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Price dynamics in public and private housing markets in Singapore ☆

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Abstract

In down-payment constrained housing consumption models, increases in house prices could trigger household mobility decisions in housing markets. This study empirically tests house price dynamics associated with the mobility of households in the public resale and private housing markets in Singapore. The results show that stochastic permanent breaks were found in the public housing resale prices and private housing prices. The relative prices drift apart occasionally, but mean-revert to a long-run fundamental equilibrium. Error correction mechanisms and lagged public housing prices were also found to have significant explanatory effects for price changes in the private housing markets. The results support the hypothesis that household mobility creates co-movements of prices in public and private housing submarkets in the long run.

JEL classification: C53; G14; R21; R31

Keywords: Housing price dynamics; Household mobility; Stochastic permanent breaks (STOPBREAK)

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1. Introduction

Housing is both an investment as well as a consumption good. Service flows derived from housing are durable. Households do not trade housing goods as frequently as other non-durable and financial goods because of the high initial equity outlay involved. Liquidity constrained households, however, trade-off consumption of other non-durables for housing goods. Increases in housing prices generate positive wealth to households, which is translated into positive consumption of housing and non-housing goods by households (Case et al., 2005).[1]

The households' mobility decision in trading up starter flats for bigger and higher quality houses is dependent on the housing wealth accumulated (Stein, 1995; Ortalo-Magne and Rady, 2004, 2006). House price changes create self-reinforcing effects that run from down payments, to demand and then back to housing prices (Stein, 1995). The chain reaction also occurs vertically across different housing segments on a property ladder (Ortalo-Magne and Rady, 2004, 2006). Credit constrained households will move, if price increases in their existing houses were large enough to cover outstanding mortgage balances and down payments for new houses. In a declining market, constrained households are more reluctant to move. They will instead "fish" for above-market sale prices.[2] As a result, transaction volume will drop, and housing prices will be adjusted downward.

In Singapore, the housing market is distinctively divided into two sub-segments. The public housing market constitutes about 80% of the total housing stock (Phang, 2004), and houses more than 90% of the population in Singapore. The supply of new public housing units is regulated by the government through the Housing Development Board (HDB). Public housing is an important source of housing wealth for liquidity constrained households in Singapore. Private housing sales in Singapore are closely related to increases in public housing wealth (Bardhan et al., 2003). Public housing policies were also found to have significant impact on private housing price dynamics (Phang and Wong, 1997; Lum, 2002; Ong and Sing, 2002).

Do the property ladder and housing wealth models (Ortalo-Magne and Rady, 2004, 2006) explain the mobility behavior of Singaporean households? The hierarchical segmentation of the housing market in Singapore offers a unique housing ladder structure for the test of household mobility decisions. In Singapore, the public housing market is a highly regulated market, where new public (HDB) houses are sold at concessionary prices to eligible households. There is also an authorized secondary public housing market established since 1971 (Phang and Wong, 1997) through which households could trade their public houses after fulfilling a 5-year minimum occupancy requirement. Price differences that exist between the new and secondary HDB housing markets create a permanent source of wealth to public house owners (Bardhan et al., 2003). Capital gains in the public housing market are an important source of down-payments that are used by households in the purchase of private houses. On the other hand, trade-down options are not usually exercised by house-

[1] In Singapore, private housing wealth is transitory. Phang (2004) found no significant positive effects of private housing wealth on aggregate consumption. However, Edelstein and Lum (2004) found that public housing wealth was significant in affecting households' consumption.

[2] The "fishing" behavior of constrained households is rational, if and only if the price process is expected to mean revert in the long run (Case and Shiller, 1989, 1990).

holds that own private houses in the upper rungs of the housing ladder. This could be due to a strong bequest culture that is prevalent among Singaporean households.

Upward mobility is more evidenced than the downward path on the housing ladder by Singapore households. Therefore, co-movements in housing prices, if triggered by housing mobility activities, are likely to be asymmetric across the housing ladder in Singapore. The paper aims to empirically test the long-run co-movements between public and private housing sub-markets in Singapore. The results offer a useful empirical verification to theoretical propositions developed by studies on the property ladder, housing wealth creation and mobility. This paper is organized into six sections. Section 1 discusses the motivations of the study. Section 2 reviews the housing literature relating to liquidity constraints and upward mobility. Section 3 describes the ladder structure of the Singapore housing market and discusses possible testable hypotheses. Section 4 discusses the empirical methodology and data. The empirical results are presented in Section 5. Section 6 concludes with possible policy implications.

2. Literature review

Stein (1995) develops a theoretical housing life-cycle model to explain down-payment effects on households' mobility decision. Stein's (1995) models show that house price shocks have significant impact on the mobility decision of liquidity constrained households. Ortalo-Magne and Rady (2004, 2006)[3] show that household mobility follows a well-defined path from a starter flat to a trade-up house. The households' decision of moving up and down the property ladder is dependent on their endowment and housing preference profiles. The ability of households to afford down payments is a key driver of the price reaction to income shocks. When the down payment constraint is binding on housing purchase, households' consumption behavior in the early phase of the cycle could be distorted (Slemrod, 1982). In the respective models of Stein (1995) and Ortalo-Magne and Rady (2004, 2006), a positive house price and transaction volume relationship is predicted in equilibrium.

Genesove and Mayer (1997) empirically tested the positive loan-to-value (LTV) effects on prices and time to sale of houses. They showed that households with higher LTV constraints sold their houses at higher prices, but over longer periods of time. The "fishing" behavior of constrained households in the Stein model that causes a decline in housing transactions in a market with falling house prices was also not rejected in the Genesove and Mayer (1997) tests. Bardhan et al. (2003) showed that the positive gains in public (starter) houses are a significant factor that drives private housing market transactions in Singapore. Lee and Ong (2005) also found consistent empirical evidence of the positive effects of housing wealth and LTV constraints on the upward mobility decisions of a sample of households who own public housing in Singapore.

The mobility of constrained households causes serial dependence in housing prices (Stein, 1995; Ortalo-Magne and Rady, 2004, 2006). Case and Shiller (1989, 1990) found evidence to support the predictability of housing prices using historical price changes and other fundamental variables. Price discovery between the public and private housing

[3] In Stein (1995), all the households are assumed to have owned a house at the initial time period, and the households could only choose to move or stay put in the existing houses. The models of Ortalo-Magne and Rady (2004, 2006) are more dynamic, which describe the inter-temporal mobility of households from starter flats to trade-up houses over time.

prices in Singapore was found by Ong and Sing (2002). They further showed that the causality effects are bi-directional in the two housing markets.

The public housing built by the government's agency, the HDB, is the predominant housing type in Singapore. It constitutes about 88% of the housing stock based on the census statistics in 2000. Government policies affecting public housing, in particular those relating to the Central Provident Fund (CPF),[4] were found to have significant impact on prices of the relatively small private trade-up housing market (Phang and Wong, 1997). The government's role in the supply of land for private houses also created significant dampening effects on private housing prices (Lum, 2002). Housing wealth created in the public housing market was more sustainable compared to private housing wealth. Gains in public housing prices have positive effects on aggregate consumption (Edelstein and Lum, 2004). The private housing gains were, however, not translated into positive consumption in Singapore (Phang, 2004).

The asymmetric wealth effects on household consumption may suggest that the two housing markets are distinct and segmented. If household mobility occurs from the public (starter) flats to the private (trade-up) houses, inter- and intra-market housing price dynamics between two distinct submarkets on the property ladder can be expected. The hypothesis of housing price predictability as found in Case and Shiller's (1989, 1990) studies should also not be rejected between the housing submarkets in Singapore.

3. The property ladder in the Singapore housing market: Empirical implications

Singapore has a two-tier housing market composed of a public market and a private market. The public housing market provides new starter houses at subsidized rates for first time home buyers, who meet specified social, demographic and income criteria.[5] There is a formal resale market for public housing units, where prices are market determined. The difference in price between the new and resale public housing markets creates a source of "fortuitous" wealth to qualified Singaporean first-time home buyers (Bardhan et al., 2003). The public housing wealth can only be cashed out by the households upon satisfying a 5-year minimum occupancy requirement. The financial gains from the sale of the original public housing units provide an important source of funding for down payments for liquidity constrained households in trading-up for private (trade-up) houses.

The private housing market in Singapore operates on a *laissez faire* basis. Private housing units are more expensive. They are also differentiated by better designs and quality of finishes. Some (condominiums and apartments) are equipped with full recreational facilities. Despite the relatively small scale of the private housing market, housing types are more heterogeneous ranging from landed units like detached houses, semi-detached houses and terraces to non-landed units like condominiums and apartments.

Based on the housing stock and average transaction prices summarized in Table 1, the public and private housing markets could be arranged in a unique pyramid struc-

[4] The Central Provident Fund (CPF) is a comprehensive pension scheme, which has been expanded to provide financing for public housing purchases in 1968, and subsequently for private housing purchases in 1981 under the Residential Property Scheme (RPS).

[5] See Phang (2004) and Bardhan et al. (2003) for detailed discussions of policy changes affecting the public housing market in Singapore over time.

Table 1
Characteristics of private and public housing markets in Singapore

Housing type	Average floor/land area (sqm)[a]	Average transaction price (S$)[a]	Average unit price (S$ psm)[a]	No. of Caveat lodged as at 4Q03)[a]	Housing stock (as at 4Q03)[b]	Total housing stock (%)
Private housing market						
Detached house	1314.75	4,927,479	4062	104	9915	0.97
Semi-detached house	340.10	1,440,098	4452	143	20,628	2.01
Terraced house	208.18	1,052,364	5344	314	36,549	3.56
Condominium	133.79	803,168	5867	1513	85,869	8.36
Apartment	125.46	743,830	6274	801	57,973	5.65
Public housing market						
HDB data	[c]	[d]		Total[e]	815,633	79.45
Executive flat	130	403,400	3103		65,143	7.99
5-Room flat	110	321,500	2923		201,152	24.66
4-Room flat	90	232,800	2587		318,668	39.07
3-Room flat	69	159,300	2309		220,696	27.06

Note: Condominium and apartment are two common non-landed housing types built by private developers, they are quite homogenous in physical, but prices differs especially between the high- and middle-end condominium, and apartment. The total stock size of apartment is also smaller, but the hierarchy structure is determined based mainly on price structure in this study. Source: URA, HDB.

[a] The statistics are computed based on caveats lodged on all private residential properties transacted from 1 September 2003 to 31 December 20003, as captured in Real Estate Information System (REALIS) of the URA.

[b] The cumulative housing stock information is obtained from the time-series data in REALIS, URA.

[c] The size of different public housing types is taken from typical new housing flat type built by HDB. The size for different HDB flats may have changed over time.

[d] The resale price was the 4Q average resale HDB flats that were published on the Business time, "Prices of HDB resale flats rise 1.2% in Q2 from Q1", by Andrea Tan, 24 July 2004.

[e] The total housing stock number was obtained from the HDB annual report 2002/2003, and the number does not include rental flats (53,141).

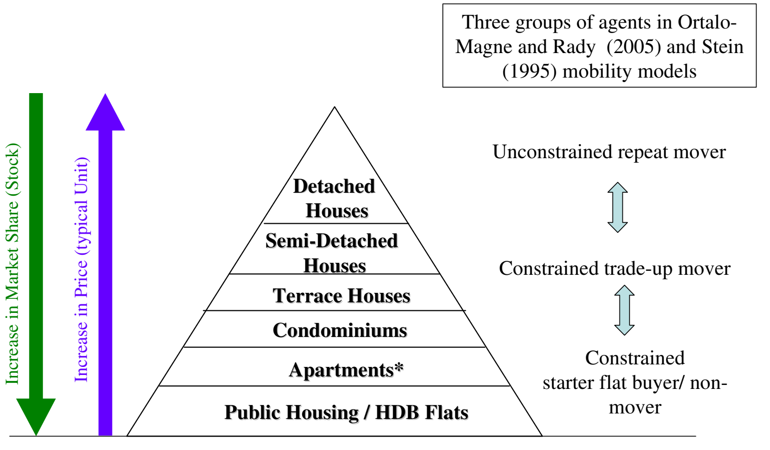

**Table 1 shows that the total housing stock of apartment is smaller than that of condominium. However, these two housing types are homogenous, and are constantly grouped in the same non-landed private housing category. Based on the absolute price measure , apartment is placed in the right hierarchy in the housing pyramid/ladder.*

Fig. 1. Property ladder in Singapore housing markets.

ture (Fig. 1).[6] The public housing market that constitutes nearly 80% of the total housing stock forms the lowest stratum in the housing pyramid. This sub-market has the lowest average transaction price of $2923 per square meter (5-room flats). The upper strata of the housing pyramid are made up of private housing markets that constitute 20% of the total housing stock. The private housing market could be further stratified into different submarkets based on the average transaction prices in an ascending order starting from apartments, condominiums, terraces, semi-detached houses and finally, detached houses. The hierarchical structure and distinct price levels in the housing sub-markets map well into the property ladder structure of Ortalo-Magne and Rady (2004, 2006).

Is the mobility of households on the housing ladder a strictly continuous process? If liquidity constraints were strictly binding, household mobility is dependent on the capital gains from the sale of their houses in the lower rung of the ladder. The gains must be at least sufficient to make down payments for houses on the upper rung immediately above the housing ladder. The condition implies that households do not upgrade by moving more than one rung at a time in this model.[7] A starter flat (public HDB unit) is the entry point of credit constrained households into the housing market. The public housing owner "*climbs up the housing ladder*" by trading up a starter home for an apartment or condominium, a terrace, a semi-detached house and finally a detached house at the top of the pyramid in a sequential process. If this hypothesis is not rejected, intra- and inter-stratum price discovery processes occur only between two submarkets on contiguous rungs of the housing ladder. Price changes between any stratum of the housing

[6] A sandwiched class of housing, known as executive condominiums (EC), was developed by the HDB in mid-1996 to cater to young professionals who could not meet the income criteria for public housing units. This segment of the market is excluded in this study.

[7] Although there are exceptional cases of households moving from lower rung starter houses to private houses that are not immediately above the existing housing on the housing ladder, the number of such cases is relatively small. The strict credit constraints condition will not be, however, violated.

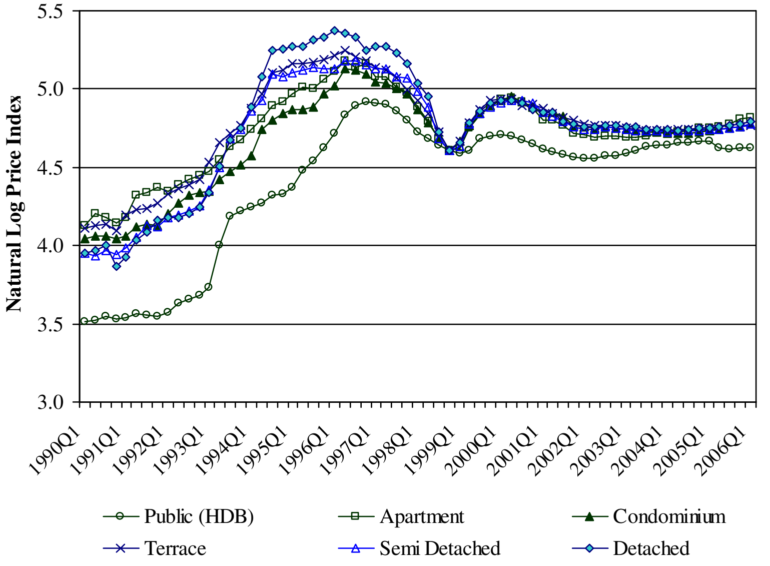

Fig. 2. Historical prices of public and private housing markets in Singapore.

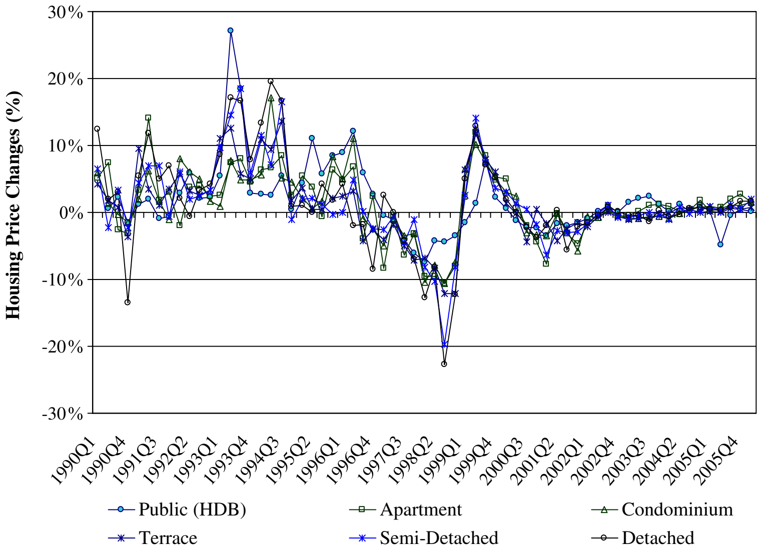

Fig. 3. Ex-post price changes of public and private housing markets in Singapore.

market and those not immediately above or below it are expected to follow independent random walk processes.

The above independent random walk hypothesis seems to suggest that housing submarkets on the housing ladder are segmented. However, if household mobility is a continuous process, and if the upward and/or downward filtration takes place simultaneously across different submarkets, price changes in one submarket may trigger a series of reactions in other housing submarkets on the housing ladder. The mobility and market segmentation hypotheses could be jointly tested by examining price dynamics across different housing submarkets. If the upward mobility and the integration of housing sub-markets hypotheses are both not rejected, long-run co-movement of prices of different pairs of housing sub-markets in contiguous rungs on the housing ladder could be expected.

Historical house prices in natural logarithm terms for the public and private sub-markets in Singapore, both in levels and first differenced, are shown in Figs. 2 and 3. Price changes in different housing sub-markets do not appear to follow random walk processes. There are common long-term trends and turning points over the sample period. More robust empirical tests will be carried out in the next section.

4. Empirical methodology

4.1. Model specifications

The 1990s witnessed a highly volatile housing market in Singapore, which saw a sharp rise in prices in 1994–1995, followed by a steep correction in 1996 and 1997 (Fig. 2).[8] This paper applies the stochastic permanent breaks (STOPBREAK) model proposed by Engle and Smith (1999) to empirically test the long-run co-movement of housing prices. In the STOPBREAK model, stochastic shocks are incorporated in the tests of long-run relationships between two time series. The hypotheses of household mobility and market segmentation could be jointly tested in the study by examining the price dynamics of different housing sub-markets. The predictability of house prices using the house price information of other sub-markets is also tested using a vector error correction model (VECM), which includes lagged-price changes and other fundamental economic variables. The two proposed modeling strategies are discussed below.

4.1.1. Stochastic permanent breaks (STOPBREAK) model

In the classical cointegration methodologies proposed by Engle and Granger (1987) and Johansen (1988), two dth order integrated time series, $I(d)$, are said to be cointegrated, if the residual of the linear combination of the two series, $[Y_t = \beta X_t + u_t]$, is stationary with an order of integration of less than d, $[u_t \sim I(<d)]$. The definition holds on the assumption that there are no short-term shocks to the equilibrium of the system. If permanent and/or transitory economic shocks are stochastic, a pair of variables may move together for a period of time and jump apart occasionally. Engle and Smith (1999) call this process temporary cointegration, and they develop a STOPBREAK model to capture the random structural shifts in the process.

Engle and Smith (1999) define the simplest form of STOPBREAK time-series process, y_t as:

$$y_t = m_t + \varepsilon_t, \quad t = 0, 1, \ldots, T \tag{1}$$

[8] The sharp reversal of housing prices from the boom occurred in 1997 and 1998 due to the government's intervention through a slew of off-budget anti-speculation measures in May 1996 and shocks from the Asian Financial Crisis in 1997 (Edelstein and Lum, 2004).

where $m_t = E[y_t | I_{t-1}]$ is a time varying conditional mean, and ε_t is an error term.

$$m_t = m_{t-1} + q_{t-1}\varepsilon_{t-1} = m_0 + \sum_{i=1}^{t} q_{t-i}\varepsilon_{t-i}, \quad t = 1, 2, \ldots, T \tag{2}$$

where $q_t = q(\varepsilon_t) \in (0,1)$ s.t $E[q_t\varepsilon_t | I_{t-1}] = 0$.

Shocks in the STOPBREAK process are permanent and endogenously determined in the process. If $[\tilde{q}_t = 1]$, the realized process at time t is a random walk. If $[\tilde{q}_t = 0]$, the conditional mean is constant, and the long-run forecast of y_t will not be deviated from the mean value of $\tilde{q}_t$.

The general STOPBREAK process for a pair of time-series variables (Y_t, X_t) can be extended as follows:

$$A(L)B(L)(Y_t - X_t\delta) = z_{t-1}A(L)\varepsilon_t + (1 - z_{t-1})B(L)\varepsilon_t, \quad t = 1, 2, \ldots, T \tag{3}$$

where $[A(L) = 1 - \alpha_1 L - \alpha_2 L^2 - \ldots - \alpha_p L^p]$, $[B(L) = 1 - \beta_1 L - \beta_2 L^2 - \ldots - \beta_p L^p]$, L is the lag operator, z_t is a measurable function consisting of information up to t, and ε_t is an innovation term.

If $[\delta = 0]$, $[B(L) = 1 - L]$, and $[A(L) = 1]$, the model complies with the simplest form of the STOPBREAK process. Alternatively, if $[\delta \neq 0]$, the two series are temporarily cointegrated, where the two series jump apart occasionally and revert back to the equilibrium relationship in the long-run.

To test the persistence of the STOPBREAK process, substitute $\left[q_t(\gamma) = \frac{\varepsilon_t^2}{\gamma + \varepsilon_t^2}\right]$ into processes (1) and (2) to derive the following specification:

$$\Delta y_t = \frac{-\gamma\varepsilon_{t-1}}{\gamma + \varepsilon_{t-1}^2} + \varepsilon_t \tag{4}$$

Based on Eq. (4), the random walk hypothesis, $[H_0\colon \gamma = 0]$, is tested against the alternative hypothesis, $[H_1\colon \gamma = \overline{\gamma}]$. If the random walk hypothesis is rejected, the time series contains a STOPBREAK process. One of the tests proposed by Engle and Smith (1999) involves testing the null hypothesis $[H_0\colon \varphi = 0]$ against a negative alternative using t-tests, where φ is estimated using the regression below:

$$\Delta y_t = \varphi \frac{\Delta y_{t-1}}{\overline{\gamma} + \Delta y_{t-1}^2} + \mu_t \tag{5}$$

The STOPBREAK methodology is applied to test the existence of temporary cointegration in the long-term price processes of housing sub-markets. The tests are conducted on a pair-wise basis for prices of public resale housing, apartment, condominium, terrace, semi-detached and detached housing.

4.1.2. Vector autoregressive error correction model (VECM)

The mobility of households on a housing ladder suggests that some forms of price discovery process are likely to occur across different housing submarkets. Price dynamics across different submarkets can be tested using a vector autoregressive error-correction model (VECM), which consists of lagged price changes in housing submarkets and other exogenous macro-economic variables. An error correction mechanism is included in the model to correct for short-term deviations of the price series.

A generalized VECM system with *n*-lags can be specified as follows:

$$\Delta y_t = \delta_i \mu_{t-1} + \sum_{i=1}^{p} \alpha_i \, \Delta y_{t-i} + \sum_{i=1}^{q} \beta_i \, x_{t-i} + \varepsilon_t \tag{6}$$

where Δy_t is a vector of natural log-price changes for different housing submarkets that include public resale HDB flats, apartments, condominiums, terraces, semi-detached houses and detached houses, x_t is a vector of exogenous variables that include GDP growth, stock market return, prime lending rate, and unexpected inflation rate, and ε_t is a vector of innovation terms. A time dummy variable, *Dum4Q98*, which is given a value of 1 for periods in 4Q1998 and after, or zero otherwise, is also included to capture the turning point that occurred in 1998. The coefficient matrices α_p and β_p are jointly estimated in the VECM system with appropriately selected p and q lags.

An error correction term, μ_{t-1}, in the VECM model represents the speed of adjustment of the house prices toward the long-run values. If $[\delta \neq 0]$, there exists a significant cointegrating vector in the system, and the house price changes can be predicted in the long-run. The hypotheses that household mobility triggers price adjustments from one segment to another segment of the housing market, and that the housing submarkets are not segmented, are both not rejected as a result.

Table 2
List of variables and derivations

Notation	Variable Description	Source
Housing price variables		
P_{hdb}	Resale HDB housing price index	HDB
P_{apt}	Apartment price index	URA
P_{cond}	Condominium price index	URA
P_{ter}	Terrace price index	URA
P_{semd}	Semi-detached housing price index	URA
P_{det}	Detached housing price index	URA
Macro-economic variables		
GDP	Gross domestic products	DOS[a]
SGX	Singapore exchange all-share index	DOS
PLR	Prime lending rate	DOS
CPI	Consumer price index	DOS
unexpinf	Unexpected inflation rate	Estimated based on Fama and Gibbons (1984) approach
First differenced variables		Derivation[b]
dp_{hdb}	ln-return of HDB price	$p_{\text{hdb},t} - p_{\text{hdb},t-1}$
dp_{apt}	ln-return of apartment price	$p_{\text{apt},t} - p_{\text{apt},t-1}$
dp_{cond}	ln-return of condominium price	$p_{\text{cod},t} - p_{\text{cod},t-1}$
dp_{ter}	ln-return of terrace price	$p_{\text{ter},t} - - p_{\text{ter},t-1}$
dp_{semd}	ln-return of semi-detached price	$p_{\text{sed},t} - p_{\text{sed},t-1}$
dp_{det}	ln-return of detached price	$p_{\text{det},t} - p_{\text{det},t-1}$
$dgdp$	GDP Growth	$gdp_t - gdp_{t-1}$
$dsgx$	Stock market return	$sgx_t - sgx_{t-1}$

[a] DOS denotes Department of Statistics of Singapore.

[b] The natural logarithm form of the variables are represented in lower case of the respective notations.

4.2. Data collection

Time series data for the private housing prices are collected from the Real Estate Information System (REALIS) of the Urban Redevelopment Authority (URA) of Singapore, and the public resale housing price data are obtained from the HDB. The data series are published on a quarterly basis, and cover a 16-year sample period from 1Q1990 to 1Q2006. Housing prices for different submarkets are represented by the subscript i in the price variable, P_i, where [i = (det, semd, ter, cond, apt, hdb)], and the corresponding natural logarithm of housing prices are denoted by p_i, where [$p_i = \log_n(P_i)$]. Change in house prices is taken as the first order difference of the natural log-price, [$dp_{i,t} = (p_{i,t} - p_{i,t-1})$].

We obtain time series data for four exogenous macro-economic variables, which include GDP growth, stock market returns, the prime lending rate, and the consumer price index from the Department of Statistics (DOS), Singapore. The unexpected inflation is estimated from the consumer price index using the interest rate model proposed by Fama and Gibbons (1984). The notations for the variables and their respective sources are summarized in Table 2.

Augmented Dickey-Fuller and Phillips-Perron tests are conducted to test the order of integration of the log-prices of different housing sub-markets and the macro-economic variables. The results show that all housing price variables are I(1) stationary. For the four fundamental variables, ADF test results show that the stock market return and GDP changes are I(1), whereas unexpected inflation and the prime lending rate are I(0).

5. Empirical results

5.1. Test of temporary cointegration in STOPBREAK process

The standard cointegration tests do not adjust for possible transitory and permanent shocks in the time series. Two price series may move together and occasionally jump apart as a result of an external shock. The random responses to shocks cause problems to the cointegration tests, which may fail to detect long-run contemporaneous relationships in price generating processes. In the Engle and Smith (1999) STOPBREAK model with time-varying stochastic shocks, price series are said to be temporary cointegrated if the random walk hypothesis is rejected. At least one Granger causality relationship is expected

Table 3
t-Statistics for STOPBREAK Tests

Variable	Apartment, p_{apt}	Condominium, p_{cod}	Terrace house, p_{ter}	semi-detached house, p_{sed}	Detached house, p_{det}
HDB resale flat, p_{hdb}	3.76[a]	4.01[a]	3.94[a]	3.62[a]	3.67[a]
Apartment, p_{apt}		−1.16	−0.74	−0.18	0.78
Condominium, p_{cod}			−0.66	0.34	1.53
Terrace house, p_{ter}				−0.69	0.79
Semi-detached house, p_{sed}					−0.78

H_o, the relative price follows a random walk process.
[a] Indicates significance at 5% level.

between the price series, although they are allowed to deviate apart occasionally following exogenous shocks.

The *t*-statistics for the STOPBREAK tests in Table 3 show that the random walk hypothesis was rejected on a pair-wise basis between the HDB resale price and the prices of all the five private housing submarkets. However, pair-wise temporary cointegration relationships are not significant among the private housing submarkets. The results imply that transitory or permanent shocks may cause the relative prices of HDB resale units and other private housing units to drift apart in the short run. These relative prices are, however, expected to converge to a long-run equilibrium level. The relative prices of two housing submarkets will revert to fundamental levels in the long-run, if the two housing price series were temporary cointegrated. Therefore, according to Engle and Smith (1999), arbitrage could be made by selling over-valued houses or buying under-valued houses, when random shocks occur.

New HDB units are sold by the government at concessionary prices to first-time homebuyers who meet the HDB criteria. Increases in resale HDB price create "fortuitous" gains to the HDB households, which can be converted into higher down payments when households choose to move up the housing ladder. As HDB households form the bulk of constrained upward movers, price changes in the HDB resale market will significantly influence the rate of upward mobility of these households. Policy changes that have direct impact on the public housing market could create "ripple" effects to the private housing market. Changes to public housing finance policies through the Central Provident Fund (CPF) schemes in the 1980s and 1990s, and the relaxation of the HDB resale housing ownership rules in 1991 (Phang and Wong, 1997; Bardhan et al., 2003) were among the significant shocks that may have caused permanent or transitory shifts to the prices in the public and private markets. The temporary cointegration processes found in the relative prices between public housing market and other private housing submarkets in the STOPBREAK test are evidence of the policies' impact on trading up decisions of households.

5.2. Predictability of housing prices in VECM

In a vector autoregressive (VAR) system comprising all the housing prices, the number of cointegrating vectors is first tested using the multivariate cointegration methodology proposed by Johansen and Juselius (1990). Four fundamental variables: *dgdp*, *dsgxa*, PLR and unexpinf, are included in the multivariate VAR model to control for exogenous effects. The trace statistics reject the null hypothesis that there are at most five cointegrating vectors, $[r \leqslant 5]$, at the 5% significance level. However, in the maximum eigenvalue tests, the null hypothesis $[r \leqslant 2]$ was not rejected, which implies that there exists at least one significant cointegrating vector in the VAR equation.

For parsimonious considerations, one cointegrating equation is estimated in the VECM for housing prices with two lags. A time dummy variable, *DUM98Q4* is included in the system to capture the break caused by the combined effects of the anti-speculation policy shocks in May 1996 and the Asian financial crisis in 1997. The estimation results for the VECM are summarized in Table 4.

The results show that the cointegrating vector, μ_{t-1}, was significant in explaining price changes in all private housing submarkets, but not the HDB resale price changes. Prices in

Table 4
Vector error correction estimates

	dp_{hdb}	dp_{apt}	dp_{cond}	dp_{ter}	dp_{semd}	dp_{det}
CointEq	−0.0392 [−0.3671]	−0.3344 [−4.7237]	−0.3391 [−4.0304]	−0.2824 [−3.3232]	−0.3594 [−3.8103]	−0.5752 [−6.7204]
$dp_{hdb}(-1)$	0.2823 [1.5447]	−0.4790 [−3.9496]	−0.4434 [−3.0762]	−0.6234 [−4.2821]	−0.3895 [−2.4102]	−0.7309 [−4.9840]
$dp_{hdb}(-2)$	−0.1065 [−0.4706]	−0.1538 [−1.0242]	−0.1491 [−0.8354]	−0.3719 [−2.0630]	−0.4572 [−2.2848]	−0.7311 [−4.0264]
$dp_{apt}(-1)$	0.1111 [0.5018]	−0.2725 [−1.8539]	−0.1219 [−0.6978]	−0.0592 [−0.3357]	0.0079 [0.0404]	0.0825 [0.4641]
$dp_{apt}(-2)$	0.3607 [1.8260]	0.0208 [0.1588]	0.0397 [0.2551]	0.0872 [0.5543]	0.0686 [0.3928]	0.0575 [0.3626]
$dp_{cond}(-1)$	−0.0736 [−0.2866]	0.82195 [4.8213]	0.6118 [3.0193]	0.7426 [3.6289]	0.8316 [3.6607]	0.9518 [4.6170]
$dp_{cond}(-2)$	−0.2694 [−1.0610]	0.4019 [2.3850]	0.4108 [2.0510]	0.1943 [0.9608]	0.1150 [0.5120]	0.1793 [0.8798]
$dp_{ter}(-1)$	0.7475 [1.6156]	−0.5474 [−1.7830]	−0.5254 [−1.4399]	−0.8804 [−2.3889]	−0.9858 [−2.4098]	−1.5260 [−4.1105]
$dp_{ter}(-2)$	0.2971 [0.9553]	−0.1239 [−0.6004]	−0.2798 [−1.1408]	−0.3287 [−1.3266]	−0.3657 [−1.3297]	−0.8065 [−3.2319]
$dp_{semd}(-1)$	−0.1617 [−0.5531]	0.4436 [2.2873]	0.3426 [1.4864]	0.8884 [3.8159]	0.6803 [2.6324]	1.3661 [5.8254]
$dp_{semd}(-2)$	−0.2453 [−0.9637]	0.4091 [2.4220]	0.0758 [0.3773]	0.6049 [2.9833]	0.6687 [2.9709]	1.1617 [5.6875]
dp_{det} (-1)	−0.2405 [−1.2944]	0.2315 [1.8778]	0.3198 [2.1824]	0.1429 [0.9653]	0.2821 [1.7170]	0.1630 [1.0933]
$dp_{det}(-2)$	−0.1568 [−0.8777]	−0.4653 [−3.9246]	−0.1658 [−1.1768]	−0.3575 [−2.5124]	−0.3546 [−2.2452]	−0.4441 [−3.0983]
C	0.2505 [3.2400]	0.0155 [0.3013]	0.09513 [1.5603]	0.2232 [3.6248]	0.18606 [2.7222]	0.3062 [4.9363]
dgdp	−0.0589 [−0.4016]	−0.0748 [−0.7684]	−0.1659 [−1.4343]	−0.2668 [−2.2844]	−0.1059 [−0.8169]	−0.1756 [−1.4927]
dsgx	0.0086 [0.1864]	0.0790 [2.5901]	0.0339 [0.9336]	0.1130 [3.0847]	0.0795 [1.9556]	0.0621 [1.6830]
PLR	−0.0348 [−3.1175]	−0.0033 [−0.4457]	−0.0156 [−1.7673]	−0.0344 [−3.8738]	−0.0296 [−2.9964]	−0.0491 [−5.4899]
unexpinf	0.0026 [0.0694]	−0.0089 [−0.3641]	−0.0412 [−1.4148]	−0.0449 [−1.5267]	−0.0417 [−1.2779]	−0.0688 [−2.3238]
DUM98Q4	−0.0573 [−2.9241]	0.0235 [1.8060]	0.0045 [0.2933]	−0.0262 [−1.6766]	−0.0102 [−0.5870]	−0.0164 [−1.0402]
Adj. R^2	0.5591	0.7740	0.6668	0.7070	0.7204	0.8431

Cointegrating equation estimates

ContEq, μ_{t-1}	$dp_{hdb}(-1)$	$dp_{apt}(-1)$	$dp_{cond}(-1)$	$dp_{ter}(-1)$	$dp_{semd}(-)$	$dp_{det}(-1)$	*C*
Coefficient	−0.7334	0.190551	2.031744	−4.5223	1.8059	1.0000	1.0825
t-Statistics	[−7.0064]	[0.8676]	[7.7727]	[−8.3145]	[4.4422]		

private submarkets were predictable, and there was clear evidence of price correction towards long term fundamental means in these markets.

The upward mobility of "starter" households to the upper rungs of the private housing ladder could be reflected in the relationships between public and private house price changes. The one-period lagged HDB resale housing price variable, $dp_{\text{hdp},t-1}$, was significant in explaining price changes in all private housing submarkets, whereas the second period lagged term, $dp_{\text{hdp},t-2}$, contains significant explanatory information on prices of three private landed housing markets, dp_{ter}, dp_{semd}, and dp_{det}. All the lagged public resale housing price variables have negative signs. There are two possible reasons for the negative price relationships.

Firstly, upward and downward housing mobility activities create short-term imbalances in the supply and demand conditions in the public and private housing markets. The action of moving up the housing ladder by HDB households brings about excess demand in the private housing markets. At the same time, starter houses sold by the constrained households cause excess supply in the resale HDB flats. Short-term inelasticity in the supply of new private housing units creates disequilibrium in prices. Prices of private houses escalate in the short run. Public housing price, on the other hand, may decline or remain unchanged in the short-term when surplus stocks are brought into the market by the trading-up households. The opposite effects are observed when trading down activities occur. Secondly, public housing policies that require HDB households to stay in their flats for a minimum period of 5 years before selling their flats restrict their mobility in the short run. Public housing wealth is not translated into new housing trading activities in the private housing markets in the short term. The negative price relationships between the two housing markets may reflect delayed mobility decisions by households in the public housing market.

The mobility behavior of constrained trade-up households and unconstrained repeat households could be examined from the price dynamics for houses in the upper rungs of the housing ladder. The results show that lagged condominium price, $dp_{\text{cond},t-1}$ exhibits significant positive price effects on the other four private housing sub-markets. The signals of house price information in the private landed submarkets were, however, mixed. The coefficients for lagged semi-detached house price variables, $dp_{\text{semd},t-1}$ and $dp_{\text{semd},t-2}$, are positive and significant, whereas, the coefficient for $dp_{\text{ter},t-1}$, and $dp_{\text{det},t-1}$ have negative signs in the landed housing price VECMs. The positive price effects of semi-detached houses may reflect the investment motive of the unconstrained households. The negative signs for the terrace coefficients could be explained by the substitution effects among landed housing goods. Trading down by unconstrained movers when prices decline as predicted by Stein's model may offer an alternative explanation to the negative price effects.

For the exogenous macroeconomic variables, the results show that stock market coefficients are positive and significant in explaining price variations in condominium, terrace and semi-detached housing markets. Prime lending rates were found to have significant dampening effects on public resale flats and all private landed houses. Unexpected inflation has negative effects on detached house prices, and GDP growth dampens price changes in terrace houses. The negative effect of the *DUM98Q4* variable was only shown in public resale housing prices. The impact of the post-1997 Asian financial crisis on private housing prices could have already been reflected in the error correction process or other lagged price variables.

In summary, private housing prices were predictable by the error correction mechanisms, μ_{t-1}, and the lagged public resale price variable, $dp_{\mathrm{hdb},t-1}$. These findings together with the earlier results on temporary cointegration between public resale housing and the five private housing submarkets suggest that the joint hypothesis that household mobility takes place from the public to private housing markets, and that the private housing submarkets are not segmented, could not be rejected.

6. Conclusion

When the liquidity constraint is binding in housing consumption, Stein (1995) and Ortalo-Magne and Rady (2004, 2006) predict that household mobility activities create a positive relationship between house prices and transaction volumes. Empirical studies thus far have focused on the impact of LTV constraints on housing price and time to sale (Genesove and Mayer, 1997). The pricing side of the story in the down-payment constraint model has not been empirically tested. This study attempts to use evidence in housing price dynamics to jointly test the price-volume and the market segmentation hypotheses. If the hypotheses were not rejected, the price discovery process should flow efficiently between different submarkets on the property ladder.

In the STOPBREAK tests, the results rejected the random walk null hypothesis for HDB resale prices and the prices of all five private housing sub-markets. Exogenous permanent or transitory shocks may cause the relative price processes of the public resale market and the private housing submarkets to drift apart occasionally, but the prices are expected to converge towards equilibrium in the long run. In the VECM estimations, the results show that the error correction terms are significant in explaining the price variations in all five private housing sub-markets. Some degree of predictability in the private housing submarkets is expected. The mobility of households on a housing ladder triggers price effects across different housing submarkets. This price information will only spillover from one market to another on the housing ladder, if they are not segmented.

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