HONG KONG INSTITUTE FOR MONETARY RESEARCH

RENTAL RATES UNDER HOUSING PRICE UNCERTAINTY: A REAL OPTIONS APPROACH

Honglin Wang, Fan Yu and Yinggang Zhou

HKIMR Working Paper No.24/2013

November 2013

Rental Rates under Housing Price Uncertainty: A Real Options Approach*

Honglin Wang

Hong Kong Institute for Monetary Research

and

Fan Yu

Claremont McKenna College

and

Yinggang Zhou

The Chinese University of Hong Kong

Hong Kong Institute for Monetary Research

November 2013

Abstract

The conventional wisdom that house prices are the present value of future rents ignores the fact that rents are not discretionary as in dividends on stocks. Housing price uncertainty can affect household property investment, which in turn affects rent. By extending the theory of investment under uncertainty, we model the renter's decision to buy a house and the landlord's decision to sell as real options of waiting and examine real options effects on rent. Using unique data from Hong Kong, we find significant a causal effect of house prices on rents and draw important policy implications.

Keywords: Investment Under Uncertainty, Real Options, House Price, Rent, Causal Effect

* We are grateful to Wenqi Liu and Michael Dai for excellent research assistance. We would also like to thank anonymous referees, Dong He, Warren Bailey, Ko Wang, Wenlan Qian, André Meier, Charles Leung, and other workshop participants at Hong Kong Institute for Monetary Research (HKIMR) for very helpful comments.

1. Introduction

From a standard financial asset perspective, house prices are the present value of future rents. This leads to a conventional discounted cash flow analysis that rents affect house prices, but not the reverse. However, Shiller (2008) shows that US house prices may be determined by something other than rents or housing construction costs in the recent period. Moreover, the housing boom and bust has focused attention on the volatility of house values, their connection to business and financial cycles, and their impact on other markets. Rents are not discretionary as in dividends on stocks or cash flow on other standard assets but determined in rental markets. This importance difference is largely unexplored in the academic literature. A new and interesting question is whether house prices can have causal effects on rents. In this paper, we examine how housing price uncertainty affects the decision making of household property investments, which in turn affects rents.

We begin by modeling both the renter's decision to buy a house and the landlord's decision to sell as the exercising of real options. Owning a house is risky because housing prices are volatile and their fluctuation can have a sizable effect on owners' wealth. Renting thus provides a hedge against housing price uncertainty by offering a put option on housing values. The decision on the timing of purchase becomes an optimal stopping problem for renters. Rational renters will delay their decision to buy if housing prices are higher than their private valuation and there is a chance that prices will fall. Landlords, by contrast, own a call option on the housing value which allows them to choose the optimal timing of sale. Rational landlords will delay their decision to sell if housing prices are lower than their private valuation and there is a chance that prices will increase. Further assuming that the private valuations of renters and landlords are drawn from normal distributions, we can then derive an equation for rental demand and supply, as well as the relation between equilibrium rental rates and housing prices and housing price volatility.

The price effect in this model is straightforward to understand. This refers to an increase in rental demand and a decrease in rental supply in a strong housing market because more renters are reluctant to buy and more landlords are willing to sell. By contrast, in a weak housing market, rental demand will decrease because more renters are willing to buy while rental supply will increase because more landlords are reluctant to sell. This induces a positive relation between equilibrium rental rates and housing prices.

Meanwhile, the volatility effect will increase both demand and supply in the rental market because with greater housing price volatility, both renters and landlords are more eager to hold on to their real options. The effect on the equilibrium rental rate depends crucially on the relative size of the increase in demand and supply. When the private valuations of the renters are more widely dispersed, the expansion in rental demand induced by higher housing price volatility will be smaller, and it is possible for the expansion of rental supply to play a more important role, leading to lower equilibrium rental rates. We discuss various scenarios that might lead to such a negative relation between rental rates and housing price volatility, including a case in which a falling housing market gradually removes renters who become homeowners, eventually leaving only renters who are insensitive to price changes (this is analogous to the notion of "burnout" in mortgage prepayment).

Our model contributes to the literature on investment under uncertainty, which recognizes irreversibility and the possibility of delay as key characteristics of most investments. A firm or household with an opportunity to invest in a real asset is holding a "real option" analogous to a financial option—the right but not the obligation to buy or sell an asset at some future time. The option value of waiting is highly sensitive to uncertainty about the future value of investments and has a significant impact on firm-level investment decisions (Henry, 1974; Bernanke, 1983; Majd and Pindyck, 1987; Brennan, 1990; Triantis and Hodder, 1990; Dixit and Pindyck, 1994; Aguerrevere, 2009) as well as macro-level cyclical fluctuations in aggregate investment (Bernanke, 1983). After the recent financial crisis, considerable attention has been paid to the impact of uncertainty shocks. Bloom (2009) shows that higher uncertainty increases the real options value to waiting so that firms scale back their investment and hiring. We demonstrate that uncertainty shocks in the property market also have real options effects on property investment by individual households and cyclical fluctuations in the rental market. Also, the real options approach has been used to value urban land (Titman, 1985) and lease contracts (Grenadier, 1995; 2005). We obtain a closed-form solution for the equilibrium rent that contains the option premium of waiting driven by housing price uncertainty, and offer a new and richer explanation based on the "hold out" phenomenon.[1]

Our model also adds to the recent literature that has abandoned the traditional "rent drives price" view. Typically, Dynamic Stochastic General Equilibrium (DSGE) models allow both rents and prices to be determined in general equilibrium simultaneously (Ayuso and Restoy, 2006; Chambers et al, 2009; Sommer et al, 2013). Consistent with Yao and Zhang (2005) and Li and Yao (2007), we assume that house prices are exogenous, which is realistic because the property market is integrated with the capital market and is more easily exposed to external shocks, while the rental market is highly segmented and local. This is a partial equilibrium framework in which the effects of housing price dynamics can be analyzed clearly.

Empirically, we find strong causal effects of house prices on rents using a unique dataset from the Hong Kong residential rental and property market. Hong Kong is an ideal laboratory to test our model predictions because it is a small open economy and housing prices are subject to external shocks.[2] Moreover, property rents tend to follow property prices in Hong Kong, as shown in Figure 1. There is strong (Granger) causality from changes in Hong Kong housing prices to changes in rental rates,

[1] Qian (2013) examines the real options effect of sellers holding out in a down housing market. In her model, the option value of waiting is driven by the exogenous rent uncertainty and the "reservation value" depends on the current value of the rent and is identical for everyone. Her model can explain why homeowners would delay selling, but then every homeowner would sell at the same time. In our model, both renters and landlords hold out in a volatile housing market, and their aggregate effect on the equilibrium rental rate depends on the distributions of their private valuations.

[2] Having soared by 90.9% since 2008, the Hong Kong property price is 84% overvalued according to the conventional gauge of the price-to-rent ratio, which ranks No.1 in the world. See *Economist*, August 31, 2013.

supporting our model's assumption of exogenous housing price dynamics. In addition, Hong Kong housing and rental markets are fairly homogenous, with rents free from government control and constructed from new lettings. Consistent with the model described above, positive housing price shocks produce rapid rental growth while negative price shocks reduce rental growth. Moreover, rental growth increases with housing price volatility when housing prices are rising and decreases with volatility when housing prices are falling.

Our empirical evidence contributes to the conventional rental adjustment literature where the vacancy rate is the sole driver of rental rate changes (Smith, 1974; Eubank and Sirmans, 1979; Rosen and Smith, 1983; Hendershott, 1996). More interestingly, in our empirical model, the vacancy rate becomes insignificant in explaining the change in the rental rate after controlling for housing price changes and volatility. This suggests that vacancy rates are an endogenous driver of rental adjustment and their micro foundation could be the real options cross-market effect on rental demand and supply.

Lastly, our findings carry important policy implications for cyclical fluctuations in the rental market. It is apparent in our model that housing price dynamics in general and uncertainty in particular play important roles in rental adjustments and contribute to cyclical fluctuations in the rental market. Property bubbles may spill over to rent inflation and the bursting of a bubble may cause rent deflation. Moreover, due to the large weight of rent in the CPI in Hong Kong (accounting for 26%), rent inflation exerts a considerable influence on measures of overall and core inflation. To curb inflation or prevent an economy from falling into deflation, it is important to stabilize housing price dynamics and reduce housing price uncertainty. In particular, policy action is needed to deal with capital inflows arising from quantitative easing by central banks, and the likely capital outflows when monetary policy is tightened. The findings also have another important implication for detecting property bubbles: the conventional gauge based on the price-to-rent ratio may underestimate a bubble because rents can be driven up by housing price uncertainty. A better measure should adjust for the option component of rent.

The rest of the paper is organized as follows. Section 2 presents our theoretical model and derives testable implications. Section 3 discusses data and relevant background on Hong Kong rental and property markets. Section 4 reports the results from our empirical model. Section 5 provides concluding remarks.

2. Theoretical Model

In contrast to the traditional literature that treats rents as fundamental and housing prices as the present value of all future rents, we model housing price dynamics as exogenously given and consider the following real options model of the renter's and landlord's decisions. The model uses the following variables:

K : Private valuation of the house held by the renter or landlord.

S_t : Market value of the house at time t , described by a geometric Brownian motion with volatility σ and drift $r-\delta$ where δ captures the market-wide property yield.

r : Risk-free interest rate.

τ : Stopping time of switching from renting to buying for the renter, or from renting to selling for the landlord.

c : The renter's enjoyment (per unit time) derived from living in the house.

b : The landlord's cost (per unit time) of maintaining the house as a rental unit.

R : Cost (per unit time) of renting the house.

2.1 Renter's Problem

First, we consider the renter's decision to rent or buy a house. The renter solves an optimal stopping-time problem. He (assumed to be risk-neutral) chooses τ to maximize his utility:

$$U=\max_{\tau} E\left[e^{-r\tau}\left(K-S_{\tau}\right)+\int_0^{\tau} e^{-ru}\left(c-R\right)du\right] \tag{1}$$

The first part of equation (1) captures the utility gain from buying the house. The second part captures the utility derived from the period that he rents before buying. For simplicity, we assume that the rental agreement has an infinite maturity and both the renter and the landlord can walk away from the agreement at any time without suffering a penalty.

Following the literature on valuing American put options (Kim, 1990; Bunch and Johnson, 2000), we conjecture that the optimal stopping policy is given by:

$$\tau=\inf\left\{t: S_t \le S_c\right\}, \tag{2}$$

where S_c , the early exercise boundary, is a constant. We then have:

$$U=\max_{S_c}\int_0^{\infty}\left[e^{-r\tau}\left(K-S_c\right)+\frac{c-R}{r}\left(1-e^{-r\tau}\right)\right] f\left(\tau\right)d\tau, \tag{3}$$

where $f(\cdot)$ is the density of the first passage time of S_t from an initial value of $S_0 = S$ down to a lower threshold of S_c. Using the following result from Kim (1990):

$$\int_0^\infty f(t) e^{-rt} dt = \left(\frac{S_c}{S}\right)^\gamma, \tag{4}$$

where

$$\gamma = \frac{1}{\sigma^2}\left[\sqrt{\left(r-\delta-\frac{1}{2}\sigma^2\right)^2 + 2\sigma^2 r} + \left(r-\delta-\frac{1}{2}\sigma^2\right)\right], \tag{5}$$

we have:

$$U = \max_{S_c}\left(K - S_c - \frac{c-R}{r}\right)\left(\frac{S_c}{S}\right)^\gamma + \frac{c-R}{r}. \tag{6}$$

Solving the first order condition with respect to S_c, we find that the renter will choose to buy the house if the housing price $S_t < S_c^R$, where:

$$S_c^R = \frac{\gamma}{\gamma+1}\left(K - \frac{c-R}{r}\right). \tag{7}$$

To better understand the renter's decision, we note that when $r << \sigma^2$ and $\delta << \sigma^2$, we can approximate γ using Taylor's expansion and rewrite S_c^R as:

$$S_c^R = \frac{2r}{2r+\sigma^2}\left(K - \frac{c-R}{r}\right). \tag{8}$$

This shows that the renter is more likely to remain renting when his private valuation of the house K is lower, when the rent R is lower, when his enjoyment of renting the house c is greater, and when the housing price volatility σ is higher.

2.2 Landlord's Problem

In comparison, the landlord chooses the optimal timing to sell her house. Her utility is given by:

$$U = \max_{\tau} E\left[e^{-r\tau}\left(S_{\tau} - K\right) + \int_0^{\tau} e^{-ru}\left(R - b\right)du \right]. \tag{9}$$

The first part of equation (9) captures the utility gain from selling the house (which the landlord privately values at K) for the market price of S_{τ}, and the second part represents the value from receiving rent payment and maintaining the house from 0 to τ.

Conjecturing an optimal stopping policy of:

$$\tau = \inf\left\{t \,:\, S_t \geq S_c\right\}, \tag{10}$$

we have:

$$U = \max_{S_c} \int_0^{\infty}\left[e^{-r\tau}\left(S_c - K\right) + \frac{R-b}{r}\left(1 - e^{-r\tau}\right)\right] g\left(\tau\right)d\tau, \tag{11}$$

where $g(\cdot)$ is the density of the first passage time of S_t from an initial value of $S_0 = S$ up to a higher threshold of S_c. Using the following result from Kim (1990):

$$\int_0^{\infty} g\left(t\right)e^{-rt}dt = \left(\frac{S}{S_c}\right)^{\beta}, \tag{12}$$

where

$$\beta = \frac{1}{\sigma^2}\left[\sqrt{\left(r - \delta - \frac{1}{2}\sigma^2\right)^2 + 2\sigma^2 r} - \left(r - \delta - \frac{1}{2}\sigma^2\right)\right], \tag{13}$$

we have:

$$U = \max_{S_c}\left(S_c - K + \frac{R-b}{r}\right)\left(\frac{S}{S_c}\right)^{\beta} + \frac{R-b}{r}. \tag{14}$$

Solving the first order condition with respect to S_c, we find that the landlord will choose to sell the house if the housing price $S_t > S_c^L$, where:

$$S_c^L = \frac{\beta}{\beta - 1}\left(K + \frac{R-b}{r}\right). \tag{15}$$

To better understand the landlord's decision, we note that when $r << \sigma^2$ and $\delta << \sigma^2$, we can approximate β using Taylor's expansion and rewrite S_c^L as:

$$S_c^L = \frac{2\delta + \sigma^2}{2\delta}\left(K + \frac{R-b}{r}\right). \tag{16}$$

This shows that the landlord is more likely to remain a landlord when her private valuation of the house K is higher, when the rent R is higher, when her cost of maintaining the house as a rental unit b is lower, and when the housing price volatility σ is higher.

2.3 Equilibrium

We assume that there are renters and landlords, each with mass one, endowed with private valuations normally distributed as $K_R \sim N\left(\mu_R, \sigma_R^2\right)$ and $K_L \sim N\left(\mu_L, \sigma_L^2\right)$, respectively.

Given a housing price of S, a current renter will continue to rent if $S \geq S_c^R$ or, equivalently, if his private valuation K satisfies:

$$K \leq \frac{1+\gamma}{\gamma} S + \frac{c-R}{r}. \tag{17}$$

Given the distribution of private valuations of the renters, the demand for rental units is:

$$\text{Demand} = \Phi\left(\frac{\frac{1+\gamma}{\gamma} S + \frac{c-R}{r} - \mu_R}{\sigma_R}\right), \tag{18}$$

where $\Phi(\cdot)$ is the standard normal CDF.

Similarly, a current landlord will continue to rent out her house if $S \leq S_c^L$ or, equivalently, if her private valuation *K* satisfies:

$$K \geq \frac{\beta - 1}{\beta} S - \frac{R-b}{r}. \tag{19}$$

Given the distribution of private valuations of the landlords, the supply for rental units is:

$$\text{Supply} = \Phi\left(\frac{-\frac{\beta-1}{\beta}S + \frac{R-b}{r} + \mu_L}{\sigma_L}\right). \tag{20}$$

Equating demand and supply for rental units, the equilibrium rent is determined as:

$$R^* = \frac{1}{\sigma_L + \sigma_R}\left[r\left(\sigma_L \frac{1+\gamma}{\gamma} + \sigma_R \frac{\beta-1}{\beta}\right)S + \sigma_L\left(c - r\mu_R\right) + \sigma_R\left(b - r\mu_L\right)\right]. \tag{21}$$

To interpret equation (21), we first note an unambiguously positive relation between the equilibrium rent and the housing price, since:

$$\begin{aligned}
\frac{1+\gamma}{\gamma} &= \frac{\sqrt{\left(r-\delta-\frac{1}{2}\sigma^2\right)^2 + 2\sigma^2 r} + \left(r-\delta+\frac{1}{2}\sigma^2\right)}{\sqrt{\left(r-\delta-\frac{1}{2}\sigma^2\right)^2 + 2\sigma^2 r} + \left(r-\delta-\frac{1}{2}\sigma^2\right)} > 0, \\
\frac{\beta-1}{\beta} &= \frac{\sqrt{\left(r-\delta-\frac{1}{2}\sigma^2\right)^2 + 2\sigma^2 r} - \left(r-\delta+\frac{1}{2}\sigma^2\right)}{\sqrt{\left(r-\delta-\frac{1}{2}\sigma^2\right)^2 + 2\sigma^2 r} - \left(r-\delta-\frac{1}{2}\sigma^2\right)} > 0.
\end{aligned} \tag{22}$$

The intuition for this result is clear. When S increases the demand for rental units increases while the supply shrinks. Hence R must increase to restore the equilibrium. When S decreases the demand for rental units drops while the supply expands. Therefore R must decrease to restore equilibrium.

The relation between the equilibrium rent and housing price volatility is more complex and depends crucially on the standard deviation of the distribution of private valuations, σ_R and σ_L. To see this, we first follow earlier derivations to assume that $r << \sigma^2$ and $\delta << \sigma^2$, yielding the following approximations by Taylor's expansion:

$$\begin{aligned}
\frac{1+\gamma}{\gamma} &\approx \frac{2r+\sigma^2}{2r}, \\
\frac{\beta-1}{\beta} &\approx \frac{2\delta}{2\delta+\sigma^2}.
\end{aligned} \tag{23}$$

Given this approximation equations (18) and (20) show that both the demand and supply of rental units will increase with housing price volatility. Moreover, the expansion of rental demand and supply will be larger when the private valuations are more tightly distributed. When σ_R and σ_L are similar in magnitude, it is clear that R^* will be increasing in σ (since $(1+\gamma)/\gamma$ clearly dominates $(\beta-1)/\beta$). However, if for any reason the renters' private valuations are much more widely dispersed than those of the landlords', it is possible for the increase in rental demand to be outstripped by the increase in rental supply, resulting in R^* decreasing in σ.

One such possibility could arise after a fresh drop in housing prices. Since landlords are generally more optimistic about the housing market, they tend to discount the drop as a temporary fluctuation and keep subscribing to their favorable view at least for a while. Renters, on the other hand, tend to be more pessimistic. Given the recent drop in housing prices, some renters are likely to drastically reduce their subjective valuation. This could result in $\sigma_R > \sigma_L$ and the equilibrium rent declining with housing price volatility.

The above setting assumes that all renters and landlords are utility maximizers who can buy and sell properties without constraints. However, in the literature, it is often assumed that financial constraints have a significant effect on the housing market (Bajari et al, 2013). In reality, market participants often notice that some renters will remain renting even if housing prices decrease substantially. For instance, some renters may not have saved enough for a down payment, and some renters may have ruled out buying because of expected job-related migration. The optimal stopping problem probably does not capture the behavior of these renters. This is akin to the notion of "burnout'' in mortgage prepayment, which refers to borrowers who do not refinance following a drop in interest rates.

To allow for this possibility, we assume that the demand for rental units is fixed at D_1 once the housing price has fallen sufficiently. In other words, all unconstrained renters who can afford and are willing to buy a house have already done so, leaving only constrained renters who have no other alternative but continuing to rent. In this case, the equilibrium condition is given by:

$$\Phi^{-1}\left(D_1\right) = \frac{-\frac{\beta-1}{\beta}S + \frac{R-b}{r} + \mu_L}{\sigma_L}, \tag{24}$$

and the equilibrium rent is:

$$R^* = \frac{r\left(\beta-1\right)}{\beta}S - r\left(\mu_L - \sigma_L\Phi^{-1}\left(D_1\right)\right) + b, \tag{25}$$

which is increasing in S and decreasing in σ.

Lastly, our notion of equilibrium considers only the rational decisions of *existing* renters and landlords to exit the rental market by purchasing or selling a house. Clearly, rental demand is also affected by people moving into the area as renters (Saiz, 2003), and rental supply is affected by people who have accumulated enough wealth to purchase multiple properties. Another issue is the searching and matching process in the rental market, which could also affect the landlord's and renter's decisions (Wheaton, 1990). We leave the modeling of these market participants to future extensions of our model.

3. Data

In order to test our theory, a well-matched dataset is necessary to get a sensible result since there are several salient features of housing and rental markets. First, housing units are always heterogeneous, and units for sale could be quite different to units for rent in the same area. For example, in the US units for sale are mostly single-family homes while the rental market is dominated by condominiums and apartments.[3] This heterogeneity suggests that the ideal sample for this study is from a large metropolitan city where units for sale and for rent are homogenous. Second, many large cities such as London, New York and Los Angeles have had rent controls under different regimes for many years. There is widespread agreement that rental controls generally short-circuit the market mechanism for housing (Arnott, 1995). Third, from the theoretical model, we need rental prices constructed from new lettings in the rental market. Rental costs from the Consumer Price Index (CPI) are not appropriate because of significant time lags (unfortunately, CPI rental indicators are much easier to obtain compared with the indices constructed from new lettings).

Given the above data requirements, Hong Kong is an ideal place to study the link between housing prices and rents for at least three reasons. First, units for sale and units for rent are homogenous in Hong Kong because most residential properties are apartments and condominiums, given the very high population density in this metropolis.[4] Second, Hong Kong has been free from rent controls for many years (Wang et al, 2012). Third, rental price indices are constructed from new lettings in Hong Kong. Therefore, we have collected the following data from Hong Kong residential rental and property markets:

a) Housing price index

The main housing price indices in Hong Kong are published by the Rating and Valuation Department (R&VD), and cover five categories of private residential units according to size.[5] The R&VD publishes

[3] See Dales, Paul. (2011). Rental market set to shine, US Housing Market Focus, Capital Economics, May 16, 2011.

[4] Hong Kong is one of the most densely populated areas in the world, with a land mass of 1,104 km2 (426 sq mi) and a population of seven million people. Most residential housing units in the city are apartments and condos with size less than 100 Square meters, which account for 92% of total housing units in 2011. Housing is the most important form of savings to most households in the city and about half of domestic credit goes to various mortgage loans in the property market and taxes from the real estate industry have been a significant source of government revenue.

[5] The five categories are from the smallest Class A to the largest Class E, representing floor areas of 39.9 m^2 and below (A), 40.0 to 69.9 m^2 (B), 70.0 to 99.9 m^2 (C), 100,0 to 159.9 m^2 (D), and over 159.9 m^2 (E), respectively.

two types of price indices at both the aggregate level and the size category level, and the price indices are designed to measure price changes with quality kept constant, which means that they have been adjusted for variations in the quality of the different housing units.

b) Rental price index

Similar to housing prices, the R&VD also publishes rental price indices constructed by new lettings for different categories. Rents are based on an analysis of rental information recorded by the R&VD for new lettings effective in the quarter being analyzed. Rents are analyzed on a net basis, i.e., exclusive of rates, management, and other charges. The rental indices are designed to measure rent changes with constant quality since rents at a certain period depend to a large extent on the special characteristics of the premises, including quality and location.

c) Volatility of the housing price growth

Based on our theoretical model, housing price uncertainty plays an important role in rental adjustment. As a proxy for uncertainty, we estimate the volatility of housing price growth. Following the volatility literature, we choose the Exponential Generalized Autoregressive Conditional Heteroskedasticity (EGARCH) model (Nelson, 1991) to better capture the volatility asymmetry in the property market (Michayluk et al. 2006). Detailed information about volatility estimates can be found in Table 2.

d) Real risk-free interest rate

Since 1983, the Hong Kong dollar has been pegged to the US dollar under the linked exchange rate system, suggesting that the risk-free interest rate in Hong Kong should be closely related to its counterpart in the US. In the real estate literature, long-term Treasury bond yields are often used as a proxy for the risk-free interest rate (Poterba, 1991, Himmelberg, et al., 2005). We select the ten-year US Treasury bond yield as an appropriate risk-free interest rate in Hong Kong because the long-term domestic government bond market in Hong Kong is quite illiquid (Wang et al., 2012).

e) Vacancy rate

The vacancy rate is also taken from RV&D reports; vacant units are defined those not physically occupied when the survey is conducted at the end of the year.[6] Premises under decoration are classified as vacant. Some vacancies could be due to units which have not been issued with occupation certificates by the government. It should be clear that vacancy rates bear no relationship to whether the property has been sold by the developers, and units sold may remain vacant pending

[6] Rating and Valuation Department (R&VD), Hong Kong Property Review 2012, available at http://www.rvd.gov.hk/en/publications/hkpr.htm.

occupation by the owner or tenant. Vacancy figures cover the entire stock in the residential market and are not just confined to new developments.

The data used in this paper is quarterly and monthly from 1980Q1 to 2011Q4. As shown in Figure 1, the Hong Kong property market has been very volatile in the last three decades. Since 2009, property prices have increased sharply in Hong Kong. The housing price index rose above its 1997 peak and is almost 40% higher than the previous peak in the first quarter of 2013. Meanwhile, the rental price index has also increased dramatically. For example, rents increased by 35% between 2009Q3 and 2010Q4, while property price rose by more than 50% over the same period. More importantly, rents tend to follow housing prices in Hong Kong. For example, in October 1995, the housing price index reached a turning point and began a two-year rally. Two months later, rents followed housing prices, resulting in sustained increases until housing prices collapsed at the end of 1997. We can observe the same pattern in both 2003 and 2008.

Table 1 shows summary statistics of housing price growth, rental price growth, interest rate changes, and vacancy rates. It can be easily observed that housing price growth is more volatile than rental growth in both the quarterly and monthly data, which is consistent with what we observed in Figure 1. The vacancy rate is quite low, only 4.7% on average in quarterly data between 1980 and 2011. The vacancy rate is even lower in recent years, only 3.5% on average, suggesting that the rental market has been extremely tight in Hong Kong.

Table 2 reports the ARMA-EGARCH estimation results of housing price growth. According to the Akaike Info Criterion (AIC) and the Schwarz Criterion (SC), we choose an ARMA (1,2)-EGARCH (2,3,2) model for the quarterly data and an ARMA(1,2)-EGARCH(2,2,2) model for the monthly data. The results show a strong EGARCH effect. We derive the series of estimated volatility from the ARMA-EGARCH models, which are then superimposed over real rental growth as shown in Figure 2.

From Figure 2 it is apparent that housing prices have become more volatile since the late 1980s, especially during the Asian financial crisis of 1997 and the more recent global financial crisis of 2008. The forecast volatility reached its highest level in 1994Q3 due to a sudden price jump at the end of 1994. Correspondingly, real rental growth was also quite strong, which suggests that housing price volatility might play a role in rental adjustment.

We also conduct a Granger causality test for housing price growth and rental price growth using both quarterly and monthly data. From the results in Table 3, we can reject the null hypothesis that rental price growth does not Granger cause housing price growth at the 5% significance level, while we can also reject the null hypothesis that price growth does not Granger cause rent growth at the 1% significance level. However, if we examine monthly data, we cannot reject the proposition that rent growth does not Granger cause price growth even at the 10% significance level. Nonetheless, we can reject the hypothesis that price growth does not Granger cause rent growth at the 1% significance level. These results clearly show that housing price growth could Granger cause rent growth, but not the other way around.

4. Empirical Analysis

4.1 Empirical Model

According to the above discussion, we can write down the following empirical model:

$$\%\Delta R_t = \beta_0 + \beta_1 Vacancy_{t-1} + \beta_2 \%\Delta S_{t-1} + \beta_3 Vol_t + \beta_4 Vol_t \times d_t + \beta_5 \%\Delta r_t + \varepsilon_t , \quad (26)$$

where $\%\Delta R_t$ is the percentage change of real rents at period *t*, $vacancy_{t-1}$ is the lagged vacancy rate, $\%\Delta S_{t-1}$ is the lagged percentage change of real housing prices, Vol_t represents the volatility of real housing price growth, d_t is a dummy for housing price trends where $d_t = 1$ if the housing price is rising and zero otherwise, and Δr_t denotes the percentage change of the real risk-free interest rate.

In the benchmark model (Model 1), we consider the lagged vacancy rate as the only determinant of rental growth, which is in line with the traditional literature on rental adjustment. Alternatively, Model 2 uses lagged housing price growth and volatility as explanatory variables to test our theoretical model predictions, which can be structured as two hypotheses. The first one is the monotonic price effect hypothesis (H1):

$$\beta_2 > 0 \quad (27)$$

which expects rental growth to be increasing with housing price growth. The second one is the regime-dependent volatility effect hypothesis (H2):

$$\beta_4 > 0 \ \beta_3 < 0 , \ \beta_4 + \beta_3 > 0 \quad (28)$$

which argues that rental growth increases with housing price volatility when housing prices are rising and decreases with housing price volatility when housing prices are falling (see our discussion on page 11 which justifies these predictions). If housing price dynamics and uncertainty play a more important role in the rental adjustment process than the vacancy rate, the R-squared of Model 2 will be higher than that of Model 1.

In Model 3, we want to examine whether these two hypotheses (monotonic price effect and regime-dependent volatility effect) still hold after controlling for interest rate changes. Also, we are interested in the impact of interest rate changes on rental growth. The sign of β_5 is not so straightforward because the first order derivative of real rents with respect to real interest rates is complicated from equation (25). Intuitively, however, when the interest rate is low, credit constraints are relaxed and housing demand increases. This seems to imply lower rental demand and lower rental rates. Therefore, we expect to see a positive β_5.

In Model 4, we put all variables into a regression. We expect the monotonic price effect and regime-dependent volatility effect to remain significant and robust after controlling for the vacancy rate. On the other hand, it is interesting to see whether the vacancy rate is still significant in explaining rental growth after controlling for house price dynamics and uncertainty. If the vacancy rate becomes insignificant, this suggests that vacancy rates are an endogenous driver of rental adjustment and their micro-foundation could be the housing price effect and volatility effect in the rental market.

4.2 Empirical Results

We test the above empirical models using quarterly and monthly data at the aggregate level. Table 4 presents the results estimated by Ordinary Least Squares (OLS) using quarterly data. In Model 1, the vacancy rate is significant, which suggests that the conventional rental adjustment explanation is supported by Hong Kong data. In Model 2, as the monotonic price effect predicts, housing prices have a significantly positive impact on rental growth, and a one percent housing price hike pushes the rental rate up about 0.28%. Since rents could also affect housing prices, here we use lagged instead of contemporaneous housing prices.[7]

The results in Table 4 show that housing price volatility has a positive impact on the rental growth when housing prices are rising ($\beta_4 + \beta_3 > 0$), while it has an opposite impact on the rental growth when housing prices are decreasing ($\beta_3 < 0$), confirming the regime-dependent volatility effect. These results suggest that the expansion of rental supply due to higher housing price volatility dominates the expansion of rental demand when the housing market is trending downward, leading to lower rental rates. Hence, it seems that Hong Kong landlords have a strong desire not to sell off their properties when the housing price drops sharply; instead, they choose to rent out their properties.

In Model 3, we add real interest rate changes as another explanatory variable. The results suggest that interest rates seem to have a positive impact on rental growth, but the estimated coefficient is not statistically significant. Interest rates could impact rental growth in at least two ways: first, a lower interest rate leads to a higher housing price, which can be passed on to rent. Since we control for housing prices in our model, the impact of this should already have been taken into accounted. Second, a higher interest rate implies that renters can obtain higher returns from investing in alternative assets instead of owning a house. This suggests that renters are willing to pay more rent as interest rates rise. In this sense, higher interest rates might lead to higher rents. However, the

[7] The impact is still significantly positive if we use the contemporaneous price.

results suggest that the impact of the second channel might not be strong enough to produce significant estimates.

In Model 4, we include all the explanatory variables in one model, and interestingly, the vacancy rate becomes insignificant while the impact from housing price changes and their volatility remain significant. As we discussed before, it suggests that the vacancy rate is an endogenous indicator of demand and supply in the rental market, and what really drives rental demand and supply are housing price changes and housing price volatility as our theoretical model illustrates. The higher R-squared after adding these theoretically motivated variables also supports our assessment.

We next turn to the monthly data to test our theory. The monthly results in Table 5 are quite consistent with what we find in Table 4: both the price effect and the volatility effect are significant in the rental adjustment process; the coefficient on the real interest rate change is not significant, though the sign is consistent with our expectations. We find that a one percent housing price increase pushes the rental rate up by about 0.29%, which is similar to the estimate using quarterly data. Finally, the lagged vacancy rate alone cannot explain rental adjustments in Hong Kong, which is not surprising because the slow movement of the vacancy rate is incapable of explaining rental rate changes at a monthly frequency.

4.3 Robustness Check

For robustness, we construct a panel dataset using observations from five categories to estimate the empirical models by fixed-effect regressions. The results shown in Table 6 are quite similar to what we find using aggregate-level data: the price effect is positive and significant, and housing price volatility boosts rental growth as housing prices rise, while it pushes rents down when housing prices fall. The size of the volatility effect is smaller than that in Table 4, presumably because the category-level data are noisier than aggregate-level data.

The real interest rate change remains positive and insignificant, which is consistent with earlier results. The lagged vacancy rate is negative and significant in Model 1, which suggests that the conventional rental adjustment explanation is valid in category-level data. However, the lagged vacancy rate become insignificant after controlling for price and volatility effects, which is consistent with what we find using aggregate-level data in Table 4.

In Table 7, for each category we include all explanatory variables to run the same regressions. The results are quite robust across categories and similar to the results reported in previous tables. One notable finding is that as the unit size increases, the price effect becomes slightly larger. This suggests that for luxury apartments, rents and prices are more closely linked.

The more interesting finding is that, for categories with larger unit sizes (Category D: unit size between 100 m^2 and 160 m^2, and Category E: 160 m^2 and above), rents increase with volatility when housing prices rise. However, rents do not decrease with volatility when housing prices fall. This makes perfect sense in light of our earlier discussions: the buyers for these luxury housing units are not constrained renters as they are very wealthy people. Therefore, when the price volatility of these luxury units falls, they are more willing to buy, and demand for rental units drops (it no longer stays fixed as in the case of constrained renters). This causes rents to decrease.

5. Conclusion

This paper explores the possibility that house prices, like other asset prices, are externally-determined and can influence rents, which contrasts with the traditional view that rents are fundamental and determine house prices. We demonstrate that housing price uncertainty has a large impact on property investment of individual households and can lead to cyclical fluctuations in the rental market. Specifically, we model the renter's decision to buy a house and the landlord's decision to sell as real options of waiting and examine the real options effect on rental demand, supply, and thus the rental rate. The predictions derived from the theoretical model are supported empirically using Hong Kong data.

Both the theoretical and empirical results show that housing price shocks could affect rents through two effects. The first causal effect is the monotonic price effect: rents increase with housing prices. The empirical results show that a one percent housing price spike would push rental rates up about 0.28%. The second causal effect is the regime-dependent volatility effect: rents increase with housing price volatility when the housing market is rising and decreases with volatility when the market is falling.

The policy implications of the paper are important given the large weight of rent in the CPI in Hong Kong. Property bubbles may spill over to rent inflation and pricking the bubble may cause rent deflation. Also, rents are not just driven by fundamentals; housing price shocks and their volatility also play an important role in rental adjustment. Therefore, the price-to-rent ratio could underestimate the size of housing bubbles.

References

Arnott, Richard (1995), “Time for Revisionism on Rent Control,” *Journal of Economic Perspectives*, 9: 99-120.

Ayuso, J. and F. Restoy (2006), “House Prices and Rents: An Equilibrium Asset Pricing Approach,” *Journal of Empirical Finance*, 13: 371-88.

Aguerrevere, Felipe (2009), “Real Options, Product Market Competition and Asset Returns,” *Journal of Finance*, 64: 957-83.

Bajari, P., P. Chan, D. Krueger and D. Miller (2013), “A Dynamic Model of Housing Demand: Estimation and Policy Implications,” *International Economic Review*, 54(2): 409-42.

Bernanke, Ben S. (1983), “Irreversibility, Uncertainty, and Cyclical Investment,”*Quarterly Journal of Economics*, 98: 85-106.

Bloom, Nicholas (2009), “The Impact of Uncertainty Shocks,” *Econometrica*, 77: 623-85.

Brennan, Michael (1990), “Latent Assets,” *Journal of Finance*, 45: 709-30.

Bunch, D. and H. E. Johnson (2000), “The American Put Option and its Critical Stock Price,” *Journal of Finance,* 55(5): 2333-56.

Chambers, M., C. Garriga and D. Schlagenhauf (2009), "Accounting for Changes in the Homeownership Rate," *International Economic Review*, 50(3), 677-726.

Dixit, Avinash and Robert S. Pindyck (1994), *Investment Under Uncertainty,* Princeton University Press.

Ederington, L. H. and W. Guan (2002), “Why are those Options Smiling?” *The Journal of Derivatives*, 10(2): 9-34.

Eubank, A. A. and C. F. Sirmans (1979), “The Price Adjustment Mechanism for Rental Housing in the United States,” *Quarterly Journal of Economics,* 93: 163-83.

Grenadier, Steven R. (1995), “Valuing Lease Contracts: A Real-Options Approach,” *Journal of Financial Economics*, 38: 297–331.

Grenadier, Steven R. (2005), “An Equilibrium Analysis of Real Estate Leases,” *Journal of Business*, 78: 1173-213.

Hendershott, P. H. (1996), “Rental Adjustment and Valuation in Overbuilt Markets: Evidence from Sydney,” *Journal of Urban Economics,* 39: 51-67.

Henderson, J. Vernon and Yannis M. Ioannides (1983), “A Model of Housing Tenure Choice,” *American Economic Review*, 73(1): 98-113.

Henry, Claude (1974), “Investment Decisions under Uncertainty: The Irreversibility Effect,” *American Economic Review*, 64: 1006-12.

Himmelberg, Charles, Christopher Mayer and Todd Sinai (2005), “Assessing High House Prices: Bubbles, Fundamentals and Misperceptions,” *Journal of Economic Perspectives*, 19(4): 67-92.

Kim, I. J. (1990), "The Analytic Valuation of American Options," *Review of Financial Studies*, 3: 547-72.

Li, Wenli and Rui Yao (2007), “The Life-Cycle Effects of House Price Changes,” *Journal of Money, Credit and Banking*, 39: 1375-409.

Majd, Saman and Robert S. Pindyck (1987), “Time to Build, Option Value, and Investment Decisions,” *Journal of Financial Economics*, 18:7–27.

Michayluk, David, Patrick J. Wilson and Ralf Zurbruegg (2006), “Asymmetric Volatility, Correlation and Returns Dynamics Between the U.S. and U.K. Securitized Real Estate Markets,” *Real Estate Economics*, 34(1): 109-31.

Nelson, D. B. (1991), "Conditional Heteroskedasticity in Asset Returns: A New Approach," *Econometrica*, 59: 347-70.

Poterba, James (1991), "House Price Dynamics: The Role of Tax Policy and Demography," *Brookings Papers on Economic Activity*, 2: 143-83.

Qian, Wenlan (2013), “Why Do Sellers Hold Out in the Housing Market? An Option-Based Explanation,” *Real Estate Economics*, 41: 384-417.

Rosen, K. T. and L. B. Smith (1983), “The Price Adjustment Process for Rental Housing and the Natural Vacancy Rate,” *American Economic Review*, 73: 779-86.

Saiz, A. (2003), "Room in the Kitchen for the Melting Pot: Immigration and Rental Prices," *Review of Economics and Statistics*, 85: 502-21.

Shiller, Robert (2008), “Understanding Recent Trends in House Prices and Homeownership,” in *Housing, Housing Finance and Monetary Policy*, Jackson Hole Conference Series, Federal Reserve Bank of Kansas City: 85-123

Smith, L. B. (1974), “A Note on the Rent Adjustment Mechanism for Rental Housing,” *American Economic Review*, 64: 478-81.

Sommer, Kamila, Paul Sullivan and Randal Verbrugge (2013), “The Equilibrium Effect of Fundamentals on House Prices and Rents,” *Journal of Monetary Economics*, forthcoming.

Titman, Sharidan (1985), “Urban Land Prices under Uncertainty,” *American Economic Review*, 75: 505-14.

Triantis, Alexander J. and James E. Hodder (1990), “Valuing Flexibility as a Complex Option,” *Journal of Finance*, 45: 549-66.

Wang, Honglin, Chu Zhang and Weihang Dai (2013), “Rental Adjustment and Housing Prices: Evidence from Hong Kong’s Residential Property Market,” HKIMR Working Paper No.01, Hong Kong Institute for Monetary Research.

Wheaton, W. (1990), “Vacancy, Search, and Prices in a Housing Market Matching Model,” *Journal of Political Economy*, 98: 1270-92.

Yao, Rui and Harold Zhang (2005), “Optimal Consumption and Portfolio Choices with Risky Housing and Borrowing Constraints,” *Review of Financial Studies*, 18: 197-239.

Table 1. Summary Statistics

This table reports summary statistics of Hong Kong's real housing price growth, rental price growth, interest rate change, and the vacancy rate. The housing price index, rental price index, and vacancy rates are obtained from the Hong Kong Rating and Valuation Department (R&VD). Real housing price growth and real rental growth are percentage changes in the housing price index and rental price index adjusted for Hong Kong inflation rate, respectively. The US 10-year Treasury bond yield is used for the Hong Kong risk-free interest rate, which is closely aligned with its US counterpart under the linked exchange rate system. Real interest rate changes are represented by the percent change of the US 10-year Treasury bond yield adjusted for the Hong Kong inflation rate.

Variables	Obs	Mean	Std. dev	Min	Max
Quarterly data (Sample period: 1980Q1-2011Q4)					
Real housing price growth	124	0.747	5.813	-16.66	17.95
Real rental price growth	124	0.020	3.462	-11.80	9.05
Real interest rate change	124	-0.022	0.080	-0.237	0.213
Vacancy rate	124	4.712	1.023	2.9	6.8
Monthly data (Sample period: January 1993- March 2013)					
Real housing price growth	242	0.291	2.865	-11.66	9.418
Real rental price growth	242	0.036	1.671	-8.648	7.587
Real interest rate change	242	-0.005	0.057	-0.312	0.204
Vacancy rate	239	3.532	0.822	1.8	4.7

Table 2. Estimation Results of ARMA-EGARCH Models

This table reports the results of the ARMA-EGARCH models for housing price growth. The conditional mean is specified as ARMA(1,2) based on the AIC and Schwarz criteria. The conditional variance is the EGARCH(q,p,r) model as follows:

$$\ln \sigma_t^2 = \omega + \sum_{j=1}^{q} \beta_j \ln \sigma_{t-j}^2 + \sum_{k=1}^{p} \alpha_i \left| \frac{\varepsilon_{t-i}}{\sigma_{t-i}} \right| + \sum_{k=1}^{r} \gamma_k \frac{\varepsilon_{t-k}}{\sigma_{t-k}},$$

where the left-hand side is the logarithm of the conditional variance, which implies that the leverage effect is exponential, rather than quadratic, and that forecasts of the conditional variance are guaranteed to be nonnegative. The parameters q, p, and r are chosen according to the AIC and Schwarz criteria.

Dependent variable: Real housing price growth						
	Quarterly data (EGARCH(2,3,2))			Monthly data (EGARCH(2,2,2))		
Variables	Coefficient	St. Error	Z-statistics	Coefficient	St. Error	Z-statistics
Constant	0.001	0.008	0.015	0.004	0.002	1.755
AR(1)	0.088	0.312	0.283	-0.043	0.348	-0.123
MA(1)	0.662	0.306	2.162	0.564	0.350	1.611
MA(2)	0.228	0.191	1.193	0.200	0.172	1.161
Variance Equation						
ω	-0.286	0.227	-1.260	-0.205	0.028	-7.298
β_1	0.336	0.432	0.777	0.032	0.061	0.525
β_2	-0.537	0.383	-1.403	-0.002	0.062	-0.034
α_1	-0.067	0.186	-0.359	-0.019	0.033	-0.566
α_2	-0.334	0.263	-1.269	0.025	0.032	0.770
α_3	0.453	0.197	2.302			
γ_1	1.226	0.370	3.311	1.930	0.021	91.93
γ_2	-0.297	0.348	-0.856	-0.954	0.021	-45.75
R^2	0.318			0.204		
AIC	-3.268			-4.629		
SC	-2.994			-4.470		

Table 3. Granger Causality Test between Price Growth and Rent Growth

The table reports the results of Granger causality tests for real housing price growth y_t and real rent growth x_t as follows:

$$y_t = \alpha_0 + \alpha_1 y_{t-1} + ... + \alpha_k y_{t-k} + \beta_1 x_1 + ... + \beta_k x_{t-k} + \varepsilon_t$$
$$x_t = \alpha_0^{'} + \alpha_1^{'} x_{t-1} + ... + \alpha_k^{'} x_{t-k} + \beta_1^{'} y_1 + ... + \beta_k^{'} y_{t-k} + u_t.$$

where the number of lags is 8 in both quarterly and monthly data according to the AIC criterion. The null hypothesis is that x_t does not Granger cause y_t in the first regression, and y_t does not Granger cause x_t in the second regression. The reported F-statistics are the Wald statistics for the joint hypothesis:

$$\beta_1 = \beta_2 = \cdots = \beta_k = 0$$

	Obs	F-statistics	Prob
Quarterly Data			
Null hypothesis: Rent growth does not Granger cause price growth	116	2.224	0.031
Null hypothesis: Price growth does not Granger cause rent growth		5.680	0.000
Monthly Data			
Null hypothesis: Rent growth does not Granger cause price growth	234	1.572	0.134
Null hypothesis: Price growth does not Granger cause rent growth		74.79	0.000

Table 4. Quarterly Results of Rental Determinants with Aggregate Data

This table presents the results of the following models using aggregate quarterly data from Quarter 1 of 1980 to Quarter 4 of 2011

$$\%\Delta R_t = \beta_0 + \beta_1 Vacancy_{t-1} + \beta_2 \%\Delta S_{t-1} + \beta_3 Vol_t + \beta_4 Vol_t \times d_t + \beta_5 \%\Delta r_t + \varepsilon_t ,$$

where $\%\Delta R_t$ is real rental growth, $Vacancy_{t-1}$ is the lagged vacancy rate, $\%\Delta S_t$ is the lagged real housing price growth, Vol_t is the volatility of real housing price growth, d_t is the price trend dummy for $\%\Delta S_t > 0$, and $\%\Delta r_t$ is the real interest rate growth.

Numbers in parentheses are standard errors. The symbols *, **, *** denote statistical significance at 10%, 5% and 1% level respectively.

Dependent Variable: $\%\Delta R_t$				
Variables	Model (1)	Model (2)	Model (3)	Model (4)
$Vacancy_{t-1}$	-0.534*			0.035
	(0.314)			(0.221)
$\%\Delta S_{t-1}$		0.280***	0.280***	0.281***
		(0.042)	(0.042)	(0.043)
Vol_t		-7.696***	-7.607***	-7.554***
		(1.855)	(0.167)	(1.904)
$Vol_t \times d_t$		10.05***	9.823***	9.842***
		(1.774)	(1.829)	(1.840)
$\%\Delta r_t$			1.425	1.342
			(2.621)	(2.682)
Constant	2.541	0.181	0.223	0.039
	(1.514)	(0.375)	(0.384	(1.218)
Obs	124	123	123	123
Adjusted R-sq	0.02	0.58	0.58	0.58

Table 5. Monthly Results of Rental Determinants with Aggregate Data

This table presents the results of the following models using aggregate monthly data from January 1993 to March 2013:

$$\%\Delta R_t = \beta_0 + \beta_1 Vacancy_{t-1} + \beta_2 \%\Delta S_{t-1} + \beta_3 Vol_t + \beta_4 Vol_t \times d_t + \beta_5 \%\Delta r_t + \varepsilon_t \text{ ,}$$

where $\%\Delta R_t$ is real rental growth, $Vacancy_{t-1}$ is the lagged vacancy rate, $\%\Delta S_t$ is the lagged real housing price growth, Vol_t is the volatility of real housing price growth, d_t is the price trend dummy for $\%\Delta S_t > 0$, and $\%\Delta r_t$ is the real interest rate growth.

Numbers in parentheses are standard errors. The symbols *, **, *** denote statistical significance at 10%, 5% and 1% level respectively.

Dependent Variable: $\%\Delta R_t$				
Variables	Model (1)	Model (2)	Model (3)	Model (4)
$Vacancy_{t-1}$	0.001			-0.001
	(0.005)			(0.001)
$\%\Delta S_{t-1}$		0.294***	0.287***	0.288***
		(0.032)	(0.033)	(0.033)
Vol_t		-3.640**	-3.622**	-3.844**
		(1.797)	(1.796)	(1.907)
$Vol_t \times d_t$		4.082*	4.211*	4.306*
		(2.254)	(2.256)	(2.278)
$\%\Delta r_t$			0.018	0.018
			(0.016)	(0.016)
Constant	-0.003	0.001	0.001	-0.001
	(0.019)	(0.001)	(0.001)	(0.001)
Obs	239	241	241	239
Adjusted R-sq	0.01	0.30	0.30	0.30

Table 6. Quarterly Results of Rental Determinants with Panel Data

This table presents the results of the following models estimated by fixed-effect regressions using panel data including five categories of housing units: Categories A, B, C, D and E have a floor area of 39.9 m^2 and below, between 40.0 and 69.9 m^2, between 70.0 and 99.9 m^2, between 100.0 and 159.9 m^2 and 160 m^2 above respectively.

$$\%\Delta R_t = \beta_0 + \beta_1 Vacancy_{t-1} + \beta_2 \%\Delta S_{t-1} + \beta_3 Vol_t + \beta_4 Vol_t \times d_t + \beta_5 \%\Delta r_t + \varepsilon_t ,$$

where $\%\Delta R_t$ is real rental growth, $Vacancy_{t-1}$ is the lagged vacancy rate, $\%\Delta S_t$ is the lagged real housing price growth, Vol_t is the volatility of real housing price growth, d_t is the price trend dummy for $\%\Delta S_t > 0$, and $\%\Delta r_t$ is the real interest rate growth.

Numbers in parentheses are standard errors. The symbols *, **, *** denote statistical significance at 10%, 5% and 1% level respectively.

Dependent Variable: $\%\Delta R_t$				
Variables	Model (1)	Model (2)	Model (3)	Model (4)
$Vacancy_{t-1}$	-0.375**			0.043
	(0.167)			(0.123)
$\%\Delta S_{t-1}$		0.277***	0.340***	0.341***
		(0.027)	(0.021)	(0.021)
Vol_t		-4.420***	-3.054***	-3.055***
		(0.824)	(0.756)	(0.756)
$Vol_t \times d_t$		4.450***	5.398***	5.416***
		(0.912)	(0.709)	(0.712)
$\%\Delta r_t$			2.484	2.402
			(1.558)	(1.579)
Constant	1.784**	0.347	-0.261	-0.469
	(0.799)	(0.247)	(0.236)	(0.639)
Obs	590	585	585	585
Overall R-sq	0.01	0.37	0.49	0.49

Table 7. Quarterly Results of Rental Determinants for Each Housing Category

This table presents the results of the following model using quarterly data from each housing category: Categories A, B, C, D and E have a floor area of 39.9 m^2 and below, between 40.0 and 69.9 m^2, between 70.0 and 99.9 m^2, between 100.0 and 159.9 m^2, and 160 m^2 and above, respectively.

$$\%\Delta R_t = \beta_0 + \beta_1 Vacancy_{t-1} + \beta_2 \%\Delta S_{t-1} + \beta_3 Vol_t + \beta_4 Vol_t \times d_t + \beta_5 \%\Delta r_t + \varepsilon_t$$

where $\%\Delta R_t$ is real rental growth, $Vacancy_{t-1}$ is the lagged vacancy rate, $\%\Delta S_t$ is the lagged real housing price growth, Vol_t is the volatility of real housing price growth, d_t is the price trend dummy for $\%\Delta S_t > 0$, and $\%\Delta r_t$ is the real interest rate growth.

Numbers in parentheses are standard errors. The symbols *, **, *** denote statistical significance at 10%, 5% and 1% level respectively.

Dependent Variable: $\%\Delta R_t$					
Variables	Category A	Category B	Category C	Category D	Category E
$Vacancy_{t-1}$	0.029	-0.061	0.048	0.108	0.077
	(0.222)	(0.255)	(0.263)	(0.294)	(0.348)
$\%\Delta S_{t-1}$	0.296***	0.312***	0.312***	0.359***	0.375***
	(0.047)	(0.046)	(0.048)	(0.053)	(0.052)
Vol_t	-3.691***	-3.063**	-5.503***	-2.931	-0.247
	(1.971)	(1.233)	(1.786)	(1.822)	(5.219)
$Vol_t \times d_t$	6.259***	5.488***	8.164***	5.296***	3.934***
	(2.189)	(1.715)	(1.844)	(1.577)	(1.651)
$\%\Delta r_t$	0.592	4.538	2.057	2.757	1.763
	(2.852)	(3.241)	(3.464)	(3.759)	(4.438)
Constant	-0.296	0.178	-0.331	-0.772	-1.699
	(1.191)	(1.336)	(1.309)	(1.558)	(2.937)
Obs	117	117	117	117	117
Adjusted R-sq	0.44	0.46	0.56	0.51	0.42

Figure 1. Hong Kong Housing Price and Rental Price Indices

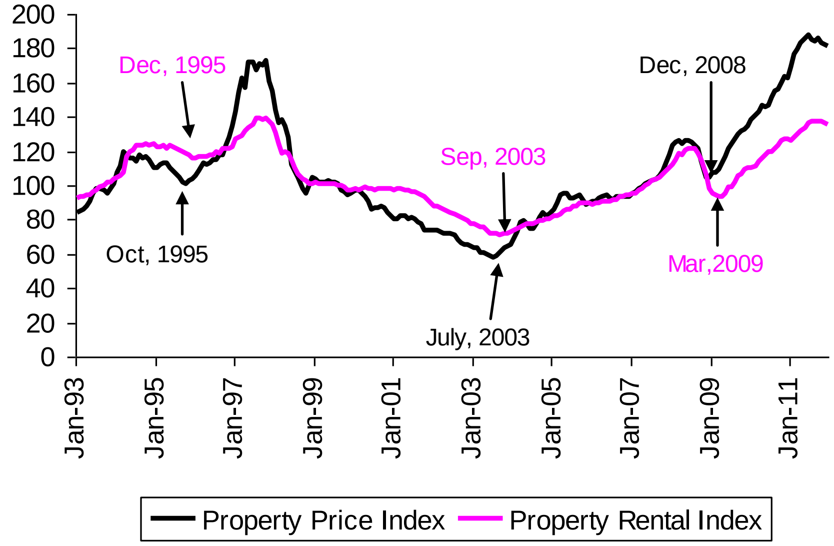

Figure 2. Rent Growth and Volatility of Housing Price in Hong Kong