from 83% in the HPM to 85% in the S-GWR model and the Akaike information criterion (AIC) of the S-GWR model (-64.97) is lower than for the HPM (-51.14), suggesting that the GWR local model gives a significantly better explanation, after taking the degrees of freedom and complexity into account.

As mentioned above, one of the advantages of S-GWR is the ability to explore the spatial variation of explanatory variables in the model. Based on geographical variability tests of local coefficients procedure, the S-GWR software can examine the significance of the spatial variability of parameters identified in the local parameter estimates. The results of the test are shown in Table 3.

Analysing the spatial variation of parameter estimates and T-surfaces

The parameter estimates of the explanatory variables are mapped using the dot distribution symbol that is available in ArcGIS. Figures 1a–1d show the influence of four explanatory variables (floor area, town centre, primary school and university) on residential property price and they have been identified to exhibit spatial heterogeneity across a geographical area by the S-GWR model. In these figures, the local parameter estimates are shown as different coloured points, whilst the green colour band is representing the *t*-score. Note that for variables to be classified as statistically significant, the *t*-score of those variables needs to be at least 1.96 or greater (positive and negative signs). Looking at the results of the S-GWR model in more detail, it is possible to arrive at some interesting conclusions concerning the effects of positive and negative externalities of residential property attributes and the interaction between them. Also, it is clear from the maps that the parameter estimates of explanatory variables exhibit significant spatial variation across the geographical area – this information is completely unseen in the HPM and is only seen in the S-GWR model.

In HPM, for every square-metre increase in floor area, the expected selling price of a residential property increases by 0.58 per cent or RM749 of the mean price of the property. However, the S-GWR model illustrates how premiums added by floor area on a residential property price that has been estimated to be constant by HPM in fact vary across the geographical area (see Figure 1a). As can be observed from the map, residential property prices enjoy a premium of between 0.39 per cent and 0.62 per cent for every square metre increase in floor area. At the mean, this equates to a premium of between RM504 and RM801. In other words, the expected selling price of some residential properties in Tanjong Malim is estimated at a much cheaper rate compared to the one estimated by HPM for every square-metre increase in floor area. For example, residential properties located in the north-western and southern areas experience increases in selling price just of between 0.39 per cent and 0.57 per cent (green and red dots) which is lower than was estimated by HPM. This equates to RM504 and RM737 at the mean. For residential properties located in the north-eastern and south-eastern areas, their floor area is estimated at a much higher rate – for every square-metre increase in floor area, the expected selling price of a residential property increases by 0.58 per cent and 0.62 per cent (dark blue dots). This equates to RM749 and RM801 at the mean.

In the case of the town centre, it has been estimated by HPM that residential property prices would increase by 0.08 per cent for every metre away from the town

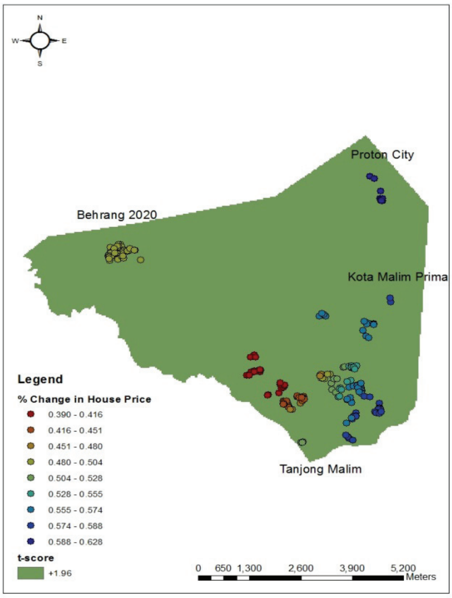

Figure 1a Map of S-GWR model estimates of floor area

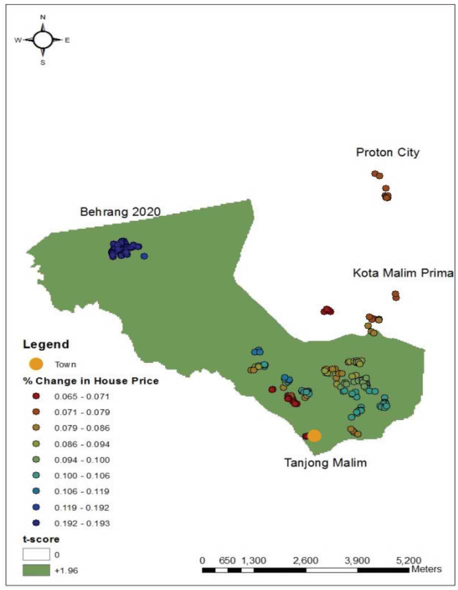

Figure 1b Map of S-GWR model estimates of town centre

centre. An examination of Figure 1b shows that it confirms that residential property prices increase for every metre away from the town centre, but the parameter estimates illustrate considerable spatial variation over the geographical area, which is completely hidden in HPM. As can clearly be seen on the map, the price of residential properties is estimated to increase of between 0.06 per cent and 0.19 per cent for every metre away from the town centre. At the mean, this equates to RM1.93 and RM6.14. The highest increase in price is estimated for residential properties located far away from the town centre, that is in north-western area (dark blue dots), which experiences increases in price of between 0.11 per cent and 0.19 per cent. This equates to RM3.55 and RM6.14 at the mean. Therefore, it can be concluded that the finding from S-GWR analysis confirms the majority of buyers in this area do not positively value the existence of the town centre when they buy a property, as explained previously.

The results from the HPM show residential properties served by a primary school would decrease in price by approximately 0.07 per cent or RM3.42 at the mean for every metre away from it. Once again, this single value has been applied for the entire area, whilst an examination of Figure 1c shows that this is not representative of the majority of residential properties in the study area. Looking at the parameter estimates in Figure 1c, the conclusion that can be made is that the decrease in price as distance from a primary school increases is only observed for residential properties located in the north-eastern and north-western areas, which experience decreases in price of between 0.08 per cent and 0.21 per cent for every metre away from a primary school together with a significant t-score. At the mean, this equates to RM3.91 and RM10.27.

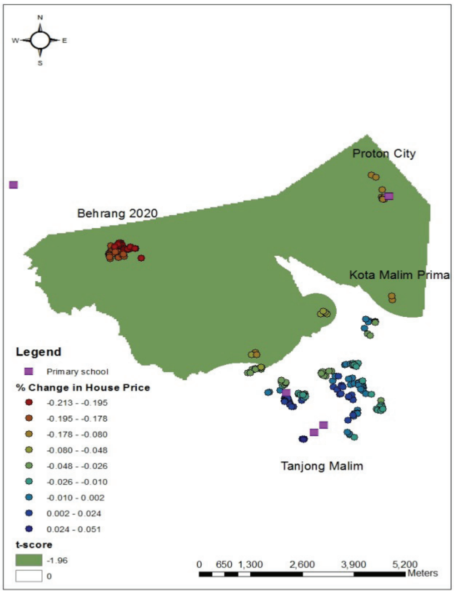

Figure 1c Map of S-GWR model estimates of primary schools

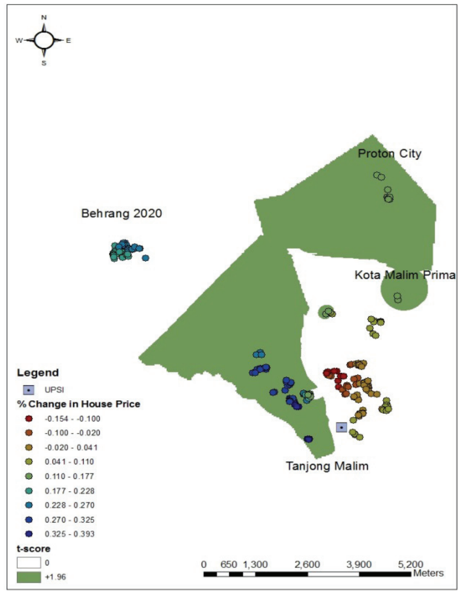

Figure 1d Map of S-GWR model estimates of the university

The possible reason why the majority of homebuyers in these areas value the existence of primary schools positively is perhaps because of the demographic composition of the area, which predominantly consists of parents with children of primary school age.

The remaining locational attribute in determining residential property prices in this research is proximity to a university. As stated in HPM, proximity to a university is estimated to increase residential property prices by around 0.09 per cent or RM 3.48 at the mean for every metre away from a university. Figure 1d shows that in the local model estimation, the relationship between residential property prices and university is not stationary, instead there is clear evidence of spatial variation across the geographical area. Although it has been estimated by HPM that residential property prices would increase as distance from the university increases, the proximity to university, as shown on the map, has a significant positive impact on residential property prices in some parts of the area. For example, residential properties located in the south-east experience a decrease in price by 0.04 per cent and 0.15 per cent (orange and red dots) for every metre away from the university – this positive impact is completely unseen in HPM. The possible reason why residential properties in this area respond positively due to the existence of a university is because these properties suit the demographics of potential renters in the area, since the majority of these properties have four or more bedrooms. It is important to note that, if it is within the catchment area of a university, a residential property with more bedrooms will be in greater demand among buyers and so is sold at a higher price.

Conclusion

As stated previously, the purpose of this paper is to analyse the local geography of the relationship between residential property prices and their determinants in Tanjong Malim, Perak. This paper established that the results of the HPM were insufficient for drawing conclusions about the relationship between residential property prices and their determinants in Tanjong Malim. This insufficiency was due to the nature of the HPM as a global model, as it does not have the capability to capture the geographical context and variation within which properties are located. To correct for this, further analysis determined that a spatial econometric model would be a better tool for analysing the relationship. Therefore, the S-GWR model was employed to analyse more directly the relationship locally.

In terms of its overall findings, the results of the HPM demonstrated that physical characteristics of the property played a greater role in determining residential property prices in the study. As discussed above, the size of the property, measured by floor area and number of bedrooms has shown to contribute more greatly to the residential property price. The results of the HPM analyses also indicated that the effect of locational attributes such as primary schools has a positive effect on residential properties where at the mean, a residential property located one kilometre away from a primary school is expected to sell at a discount of approximately RM3400.

However, further analysis using the S-GRW revealed that such elementary analysis effectively hides a more complex relationship between residential property prices and their determinants under study. The results of the S-GWR model clearly demonstrated that this relationship varies across geographical area; that is, the magnitude and direction of the relationship is geographically dependent, with residential property prices in some parts affected positively and greatly, and in other parts positively but with less magnitude. This is evidently true for floor area where the results from the HPM indicated that the size of floor area has shown to contribute more greatly to the residential property price. However, the analysis using the S-GWR model revealed that the effects and magnitudes of this attribute on residential property prices varies across the geographical area. Similarly, for primary schools, it was estimated by the HPM that residential property prices tend to decrease with increasing distance from a primary school. However, the results from the S-GWR suggest that the relationship between residential property prices and a primary school also varies geographically, that is in terms of magnitude and direction, with residential property prices in some areas affected positively and in other areas negatively by distance from a primary school.

The conclusion that can be made from this study, however, is that structural and locational attributes indeed do have an impact on pricing, but this impact varies depending on residential location. Along with its contribution to knowledge in this field, at the very least, then, such information may be relevant and beneficial to future urban development in Tanjong Malim and other urban settings where attention should be given to providing more amenities within close proximity to residential areas in order to boost residential property prices – increases in residential property prices indirectly can generate more revenues for local council through taxing.

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References

Crespo, R. & Grêt-Regamey, A. (2013). 'Local hedonic house-price modelling for urban planners: Advantages of using local regression techniques'. *Environment and Planning B: Planning and Design*, 40, pp. 664–682.

Cropper, M. L., Deck, L. B. and McConnell, K. E. (1988). 'On the choice of functional form for hedonic price functions'. *The Review of Economics and Statistics*, 70 (4), pp. 668–675.

Dziauddin, M. F., Alvanides, S., and Powe, N. A. (2013). 'Estimating the effects of light rail transit (LRT) system on the property values in the Klang Valley, Malaysia: A hedonic house price approach'. *Jurnal Teknologi* (Sciences and Engineering), 61, pp. 37–49.

Fotheringham, A. S., Brunsdon, C. and Charlton, M. E. (1998). 'Geographically weighted regression: A natural evolution of the expansion method for spatial data analysis'. *Environment and Planning A*, 30, pp. 1905–1927.

Fotheringham, A. S., Brundson, C. & Charlton, M. E. (2002). *Geographically weighted regression: The analysis of spatially varying relationships*. West Sussex: John Wiley & Sons Ltd.

Garrod, G. & Willis, K. (1992). 'Amenity value of forests in Great Britain and its impact on the internal rate of return from forestry'. *Forestry*, 65 (3), pp. 331–346.

Nakaya, T., Fotheringham, A.S, Charlton, M.E. & Brunsdon, C. (2009). *Semiparametric geographically weighted generalised linear modelling in GWR 4.0*, [online], Available: http://www.geocomputation.org/2009/PDF/Nakaya_et_al.pdf [7 March 2014].

Ohsfeldt, R. L. (1988). 'Implicit markets and the demand for housing characteristics'. *Regional Science and Urban Economics*, 18, pp. 321–343.

Orford, S. (1999), *Valuing the built environment: GIS and house price analysis*. Aldershot: Ashgate Publishing Ltd.

Powe, N. A., Garrod, D. & Willis, K. G. (1995). 'Valuation of urban amenities using an hedonic price model'. *Journal of Property Research*, 12, pp. 137–147.

Tyrvainen, L. & Miettinen, A. (2000). 'Property prices and urban forest amenities'. *Journal of Environmental Economics and Management*, 39, pp. 205–23.