

Structural Change Modeling of Singapore Private Housing Price in Simultaneous Equation Model

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This paper investigates the structural change behavior of Singapore's private housing market and in particular the impact of government policies on housing price determination. A structural model of price is established and the "Regressive Segmentation (RS)" method is applied to detect the changing points without prior knowledge of the structural changes. Our study shows that the changing points indicated by the RS method are consistent with the timing of the policy changes.

Keywords: Private Housing Market; Structural Change; Simultaneous Equation Model

Introduction

Booms and slumps in housing prices have attracted the attention of both the general public and academic economists ever since. From the academic point of view, the ready availability of time-series data and the important policy implications of high and volatile prices have meant that empirical modeling of housing prices has been both a fertile and a challenging area.

In Singapore there are two segments in residential housing market, the private housing market and the HDB¹ resale housing market. The main difference between the two is that the HDB resale housing market is, to some extent, regulated and subsidized, while the private housing market receives limited government intervention although the prices in both markets are determined by the market forces.

Private housing market operates in a laissez-faire economic system, where housing prices are mainly determined by a function of the demand and supply in the market. (Sing, Tsai, & Chen, 2004) This segment of the market is dominated by few major private developers. A variety of housing forms, with the hierarchical structure from apartment, condominiums, terrace, semi-detached house to detached housing, is made available by private developers to meet different preference and aspiration of potential buyers. The private housing units have much higher housing prices with better designs, quality of finishes and fully-equipped recreationally facilities. Getting into the private housing market is therefore viewed as the upper end of Singapore owner-occupiers' housing career. Ownership of private residential property is well regarded as a social status, and a dream of HDB dweller, and those who have not owned a house.

Although being relatively small, the private housing market has a significant impact on the Singapore economy. According to the estimation given by Phang (2001), the ratio of gross housing wealth in the private housing sector to GDP is 1.48, while the same ratio in the public housing sector is 1.38. This implies that the fluctuation of private housing prices could have important implications for the national wealth holding. More-

over, becoming a private home-owner has become a national phenomenon, attracting a significant proportion of public home-owners to upgrade to private housing. The public housing subsidies therefore leak out into the private housing sector through such upward mobility and its social economic impacts are significant.

Although Singapore has a relatively free economy, its housing market is far from being perfect. It is strongly dominated by the public sector, in the forms of both direct provision and control of major housing stock, and regulating the eligibility criteria, housing finance, prices, rentals and transaction costs. The government's intervention through the sale of leasehold private residential lands program and the government linked property companies also helps indirectly to cushion unnecessary price inflation. The impacts of the public housing policies on the private housing prices are profound, albeit indirect. As pointed out by Phang et al. (1995), the effect of government intervention on the public housing could filter into the private housing market. Changes in the supply, expected price, finance and eligibility criteria of public housing will influence the private property market significantly. These policy distortions have resulted in remarkable structural changes in the private property market over time.

With the market more responsive and susceptible to external shocks, price correction should be less sticky vis-à-vis public housing market. In recent years, Singapore's residential property market, especially the private housing market has been suffering from irregular price fluctuations. This has caused much public concern about the affordability of private housing. Thus the study of the structure of Singapore private housing market and the behavior of the market is of great importance in controlling real estate inflation. Interest in this sector also stems from the fact that it is subject to the full rigor of market forces, in sharp contrast to the established public housing market where state-administered social pricing prevails mainly through subsidies and loans to the HDB.

This paper investigates structural changes in Singapore's private housing market and in particular the impact of government policies on housing price determination. A structural

¹HDB, Housing Development Board, is a statutory board of the Ministry of National Development, considered to be the national housing agency.

model on price is established and the “Regressive Segmentation” (RS) method is applied to detect the changing points without prior knowledge of the structural breaks. The rest of the paper is arranged as follows. **Literatures** provides a review of literatures and **Method** presents the method which is able to detect, in simultaneous equations model, the changing points with no prior information on the timing of the structural changes. Empirical results are discussed in **Empirical Result and Discussion** and **Conclusion** concludes.

Literatures

The literature on modeling of housing prices is very extensive, especially in the developed housing markets in the UK and North America. Many empirical housing models have been developed based mainly on the stock-flow adjustment or the classical Hendry’s neo-classical frameworks. In Hendry’s theory of equilibrium demand and supply functions, the price of existing houses was derived as a function of personal disposable income, rental rate, interest rate, stock of mortgage, tax rate, and number of families. Dicks (1990) extended Hendry’s model for prices of new housing in the UK. Hsieh (1990) further separated housing demand into service and investment demand in a study of Taiwan’s housing market.

Following the traditional two-equation stock-flow model of the residential market, the demand is typically stated as a function of the real price of housing, the user cost of financing that price, the alternative cost of renting as well as demographic characteristics and real permanent income. In supply side, construction is always assumed to depend on housing prices, factor costs and various interest rates (Di Pasquale & Wheaton, 1994). Empirical practices show that the functional forms and lags used tend to be largely data determined (Muellbauer & Murphy, 1997).

The stock-flow approach posits that the housing market will clear through prices that equate demand with the existing stock of housing. Supply is often taken to be exogenous as it is determined by the decisions of housing producers in prior periods. Such a specification fails to include supply-side features (Muellauer & Murphy, 1997) and ignores the relationship between housing stock and land market conditions (Di Pasquale & Wheaton, 1994). Taking housing stock as fixed will lead to a short run fluctuation in which price are completely demand-driven. However, as shown in many studies (Peng & Wheaton, 1994; Rosen & Smith, 1983), the effect of a demand shock on prices depends on the state of supply. This is particularly relevant for the Singapore market where land sales program is potentially useful mechanism for bringing the housing market into steady-state equilibrium (Lum, 2002).

Despite the small market share of the private residential property market in Singapore, research, however has been concentrated on this sector of the market. In the city-state of Singapore, the studies focusing on modeling private residential housing market dynamics contain only limited theoretical structure. Empirical analysis includes the impacts of government policies on private housing prices (Phang & Wong, 1997) and the inflation-hedging characteristics of private housing prices (Chen & Sing, 2000).

Ho and Cuervo (1999) and Tu (2001) incorporated an error correction term in the cointegration models to adjust for the short-term non-stationary variations. Ho and Tay (1993) developed a system of six simultaneous equations for the supply of

and demand for private residential properties in Singapore in a two-stage least squares process. Other studies include Ong and Sing (2002) on price discovery between private and public housing market using a Granger causality error-correction model and Sing (2001) on the dynamics of the condominium market in Singapore.

The free-market operation of the private market implies that the market is more responsive and susceptible to shocks in economics. But few have been seen to study the structural change of long run behavior of private housing market in Singapore, especially in structural equation model. This provides the basic rational for this empirical work.

Method

The basis of the method, for specialized cases, is documented by Fisher (1958) and Guthery (1974). Thorough treatment and description of the main idea in the context of simultaneous equation model seems still sparse, with recent treatment in Huang and Zhang (2004). Normally, structural change is said to be present within the range of the index i , which in time series data, corresponds to time or observation. With the index or partitioning variable identified, the inferential problem confronting us involves three parts: 1) the specification of the number of changes in the model, l ; 2) the detection of the change point $\{i_s\}$, or the boundaries of intervals over which each of the model pieces applies; 3) the estimation of the model parameters within each subdomain. If l and the $\{i_s\}$ were specified, step 3 would simply consist of applying the classical theory, interval by interval. Summing the residual sums of squares for the various intervals yields an overall index of the quality of fit of the segmented model. With l fixed, the $\{i_s\}$ may be estimated by minimizing this index. Further minimization of the index to estimate l will base on information criterion for model selection problems.

In estimating the appropriate sample separation in simultaneous equation system, there are two approaches to analyze the timing and form of structural changes, either to estimate equation by equation individually using a limited information estimator, or globally consider joint estimation of the entire system. First using limited information estimation, without loss of any generality, we may consider the first equation in the system with normal assumptions applied, and write it as

$y_i = Y_i\beta_i + X_i\gamma_i + u_i$. The reduced form corresponding to this is $Y_i = Z\Pi_i + V_i$, where $Y_i = (y_i, Y_i)$, $Z = (X_i, X_2)$,

$\Pi_i = (\pi_i, \Pi_i)$ and $V_i = (v_i, V_i)$. Z is the $(N \times G)$ matrix of non-stochastic exogenous variables in the complete system, Π_i is a $G \times (m_i + 1)$ matrix of reduced form coefficients, and V_i is a $G \times (m_i + 1)$ matrix of reduced form disturbances whose rows are assumed to be normally and independently distributed with zero mean and covariance Ω_i . Comparing the structural and reduced forms of the model, we have

$u_i = v_i - V_i\beta_i = V_i\beta_i^0$ where $\beta_i^0 = (1, -\beta_i')$. Thus, one may estimate u_i by utilizing appropriate estimators for V_i and β_i^0 . Then V_i may be estimated by applying OLS to yield $\hat{V}_i = Y_i - Z\hat{\Pi}_i$, since V_i is reduced form coefficient and OLS will give consistent estimation. Meanwhile, β_i^0 can be estimated from structural form equation using 2SLS. Thus, the appropriate estimator of u_i would then be $u_i^* = \hat{V}_i \cdot \hat{\beta}_i^0$. Since we know that $\hat{V}_i = M_Z Y_i$, where $M_Z = I - Z(Z'Z)^{-1}Z'$, it follows that u_i^* may be obtained directly as the residual vector of the unrestricted OLS regress of $y_i - Y_i\hat{\beta}_i$ on Z , that is,

regressing $y^* = Y_1 \hat{\beta}_1^0$ on Z . Denoting the $G \times 1$ coefficient vector of said regression by δ and u_1^* would be expressed alternatively as $u_1^* = y^* - Z\delta$.

Applying recursive segmentation method, we define target function, e , as the statistics that describe the overall goodness-of-fit of the model using certain estimation criteria. The value of the target function within a segment is called the diameter, denoted as d . Obviously, e is a function of d . The use of ordinary least square (OLS) gives specific form to the target function and diameters and simplifies the discussion. We therefore have

$$d(i_s, i_{s+1} - 1) = \min_{\delta} \sum_{t=i_s}^{i_{s+1}-1} (y_t^* - Z_t \delta_t)^2 = \sum_{t=i_s}^{i_{s+1}-1} (y_t^* - Z_t \hat{\delta}_t)^2$$

$s = 1, 2, \dots, l$

where y_t^* is the t^{th} element of y^* matrix. And e is defined as:

$$e[p(N, l)] = \min_{\delta^{(s)}} \left\{ \sum_{s=1}^l \sum_{t=i_s}^{i_{s+1}-1} (y_t^* - Z_t \delta_t)^2 \right\}$$

$$= \sum_{s=1}^l \sum_{t=i_s}^{i_{s+1}-1} (y_t^* - Z_t \hat{\delta}_t)^2 = \sum_{s=1}^l d(i_s, i_{s+1} - 1)$$

$s = 1, 2, \dots, l$

As shown above, target function $e[p(N, l)]$ can be decomposed into the sum of individual diameters. Therefore the ultimate goal is to obtain the optimal segmentation:

$\tilde{p}(N, l) = \{\tilde{i}_1, \tilde{i}_2, \dots, \tilde{i}_l\}$, which minimizes the target function, i.e., $e[\tilde{p}(N, l)] = \min_{p \in p(N, l)} e[p(N, l)]$. let $\hat{\delta}$ denote the resulting estimates based on the given l partition (i_1, i_2, \dots, i_l) .

Substituting these estimates in the objective function and denoting the resulting sum of squared residuals as $SSE(i_1, i_2, \dots, i_l)$, the estimated break points $\{\tilde{i}_1, \tilde{i}_2, \dots, \tilde{i}_l\}$ can be alternatively denoted as $\{\tilde{i}_1, \tilde{i}_2, \dots, \tilde{i}_l\} = \arg \min_{i_1, i_2, \dots, i_l} SSE(i_1, i_2, \dots, i_l)$.

As an additive function of diameters, the target function $e[p(N, l)]$ satisfies the separability condition in a multi-stage decision-making problem in dynamic programming. Thus, by using the technique of backward recursive optimization, $\{\tilde{i}_1, \tilde{i}_2, \dots, \tilde{i}_l\}$, or the optimal changing points can be identified recursively without an exhaustive grid search. Details of this algorithm are shown in Huang and Zhang (2004).

If full information, or systems methods of estimation is used, we may formulate the full system as $Y = Z\delta + U$, where $E(U) = 0$ and $E[UU'] = \Sigma \otimes I$. In line with the principle of system methods, the technique of three-stage least square is used for joint estimation of the entire system of equations. Thus the 3SLS estimator is $\hat{\delta}_{3SLS} = [\hat{Z}'(\Sigma^{-1} \otimes I)\hat{Z}]^{-1} \hat{Z}'(\Sigma^{-1} \otimes I)Y$ where \hat{Z} is the IV estimator for 2SLS. Again, the model is assumed to have $l-1$ structural changes in the whole sample period, i.e., l subsamples. Following the definition of diameter and target function stated previously and after a choice of a

normalization rule, we have $d(i_s, i_{s+1} - 1) = \sum_{h=1}^M d_h(i_s, i_{s+1} - 1)$,

where $d_h(i_s, i_{s+1} - 1)$ is the diameter of the h^{th} equation, for the individual segment starting from i_s to $i_{s+1} - 1$.

$d(i_s, i_{s+1} - 1)$ is the summation of all the diameters throughout the system. Given the structural changes in the form of $P(N, l) = \{i_1, i_2, \dots, i_l\}$, we have

$$e[p(N, l)] = \sum_{s=1}^l d(i_s, i_{s+1} - 1) = \sum_{s=1}^l \sum_{h=1}^M d_h(i_s, i_{s+1} - 1).$$

Those corresponding diameters can be calculated from 3SLS estimators. Similarly, we have the optimum of target function as

$$e[\tilde{p}(N, l)] = \min_{p \in p(N, l)} e[p(N, l)].$$

Again, the estimated break points will be $\{i_1, i_2, \dots, i_l\} = \arg \min_{i_1, i_2, \dots, i_l} SSE(i_1, i_2, \dots, i_l)$. It is apparent that the technique of backward recursive optimization and dynamic programming procedure are applicable and again RS procedure can be implemented to detect the structural changes without grid search calculation.

By using recursive classification, we can obtain different recursive segmentations simultaneously, given exact number of segments l , on which in practice we may not have such information. Another standard problem is that improvement in the objective function is always possible by allowing more breaks. That is to say, in determining optimal l^0 , it is expected intuitively that a more complicated model will provide a better approximation to reality. But, on the contrary, in most practical situations a less complicated model is likely to be preferred if we wish to pursue the accuracy of estimation. Information criterion which derives from maximizing the posterior likelihood in a model selection paradigm and enjoys widespread use in model identification provides a natural baseline. Akaike (1973) found a simple relationship between expected Kullback-Leibler information and Fisher's maximized log-likelihood function. This relationship leads to a simple, effective, and very general methodology for selecting a parsimonious model for the analysis of empirical data.

The general form of Information Criterion (IC) is: $IC_s = -2 \ln[L(M_s)] + P(m_s)$, where $L(M_s)$ is the value of the maximum likelihood function of the model, while $P(m_s)$ is the penalty function. Thus, the RS method should choose the model with smallest IC value. By using computer simulation, the investigation of the penalty function with different values of observations, variables and variance suggests that the AIC function by Akaike, BIC of Schwarz and CAI of Sugiura are all appropriate. Based on the results obtained in previous section, for given number of l , we have found the optimal segmentations and the corresponding estimation of the whole sample. Now the determination of l^0 will be obtained according to the IC criteria, i.e., the one which allows the greatest reduction in the IC value: $l^0 = \arg \min IC(l^0, i_1, i_2, \dots, i_{l^0})$.

Empirical Result and Discussion

Model Specification

As indicated in Ho and Cuervo (1999), "structural demand and supply" model would have been more appropriate compared with the VECM (Vector Error Correction Model) if the objective of the study were to establish causal relationships for structural analysis; to determine elasticities and multipliers for policy analysis; and to make forecasts for planning purposes. Because of these merits of system analysis, we will in this study look at the demand and supply of private housing market using simultaneous equation model. Our model extends the analysis in previous literature by proposing a new approach to structural modeling of the time series path of private housing market. This allows us to disentangle supply-side factors from demand-side influence, and in particular, the structural breaks

in housing market behaviors over time. Several important macro-economic determinants of private housing prices are identified and tabulated in **Table 1**.

The Demand Model

Private housing prices (RPPI)

In order to obtain an aggregate measurement of price level in the private residential property market, the private Residential Property Price Index (RPPI¹) is used. The RPPI data from first quarter of 1990 to the first quarter of 2004 is collected from REALIS²—Real Estate Information System.

Public Housing Prices (HDB)

Prices of public housing units serve as the benchmark of the price of private housing market. The Resale Price Index of HDB Flat³ was used as a proxy⁴. This HDB variable is supposed to capture the price level of public housing. This data is obtained from the website of Housing Development Board, where 1998Q4 is adopted as the base period with index at 100. The pricing of HDB flats is largely determined by the statutory board and is considered a policy decision, bearing in mind that affordability is the main thrust of public housing here, although it does take into account prevailing property market conditions.

The intermarket mobility between public and private market occurs as the income of the population increases and preferences change. Appreciation in the values of public flats enhances the affordability of flat-owners to upgrade. Upgraders, defined as those who upgrade from public to private housing, typically rely on the capital appreciation of their flats to enable them to purchase private properties (Ong, 1999).

On this account, the rising public resale price directly increased the accessibility of public home-owners to upgrade to private housing, which will transfer the public housing subsidies to private housing. So public housing price is an important determinant in demand for private housing. This upgrading effect exceeds the effect of being substitute for private housing. Therefore the HDB resale price is expected to be positively related to the demand for private housing.

National income (GDP⁵)

An earlier Ministry of Trade and Industry's article (2001) has

¹The Residential Property Price Index is computed for all residential transactions on a quarterly basis. It should be differentiated from the Property Price Index that is an agglomeration of residential, commercial and industrial property sales.

²This database is provided by Urban Redevelopment Authority (URA), the national planning authority of Singapore which is entrusted with the responsibility of planning the physical development and optimizing the scarce land resource in Singapore. The URA provides comprehensive and up-to-date data and information of the real estate market to improve the market's efficiency and transparency. The private residential property price indices published by the URA are transaction based indices compiled from caveats lodged with the Land Registry.

³The HDB Resale Price Index is based on the transactions of public Housing Development Board flats on the resale market. In other words, resale transactions are open-market transactions that occur subsequent to the initial sale, which is heavily subsidized by the government.

⁴Both RPPI and HDB resale price indexes are compiled based on transactions and do not suffer from the smoothing biases in appraisal price series.

⁵Rate of the GDP growth, used to estimate the changes in the income level, obtained from TRENDS, the Time Series Retrieval and Dissemination database maintained by the Department of Statistics in Singapore is used to construct the time-series for the variables identified in the model. All the variables are in their quarterly series. The TRENDS database is the national repository of macroeconomic variables and sector-specific variables for the Singapore economy. The reliability and integrity of this database, which is maintained and updated by the Ministry's DOS, are beyond any measure of doubt.

Table 1.

Private housing market determinants.

Demand Side Factors	Supply Side Factors
Private housing prices	Private housing stock
National income	Private housing price
Mortgage rate	Basic materials costs
Public housing prices	Labor costs
Consumer price index	Mortgage rate

shown that private residential property prices in Singapore are fundamentally driven by economic growth, which captures both the improvement in household purchasing power as well as population growth. Phang et al. (1995) also suggests that the fundamental of the private property market is determined by factors of the macro-economic environment.

Singapore's housing finance system allows the would-be private home buyers to use their monthly Central Provident Fund⁶ (CPF) contribution to pay off their mortgage debts. The contribution rates are adjustable and are positively related to medium to long term economic performance. This positive relationship implies that macroeconomic performance may directly affect the would-be home-buyers's housing affordability.

Ong and Sing (2002) provides evidence that real GDP is a significant variable reflecting the impact of long-run economic performance on the housing market. From the third quarter of 1986 until end of 1996, the growth of Singapore economy has been strong. The growth in household income and their CPF boosted the private housing market. Conversely, the poor economic performance in 1996 and 1997 has resulted in a dramatic fall in the prices of private properties. Therefore, GDP value is chosen as one of the potential key factors determining private housing prices, with a positive relationship expected.

Mortgage rate (PLR)

It has been suggested by economic theory that interest rates and house prices be inversely related. Generally, lower interest rates tend to increase housing demand, and therefore pushing up housing prices. However, this effect is softened by a similar increase in the supply of housing in response to higher house prices and lower construction financing costs result from reduced interest rates. Thus, interest rates influence house prices through the demand for, and supply of private housing. We use PLR (Prime Lending Rate)⁷ in our model, which is the average of nominal bank lending rate, serves as the measure of the cost of housing finance or the cost of borrowing.

Other variables

It is shown from housing economics literature that wage, as a

⁶CPF is the Singaporean's social security system, mainly providing pension schemes and medical care schemes. It is mandatory for both the employee and the employer to contribute monthly a certain fraction of the employees' salary to the fund to take care of the retirement, homeownership, and health-care needs of the members. The CPF Board was set up to administer and preserve the value of the savings of its members. The CPF enables easy home-ownership through two popular schemes—the Public Housing Scheme for HDB flats and the Residential Properties Scheme for all housing properties built on freehold land or with a lease of at least 60 years remaining.

⁷Prime leading rate, the average of nominal bank lending rate, obtained from International Financial Statistics (IFS), the International Monetary Fund's principal statistical publication and is the standard source for all aspects of international and domestic finance.

representative of the average real household income, could be an important factor affecting housing prices. Yet, wage rate per employee may not be a significant determinant in explaining private housing prices in Singapore. Private housing market in Singapore attracts either foreigners or local residents from middle or upper-middle income groups, whose incomes are not available in time-series format. Measurement bias would exist if simply using the average income for all employees. Therefore, household income is not included in our model for private housing demand.

Finally, demographic variable like household formation, which is often used in housing study of UK and US, is not included. The reason is that about 86 per cent of the population is absorbed by the public housing sector in Singapore, while private housing sector acts as the upper end of the home-owner's housing career. Therefore, new household formation is not expected to be significant in explaining private housing prices movements.

The Supply Model

In contrast to the demand side, housing supply is necessarily specified in terms of the flow of new investment. In the market for new construction, the supply of new housing units can be expected to increase in response to positive production signals provided by rising prices and/or declining costs.

Profit-maximizing firms will have a positive supply response to selling prices for structures and a negative response to their own costs of production (Basic material costs index base year 1985, and Labor cost index, collected from TRENDS). We use index of supply of private residential units in the pipelines⁸ as well as price and cost variables. Total housing stock⁹ is also included in the supply function and a negative sign is expected reflecting the responsiveness of new housing construction to housing stock. Given other factors unchanged, available urban land becomes scarce as the total housing stock increases. Higher negative responsiveness of new housing construction to the total housing stock would be an indication of a slow-down in new housing construction with respect to the level of housing stock, especially in a highly urbanized city state like Singapore.

Empirical Results

As discussed earlier, we have two endogenous variables—price and quantity¹⁰—and two equations determining them in the form of supply and demand equations. The error terms are likely to be correlated across equations as well, given the tight relationship between variables. Therefore we use three stage least squares instrumental variables estimator to avoid statistical problems involved with using endogenous explanators. We

⁸This comprises statistics on the supply of uncompleted private residential units in the pipeline. This supply in the pipeline covers all developments under construction as well those on which construction have not commenced. Developments on which construction have not commenced comprised those with written permission, provisional permission and those submitted to the Competent Authority and are under consideration for planning approval, and planned land sales by the government. The data are obtained from a combination of administrative records from the Development Control Division, URA and the Building and Construction Authority and field surveys to update the construction status.

⁹Stocks of completed private housing represented by available private residential units—from TRENDS.

¹⁰Private housing quantity (demanded and supplied) represented by the index of supply of private residential units in the pipelines, data collected from REALIS.

found all the series non-stationary in level. Rather than applying the commonly used error correction model, we use RS method to study the structure changes of private housing market. The analysis of data using RS method is implemented by the program written in SAS.

Using the whole sample data from 1991Q1 to 2004Q1, we have the simultaneous equations model for private housing market. All series are transformed to logarithmic form for the usual statistical reasons, and hence the variable coefficients estimate the percent change in quantity for a 1 percent change in the variable. Regression results and parameters estimation are shown in **Table 2**.

RS method then is applied to estimate the structural break during the data time period. **Figure 1** shows the corresponding value for e and l . Here we apply the system methods of detecting structural changes, i.e., we examine the structural instability globally, using the technique of joint estimation of the entire system of equations.

As can be seen from **Figure 1**, value of target function reduces dramatically, as the number of segments increases. Typically, its value starts to converge to 0 at point $l = 2$. Using Schwarz's Bayesian Criterion (SBC) to reconfirm our finding given $SBC_l = N \ln \left(\frac{e[\tilde{p}(N, l)]}{N} \right) + 2ml \ln N$, we have the following results as summarized in **Table 3**.

As can be seen the minimum value of SBC is reported at $l = 2$. Should there be one structural break during the sample period, the program implemented by SAS indicates that the 31st data point is the structural break point by using RS method. To further clarify this point, various tests and sensitivity analysis are conducted to justify the number of segments specified and to examine the general robustness of the model specification. The CUSUM and CUSUM of squares tests are applied to examine the stability of the coefficients. The test statistics were beyond the pair of 5-percent critical values for both tests indicating the instability of the coefficient and hence favor the significance of the stated structural change occurred at the above-mentioned date.

In view of this, we conclude that the optimal number of segments is 2, given the result from above tests. The corresponding periods are the first quarter of 1991 and the second quarter of 1999. This indicates one significant structural change during the whole sample period and suggests segmenting the data set into two sub-samples for further investigation. This can be simply illustrated by **Figure 2**.

Now we look at two parts separately. We have individual model whose estimation results are summarized in the **Tables 4** and **5**.

After taking into consideration of structural change, each individual segment achieves much better goodness-of-fit. Moreover, from the view of forecasting power, we find that the segmented model outperforms the whole sample model in term of prediction power. The model's efficiency is tested by dynamic simulation involving prediction and simulation under 'PROC SIMLIN' of the SAS software¹¹. The graphical plot of predicted and actual values of the endogenous variable, RPPI, against time is reproduced in the **Figures 3** and **4**. The figures show simulation results, where the simulation using the second segment indicate a forecast much more closer to the real data than

¹¹The SIMLIN procedure reads the coefficients for a set of linear structural difference equations (usually from a data set produced by PROC SYSLIN), computes the reduced form, and uses the reduced form equations to generate predicted and residual values for the endogenous variables.

Table 2. Structural Model Estimation for Private Housing Market in Singapore (using whole sample data).

<i>Regression Model:</i>	Demand Model	Supply Model
Variables:	Regression Coefficients	
Constant	-0.077 (0.082)	-0.003 (-0.008)
PLR	-0.158 (0.501)	-0.128 (0.148)
HDB	2.347 (2.609)	
GDP (one period lag)	0.126 (0.314)	
RPPI	-3.797 (4.999)	0.749 (0.196)
CPI	22.839 (25.056)	
BMC		-0.182 (0.966)
STOCK		-0.017 (0.115)

Note: values in the parentheses are standard errors for the coefficients.

Table 3. IC Test for value of *l*.

<i>l</i>	4	3	2	1
Target Function	0.122129	0.14006	0.198682	1.409757
SBC	-58.5252	-74.2742	-85.3134	-60.6964

Table 4. Structural model estimation for the first segment (91Q1-99Q1).

<i>Regression Model:</i>	Demand Model	Supply Model
Variables:	Regression Coefficients	
Constant	-0.026 (0.021)	0.008 (0.019)
PLR	-0.570* (0.201)	-0.081 (0.177)
HDB	0.322 (0.595)	
HDB(one period lag)	0.156 (0.178)	
GDP	0.283** (0.134)	
GDP (one period lag)	0.291** (0.148)	
RPPI	-0.262 (0.353)	0.834* (0.315)
RPPI (one period lag)	0.679* (0.387)	
CPI	4.047 (4.633)	-1.250 (4.410)
BMC		-0.429 (1.378)
STOCK		-0.017 (0.137)
LC (two periods lag)		-0.283* (0.113)

Note: values in the parentheses are standard errors for the coefficients; *(**) Denotes coefficient is significant at 1% (10%) level.

the prediction from whole sample data. This is firstly due to the occurrence of structural change during the sample period, resulting in the poor prediction performance out of an unstable series from the whole sample. Another reason behind is that the most recent past contains more information about the immediate future than the distant past and on this account, most recent regime may lead to better forecasts.

Discussion and Policy Implication

Singapore private residential property market is driven primarily by market demand and supply, although it is subjected

Table 5. Structural model estimation for the second segment (99Q2-04Q1).

<i>Regression Model:</i>	Demand Model	Supply Model
Variables:	Regression Coefficients	
Constant	-0.024** (0.010)	0.025** (0.012)
PLR (one period lag)	-0.108 (0.422)	-0.128 (0.148)
HDB	1.030** (0.476)	
GDP (one period lag)	0.255 (0.272)	
GDP (two period lag)	0.055 (0.254)	
RPPI	-0.081 (0.642)	0.412** (0.161)
RPPI (one period lag)	-0.126 (0.450)	
RPPI (two period lag)		0.173 (0.129)
CPI (two period lag)	3.390** (2.124)	
CPI	1.065 (1.962)	
Quantity demanded (two period lag)	(-0.225) (0.217)	
BMC		-0.326 (1.040)
LC		-0.051 (0.120)
LC (two period lag)		-0.131 (0.112)
STOCK		-3.565* (1.161)

Note: values in the parentheses are standard errors for the coefficients; *(**) Denotes coefficient is significant at 1% (10%) level.

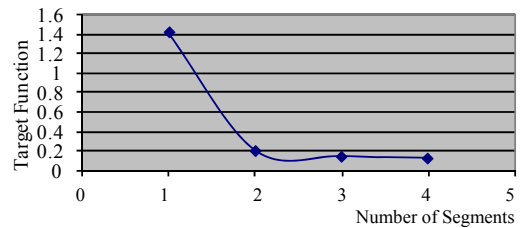


Figure 1. *e* VS *l*.

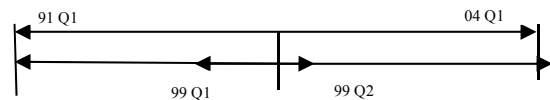


Figure 2. Segmentation of whole sample data.

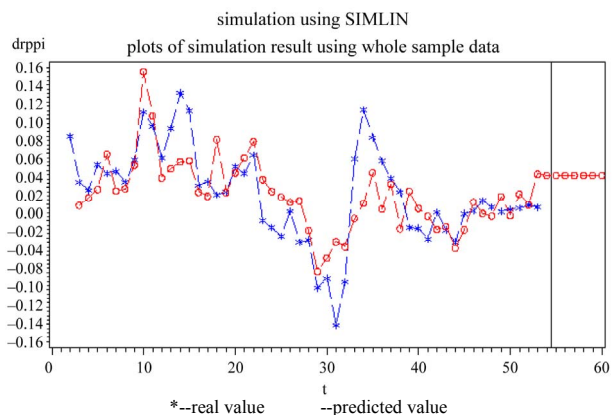


Figure 3. Simulation results using whole sample data.

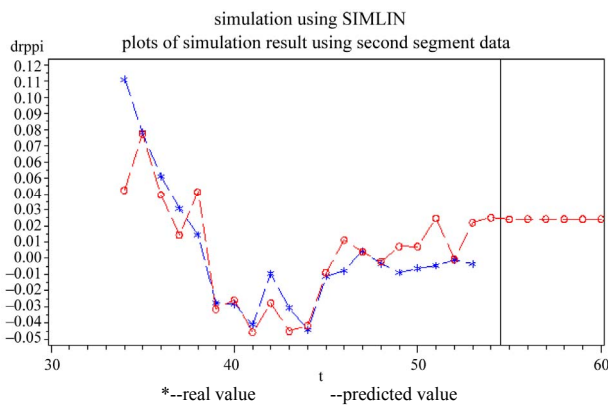


Figure 4. Simulation result using data from second segment.

to prudential government regulations and, to some extent, competition from public housing. It is important to model economic forces and market factors that drive the private housing market in Singapore, from the perspective of policy makers, developers as well as investors. That will help to improve the judgment of the market dynamics and thus to ensure a more effective implementation of housing policy.

Singapore private housing market has undergone cycles of boom and bust over the last twenty years. In early to mid of 1990's, the relaxation of the HDB rules and further liberalization of Mortgage Loan Financing Scheme had expanded demand and explained the sharp increase in the prices. In the following boom years of 1994-1996, prices in the residential markets more than doubled, driven by strong income growth, bullish stock market performance, ease of obtaining financing through banks and property speculation. The latest escalation in price of private housing had sustained until 15 May 1996 when some anti-speculative measures were imposed. The launch of Executive Condominiums¹² also set the benchmark of the private housing prices at a relatively low level.

Moreover, Singapore economy was badly affected by the global recession in the electronic sector in the fourth quarter of 1996, which resulted in several downward adjustments in the growth projection in the year. The transaction volume and the take-up rate of new private property fell dramatically. The RPPI index fell 1.9% and 2.7% in the third and fourth quarter of 1996. Subsequently, the Asian financial crisis and a recession in 1998 further weakened the property market, as prices bottomed out in the fourth quarter of 1998.

As discovered by our model, the private housing market experienced a significant structural change in year 1999. Prices of residential properties rose 11.4% in the 2nd Quarter 1999, compared with 4.4% in the previous quarter. Prices of landed properties rose 13.9% compared with 4.3% in the previous quarter, among which prices of semi-detached 15.7%, detached houses and terrace houses 13.4% and 13.1% respectively. Prices of non-landed properties rose 9.4%, compared with 4.5% in the previous quarter. Of this, prices of condominiums rose 9.0% while those of apartments increased by 10.5%. The number of private residential units under construction decreased by 6.6% to 30,455 units as at the end of 2nd Quarter 1999. The

¹²Executive condominium (EC) is a hybrid housing class that is created in the mid 1996 to meet the "sandwiched" class of young professionals, and also to stabilize the overheating private housing prices. The EC sites are sold by the government at discounts to make ECs more affordable.

number of uncompleted private residential units with sale licenses and building plan approvals declined 4.8%. A total of 1360 new private residential units were launched for sale in the 2nd Quarter 1999, 5.1% lower than the 1433 units launched in the 1st quarter. During the 2nd quarter, 2723 new private residential units were sold by developers, 17.8% lower than the 3313 units sold in the 1st quarter 1999. Moreover, the occupancy rate of completed private residential units as at end 2nd Quarter 1999 is 0.1% percentage point higher than the occupancy rate of the previous quarter.

From our segmented model we notice that, for demand side, price of private housing is significant, and reversely related, to housing demand in both two subsample periods. While the sign for price with one time lag change from positive for the first segment to negative for second segment. This could partly be explained by the decreasing demand for speculation purpose. GDP, together with its lag terms, remain to be significant and positively associate with demand in two subdomain of data. The coefficient of PLR is negative for both segments. The negative coefficient may be due to less demand for private housing as a result of a higher cost of borrowing money.

As shown from supply model, we find that, supply of private housing is conversely related to current housing stock, basic material cost and labor cost. Positive relationship is found between supply and price level. Especially for the 2nd segment, price with two periods lag becomes significant in determining housing supply. Another worth noting fact is the big jump of coefficient of stock in supply model, indicating an increasing responsiveness of new housing supply to the current stock.

As has been demonstrated by our model, the private housing market is sensitive to changes in the public housing market with high correlation coefficient. On this account, it should be realized by policy makers that the measures directed at the public housing sector may have increasingly significant implications for private housing price movements. This dynamics of these two markets normally reinforces each other and this calls for a more integrated approach to study the housing market as a whole.

The private housing market is expected to turnaround in late 2004, yet caution continues to reign. From demand side, well-located and reasonably priced projects continue to draw crowds to the show flats. However, potential home buyers and upgraders have been more prudent with their buys as the government move to encourage a more flexible wage system and in the light of CPF cuts. Uncertainty to the incomes of potential home owners is thus introduced. From the supply side, investment market is getting active with some developer restocking their residential landbank. Another positive fact is the number of unsold units in projects decreased. Some firmer signs of pick-up of the price are shown from these sale activities. Currently the mood in the private residential property market continues to be cautious. Buyers remain concerned in the light of the CPF cuts and ongoing restructuring of the economy.

Conclusion

In this paper, we have estimated structural models for housing supply and demand for Singapore private housing market that fit the data reasonably well for the chosen time periods. The RS regression model is established which is able to detect the structural changes in the market, without any prior information about the changing points or the timing of the external

shocks. This method provides a systematic and operational approach that can accurately detect structural changing points without any knowledge of the pattern and timing of possible structural shifts. The method is based on the principle of dynamic programming and the use of recursive regression allows global minimizers to be obtained using a number of sums of squared residuals rather than an exhaustive grid search.

By applying structural change analysis, we are able to detect the structural break point and segmented models show better goodness-of-fit in estimation and improved accuracy in forecasting. The structural changes we detect are proved to be consistent with policy change and external shocks to the model. Our model reconfirms the findings by Lum (2002), that demand and supply macro-variables are found to be significant determinant for private housing prices over the long run. The land sale program and the liberalization of public housing market were proven to be effective short-run policy tools adopted by government in stabilizing the private housing market.

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