Price Discovery between Private and Public Housing Markets

Seow-Eng Ong and Tien-Foo Sing

Urban Stud 2002; 39; 57

DOI: 10.1080/00420980220099069

Urban Studies, Vol. 39, No. 1, 57–67, 2002

Carfax Publishing
Taylor & Francis Group

Price Discovery between Private and Public Housing Markets

Seow-Eng Ong and Tien-Foo Sing

[Paper first received, September 2000; in final form, April 2001]

Summary. Public and private housing markets are usually differentiated in terms of price, regulations and policies, but they are not necessarily segmented. Any integration, as opposed to segmentation, between private and public markets implies that the prices of private housing are interrelated with the prices of public housing determined in the open market. If so, information revealed in one market will be pertinent for making inferences on prices in the other market. This paper addresses the price discovery or relation between public and private housing in view of Singapore's substantial public housing programme that has an actively traded secondary market. Implications for the direction of price causality and upward mobility for households between housing price strata are examined.

Introduction

Price discovery is about how agents discover the true value of assets among different markets (O'Hara, 1995). The literature on price discovery in real estate has focused primarily on unsecuritised and securitised real estate (Giliberto, 1990, 1993; Sagalyn, 1990; Chau *et al.*, 1998). The focus is to ascertain in which market price formation first occurs. The market in which price formation occurs is deemed to lead the other market. Research on price discovery between different segments of the unsecuritised real estate market has been confined to the price interaction between housing sub-markets defined along geographical lines (He and Winder, 1999). Price discovery between housing sub-markets is a natural extension to the academic literature on housing sub-markets (Maclennan and Tu, 1996; Tu and Goldfinch, 1996).

This study focuses on the price discovery and interaction between public and private housing markets using Singapore as a case study.[1] Singapore provides an ideal case for study since the public housing market is the dominant form of housing and an active secondary market exists for public housing. More than 80 per cent of the population lives in public housing provided by the government through the statutory board, the Housing Development Board (Teo and Kong, 1997). Public housing is heavily subsidised when purchased directly from Housing Development Board (HDB), but buyers are permitted to sell their flats in the open market after a time-bar of 5 years. The HDB resale secondary market is an active and dynamic one. In the second quarter of 1998, a total of 14 357 resale transactions took place in contrast to only 1542 private (non-public) residential property transactions.

Seow-Eng Ong and Tien-Foo Sing are in the Department of Real Estate, School of Design and Environment, National University of Singapore, 4 Architecture Drive, Singapore 117566. Fax: 65 774 8684. E-mail: seong@nus.edu.sg and rststf@nus.edu.sg. *The authors would like to thank two anonymous referees for their helpful comments and members of the steering committee for the Housing Policy and Research Group for comments during the initial stages of this research.*

0042-0980 Print/1360-063X On-line/02/010057-11
DOI: 10.1080/0042098022009906 9

Another important feature of the Singapore housing market is that the prices of private housing are much higher than those of public housing.[2] In spite of this, there exists a steady stream of HDB flat-owners who switch or upgrade to private housing. The existence of two distinct and separate housing markets differentiated by price enables us to make inferences, in the wider context, about price discovery between properties in different price strata.

Given that the public flats resale market is a substantial and active segment of the residential market in Singapore, the research question is whether, and to what extent, the prices of public and private housing markets interact. Do resale flat prices provide information relating to the value of private residential properties? Or perhaps the converse is true, that the public resale market takes its cue from the private property market? This paper seeks to examine the process of price discovery between the public and private residential property markets by analysing the relations between their prices and returns.

This paper is motivated by two hypotheses—the upgrading and market-forces hypotheses—that characterise the price discovery process between housing markets in Singapore. The upgrading hypothesis says that, in a land-scare economy with a dominant public housing market, home-owners are able to upgrade to private property as a result of capital appreciation on their public flats. Thus, price changes in the public housing market should affect those in the private housing market. In contrast, the market-forces hypothesis notes that the public housing market is more regulated and is consequently less responsive to economic forces. Hence, the private housing market tends to respond to changes first, and returns in the private market lead those in the public housing market.

In testing the hypotheses, the results show that a long-term cointegrating relationship exists between the prices of public and private housing. Given the relatively short time series for public prices, we have turned to the autoregressive distributed lag (ARDL) methodology advocated by Pesaran and Shin (1998) and Pesaran *et al.* (1996). The presence of cointegration necessitates the estimation of an error correction model and tests for price discovery between public and private housing returns are carried out in a Granger causality-error correction framework. We find that price discovery is bidirectional in that past public and private housing returns both affect the current public and private housing returns.

The next section provides a brief review of the literature in price discovery and the theoretical motivation is discussed in the following section. The well-accepted methodology for cointegration is then detailed, followed by the empirical results. The last section concludes.

Literature Review

The literature on the relations between unsecuritised and securitised real estate markets can be viewed from two perspectives: short-term and long-term relations. Short-term relations cover cross-correlation (Firstenberg *et al.*, 1988; Sagalyn, 1990), autocorrelations (Blundell and Ward, 1987; MacGregor and Nanthakumaran, 1992) and causality tests (Myer and Webb, 1993; Gyourko and Keim, 1992, 1993; and Barkham and Geltner, 1995, 1996). Macroeconomic factors also explain price changes in securitised real estate (Mueller and Laposa, 1995; Seck, 1996).

Studies that analyse long-term relation between direct and securitised real estate prices typically test for a cointegration relation (Ong, 1994, 1995; Matysiak *et al.*, 1996). Evidence of cointegration means that a long-term equilibrium relation exists between direct and securitised property prices. More recently, He (1998) examined the price discovery between equity and mortgage REITs.

However, very few studies have attempted to test for price discovery by simultaneously capturing long-term and short-term relations. In particular, this paper applies a test of Granger causality in an error-correction framework. The error correction term captures any long-term cointegrating relation while the short-term dynamics are captured in the lagged returns (for details, please refer to the Methodology section).

As far as we know, the process of price discovery between public and private property markets has not been well examined. This is due, in part, to the lack of a well-established market-oriented mechanism for public housing transactions in most countries.

Motivation for Price Discovery between Public and Private Housing Markets

One view is that the public and private real estate markets are segmented since they cater for different economic-demographic groups and face different sets of demand and supply conditions. This view suggests that price discovery within the two markets is independent. The second view is that public and private real estate markets, although operating under different demand and supply conditions, are interrelated for the following reasons.

First, intermarket mobility between the two markets occurs as the income of the population increases and preferences change. In land-scarce Singapore, for instance, ownership of private residential property confers social status. Since most of the population is housed in public flats, the aspiration of many Singaporeans is to upgrade to private property. In Singapore, it is estimated that upgraders constitute about 60 per cent of annual demand for private housing (Ong, 1999). In contrast, the elderly owners of private properties have been known to downgrade by selling their private houses and moving into public housing after their dependents grow up and move out.

Secondly, public housing is viewed as an "investment of a large part of [flat-owners'] long term savings" (Chua, 2000, p. 49). In other words, public housing is a source of wealth. 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 (Lum, 1996; Ong, 1999). By this reasoning, changes in the prices of public flats should increase the potential demand for private housing and, consequently, boost the prices of private properties. This linkage is a two-sided sword. As the value of a public flat falls, so does the affordability of the upgrader. This would mean that prices of private dwellings would subsequently fall as well (Ong, 1998).

Thirdly, changes in the regulations affecting the ownership of public housing may also affect prices in the private property market (Phang and Wong, 1997). One example of this is the relaxation of financing for resale flats in Singapore in 1992. Prior to 1992, loans to finance resale flats were based on board values but, subsequently, loans have been pegged to market values.

The reasons cited above motivate a causal relation between the public and private housing markets in Singapore. More specifically, price changes in the public market should lead price changes in the private market. This will be referred to as the 'upgrading hypothesis.'

However, an alternative view is that the private residential market should lead the public housing market. This can be so for a few reasons. First, the public property market is subject to more stringent rules and regulations (Chua, 1991). For instance, owners of public flats can only sell their flats to qualified buyers, defined as buyers forming a family unit subject to a household income ceiling.[3] Furthermore, buyers of new HDB flats are barred from selling for 5 years. In contrast, the regulation of the private residential market is less stringent. The public housing market is modulated by regulatory restrictions and is less sensitive to changes in underlying factors affecting the demand for housing. Macroeconomic changes are more likely to affect the private residential market first.

Secondly, the supply of public housing in Singapore is determined entirely by the authorities, while the supply for private residential properties is determined by market forces (see Yuen *et al.*, 1999, for an extensive review). Since the objective of public housing in Singapore is to a large extent, social and political in orientation (Chua, 1991, 2000; and Ooi, 1992), the supply of public housing should be more stable. Changes in the supply of private housing, on the other hand, are determined by market forces and can be more volatile. To the extent that the supply of resale flats is underpinned by the supply of new flats, this line of reasoning argues that price discovery should occur in the private property market.

Thirdly, the prices of new HDB flats provide a floor for resale flats. New flat prices are set by the Housing and Development Board and are subsidised. The rate of adjustment for new flat prices does not depend on market forces. Instead, prices depend on social factors and affordability considerations. Since flat-owners can sell their flats in the resale market after 5 years, the prices of resale flats are determined by market forces subject to the restrictions mentioned above. The buyers of resale flats are typically eligible families who prefer to purchase on the resale market rather than directly from HDB. The prices of resale HDB flats are usually higher than those for new flats. Since the alternative to buying on the resale market is to purchase directly from HDB, the prices of new HDB flats act as a floor. In contrast, no floor exists for the private housing market.[4]

We refer to such a private-market-led phenomenon as the 'market-forces hypothesis.' The actual price discovery between public and private housing markets (in Singapore) is an empirical question this paper attempts to address.

Data

The most widely used indicator of private property prices in Singapore is the Urban Redevelopment Authority (URA) Residential Property Price Index.[5] Public property prices are captured in the Housing and Development Board (HDB) Resale Price Index.[6] Both price indexes are compiled based on transactions and do not suffer from the smoothing biases in appraisal price series.[7] The HDB Resale Price Index started only in 1990. Hence, our analysis will commence only from 1Q1990 through 1Q1999. Summary statistics for both price indexes are tabulated in Table 1.

All price data are transformed by taking the log so that the difference in the log of the price variable can be interpreted as the relative price change or return.[9] Tests for unit roots (Dickey and Fuller, 1979, 1981) are tabulated in Table 2. For the DF and ADF tests, the optimal lag is ascertained by searching from a maximum lag of 4.[9] The DF and ADF tests are carried out with and without trend. Both price indexes have t statistics that are above the 5 per cent critical value for 33 observations of -2.9558, indicating that the null hypothesis cannot be rejected. Unit root tests on the first differences in the price indexes provide t statistics of less than -2.00. Although the t statistics are still higher than the critical value, this could be due to the short nature of the time series (34 quarters). Other works (Ong, 1994, 1995) have encountered the same problem in the private property price index, but concluded that the first difference in the private property price index is stationary. However, since the HDB resale price index starts only in 1990 and no data exist before then, we cannot

Table 1. Descriptive statistics

Variable	N	Mean	Standard deviation	Minimum	Maximum
PPI	37	5.2108	0.4039	4.5829	5.7513
HDB	37	5.3058	0.5293	4.5921	6.0068
ΔPPI	36	1.6732	6.1341	−14.0742	13.0579
ΔHDB	36	3.0139	6.7730	−7.5215	27.2515

Table 2. Tests for unit roots

	DF		ADF			
	Level	Difference	Level (1 lag)	Level (2 lags)	Difference (1 lag)	Difference (2 lags)
PPI	− 1.84	− 2.18	− 1.71	− 1.76	− 2.43	− 2.43
HDB	− 1.28	− 2.62	− 1.41	− 1.27	− 2.76	− 1.94

Note: Critical value for ADF statistic = − 2.9558 (5 per cent).

conclude with any probability the order of integration for the HDB resale price index.

Methodology

The well-established approach to testing for long-run relations between variables is the Engle–Granger (1987) bivariate cointegration test. However, the approach requires that the relevant variables (regressors) must be integrated of order 1 before the cointegration test can be carried out. The ability of unit root tests to detect the order of integration depends, in part, on the length of the time series. A time series may appear to be non-stationary over a short time-horizon, but stationary over a longer period. As the time-period for this study is relatively short (9 years), the Engle–Granger approach may not be the most suitable approach (Shiller and Perron, 1985).

We employ the autoregressive distributed lag (ARDL) approach of testing for cointegration, as advocated in Pesaran *et al.* (1996) and Pesaran and Shin (1998). The advantage of the ARDL approach is that it can be applied regardless of whether the regressors are $I(0)$ or $I(1)$. The first stage of the ARDL approach requires an F test of the existence of the long-run relation between private and public house prices. Essentially, the lagged level terms are added to an error correction form of the underlying ARDL model. Given that there are only two quarterly price variables in our model, the error correction ARDL model with 4 lags, denoted as ARDL(4, 4), is

$$\Delta HBD_t = a_0 + \sum_{i=1}^{4} b_i \Delta HBD_{t-i} + \sum_{i=1}^{4} c_i \Delta PPI_{t-i} + \delta_1 HBD_{t-1} + \delta_2 PPI_{t-1} + u_t \quad (1)$$

where, HDB_t and PPI_t are the price indexes for public and private property, respectively, at time t. The Δ prefix denotes the first difference or returns.

The null hypothesis of no cointegration in the two prices is H_0: $\delta_1 = \delta_2 = 0$ against the alternative hypothesis H_1: $\delta_1 \neq 0$, $\delta_2 \neq 0$. The F statistic for testing the joint null hypothesis has a non-standard distribution regardless of whether *HDB* and *PPI* are $I(0)$ or $I(1)$. Based on the critical value bounds computed by Pesaran, *et al.* (1996), the critical value bounds for one forcing variable (*PPI* in the above equation) at 95 per cent are 4.934 and 5.764. The null hypothesis is rejected if the computed F statistic is above the upper critical value bound; hence the ARDL approach to test for cointegration is also referred to as the bounds test.

The second stage of the ARDL approach is to estimate the coefficients of the long-run cointegrating relation and the corresponding error correction model. The long-run cointegrating regression is

$$HDB_t = \alpha + \beta PPI_t + e_t \quad (2)$$

The appropriate lag structure of the error correction model is determined by way of three model selection criteria: Schwarz Bayesian criteria (SBC), Akaike information criteria (AIC) and the Hanna Quinn criteria

(HQC). A maximum lag of 4 is specified in this study in view of the quarterly data and limited number of observations. The error correction model will be

$$\Delta HBD_t = a_0 + \sum_{i=1}^{J} b_i \Delta HBD_{t-i} + \sum_{i=1}^{K} c_i \Delta PPI_{t-i} + \gamma \hat{e}_{t-1} + \upsilon_t \quad (3)$$

where, $\hat{e}_{t-1}$ is the lagged error correction term. The lagged error correction term is an important element in the dynamics of cointegrated systems in that it allows for adjustment back to the long-term equilibrium relationship given a deviation in the last period.

The ARDL approach described above assumes that the relevant dependent variable is public house prices (*HDB*). The entire procedure is repeated using the private house price (*PPI*) as the dependent variable

$$\Delta PPI_t = a_1 + \sum_{i=1}^{4} b_{1i} \Delta PPI_{t-i} + \sum_{i=1}^{4} c_{1i} \Delta HBD_{t-i} + \delta_{11} PPI_{t-1} + \delta_{12} HBD_{t-1} + u_{1t} \quad (4)$$

$$PPI_t = \alpha_1 + \beta_1 HBD_t + \vartheta_t \quad (5)$$

$$\Delta PPI_t = a_1 + \sum_{i=1}^{J} b_{1i} \Delta PPI_{t-i} + \sum_{i=1}^{K} c_{1i} \Delta HBD_{t-i} + \gamma_1 \hat{\vartheta}_{t-1} + \upsilon_{1t} \quad (6)$$

Finally, we test for Granger causality (Granger, 1969) using the Granger causality-ECM framework where additional lags of the right-hand-side variables are introduced

$$\Delta HBD_i = \sum_{j=1}^{J} \phi_j \Delta HBD_{t-j} + \sum_{j=0}^{J} \lambda_j \Delta PPI_{t-j} + \gamma \hat{e}_{t-1} + u_t \quad (7)$$

The conventional F test is then conducted to see if the lagged changes in private property returns have a causal effect on the changes in public property returns, and vice versa. The null hypothesis is that $\lambda_1 = \lambda_2 = \dots \lambda_J = 0$. Studies such as Miller and Russek (1990, 1991) and Fung and Isberg (1992) show that Granger causality may not be detected using the standard test, but incorporating the error correction term enables causality to be detected. Moreover, Granger (1986) notes that the existence of significant error correction terms is evidence of causality in at least one direction. Thus the significance of the error correction terms will also be examined. If changes in the private price index Granger-cause the changes in the public price index, then private property returns are strongly exogenous to public property returns. Evidence of causality is also indicative that the past history of price changes contains valuable information for future price movements.

If the null hypothesis that $\lambda_1 = \lambda_2 = \dots \lambda_J = 0$ is rejected, then we conclude that the market-forces hypothesis holds since private property returns Granger-cause public property returns. By the same rationale, if public property returns Granger-cause private property returns in equation (8), then the upgrading hypothesis is supported.

$$\Delta PPI_i = \sum_{j=1}^{J} \phi_j \Delta PPI_{t-j} + \sum_{j=0}^{J} \lambda_j \Delta HBD_{t-j} + \gamma \hat{\vartheta}_{t-1} + \nu_t \quad (8)$$

It should be noted that the two hypotheses are not mutually exclusive; it is possible that the past history of public and private property returns affects current returns.

Empirical Results

Bounds Test for Cointegration

The ARDL models are specified as in equations (1) and (4) with a maximum of 4 lags. The F statistics for including the lagged level prices (HDB_{t-1} and PPI_{t-1}) are summarised in Table 3. The critical value bounds are 4.934 and 5.764 for one forcing variable (Pesaran *et al.*, 1996). The computed F statistic for including *HDB* and *PPI* in equation (1) is 5.9292 and exceeds the upper bound of the critical value band. We reject the null hypothesis of no long-run relationship between *HDB* and *PPI*.

The F statistic for the lagged level terms in

Table 3. Bounds test for lagged level variables in ARDL (4,4) models

Dependent variable	F statistic
ΔHDB	5.0355*
ΔPPI	5.9292**

**indicates statistically significant at the 5 per cent level; *indicates statistically significant at the 10 per cent level.
Note: Upper bound critical value = 5.764 (5 per cent) and 4.788 (10 per cent)

equation (4) is 5.0355 and is below the upper band at 95 per cent. However, the computed F statistic exceeds the upper band critical value at the 90 per cent level of 4.788. A robustness check over shorter lags reveals that if only 2 lags were specified in equation (4), then the F statistic for including HDB_{t-1} and PPI_{t-1} is 5.8313. Given the relatively small sample size, we interpret the evidence to reject the null hypothesis of no long-run relationship between *HDB* and *PPI*.

The long-run relationships are estimated next as in equations (2) and (5). The results are summarised in Table 4.

Error Correction Models

As noted earlier, since the private and public property prices are cointegrated, price changes must be modelled with an error correction term. The appropriate lags (J and K) in equations (3) and (6) are ascertained by maximising the Schwarz Bayesian criteria (SBC), Akaike information criteria (AIC) and Hanna Quinn criteria (HQC). The results (not reported) indicated 2 lags in *HDB* and 3 lags in *PPI* for modelling public housing prices and 2 lags in *PPI* and 3 lags in *HDB* for the private housing price equation.[10] Taking the first difference and including the lagged error correction term, the ARDL models are then estimated. The results are tabulated in Table 5.

We note that the lagged error correction terms are both negative and significant as expected. The coefficients of -0.2548 and -0.1416 for the lagged error correction terms in equations (3) and (6) respectively, suggest a moderate rate of convergence to equilibrium. As Engle and Granger (1987) noted, the significance of the lagged error correction term is indicative of causality. In other words, a deviation from the long-term relation between the private and public price indexes will result in a reversion in the public property prices, and vice versa. This suggests that both public and private property prices respond to deviations from the long-run cointegrating relation.

Granger Causality

A test for Granger causality is conducted as in equations (7) and (8) with different lags (J), ranging from 2 to 4. We do not assume, *a priori*, the lag structure determined under the ARDL approach since that would be contradictory to the spirit of the Granger causality test. The results are reported in Table 6. First, we note that the F statistics for omitting the lagged private property returns in predicting public property returns are statistically significant for all lags tested.

Table 4. Estimated long-run coefficients using the ARDL (2, 3) approach

	PPI			*HDB*		
	Coefficient	Standard error	t	Coefficient	Standard error	t
Constant	2.0948**	0.7819	2.68	−1.0925**	0.4522	2.42
HDB	0.5868**	0.1455	4.03			
PPI				1.2369**	0.0858	14.42

**indicates coefficient is significant at the 5 per cent level.
Note: Adjusted $R^2 = 0.9322$.

Table 5. Error correction models

Regressor	Coefficient	Standard error	T Ratio (probability)
Panel A: ARDL(2, 3)-ECM model for ΔHDB			
Constant	−0.2785*	0.1264	−2.20 (0.036)
ΔHDB_{t-1}	0.6169*	0.1399	4.41 (0.000)
ΔPPI_t	0.5804*	0.1902	3.05 (0.005)
ΔPPI_{t-1}	−0.5157	0.2757	−1.87 (0.072)
ΔPPI_{t-2}	−0.4456	0.2288	−1.95 (0.062)
$\hat{e}_{t-1}$	−0.2548*	0.0662	−3.85 (0.001)
Adjusted $R^2 = 0.6675$			
Panel B: ARDL(2, 3)-ECM model for ΔPPI			
Constant	0.2966*	0.0955	3.10 (0.004)
ΔPPI_{t-1}	0.7397*	0.1879	3.93 (0.001)
ΔHDB_t	0.4834*	0.1329	3.63 (0.001)
ΔHDB_{t-1}	−0.3398*	0.1629	−2.09 (0.047)
ΔHDB_{t-2}	0.2029	0.1194	1.69 (0.101)
$\hat{\vartheta}_{t-1}$	−0.1416*	0.0661	−2.14 (0.041)
Adjusted $R^2 = 0.7114$			

Table 6. Granger causality tests

	F Test (p values in parenthesis)		
Max lag (J)	2	3	4
ΔPPI gcΔHDB	5.47** (0.01)	3.27** (0.04)	2.37* (0.08)
ΔHDB gcΔPPI	3.76** (0.04)	2.54* (0.08)	1.78 (0.16)

**indicates statistically significant at the 5 per cent level; *indicates statistically significant at the 10 per cent level.

Note: gc means Granger-cause.

This means that private property returns Granger-cause public property returns. However, if the error correction term is excluded from the Granger causality test, then an erroneous conclusion that the lagged *PPI* returns are not significant in explaining the current *HDB* return would be obtained (results not reported). This, in addition to the observation made earlier about the significance of the $\hat{e}_{t-1}$ term, reinforces the point made by as Miller and Russek (1990, 1991) and Fung and Isberg (1992) that Granger causality results can be misleading if the error correction term is incorrectly omitted.

Secondly, lagged *HDB* returns weakly Granger-cause the current *PPI* return. The F statistic is significant at the 5 per cent level only if 2 lags are used. Lags in *HDB* returns in excess of 2 lags are not significant in determining *PPI* return. Given the finding that Granger causality is stronger from private to public property returns, we conclude that private property (*PPI*) returns lead the public property (*HDB*) returns. This lead relation is approximately 2 quarters.

The evidence from the Granger causality tests supports the market-force hypothesis and, to a limited extent, the upgrading hypothesis. In addition, the significant lagged error correction terms mean that private and public property prices tend to revert to the long-run relationship should any deviation occur in the short run. The evidence of cointegration means also that the public and private housing markets are integrated and that prices are interrelated over time.

Conclusion

Even though the public and private housing markets of Singapore are differentiated by price levels, regulations and policies, this study postulates that their prices could be interrelated through intermarket mobility and price discovery could occur through market forces. The empirical results show that the prices of public and private housing exhibit a contemporaneous long-run relationship, which suggests that the two markets are not segmented but are in fact integrated.

In addition, the presence of cointegration means that deviations from the long-term relationship tend to be corrected over the short run. As Granger (1986) noted, cointegration is evidence of causality. In addition, when public and private house prices are cointegrated, tests for price discovery between public and private housing returns are to be carried out in a Granger causality-error correction framework.

Evidence of causality is established in that past public housing returns affect the current private housing returns and vice versa. The bi-directional causality supports both the upgrading and market-forces hypotheses, and is clear evidence that price discovery occurs between the public and private housing markets. In other words, past price movements in one market provide useful information for understanding the current price movement in the other market. We also find that the causality from private to public housing markets is stronger that the other way around.

Such information will be pertinent to real estate analysts, urban economists and planners, and households desiring to move between housing markets. The first implication is that any policy decisions affecting one housing market are likely to impact the other, albeit with a time lag. Hence, any changes in supply, financing or regulations affecting the public housing market are likely to affect the private housing market as well. Likewise, developments in the private housing market, being more sensitive to macroeconomic factors, are likely to filter through to the public housing market subsequently.

Secondly, any analysis or projection in market outlook for the private housing market (as it is frequently done) is incomplete without incorporating the analysis or outlook for the public housing market. A final policy implication is that an integrated approach to studying the housing market, encompassing both the public and private housing markets, should be adopted.

In the wider context, the work here suggests that prices of housing sub-markets characterised by price stratum may be interrelated. Future work could test if a similar relation holds in other countries. In addition, ongoing research is undertaken to evaluate the ability of the price discovery mechanism to forecast price movements.

Notes

1. Public housing refers to housing provided by public authorities or municipalities, while private housing refers to housing built by private developers.
2. The desire to upgrade to private housing has been labelled the ‘Singapore dream’ (Chua, 2000).
3. In recent years, singles have been allowed to purchase HDB flats as well, but certain conditions apply.
4. It can be argued that the prices of public flats act as a floor for private house prices. By this logic, it can be inferred that private house prices should lead prices for HDB flats.
5. The URA Residential Property Price Index is computed for all residential transactions on a quarterly basis. It should be differentiated from the URA Property Price Index that is an agglomeration of residential, commercial and industrial property sales.
6. The 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 subsidised by the government.
7. These price indexes are not quality-controlled. Since no quality-controlled price index for Singapore is available, we recognise this as a data limitation.

8. The returns are in nominal terms. Since inflation in Singapore is low and stable, the quarterly changes in inflation are of small magnitudes. In addition, adjustment for inflation would affect both variables to the same extent.
9. The maximum lag is set at 4 due to the limited number of observations (34 quarters).
10. The Schwarz Bayesian Criteria (SBC) is maximised at 2 lags in *PPI* and 1 lag in HDB. But the other two criteria are maximised at 2 and 3 lags.

References

BARKHAM, R. and GELTNER, D. (1995) Price discovery in American and British property markets, *Real Estate Economics*, 23, pp. 21–44.

BARKHAM, R. and GELTNER, D. (1996) Price discovery and efficiency in the UK housing market, *Journal of Housing Economics*, 5, pp. 41–63.

BLUNDELL, G. F. and WARD, C. W. (1987) Property portfolio allocation: a multi-factor model, *Land Development Studies*, 4, pp. 145–156.

CHAU, K. W., MACGREGOR, B. D. and SCHWANN, G. M. (1998) *Price discovery in the Hong Kong real estate market*. Paper presented at the *AREUEA-ERES International Conference*, Maastricht.

CHUA, B. H. (1991) Not depoliticized but ideologically successful: the public housing program in Singapore, *International Journal of Urban and Regional Research*, 15, pp. 24–41.

CHUA, B. H. (2000) Public housing residents as clients of the state, *Housing Studies*, 15, pp. 46–60.

DICKEY, D. A. and FULLER, W. A. (1979) Distributions of the estimators for autoregressive time series with a unit root, *Journal of the American Statistical Association,* 74, pp. 427–431.

DICKEY, D. A. and FULLER, W. A. (1981) Likelihood ratio statistics for autoregressive time series with a unit root, *Econometrica*, 49, pp. 1057–1072.

ENGLE, R. F. and GRANGER, C. W. J. (1987) Co-integration and error correction: representation, estimation and testing, *Econometrica,* 55, pp. 251–276.

FIRSTENBERG, P. A., ROSS, S. A. and ZISLER, R. C. (1988) Real estate: the whole story, *Journal of Portfolio Management*, 3, pp. 22–34.

FUNG, G. G. and ISBERG, S. C. (1992) The international transmission of eurodollar and US interest rates: a cointegration analysis, *Journal of Banking and Finance*, 16, pp. 757–769.

GILIBERTO, M. S. (1990) Equity real estate investment trusts and real estate returns, *Journal of Real Estate Research*, 5, pp. 259–264.

GILIBERTO, M. S. (1993) Measuring real estate returns: the heged REIT index, *The Journal of Portfolio Management*, 19(3), pp. 94–99.

GRANGER, C. W. J. (1969) Investigating causal relations by econometric models and cross spectral methods, *Econometrica*, 43, pp. 617–633.

GRANGER, C. W. J. (1986) Development in the study of cointegrated economic variables, *Oxford Bulletin of Economics and Statistics*, 48, pp. 213–228.

GRANGER, C. W. J. and NEWBOLD, P. (1974) Spurious regressions in econometrics, *Journal of Econometrics*, 2, pp. 111–120.

GYOURKO, J. and KEIM, D. (1992) What does the stock market tell us about real estate returns?, *Journal of the American Real Estate and Urban Economics Association*, 20, pp. 457–486.

GYOURKO, J. and KEIM, D. (1993) Risk and return in real estate: evidence from a real estate stock index, *Financial Analysts Journal*, September, pp. 39–46.

HE, L. T. (1998) Cointegration and price discovery between equity and mortgage REITs, *Journal of Real Estate Research*, 16, pp. 327–337.

HE, L. T. and WINDER, R. C. (1999) Price causality between adjacent housing markets within a metropolitan area: a case study, *Journal of Real Estate Portfolio Management*, 5, pp. 47–58.

LUM, S. K. (1996) *The Singapore private property market-price trends and affordability*. Paper presented at the *NUS InterFaculty Conference on 'The Singapore Dream: Private Property, Social Expectations & Public Policy'*.

MACGREGOR, B. D. and NANTHAKUMARAN, N. (1992) The allocation to property in the multi-asset portfolio: the evidence and theory revisited, *Journal of Property Research*, 9, pp. 5–32.

MACLENNAN, D. and TU, Y. (1996) Economic perspectives on the structure of local housing systems, *Housing Studies*, 11, pp. 387–406.

MATYSIAK, G., HOESLI, M., MACGREGOR, B. D. and NANTHAKUMARAN, N. (1996) The long-term inflation-hedging characteristics of UK commercial property, *Journal of Property Finance*, 7(1), pp. 50–61.

MILLER, S. and RUSSEK, F. (1990) Cointegration and error correction models: the temporal causality between government taxes and spending, *Southern Economic Journal*, 57, pp. 221–229.

MILLER, S. and RUSSEK, F. (1991) The temporal causality between fiscal deficits and interest rates, *Contemporary Policy Issues*, 9, pp. 12–23.

MUELLER, G. R. and LAPOSA, S. P. (1995) *Factors affecting public REIT pricing*. Working paper, ABKB/LaSalle Securities Ltd.

MYER, F. C. N. and WEBB, J. R. (1993) Return properties of equity REITs, common stock and commercial real estate, *Journal of Real Estate Research*, 8, pp. 87–106.

O'HARA, M. (1995) *Market Microstructure Theory*. Cambridge, MA: Basil Blackwell.

ONG, S. E. (1994) Structural and vector autoregressive approaches to modeling real estate and property stock prices in Singapore, *Journal of Property Finance*, 5(4), pp. 4–18.

ONG, S. E. (1995) Singapore real estate and property stocks: a cointegration test, *Journal of Property Research*, 12, pp. 29–39.

ONG, S. E. (1998) Affordability and the threshold buyer: effect of interest rate and CPF changes on property prices, *The Real Estate Times*, 1(2), pp. 79–85.

ONG, S. E. (1999) *Housing affordability and upward mobility from public to private housing in Singapore*. Paper presented to the *Workshop on Housing Policy in Emerging Economies*, Singapore.

OOI, G. L. (1992) Managing change and continuity in the public housing process in Singapore, *Ekistics*, 354, pp. 170–179.

PESARAN, M. H. and SHIN, Y. (1998) An autoregressive distributed lag modeling approach to cointegration analysis, in: S. STROM, A. HOLLY and P. DIAMOND (Eds) *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium*, pp. 371–413. Cambridge: Cambridge University Press.

PESARAN, M. H., SHIN, Y. and SMITH, R. J. (1996) *Testing for the existence of a long run relationship*. Working Paper No. 9622, Department of Applied Economics, University of Cambridge.

PHANG, S. Y. and WONG, W. K. (1997) Government policies and private housing prices in Singapore, *Urban Studies*, 34, pp. 1819–1829.

SAGALYN, L. B. (1990) Real estate risk and the business cycle: evidence from security markets, *Journal of Real Estate Research*, 5, pp. 203–219.

SECK, D. (1996) The substitutability of real estate assets, *Real Estate Economics*, 24, pp. 75–95.

SHILLER, R. J. and PERRON, P. (1985) Testing the random walk hypothesis: power versus frequency of observation, *Economic Letters*, 18, pp. 381–386.

TEO, S. E. and KONG, L. (1997) Public housing in Singapore: interpreting 'quality' in the 1990s, *Urban Studies*, 34, pp. 441–452.

TU, Y. and GOLDFINCH, J. (1996) A two-stage housing choice forecasting model, *Urban Studies*, 33, pp. 517–537.

YUEN, B., TEO, H. P. and OOI, G. L. (1999) *Singapore Housing: An Annotated Bibliography*. Singapore: National University of Singapore.