Price Fluctuations in Housing Market and Homeowners' Options to Move

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Summary

This study attempts to explain the causes of turning points in real estate cycles and try to relate the housing price cycle to households' moving decisions. The main contribution of the thesis is that it extends Stein (1995) hypothesis by incorporating real option theory and voting theory into the housing moving decision model. Building on the theory by Stein (1995), we surmise that a positive exogenous shock will swing the households to move up their housing career. The down payment requirements further reinforce the effects and the number of transactions increases. Yet the increase in both transactions and price volatility entices households to wait for possible increase in price in future. The waiting phenomenon further dampens the demand for new dwelling. Coupled with possible new supply, we expect price to fall. The effects of loss aversion and equity constraints set in and the number of transactions and price volatility fall, until some point when it is beneficial to exercise the option. We further extend the above analysis by including the households' improvement decisions into the picture. Further to the above, we also note that housing improvement decisions in the multi-family picture are collectively made. We further test the model postulated by Ben Shahar and Sulganik (2003) whether households make their votes based on minimizing disutility. In addition, we further test whether households do learn new strategies to abstain, or move over time, especially if they find the new strategy is more optimal.

List of Exhibits

Chapter 1 Introduction

1.1 Background and Justification of Study

Housing has consistently captured a fair amount attention from urban economists, geographers and social scientists (Mills, 2000). Many new scholarly journals, professional publications, and trade magazines have begun and expanded the literature during the past thirty years. In United States, the Department of Housing and Urban Development and the Federal National Mortgage Association publish at least a half-dozen housing periodicals. Internationally, housing research is also extensive throughout the OECD countries; organizations such as The World Bank and The Asian Development Bank have made much progress in understanding even the chaotic housing markets in China and Russia. In addition, research on housing, which first began in Europe, continues to flourish.

The interest in housing market and house price dynamics is further driven by many motivations. First, housing encompasses a large proportion of households' consumption expenditure. In United States, housing is the largest consumer expenditure in United States, after medical care and food. In 1994, personal consumption expenditures on housing were about $2,600 per capita, or 14.9% of household budget (Green and Malpezzi, 2003). From the investment side, housing is the largest form of fixed capital investment in United States, comprising more than $9 trillion, or half of its gross fixed private capital. In Singapore, 92% of the households own the dwelling units they lived in. Furthermore, 61% of the households' withdrawals of their pension savings are used to finance their housing. The total worth of the housing loans in Singapore is about S$5.1 billion as in 1998. Housing is an important component of a household's portfolio and house price dynamics have an important impact on the households' financial situations. Furthermore, given the high cost of housing, most homeowners have to borrow heavily to finance their purchase. The cyclical nature of house price imposes credit risk on lenders, in terms of default and prepayment risks.

Second, the sociological implications of housing market outcomes are as profound as the economic implications. Since housing is the largest asset held by most households, changes in prices in housing market affect how wealth is distributed. Stein (1995) postulated that housing price appreciation enabled households to move to better housing for constrained households. For instance, the sustained price appreciation of the public housing in Singapore enabled the households living in public housing to purchase private condominium units. Alternatively, the high price swings may prevent less affluent households from having access to housing. From the political perspective, governments need to provide affordable housing, so that less affluent households have an opportunity to own a flat; the governments either provide subsidized housing, or offer cheap financing. Fluctuations in housing price, together with co-ordination problems will, however, make such financing programs unsustainable. An understanding of the inherent causes of house price cycle and fluctuations is crucial for institutions to price such subsidies correctly.

Chapter 1 Introduction

In the past decade, the number of studies on inter-temporal changes in house prices have further increased rapidly because of wider availability of extensive micro-level data sets, improvements in modeling techniques and expanded business applications (Cho, 1996). The availability of mortgage and transaction data sets also allow researchers to further test the micro-foundations on the households' decision to move; Genosove and Mayer (2001), Chan (2001) and Englehardt (2003) used the transaction data sets to further test on their hypothesis of households' loss aversion. At the same time, the housing market literature also advanced several theories attempting to explain the relationship between prices and moving decisions.

The theories can be divided into 3 categories. The first category of theories explains how households' mobility decisions are triggered by a "mismatch" through an anticipated economic or demographic shock (Hanushek and Quigley, 1979). Wheaton (1990) further built upon the study by postulating that house prices were determined by the strength of the bargaining power between the buyers and sellers. In other words, the price determined depends on how many similar vacant units are in the market. Hence, this group of theories implies that house price is exogenously determined and the house price pattern observed depends on the speed of adjustment by the suppliers and changes in expectations of the buyers. These theories are consistent with the house price cycle literature (Lange and Mills, 1979; Poterba, 1984; Chinloy, 1996).

Nevertheless, the housing price theories postulated by Poterba (1984) and others do not predict the behavior of house price very well. Many authors observed that house price tend to remain higher than what is predicted by the past models. While Case and Shiller (2003) attributed the cause to fads and speculation, Stein (1995) provided an alternative insight and spearheaded the second group of theories. He explained that a positive exogenous shock in housing market would result a series of self-reinforcing effects; highly leveraged households were able to move up because of a decline in prices. Alternatively, a decline in price would result a fall in transactions due to equity constraints, households would try their luck by 'fishing'.

Genosove and Mayer (2001) and Englehardt (2003) put forth the third group of theories on the relationship between price and households mobility decisions during a house price downturn. Borrowing concepts from behavioral economics, they postulated that sellers experiencing nominal losses tend to set higher list price and keep properties on the market longer as compared to those experiencing gains. In other words, why households do not move during downturns is attributable not only to the equity constraints faced by them, but also to the fear of nominal loss. Their results further showed that equity constraints might not be critical in influencing households' decision to move during bad times.

Interestingly, Stein's hypothesis and the loss aversion hypothesis are driven by different wants and needs of households. Stein's hypothesis is formulated from the maximization of utility from consumption of housing and income, subject to a budget constraint; homeowners are driven by consumption decisions. The loss aversion hypothesis, however, centers more on the homeowner's investment motivations. Hence, the test on both hypothesis implicitly uncover whether the price behavior is influenced by investment objectives or consumption objectives.

It is further observed from past literature that the explanation of the turning point of house prices is unclear. The theories that attributed house price movements to supply lags largely postulated that prices started to fall when the households formed expectations that there had been excess supply, or that prices would fall due to some exogenous factors. Yet, if there is excess supply, what then causes the over-exuberance in the housing market to end? In addition, the loss aversion theory and equity constraints theory implies that households will probably not move when price falls. Thus, what causes the households to break from an immobility trap during a downturn? Is it another exogenous shock, or simply a sudden awareness of excess demand?

I attempt to explain the turning point using the real option framework. I hypothesize that households have the option to relocate or stay in their existing home. The homeowner's freedom to move or modify his dwelling is akin to the manager's flexibility to expand, contract, defer the operations of the firm. Like the manager who is financially constrained to invest, the homeowner is constrained by the availability of financing to purchase his desired houses. Given that a large proportion of the homeowners' wealth is spent on their dwellings, the capital gains/equity from the sale of their dwelling will help the homeowners to purchase the desired homes. This is especially so, if the price of the current dwelling has grown sufficiently or the homeowners have build up sufficient equity over the years through the amortization of the mortgage. There are two implications arising from the option to relocate; households will tend to stay when the house price volatility is high or if the price differential between the households' current and desired dwellings widens. The option to move will not be in-the-money if the down payment payable exceeds the capital obtained from the sale proceeds.

How do we incorporate the option theory into the household decision model? As suggested in most models, when there is a positive exogenous shock, housing demand increases and housing supply slowly adjusts to meet the demand. The slow adjustment in supply exerts an upward pressure on price. In addition, given the shortage in supply, sellers have greater bargaining power and can demand higher prices. The effect of leverage further fuels price increase, as equity constrained homeowners trade their current dwellings for better ones. As prices and transaction volume increase, house price also becomes more volatile. The option premium to wait, which depends on the difference between the purchase and expected selling prices of current dwelling and the volatility of prices, subsequently outweighs the present value appreciation and households will start to delay their housing investment. The decrease in demand makes the increase in supply unsustainable and price starts to fall, changing the expectations of households. In addition, the equity constraint and loss aversion effects start to set in. As the price declines lead to lower transaction volume, the option premium will be lower. When the price differential between the desired dwelling and current dwelling is lowered and the volatility of housing price becomes lower, households start to trade off or exercise their options. I further attempt to empirically test whether my hypothesis is plausible, using Singapore housing market. The clear segmentation of the housing sector – public and private housing sectors- provide us the unique opportunity to test our theory empirically. The segmentations of housing markets in other countries are less clearly defined. Hence, it is harder for us to model the households' upward or downward movements along their housing career.

Our theory is, however, incomplete if we do not consider the households' decision to improve their current dwellings. In 1995, expenditures on maintenance, repair, improvements, and alterations of the housing stock in United States totaled $111.7 billion; expenditures on private construction of new residential buildings totaled $162.4 billion[1]. According to estimates from the Joint Center for Housing Studies at Harvard University based on the 1995 and 1997 American Housing Surveys, home owners' spending on housing improvements during 1994 to 1997 averaged in excess of $100 billion. Including the spending by rental property owners, total expenditure on residential improvements and repairs averaged $165 billion per year between 1994 and 1997, just slightly less than the $184 billion average annual spending on construction of new private housing units over this period according to U.S. Commerce Department (Baker and Kaul, 2002). However, inclusion of the improvements variable will make our initial hypothesis more complicated. First, improvements will affect the supply function. Increasing housing improvements

[1] Bureau of the Census, Construction Reports, Series C-50 and Series C-30 respectively.

indirectly increases the supply of housing. Second, improvements affect the households' demand of housing services. On the one hand, such improvements may serve as a substitute to moving. On the other hand, sellers may improve the housing to fetch a higher price. Third, the housing improvements can also be treated as real options (Downing and Wallace, 2000). By incorporating the improvement decisions into the mobility option model, we attempt to extend the theoretical basis and test the implications of the model. The availability of Main Upgrading Programme (MUP) and the Interim Upgrading Programme (IUP) in Singapore, which are major improvement works on the households' current dwellings initiated by Government, allow us to observe and model the households' decision to invest in their housing.

However, the Main Upgrading Programme also complicates matters because the Main Upgrading Programme can only be carried out if 75% of the households living in the affected precinct vote for it. Thus we need a voting game in place to model the choice. In the voting game, we assume that there are two groups of households, one for MUP and the other against MUP. The households can agree, disagree or abstain. In this case, the households can abstain by moving. Ben-Shahur and Sulganik (2003) first studied how the voting rules favored by opposing parties are determined under different scenarios in a gated community. We first test their assumption on minimization of disutility, which is similar to the minimax regret model (Ferejohn and Fiorina, 1974). In addition, we attempt to extend our understanding in the voting game within the gated community. We hypothesize that the households may learn other strategies in their course of playing the voting game, like moving to a new apartment. We further test the strategies using a separate microdata sample.

1.2 Objectives of Research

I. The first objective of this study is to model the households' option to move or relocate.

II. The second objective is to verify the households' forward-looking response to house price appreciation.

III. The third objective is to empirically test the option to move or relocate using household microdata.

IV. The fourth objective is to model how improvement decisions interact with household decisions. We further to test whether our hypothesis on the interaction holds true or not.

V. The fifth objective is to test the assumption of Ben-Shahur and Sulganik's model and to expand our understanding of the voting strategies of co-owners.

1.3 Organization of Report

I will cover the related literature in the following chapter. In Chapter 3, we provide a brief overview of the housing market and the housing policies in Singapore. In Chapter 4, a conceptual model of the option model and the voting model will be presented. In Chapter 5, I present the results of the preliminary tests for the real option theory. I further compute the option and further test the hypotheses using data from Singapore housing market in Chapter 6. In Chapter 7, I test the voting model postulated in Chapter 4 and analyze the empirical results. Using the results in the earlier chapters, I conclude by discussing the limitations of the study and the direction of possible future research in Chapter 8.

Chapter 2 Literature review

2.1 Households' Mobility Decisions and Price Dynamics

Why do people move? Rossi (1955), a sociologist, first suggested that mobility is "the process by which families adjust their housing to their housing needs that are generated by shifts in family composition that accompany life-cycle change" in 1955. Following his study, many geographers, and economists further explore the underlying motivations that influenced the owners' decisions. The early studies generally postulate that owners move because they cannot fulfill their housing needs in their current dwellings, or their current dwellings more than satisfy their housing wants. Yet the relationship between house price and mobility decisions is not discussed in these studies. In fact, house price is rarely featured in the modeling of households' decision to move (Coupe and Morgan, 1981; Goodman, 1976; Pickles and Davis, 1985).

The relationship between price and moving decisions is first put forth by Hanushek and Quigley (1979). They explain mobility decisions as precipitated by a "mismatch" through an unanticipated economic or demographic shock. They assert that such adjustments are not smooth or necessarily symmetric over price increases and decreases, but they do not attribute the friction to any particular characteristic of the market. Wheaton (1990) and DiPasquale and Wheaton (1996) further formalize the households' decisions in a bargaining model. They assert that household income, life cycle and demographic factors influence the preferences of total household consumption. When an exogenous event initiate a series of changes in the housing demand changes, the household will conduct a search and contemplate the net gains or losses of moving as opposed to staying in the current dwelling. The relative bargaining powers of buyers and sellers, which can be proxied by the vacancy rate of housing market, further push up house price. If the vacancy rate is high, buyers can easily match their wants. If not, they have to pay more for less desirable housing.

Using the above framework, Dispaquale and Wheaton (1996) further describe the market dynamics of housing in different setups where households form their expectations differently. They further attribute the fall in house price from the peak of cycle to excess vacant units caused by overbuilding. They reason that suppliers overbuild because of supply lags and information asymmetry between suppliers and buyers. Dispaquale and Wheaton's framework has many similar aspects with Poterba's asset market approach (1984) and Topel and Rosen's investment approach (1988) in modeling of the housing market. The only exception is that Dispaquale and Wheaton incorporates the stock flow methodology to account for land as an input whereas Poterba and Topel and Rosen do not do so.

Poterba (1984) examines the impact of a shock to the steady state, mapping out the adjustment process to a new steady state. A shock such as an increase in income initially results an increase in real housing price since the housing stock is fixed. The market thus adjusts with growth in the housing stock and decline in property price to a new steady state. On the supply side, he assumes that the home-building industry composes of competitive firms and that the industry's aggregate supply depends on its output price, the real price of housing structure. Assuming there are limits to supply of any factor of production, increases in demand for construction will boost the equilibrium price of dwellings. Topel and Rosen (1988) examine the extent to which housing investment decisions are determined, by comparing current asset prices with current marginal costs of productions. They posit that current asset prices are sufficient statistics for housing investment if short-term and long-term supplies of housing are the same. They further assert that the divergence between short-term and long-term elasticities indicates that current asset prices are not sufficient to make investment decisions, and suggests that builders must form expectations about future prices in order to project the expected earnings.

Numerous studies have lent support to the "mismatch" theories, and have confirmed a positive correlation between housing prices and trading volume. Berkovec and Goodman (1996) further formalize Wheaton's search model (1990) and conduct an empirical test on the correlation between the changes in turnover rates and demand. Their findings lend support to the search theories. Ortalo-Magne and Rady (1998), Andrew and Meen (2003), and Leung et al (2002) also present empirical evidence in support of the Wheaton model for US, UK and Hong Kong respectively. Yet, such empirical evidence, which is based on aggregate data, can only at most establish some causality between the correlated series of housing prices and trading volume. Without controlling for the demographic and socio-economic factors, these aggregate results suffer from significant omitted variable bias (Seslen, 2003) because past literature shows that these factors affect households' decision to move. In addition, the "efficient market" approach to house price determination has also encountered empirical difficulties. Case and Shiller (1989, 1990) present evidence that changes in house prices can be forecasted, based on both past price changes and on some fundamental-based measures such as rent-to-price and construction-cost-to price ratios. Many observers also reach similar conclusions that house prices are in part driven by non-fundamental speculative phenomena such as fads or bubbles (Chinloy, 1996; Abraham and Hendershott, 1996).

Stein (1995) offers a theory to explain both large price swings as well as the correlation between prices and trading activity in the context of equity constraints. Stein (1995) proposes that such a phenomenon is a result of self-reinforcing effects from down payment to house prices. He further explains his proposal by modeling the would-be home buyers' behavior. Stein's model is one of repeat buyers-families who already own a home but have reasons for wanting to move (e.g. new job, better schools, etc). These families are assumed not forced to sell their homes under adverse conditions, but would choose to move only if the gains from moving are large enough. In particular, at any level of house prices, families can be divided into three groups: "unconstrained movers," "constrained movers," and "constrained non-movers".

The "unconstrained movers" consists of families whose debts are so low that the down payment requirement does not affect their behavior. Hence, the housing demand for this group of movers is a decreasing function of price and they perform a stabilizing role. Unlike the previous group, the "constrained" movers have an intermediate level of debt and they face binding financial constraints. In equilibrium, each of the "constrained" movers chooses to sell their old house and buys a new one. Nevertheless, the new dwelling is smaller than what they would like because they do not have enough money for a larger down payment. However, this group of constrained movers would be able to realize more from their sale of house upon an increase in price and would use the extra money to make the down payment for a better dwelling. Hence, the housing demand for this group of "constrained" movers is an increasing function of price and this group of movers performs the crucial destabilizing role in Stein's model. Finally, families in the group of "constrained non-movers" are so financially constrained that they would be better off sitting tight than moving, despite the potential gains from moving. Thus they would not react to increase in house prices. Yet, when house prices fall, these households may rationally choose to stay where they are than move to a much smaller house. Or, the constrained non-movers may list their current house (fishing) at an above market price in the hope of getting lucky and raising enough money to make a reasonable down payment. Hence, he surmises that this could be one of the reasons the transaction volume is lower when prices are falling than that if prices are rising.

Lamont and Stein (1999) find empirical evidence to support Stein's hypothesis. Studying the borrowing patterns at the city level from the American Housing Survey for 44 metropolitan areas between 1984 and 1994, they find that house prices react more sensitively to city specific shocks in cities where a greater fraction of homebuyers are highly leveraged. In addition, Chan (2001) tests the Stein's hypothesis by analyzing the mobility of homeowners, using a sample of 5,094 residential single family 30-year mortgages originated in New York, New Jersey and Connecticut. Chan (2001) find that there are severe constraints to mobility as a result of negative housing market shocks. Her test supports Stein's theory on why lower transaction volume coincides with the fall in prices. Stein's model, however, also implicitly assumes that households' decision to move is dominated by price movements. This basis, which the model depends on, may not be true, since other socioeconomic factors can trigger off household decisions to move. In addition, households also need not move in order to increase their housing consumption; they may choose to renovate their house or increase their floor area of current house.

Unlike the mismatch theory postulated earlier, Stein implicitly assumes that price changes are caused by changes in demand, rather than supply lags. He asserts that the interaction between demand and price depends on the change in demand due to unconstrained movers-the change in demand that arises from families that switch from being non-movers to constrained movers and the change in demand of constrained movers. Of all the demand functions of the three categories of movers, only the change in demand of constrained movers is positively influenced by the price change. Hence, if most constrained movers have acted upon a change in price and become constrained non-movers, the self-reinforcing effects will dwindle, and subsequent changes in demand of housing of unconstrained movers and constrained non-movers are likely to offset the effect of constrained movers. The price will, thus, fall.

One of the criticisms leveled on Stein's model is the static nature of the model. Ortalo-Magne and Rady (1998, 1999, 2001) further extend his model by incorporating the life-cycle model into Stein's existing framework. In their model, agents face credit constraints and their housing consumption is restricted to a discrete set of possibilities. There are two sets of agents; one group consists of agents who are younger, credit constrained and going for starter housing, and the other group consists of agents who are older and not credit constrained. These agents can choose to rent, stay with parents, or move to a starter housing or a more expensive housing. Generally, the prospective buyer prefers to own its dwelling than to rent. In addition, they would like to live in more expensive housing rather than the starter housing, which they could first afford.

Assuming four periods, Ortalo-Magne and Rady further set several parameters determining the distribution income levels of the households. At each period, the prospective buyer decides which type of accommodation to occupy in the following period, execute the corresponding transactions on the housing and credit markets, and last, consume the numeraire good. By specifying the age of the households, they further identify the equilibrium price and demand, given a positive income shock. Ortalo-Magne and Rady find that the income of credit-constrained households has a great influence on the credit-constrained households' housing demand, and the fluctuation of prices. In addition, they find that the property prices of the better dwellings are supported by the price of starter housing, which is further determined by the income of the credit constrained households. In addition, the relative difference in user costs of both types of housing to the utility premium of the better housing also determines the price, since households in the later stages of the life cycle tend to substitute the better dwellings for the starter flats.

Using the theoretical construct of Ortalo-Magne and Rady, Bardhan et. al. (2003) further examine the determinants of new private residential units sold in Singapore during the 1990s. Their findings show that there is a statistically significant "wealth effect" driving the sales of new private residential properties. Second, the real local interest rates have a statistically significantly negative impact on these sales. Thirdly, they further discover that an increase in the rate of change of public resale prices has an important and significant effect on the sales of private residential units.

Grossman and Laroque (1990) present a model that spans both theories reviewed above. They assert that the transaction costs play a critical role in households' decision to move. In their model, housing consumption is determined by an ideal ratio of housing to total wealth, which is based on household preferences with regard to consumption value, risk aversion and other factors. With no transaction costs, any deviation from the ideal level of usage of housing services should induce the household to readjust their housing consumption. As transaction costs grow, a band of inactivity develops around the ideal, and the disequilibrium between the actual and ideal ratios must increase in order to induce a move. Hence, duration dependence is very strong especially among older individuals, occurring as a result of an increasing psychological and economic attachment to the home over time (Venti and Wise, 1990; Seslen, 2002). Ferreira (2003), who analyzes how moving costs generated by property laws affect household mobility, further support Grossman and Laroque’s model with his empirical results.

Genosove and Mayer (2001) and Englehardt (2003) offer an alternative explanation for the low transaction volume during the down turn in house price, as opposed to Stein (1995). Borrowing concepts from Kahneman and Tversky (1979) on behavioral economics, they explain that households do not move during down markets because of loss aversion, as opposed to equity constraints. Genosove and Mayer (2001) explain that households, in fear of nominal loss, will put up their property for sale at higher prices than their initial price in a down market. The time in market will be longer and total transaction volume will be lower. Genosove and Mayer (2001) assert that the loss composes of two components; loss due to change in market indices and loss due to overpayment or underpayment of current attributes. However, the latter component is not easily observable and this results a measurement problem. Genosove and Mayer come up with two models to measure the loss. In the first model, loss is estimated as the truncated difference between the purchase and predicted price of a hedonic equation. Their second model adds the previous selling price from the price regression as a noisy proxy for unobserved quality. Using individual property listings in the Boston Condominium market at weekly intervals between 1990 and 1997, their empirical results support the prospect theory.

Englehardt (2003) further uses interactions between initial period loan-to-value ratio and nominal gains and losses in housing value to clarify the role of loss aversion. Using detailed data from 1985-1996 National Longitudinal Survey of Youth (NLSY79), which were matched with house price data from 149 metropolitan areas to estimate instrumental variables linear probabilities, he discovers that loss itself, not the tightening of equity constraints due to declining prices, lowers mobility. Englehardt argues that the households that have low loan-to-value ratio debt level are not equity constrained. Hence, if nominal losses are significant in positively influencing theses households' decision to stay, we can draw conclusions that prospect theory and loss aversion hypothesis are supported. His results should, however, be interpreted with care, given that the study focuses only on the young, and does not account for individual heterogeneity in mobility behaviour. Wong (2003) also tests the loss aversion theory, using SARS epidemic as a natural experiment and her results support the loss aversion model.

Although Stein (1995), Englehardt (2003) and Genosove and Mayer (2001) offer robust explanations on the low transaction volume during a price downturn, what causes demand of housing to recover remains unanswered. If the equity constraint and loss aversion effects remain influential in affecting households' decision to stay, we are likely to observe a persistent fall in housing price until it reaches the floor price, which is likely to be determined by the cost of construction. Hence, the question is whether the market can recover endogenously by its dynamics or require an exogenous shock remains to be explored.

Seslen (2003) further studies the above models and tries to link to the consumption decisions of household. Her analyses show that households respond strongly to housing price dynamics in the trading decision, but the demographics play a far stronger role in the decision to trade down. She finds that a Grossman and Laroque model coupled with the existence of loss aversion come closest in explaining the positive effects of rising markets and negative response to price declines. Using a structural estimation technique on a sample of movers, she finds that households show a significant evidence of a forward-looking response to price appreciation.

As mentioned earlier, I attempt to use real options concept to further explain the turning points of price cycle. Implicitly, all the above studies recognize that the homeowners have some flexibility to adjust their housing consumption. Such flexibility means that a homeowner has an option to move, subject to his or her affordability of the desired house. Given that the sale of the current dwelling provides capital gains to the owner, the owner can utilize the realized equity to move. The homeowners' decision to move is similar to the investment decision of developers. Capozza and Sick (1991), Williams (1993) and Capozza and Li (1994) model the investment decisions as real options. Similarly, we can follow their example by modeling the homeowners' decision to move using real options.

One critical assumption based on real options approach is that the households must be forward looking and they make rational expectations. The household's decision to move is analogous to an economic decision because he or she has to circumspect all future benefits or decisions that depend on his or her decision to move. The concept of expectations is well established in macroeconomics and is instrumental in explaining the efficiency of markets and the impact of exogenous changes introduced into the market.

The adaptive expectations or backward looking expectation model assumes market participants form expectations based on some pattern or past behaviour in the market. The adaptive expectations model is widely employed in modelling of agricultural markets (see Nerlove, 1958) because models embodying this assumption are readily able to generate stable cyclical fluctuations. Although such adaptive expectation models are frequently criticised as being ad hoc, there is evidence from consumer surveys that consumers frequently operate in this manner (Case and Shiller, 1988). A characteristic of the adaptive expectations model is that the price cycle will be unable to converge to its steady state, and the cycle will exist by itself without any cyclical movements in the market exogenous variables (Dispaquale and Wheaton, 1996).

The rational expectations hypothesis is first put forth by Muth (1961). The rational expectations hypothesis assumes that people's subjective probability distributions about the future outcomes are the same as the actual probability distributions, conditional on the information available to them. In other words, the consumers are perfectly informed about the operation of the market. The tests of the rational expectation hypothesis are made possible, through the form of tests of the 'efficient market hypothesis' pioneered by Fama (1970, 1976). Essentially, under rational expectations, prices follow a random work. Prices are efficient and unpredictable because lagged values of no variable have an influence on price movements. In other words, a market shock does not set off a cyclical pattern; there is only a single price overshoot (Dispaquale and Wheaton, 1996).

Alternatively, under the exogenous expectations hypothesis, agents formed expectations independently of the local market behaviour. Such attitudes exist if households believe that future prices will rise with general economic inflation or some long-run growth rate that is largely unaffected by short run movements in price. The exogenous expectations model relies on the assumption that the market participants' beliefs are constant over time and are not affected by recent price behaviour in the market (Dispaquale and Wheaton, 1996). Although the assumptions are restrictive, the exogenous expectations model offers a useful intellectual exercise.

The concept of expectations was tested indirectly in the real estate literature through examinations of the efficiency of the housing markets. Life Cycle models under rational expectations imply that house prices follow a random walk and exhibit seemingly cyclical behaviour only if the exogenous variables that affect the market have cyclical movements (Meen, 2003). All evidence, however, suggests that housing markets are neither efficient nor can be characterised as a random walk (Englund and Ioannides, 1997; Gatzlaff and Tirtiroglu, 1995; Cho, 1996; Dispaquale and Wheaton, 1994; Mankiw and Weil, 1989). The factors that account for the market inefficiency appear to be the presence of transaction costs and credit market constraints (Quigley, 2003).

Since housing prices are reflective of the actions of would-be movers, the above implies that the expected returns from housing and other form of housing will influence the decisions of would-be movers. In addition, the inefficient market also implies that households expect the market to rise if past prices are rising. Case and Shiller (1988) find evidence that this is true- house buyers' attitudes about likely future price appreciation are highly correlated with recent price behaviour.

2.2 Households' decisions and Housing Investments

As mentioned in Chapter 1, households can consume more housing good, not only by moving to a better house, but also by improving the facilities and characteristics of its current dwelling. Much of the work done to date focuses on the demand for home improvement because homeowners are both suppliers and consumers of housing (Dispaquale, 1999). Bogdan (1992) provides a detailed review of the literature on renovation and repair decisions. She asserts that the basic modeling approach in this literature is to assume that the property owner maximizes the value of net benefits from the housing unit. For owner-occupants, the benefits include housing consumption and the return on the housing investment in the form of capital gains when the house is sold. Expenditures on renovation, repair and maintenance increase with the marginal value the household places on housing services, the additional flow of services produced by the expenditures, and the expected price the property is sold.

Potepan (1989) first analyzes the decision between home improvements and moving. He surmises that higher interest rates increase the attractiveness of home improvements assuming that homes are purchased with a fixed rate mortgage. If moving results in taking a mortgage at a higher interest rate than that of the current mortgage, the household finds home improvement more attractive to moving. He further argues that increases in income make home improvement less attractive because there are technical limits to the increase in housing services that can be achieved by making improvements on an existing structure. Using the 1979 Panel Study of Income dynamics, which provides micro-level data on households, he test his hypothesis by estimating a logit model where the choice is defined as making improvements or moving. He finds that higher interest rate increase the chances of households improving their current dwelling, while increases in income decreases the probability of choosing to improve.

Montgomery (1992), however, contends that Potepan’s results are difficult to interpret because he does not consider households who choose neither improvement nor moving. She constructs a model where households choose the optimal level of housing and the means to achieve the level given their current housing. She estimates her ordered probit model using 1985 American Housing Survey, which provides detailed information on the households and their housing characteristics and expenditures for renovation and repair. Her results suggest that high income households are more likely to improve their existing unit. The probability of improving and the size of expenditures on improvements are lower for mature and minority households, as well as for those who stayed in their dwellings for an extensive period. In rapidly growing markets, households are more likely to improve and spend on those improvements, probably reflecting expectations about house price growth. Occupants of older houses are also found to be more likely to improve and spend more on those improvements.

On the one hand, the above models by Montgomery (1992) and Potepan (1989) assume moving and improving to be competing means for households in disequilibium to achieve equilibrium in housing consumption. If the outcomes in terms of housing consumption are broadly the same, move or improve decisions become cost minimizing problems (Montgomery, 1992; Shear, 1983; Amundsen, 1985; Galster, 1987). On the other hand, Littlewood and Munro (1997), extending from Edin and Englund's (1991) argument that recent movers are no more nearer to equilibrium consumption than the non-movers, assert that moving and improving can be complementary strategies utilized by households to reach their equilibrium housing. Using the 1991 Scottish House Condition Survey (SHCS), Littlewood and Munro (1997) construct a model to test three hypotheses. First, they want to know whether improvement activity is an 'inferior' mode of housing adjustment to moving, where 'inferiority' is established by experiencing relative socio-economic disadvantage. Second, they attempt to find out the extent to which movers are in their equilibrium state. Third, they attempt to explore the factors associated with a move-and-improve decision. They find no evidence that improvement is an 'inferior' mode of housing adjustment and not all recent movers are in equilibrium. Baker and Kaul (2002) further explore the home improvement decisions further, by incorporating dynamic factors, namely changes in the composition of the household and previous spending on home improvements. Their results show that adding a child or an adult increases the odds of expansion by 27% and 32 % respectively and income positively influenced households' decision to move. Their study, however, fails to account for households' decision to move.

Downing and Wallace (2000) offer a different approach to model homeowner improvement decisions. In their model, the value of a house is equal to the expected net present value of a perpetual stream of service flows, which are a function of a set of attributes describing the structure. This set of attributes is further allowed to evolve over time. Given the fluctuating stream of service flows, Downing and Wallace model the homeowner's decision to invest in house attributes as real options. The homeowner compares the value of an additional unit of attribute, net of the value of the opportunity to invest in the future, to the cost of the investment whether or not to invest. Using panel data from the American Housing Survey, Downing and Wallace construct the mixed-logit model and conduct an empirical test of whether observed homeowner investment behavior is consistent with the real option theory of investment or not. Consistent with real option theory, they discover that homeowners are more likely to invest when the spread between the return on housing and user cost of capital is wide. In addition, they find that the value of waiting to invest increases, when the net return on the investment is more volatile. Although their approach is novel, they do not consider households' decision to move as covered by the past literature. Furthermore, given that most of the residential developments in Singapore are gated communities or multi-family residential properties, improvement works on common property cannot be initiated by any individual and require consensus among the other residents.

2.2 Households' Improvement Decisions, Mobility Decisions and voting strategies

Households living in multi-family residential properties may not obtain the expected returns spent on housing investments. First, the increase in asset value in the absence of cooperative effort is marginal since part of the expenditure generates external benefits to owners of proximate properties (Fischel, 1985). Second, financial institutions are reluctant to lend residents in blighted neighborhoods and owners of old buildings and the costs of borrowing would be high. Besides the higher costs involved, owners of multi-family properties co-own the common areas and any improvement decision requires a general consensus under the lease contract.

One of the ways for co-owners to arrive a consensus is by voting- "a method by which to achieve simultaneously joint ownership and decision making." De Geest (1992) finds various voting rules for different decision types by examining practices in apartment buildings in five European countries. For instance, he finds that decisions which result in value redistribution often required a unanimous agreement, while decisions about maintenance of existing public goods in apartment buildings are generally reached by simple majority voting. Ben-Shahur and Sulganik (2003) also explore the optimal voting rule for co-owners whose future debates are resolved by voting. By adopting the optimality criterion and the general methodology by Rae (1969) and then developed by Badger (1972), they further examine the arguments of Buchanan and Tullock (1962) and Barzel and Sass (1990)- heterogeniety in interests among voters optimally leads to a larger majority voting rule. They define a voting rule as optimal if it minimizes the expected disutility for each voter from failing to vote according to the adopted decision.

Ben-Shahur and Sulganik (2003) found that their results were consistent with those of Barzel and Sass (1990). They showed that a relatively small (large) majority rule would persist for the types of proposals around which the voting group was expected to be homogenous (heterogeneous). However, they show that individuals who exhibit distinct preferences and/or different prior beliefs on the own and other stances in future potential votes might still opt for the same voting rule. They also proved that raising disutility generated by rejection (acceptance) of a proposal, which the individual supports (opposes), generally decreases (increases) the level of the optimal voting rule. They concluded that one could not make deductions about the characteristics of the co-owners by making deductions about the characteristics of the co-owners. Although the results of Ben-Shahur and Sulganik's (2003) study offered new insights, they assumed that co-owners strategize their vote to minimize their disutility, rather than maximize their expected utility. In other words, their model calls for extremely conservative behavior on the part of voters

From the above, we can further imply that co-owners can judge whether their position is optimal or not if the voting rule is provided. Yet, whether they vote or abstain remain unanswered after they have judged their position based on the voting rule. If the position is non-optimal, the co-owners may move so that their utility positions remain unchanged. Hence, if the co-owners, who feel they belong to the minority, abstain by moving, the distribution of voters will change and the majority becomes stronger.

Borrowing concepts from the economic theories on voter turnout, we attempt to model how co-owners vote or abstain after the voting rule is established. Dhillon and Peralta (2002) provided a good review of the voter turnout literature. In order to adapt to our context, we propose the bounded-rationality models to study how the voters behave, as proposed by Sieg and Schulz (1995). Sieg and Schulz (1995) replaced the full rationality of a voter assumed in a game theoretic model, by a model of adaptive learning. In their model, no voter knows the optimal strategies but learns voting strategies that are of high economic fitness. The objective of the voter is to raise her voting status, which is denoted as the ratio of the voter's payoff to the average payoff of other voters. Learning is through trial and error: a voter changes his strategy by accident. One trial shows whether the status quo or the new strategy is better. A voter is able to learn a new strategy if this increases his social position. An evolutionary voting equilibrium is reached whenever no other strategy can increase the relative payoff and thus no other strategy can be learned. . In our context, the upward movement from public housing to private housing is viewed as improvement of household social status (Koh and Ooi, 1996) and is deemed as one of the deviant strategies.

Chapter 3 Singapore Housing Market and Housing Policies

3.1 Housing Market in Singapore

As mentioned in Chapter 1, the Singapore housing market offers us a unique opportunity to test our hypothesis. First, the clear demarcation of the housing market allows us to test the households' option to move. Second, the unique Main Upgrading Programme allows us to test the various hypotheses posited by the housing improvement literature. In addition, the voting procedures required by the guidelines for Main Upgrading Programme allow us to understand how homeowners make their voting and mobility decisions concurrently.

Singapore's housing market is segmented into two sectors; the public housing sector and the private housing sector. In 2002, 85% of the population lived in public flats (See Yearbook of Statistics Singapore, 1995). Of the 866,071 units of public housing, 83% were owner-occupied housing while the remaining 17% of the public housing stock comprised of rental units. The high proportion of owner-occupied housing is an anomaly, since most countries have a relatively strong rental sector. The high rate is attributed to the Government policies to retain talent in Singapore. When Singapore gained its independence on 1965, there was great political instability and there is a growing exodus of talent to other countries. In order to cultivate the sense of belongingness to Singapore, the government came up with measures to allow Singaporeans to afford good quality housing. In addition, during the 1960s, Singapore was facing a shortage of housing supply and living conditions were bad. The Singapore Improvement Trust (SIT) then was incapable of providing sufficient housing to the residents. On 1 February 1960, the Housing and Development Board (HDB) was established under the Housing and Development Act (Cap. 129, 1985 Ed.) to take over the role of constructing affordable housing units. The successful provision of shelter and together with good management of the economy, gave the ruling party, People's Action Party, the required legitimacy to rule Singapore.

One of the reasons of the astounding success of Singapore's homeownership policy is the unique finance arrangement offered to Singaporeans purchasing public housing. All Singaporeans keep a permanent savings account known as the Central Provident Fund (CPF), and they can use the savings in (CPF) to finance their housing purchase. The fund is essentially a fully funded, pay as you go social security scheme which requires mandatory contributions by both employers and employees of a certain percentage of the employees' monthly contractual wage to his/her account in the fund. The percentage, determined by the government, varies over the years. The percentage contributed by the employers is usually reduced during economic downturns. These fairly substantial forced savings may be withdrawn at age 55 or earlier for various approved purposes. Between 1968 and 1981, they could be withdrawn for the purposes of down payment, stamp duties, mortgage and interest payments incurred for the purchase of private housing. This policy of allowing households to use their CPF savings to finance their purchase of homes enables the homeownership policy to be successful (see Asher, 1994, 1995).

During the past decade, rules governing the use of CPF savings have been gradually liberalized to allow for withdrawals for medical and education expenses, insurance and investments in various financial assets. In addition, the HDB also provide mortgage financing to its flat-buyers. The loan quantum is either 80% or 90% depending on the government policy at the point in time, and the maximum repayment period ranges from 25 to 30 years. The HDB mortgage rate is pegged at 0.1 per cent above the CPF interest rate, which is below the housing mortgage interest rates of commercial banks. This represents another subsidy for the purchaser of an HDB flat. Nevertheless, this subsidy may not be accessed by all HDB owners; the resale flat buyers who do not meet the eligibility requirements for the HDB loan has to take up a private loan.

Within the public housing sector, we can further subdivide into three sectors: the public new housing sector, the public resale housing market and the public executive condominium market. In the public new housing sector, HDB sell newly built dwellings at subsidized price, and offer the owners subsidized mortgage rates. But accessibility to this sector is strictly regulated. In addition, the allocation schemes of the public housing changes over time, the latest scheme is a build-to-order allocation system where the supply is determined by the demand generated by the buyers. The public resale housing market is first introduced in 1971 and is subject to the regulations laid down by the HDB. The minimum occupancy period is 30 months if the flat had been purchased in the resale market. A resale unit differs from a new unit in that buyers do not have to be on a waiting list for new units to be completed.

In contrast to the prices for new flats, prices in the resale market are determined not only by market forces, but also by changes in prices for new HDB flats and HDB credit and valuation policies for resale flats. In addition, the subsidies are offered less freely to buyers of resale flats. More importantly, there are no income ceilings for those who want to purchase public housing. Exhibit 3.1 shows the changes in price over the years. The resale property price rose from 1990 till 1996, and declined thereafter. There was a slight recovery at 1999, but price fell again to 1998 level from 2000 onwards.

[Insert Exhibit 3.1]

The increase in resale price from 1990 to 1996 is likely to be caused by the housing policies implemented then. In 1991, the authorities allowed singles above 35 years old to purchase 3 room or smaller resale flats outside the central area. This effectively increased the demand for 3-room resale flats. In addition, financing was made easier with the relaxation of the use of the owners' savings in Central Provident Fund (CPF), and the provision of grants to first time buyers. For instance, with effect from 1993, CPF members can make additional withdrawal to service interest payments even if the total sum exceeds the purchase price of the private property. Also, with effect from June 1995, all first timers who purchase resale flats are eligible for grants, even if they do not live near their parents. Alternatively, the reasons for the in fall in price in 1997 are likely to be the Asian Currency Crisis and the Anti-Speculation Curbs implemented by the Government on 1996.

The public executive condominium sector was first established in Aug 1995, and was aimed at satisfying the growing demand for private housing and to replace the executive apartment programme. The building of executive condominiums is carried out by developers appointed in the Gazette by the Minister for National Development under sec. 4 of the Executive Condominium Housing Scheme Act. The executive condominium resembles private property in its form, except that they have restrictions because of the implicit subsidy in its final price. They are strata-titled, have facilities and finishing similar to private condominiums, and sell at prices 20%-30% below the prevailing market prices of comparative properties. They are, however, smaller in size than the executive apartments that they are designed to replace. Also, buyers can only sell or transfer their units to citizens and permanent residents after five years and to anyone after another five years. Unlike the housing offered by the former sub-sectors, HDB will not offer any mortgage financing to buyers of executive condominiums. The 20% down payment required for private housing loans also applies to executive condominiums.

Like the executive condominium market, the housing prices in the private housing sector are directly determined by market forces. Government does influence the housing prices by stipulating the minimum amount of down payment required and the employers' CPF contribution. Other than financial rules to be followed, there are no regulatory barriers to entry and exit of the private housing market. Given the better design and the greater exclusivity, private housing is much preferred to public housing.

Exhibit 3.2 further shows the private house price cycle based on the Urban Redevelopment Authority Index. There are four peaks in 1973, 1983, 1996 and 2000 corresponding to a period of 10, 13 and 4 years respectively. The short cycle from 1996 to 2000 is due to the regional economic crisis. Lee-Khor and Tay (2001) provide a brief discourse on possible causes of the cycle. From the late 1960s, foreigners helped to boost housing demand and house prices peaked in 1973. However, excess supply, curbs on foreign demand, global slump and the 1973 OPEC oil hike halted the boom. This was followed by a period of consolidation until about 1980 as the excess supply began to disappear with the onset of economic recovery from the 1974-5 recession. The sharp rise in house prices was also due to another OPEC price hike in 1979. The large increase in wages between 1979 and 1981 further boosted the prices.

[Insert Exhibit 3.2]

In Singapore, a unique upward movement from public housing to private housing is observed, and there is a linkage between the two sectors. Phang and Wong (1997) regress the private property price index with the relevant macroeconomic factors and let the years to proxy the policy change and find that the liberalization of rules on public housing ownership criterion and housing finance had a significant impact on private housing prices. Ong and Sing (2002) also find that both markets are integrated and the causality from private to public housing markets is stronger than the other way round.

3.2 Main Upgrading Programme

The Housing Development Board announced the Upgrading Programme in 1989 and launched it in 1992 to give older HDB housing estates a new lease of life. The main objective of the policy was to stanch the gradual outflow of residents from older estates to new towns that arises from the residents' desire to have better quality housing and amenities (HDB Annual Report 1989). Alternatively, some studies view the upgrading as a tool used by the ruling party to establish its legitimacy to rule Singapore (Chua, 2001) The 15 billion upgrading initiative, targeted at the majority of the households living in public flats, is to be implemented over a period of 15 years. The upgrading of six demonstration precincts, Lorong Lew Lian, Marine Parade, Ang Mo Kio, Telok Blangah, Clementi and Kim Keat, were completed in 1995. The Upgrading Programme aims to transform old estates into quality precincts comparable in quality and environment to new HDB towns. Numerous selection criteria have been established to prioritise the blocks for upgrading; age of blocks, presence of a large number of 3-room flats, environmental conditions of the blocks.

The Upgrading Programme comprises the Main and Interim Upgrading Programmes. The Main Upgrading Programme (MUP) is designed for HDB precincts which are 18 years and older. Under the MUP, improvements are implemented at three levels- in the precinct, in the block and within the flat. The improvements may consist of an additional utility room or balcony, improved lift lobbies, new facades, more landscaped areas and provision of a multi-storey car park. Generally, the Government bears between 93% to 58% of the cost of improvement works depending on the type of upgrading package chosen and the size of flats. The MUP is carried out in batches; fifteen precincts are scheduled for upgrading under this programme every year. It is estimated that the MUP will involve more than 370,000 flats (Lee-Khor and Tay, 1995-2001). Nevertheless, flats have to be 15 to 20 years old to qualify for MUP, which implies that residents of relatively new flats have to wait a long time for their turn. The upgrading will only proceed if at least 75% of the flat owners in that precinct indicate their support for the exercise.

The Interim Upgrading Programme (IUP) was launched in 1993 to help owners of relatively new flats to overcome the long wait for MUP. About 20 precincts or 20,000 flats per year will be scheduled for IUP. This is to ensure that some 210,000 units, which are between 10 to 17 years old, can enjoy some for of upgrading within the next eight to nine years. The budget for IUP is only about 10% of the MUP budget and is meant only to satisfice certain critical needs of the precincts, which includes upgrading of lift lobbies, provision of new letter boxes, new garden pavilions and/or barbeque pits, but does not include works within the flat. The costs of IUP are entirely borne by the government, while the costs of upgrading work under the MUP are shared between the government and the flat owners.

As part of the government's plan to renew and optimize land use in older estates, another alternative scheme, Selective En-bloc Redevelopment Scheme (SERS), was introduced at the 1995 National Day rally. Under this scheme, residents of obsolete blocks in selected matured estates, which are old, low rise, underutilized and have adjoining vacant land, will be offered new 99 year leasehold flats built on nearby vacant sites. Their existing flats will be acquired under the Land Acquisition Act. The compensation package to be offered entails a land acquisition award and an ex-gratia payment, priority in booking flats in redeveloped blocks and a 20% discount on the price of the new replacement flat, subject to a maximum amount of $30,000. Affected singles, whose current entitlement is a 3 room flat, will be offered 4-room flats nearby. The singles will, however, cannot enjoy the discount on the new flats.

Chapter 4 The Model

4.1 Housing mobility Option

We further extend Stein's model (1995), incorporating the households' option to improve and move, and attempt to use his framework as the foundation to explain the cyclical movements of house price. Adopting the assumptions and structure laid by Stein, I let the model span through three time periods, 0, 1 and 2, and consist of a continuum of families indexed by i. At time 0, each family is endowed with one unit of housing stock, as well as some outstanding mortgage debt outstanding. The mortgage loan owed to the bank, K_i, is further distributed on an interval $[K^L, K^H]$ according to the cumulative distribution function of $G(K)$. The debt is denominated in units of the numeraire good, "food". K_i can be negative, i.e. it is possible that $K^L < 0$. This is interpreted as some families having liquid assets at time 0 above and beyond their houses.

At time 1, families can trade houses with each other. The housing stock is assumed to be divisible, so it is possible for any family to own more or less than one unit after moving. It is also assumed that the housing stock is fixed at time 0 level; there are no new houses built at time 1. The per unit price of housing at time 1 is P, so that the cost of buying a house of size H is PH. According to Stein, three crucial assumptions are made about the trading process. First, when a family sells their old house, it must repay the outstanding debt immediately, leaving the family with net liquid assets of P-K_i. Second, a minimum down payment is required to buy a new house. Specifically, if the new house costs PH, the down payment must be at least γ PH, with $0<\gamma<1$. Once this minimum down payment requirement is met, a buyer is able to borrow the rest of the purchase price at the riskless rate of interest, r. Third, there is no rental market: the only way a family can occupy a house is by owning it. An implicit assumption made by Stein is that buyers are able to afford the monthly payments.

Given the above structure, I let the families have the option to wait till period 2 to trade their old house. The families may find it more worthwhile to wait because of the uncertainty of the price movements. By pricing the option, households may find it more optimal to wait for next period to purchase their new housing. Nevertheless, waiting also incurs a cost; the buyers' desired house may be sold to another party, and the buyers have to incur interest payable and user costs for another period.

At time 1, the family has the option to sell and purchase a new dwelling. Yet the amount of housing the household can consume is constrained by the following,

$$H_{i,1} \leq \frac{P-(1+r)K_i}{\gamma P}. \qquad (1)$$

After exercising the option to move at time 1, the families will receive their labor income to repay all their outstanding debts, and enjoy utility from their consumption of both food and housing services at time 2. Family i's labor income L_i is hence equal

$1+K_{i,2}$ units of food, where $K_{i,2}$ is the sum of the amount of debt undertaken at time 1 and the interest payable. $K_{i,2}$ can be further denoted as follows,

$$K_{i,2} = \left[P(H_{i,1}-1)+(1+r)K_{i,1}\right](1+r)\,. \tag{2}$$

Stein (1995) also let each family's total net income, including the initial time 0 endowments and the time 2 labor, be the same. In other words, H_1 is assumed to be 1 and d be zero. In our context, we relax the assumptions so that we can observe the payoff if the family decides to move at time 2.

Alternatively, the family can delay its purchase till time 2. If the price of its current dwelling rises, the family can purchase and consume more housing good than it could at time 1. In addition, if price falls, the present dwelling serves as a safety net; the family can still consume the present amount of housing good. Following real option theory, we surmise the family's flexibility to terminate its tenure of current dwelling by moving is valuable, especially if price volatility is high. Hence, at time 2, the housing constraint is

$$H_{i,2} \le \frac{(1+\eta)P-(1+r)^2 K_i}{\gamma(1+\eta)P}, \tag{3}$$

if the household decides to exercise its option at a later time. The debt undertaken at time 2 by the household will be

$$K_{i,2}' = \left[(1+\eta)P(H_{i,1}-1)+(1+r)^2 K_{i,1}\right], \tag{4}$$

which is payable in the future, say time 3.

As before, family *i* receives an income of $1+K_{i,2}$ at time 2. Family *i* further uses part of the income to pay the down payment. It also borrows the maximum debt determined by the down payment constraint, even though it may have the means to finance the purchase by equity, when $K'_{i,2}$ is less than $K_{i,2}$. Hence, $K_{i,2}$ units of food are saved and used to repay the loan at the time 3. Any shortfall will be covered by additional income earned at time 3. Assuming the savings rate is *s*, and the discount rate is λ. Hence, the net benefit from taking the loan at time 2 is

$$\frac{\lfloor (1+r)K'_{i,2} - (1+s)K_{i,2} \rfloor}{(1+\lambda)}, \tag{5}$$

which can be positive or negative. Whether the family will exercise the option to move depends on how much more housing good the family can expect to consume at time 2 and the relative costs associated in delaying the option to move. In other words, the decision to exercise the option to move at time 1 depends on the expected amount of benefits received, which is given by

$$B_{expected} = \max\begin{bmatrix} 1+\dfrac{1+(1+\mathrm{r})\mathrm{K_i} - K_{i,2}}{1+\lambda}, \dfrac{P-(1+r)K_i}{\gamma P}\left(1+\dfrac{1}{1+\lambda}\right), \\ 1+\dfrac{(1+\eta)P-(1+r)^2 K_i}{\gamma(1+\eta)P}\left(\dfrac{1}{1+\lambda}\right)+\dfrac{\left[(1+r)' K_{i,2} - (1+s)K_{i,2}\right]}{(1+\lambda)^2} \end{bmatrix}. \tag{6}$$

The first term represents the amount of housing units consumed and extra food units gained by the household had the family not moved in the next two periods. The extra units of food arise because of the lower debt that is used to finance the purchase of the original dwelling. The second term refers to the amount of housing units consumed by the family if they move at time 1 and the third term is the amount of food gained or lost had it moved at time 2. The first component of the third term refers to the housing units consumed at time 1, the second component refers to the housing units consumed at time 2 and the third component refers to the amount of benefits received as a result of the difference in level of debts undertaken to finance the purchase of the housing for both strategies.

Extending Stein's model, we postulate that a family's utility is a function of four things: the amount of food they consume, the size of the house they live in, the ability to move to a new house, and the option premium to move at a latter period. By adopting the Cobbs-Douglas function to represent the preferences of the family, the utility is given by

$$U_i = \alpha \ln H_i \mid B_{\exp ected} + (1-\alpha) \ln F_i + \theta M_{i,t} \mid B_{\exp ected}\,, \qquad (7)$$

where F_i is *i*'s food consumption and $M_{i,t}$ is an indicator variable that takes on the value one if family *i* moves at time t, and zero other wise. The amount of housing good consumed, H_i and the trading gains from moving, $M_{i,t}$ are further dictated by the expected payoffs of each strategy. As suggested by Stein (1995), $M_{i,t}$ is included to capture the gains from trading in housing market at time 1.

The price of dwelling is assumed to follow a geometric Brownian motion, and is provided by the following

$$\frac{dP}{P} = \alpha_P dt + \sigma_P dz, \tag{8}$$

where α_p is the expected change in house price, σ_p is the volatility of house process and *dz* is a Wiener process. It is noted that at this juncture that the volatility is an exogenous variable to make our analysis more tractable; our objective is to show that growing volatility will reduce the excess demand and result the change in the peak. There are several reasons why we assume housing price to follow such a process. First, the assumption makes our analysis more tractable because it enable us to have a close-form solution. Second, the Wiener process a Markov process, where the probability distribution for all future values of the process depends on its current value, and is unaffected by past values of the process. In other words, the households are assumed to hold rational expectations of the future prices. As we will see in Chapter 5, this assumption is reasonable for our test.

From (6), (3) and (1), we observe that the difference between the sale price and debt owed positively influences the amount of housing a family can consume, after accounting for the higher cost of debt that comes with higher consumption. Applying the multi-period binomial approach by Cox, Ross and Rubinstein (1979), we further can compute the option premium of waiting as shown in Exhibit 4.1.

{Insert Exhibit 4.1}

The total option premium of delaying to move is hence

$$Option = \left(p_u V_u + p_d V_d\right)e^{-\lambda} - \left(P - (1+r)K_i\right). \tag{9}$$

Following Cox, Ross and Rubinstein (1979), *P* follows a symmetrical binomial inter temporal price process defined by an up (u) and a down (d) path,

$$u = e^{\sigma_v \sqrt{dt}}; \qquad d = e^{-\sigma_v \sqrt{dt}}. \tag{10}$$

where *dt* is the discrete time interval. The probability that *P* will move up can be written as the following:

$$p_u = \frac{a-d}{u-d}, \tag{11}$$

where $a = e^{r_{f_j} \delta t}$ and r_{f_1} is the risk free rate at period 1. The probability that *P* will move down is $1 - p_u$.

Thus if *Option* is greater than zero, it implies that

$$1 + \frac{(1+\eta)P - (1+r)^2 K_i}{\gamma(1+\eta)P}\left(\frac{1}{1+\lambda}\right) + \frac{\lfloor (1+r)K'_{i,2} - (1+s)K_{i,2} \rfloor}{(1+\lambda)^2} > \frac{P-(1+r)K_i}{\gamma P}\left(1+\frac{1}{1+\lambda}\right), \tag{12}$$

and that the family should move only in the second period.

4.1.1 Equity Constraints, loss aversion and Option to move

Like Stein (1995), we first work through the "perfect capital markets" case where there is no down-payment requirement. In this case, the constraints in equations (1) and (3) are never binding. It follows that everybody will trade in the housing market at time1 or 2 for their desired housing, since this increases utility by θ and delaying their decision will not increase the families' ability to consume more housing goods.

Since the liquidity constraint is never binding, each family's demand for housing is independent of their initial debt K_i, and depends only on their total lifetime wealth and consumption patterns. At time 1, their total wealth has value of $1+P$ units of food. Given the utility function as shown in (7), families will spend α of their wealth on housing. Hence, the price of housing a family will pay is

$$PH_{i,1} = \alpha(1+P), \tag{13}$$

and the number of housing units consumed by the family demands is

$$H_{i,1} = \frac{\alpha(1+P)}{P}. \tag{14}$$

Were the family to delay its purchase, their wealth would have changed to $(1+p_u uP)$ at time 2, and the family would demand

$$H_{i,2} = \frac{\alpha(1+p_u uP)}{P} \text{ at time 2.} \tag{15}$$

Hence, whether the family will delay its purchase depends on the size of the present value of $H_{i,2}$ compared to $H_{i,1}$. If $H_{i,1}$ is higher, the family will move at time 1. The per capita supply of housing will be 1 unit. Equating demand and supply, the price at time1 has the same formulation as Stein (1995),

$$P_1 = \frac{\alpha}{1-\alpha}. \tag{16}$$

If the price volatility is high and the present value of $H_{i,2}$ is higher than H_i , the family will move at time 2, and the supply of housing will be 0, and the family continue to consume 1 unit of housing at time 1. At time 2, the supply of housing will be one unit and the price at time 2 will be

$$P_2 = \frac{\alpha}{1-\alpha(p_u u)}, \text{ given that } \alpha p_u u \neq 1. \tag{17}$$

If the probability of price raise is very low or the raise in price is small such that, $\alpha\, p_u u \neq 1$, then the expected price is higher than that at time 2. Such circumstances usually occur when volatility is high. Alternatively, if the volatility of price returns is low and the probability of price rise is high, $p_u u$ >1, the price may decrease. Thus, when the volatility is high, the excess demand is reduced to zero at time 1, as the option premium is valuable. The question is then how the generation of excess demand by equity constrained households, as proposed by Stein, is affected with the presence of the option to delay purchase.

In the case of 'unconstrained movers'-families whose debt is sufficiently low that the down payment requirement does not affect their behavior- as defined by Stein, the highest amount of debt, K^*, a family can hold to qualify in this group is obtained by equating the unconstrained demand to the constrained demand. When it is viable to exercise the option to move at time 1, K_w^* is given by

$$\frac{\alpha(1+P)}{P} = \frac{P-(1+r)K_w^*}{\gamma P} \tag{18}$$

$$\text{or} \qquad K_w^* = \frac{P-\gamma\alpha(1+P)}{(1+r)} \tag{18'}$$

as suggested by Stein.

Alternatively, if the volatility is sufficiently high to induce the household to wait, *K** must also satisfy the constrained demand at time 2. In other words, the debt amount is provided by

$$\frac{(1+\eta)P-(1+r)^2 K^*}{\gamma(1+\eta)P} = \frac{\alpha(1+p_u uP)}{P} \quad \text{or,} \tag{19}$$

$$K_0^* = \frac{(1+p_u(u-1))P-\gamma\alpha(1+p_u(u-1))(1+p_u uP)}{(1+r)^2}\ , \tag{19'}$$

rearranging and substituting $p_u(u-1)$ for η.

Hence the maximum debt undertaken is the minimum of K_w^* and K_0^*. If the house price volatility is sufficiently high, we will expect the numerator to be smaller because the effects of p_u and *u* are squared. Nevertheless, the effect of high volatility is muted by the interest payments charged for the next period.

At time 1, if the benefits of delaying their option are more viable, the unconstrained movers will not unload any units of housing and will only demand 1 unit of housing good and excess demand is zero. If the volatility is not high enough or the cost of waiting outweighs the premium to delay the decision to move, the total population-weighted net excess demand is

$$D'(P) = G(K^*)\left[\frac{\alpha(1+P)}{P} - 1\right]. \quad (20)$$

Thus, the higher the volatility of price will cause excess demand to be 0 at time 1.

Yet, if the family only exercises its option to move at time 2, the demand at time 2 will be

$$D'(P)_{time2} = G(K_0^*)\,\frac{\alpha(1+p_u uP)}{P} - 1. \quad (21)$$

In other words, the excess demand will be higher than that at time 1.

Stein's explanation of the large price swings lies with the behavior of the "constrained" movers- families who are constrained by debt levels, but still able to capture the gains from trade when it moves. Stein suggests that the constrained movers debt level, K_i, is within the interval $[K^*, K^{**}]$, where K^* is derived earlier in (18') and (19') and K^{**} is determined by equating the utility from moving to that of not moving. With the option to move, we have to determine whether families are not moving or simply delaying their decisions to move.

If the constrained mover moves at time 1, then the size of the new house bought by a family *i* will be smaller than 1 and is denoted by

$$H_i^c = \frac{(P-(1+r)K_i)}{\gamma P}. \tag{22}$$

The cost of this dwelling will be PH_i^c, leaving family *i* with an endowment of $1+P-PH_i^c$ at time 1 that can be spent on food. Thus the utility of this family, U_i^c, will be

$$U_i^c = \alpha \ln(H_i^c) + (1-\alpha)\ln(1+P-PH_i^c) + \theta \ , \tag{23}$$

if it moves. Letting equation (23) equals 0, we further derive K^{**} by substituting H_i^c.

Yet alternatively, the household can delay its decision till time 2. If that occurs, the utility enjoyed by the family will be the present value of the expected amount of housing good and food it can consume. In this case, it will be

$$U_i^c{}' = \frac{\alpha \ln(H_{i,2}^c) + (1-\alpha)\ln\left[(1+r)K_{i,2}{}' - (1+s)K_{i,2}\right] + \theta}{1+\lambda}, \tag{24}$$

where $(1+r)K_{i,2}{}' - (1+s)K_{i,2}$ is the difference in the cost of debt when the family repays the debt on time 2 after purchasing their new dwelling at time 1, and the cost incurred if the actions are made one period earlier, taking account the larger amount of housing good to be consumed at time 2. It is noted that $H_{i,2}^c$ can be more than its original endowment *1+P*. Thus if the volatility is sufficiently high to prevent households from moving at time 1, the net excess demand will be 0. If not, the excess demand from the constrained movers will be

$$D(P)_{constrained} = \int_{K_i=K^*}^{K^{**}} (H_i^c - 1)G'(K_i)dK_i \quad , \tag{25}$$

as suggested by Stein (1995).

Unlike the former cases above, some families uses so much debt to finance their initial purchase that they find it optimal to remain in their old house rather than moving to smaller dwellings. They have a debt level in the interval [K^{**},K^H], and they will contribute nothing to net excess demand.

According to Stein, the necessary condition for equilibrium is that the price be such that the total economy-wide excess demand for houses, $D(P) = D(P)_{constrained} + D(P)_{unconstrained}$, equals zero and that it is possible that there are more than one equilibrium when *D(P)* is not monotonically decreasing.

Differentiating with respect to *P*, we obtain

$$\begin{aligned}\frac{dD}{dP} = -\frac{\alpha}{P^2}G(K^*) + G'(K^{**})\frac{dK^{**}}{dP}[H_i^c(K^{**}) - 1] + \\ \frac{[G(K^{**}) - G(K^*)]}{\gamma P^2}\left\{E(K \middle| K^* \leq K \leq K^{**})\right\}\end{aligned} \quad , \tag{26}$$

where the first the term represents the change in demand due to the unconstrained mover group, the second term represents the change in demand due to the switch of non-movers to constrained movers and the last term represents the change from the constrained movers. If the equation only consists of the first term, the demand function represents a monotonically decreasing function. There will be a single equilibrium because of the satisfaction of the derivative condition of the benchmark case, where no down payments are required. The second term is negative, since the non movers will sell their current dwellings for H_i^c units of housing, which are less than 1. The last term is positive, because as price increases, the down payment restrictions are relaxed and demand of the constrained movers increase.

If we consider the households' likelihood to delay its decision, then

$$\frac{dD}{dP} = \{0, -\frac{\alpha}{P^2}G(K^*) + G'(K^{**})\frac{dK^{**}}{dP}[H_i^c(K^{**}) - 1] + \frac{[G(K^{**}) - G(K^*)]}{\gamma P^2}\{E(K|K^* \le K \le K^{**})\}\}, \quad (27)$$

depending on the expected benefits the families will receive as derived in (12). The higher the price volatility, the more likely that the excess demand is zero, regardless of the value of the above derivative function.

Up till this point, we assume volatility is exogenously determined to show how the premium of waiting actually deterred the family decision to move. Yet, the purported volatility of house price is endogenously determined. In other words, the volatility has to be simultaneously determined by the following,

$$\bar{\sigma}_p = f(\frac{dD}{dP})_{t-1} \ . \quad (28)$$

Looking from a multi-period perspective, if the level of price volatility before time 1 is low, most households will exercise the option to move. Coupled with a majority of coupled households, multiple equilibra will prevail and hence, multipliers will be generated. Yet, as the excess demand gain momentum, the growing volatility increases the option premium to wait in time 2. Fewer households will exercise at time

2, since it is more worthwhile to move at time 3. The excess demand will fall to 0 when all households anticipate for capital gains fall until zero. If the new supply of housing is provided by exogenous suppliers, the price level will fall. The fall in price also means that the households can only sell their dwellings at lower prices. For the families who exercise earlier, equity constraints and loss aversion (Englehardt, 2003; Genosove and Mayer, 2001) force them to 'fish'- list their properties at prices where they can earn a nominal profit. What follows is the decline in the number of transactions and volatility until such point that the family finds it worthwhile to exercise the option to move again.

4.2 To Move or to Improve

One possible criticism of the model exposited above is my exclusion of the family's possible investment to improve the existing stock of housing. Given the great expenditure on improvement as shown in Chapter 1, our understanding of housing investment is incomplete without an understanding of investment in the existing housing stock. We further incorporate the frameworks posited by Littlewood and Munro (1997) and Downing and Wallace (2000) to extend our model above.

Littlewood and Munro (1996, 1997) find recent movers are more likely to invest than longer-term residents, suggesting that a decision to move does not preclude a positive improvement strategy. Hence, unlike Montgomery (1991) and Potepan (1989), they argue that improving and moving are complementary choices rather than competing choices with the objective to improve their housing consumption towards the desired state. In their framework, they posit that households try to adjust the housing consumption level by moving and improvement. They model the desired housing consumption level of the family across the life cycle as shown in Exhibit 4.2; housing demand typically increases during child-rearing stage of the life cycle towards a 'peak' of housing consumption, before diminishing towards a lower life cycle. In order to match more closely to the continuously adjusting demand equilibrium, households adopt the strategy of moving and improving as shown in Exhibit 4.3. Their study offers an interesting insight; they find owners may deliberately buy a property embodying fewer housing services than they would want, with the intention of improving it over the lifetime.

[Insert Exhibit 4.2 here]

[Insert Exhibit 4.3 here]

Extending from our earlier analysis, we further denote H^*, which is more than 1, as the desired amount of housing good the buyer wishes to consume at the end of the two periods; H^* is assumed fixed in our model. As above, the amount of housing family *i* can consume is $H_{i,1}$, where $H_{i,1} = \dfrac{P-(1+r)K_i}{\gamma P}$ and $H_{i,1} \le H^*$. If the amount of housing that family *i* can afford is less than H^*, family *i* can adopt a strategy from a number of options to overcome the problem. Firstly, family *i* can delay its housing decision to time 2, so that the possible appreciation in the future can relax their financial constraints. The amount of housing good to be consumed at time 2 will, hence, be $H_{i,2}$, which is $\frac{(1+\eta)P-(1+r)^2 K_i}{\gamma(1+\eta)P}$ units of housing.

The other option for the family is to invest in its current dwelling. The family can act like a developer; it can improve the current dwelling, sell it at a premium at time 1 and use the proceeds to pay the initial down payment for a better unit. In this instance, the family will enjoy $H''_{i,1}$ units of housing, where

$$H''_{i,1} = \frac{P(1+H_{investment})-(1+r)K_i - IH_{invesment}}{\gamma P}. \tag{29}$$

Besides the above strategies, the owner can sell its current dwelling, and use the proceeds to purchase a moderate dwelling that offers services less than $H_{i,1}$. Denoting the housing services offered by the moderate dwelling be $H^-_{i,1}$, the savings from the purchase of the moderate dwelling, $\gamma P\left(H_{i,1}-H^-_{i,1}\right)$, is further used to finance the improvements $H'_{investment}$, , as motivated by Littlewood and Munro (1997). Hence, the total amount of housing the family can enjoy is $H^-_{i,1}+H'_{investment}$.

Assuming the family can only invest on its dwelling at time 1, the investment is financed by equity and all user costs except interest payments is zero, then the choice depends on the amount of housing good each option offers, i.e.

$$H_{best} = \begin{pmatrix} H_{i,1}, \dfrac{(1+\eta)P-(1+r)^2 K_i}{\gamma(1+\eta)P}, \\ \dfrac{P(1+H_{investment})-(1+r)K_i - IH_{invesment}}{\gamma P}, H_{i,1}^{-} + H'_{investment} \end{pmatrix}. \tag{30}$$

By considering housing investment in (30), we observe that a much higher volatility than what may be predicted earlier is required to induce households to delay the option to move, especially if the market valuation of the improvements is much higher than the cost of improvement. Whether this is empirically supported has to be further determined.

What we have established at this juncture hinges on our assumption that the families will invest their current dwelling at time 1. Yet, as in Littlewood and Munro's study, the families may delay their improvement till a later date. On the one hand, the delay may be the households' strategy to time the expected increase in demand in the future. For instance, some households may only add a room when the size of family increases. On the other hand, homeowner may postpone their decision to improve for investment intentions. Adopting the model by Downing and Wallace (2000), we can model the homeowner's decision to invest in house attributes as real options, as in the case of our earlier option to move. Downing and Wallace (2000) assume each attribute of a house generates a flow of services over time, so that the value of an additional unit of an attribute is the expected net present value of the stream of services that it provides. The homeowner compares the value of an additional unit of an attribute, net of the value of opportunity to invest in the future, to the cost of the investment when deciding whether or not to invest. Generalizing from the real option model, Downing and Wallace further contemplate that the spread between the return of housing and the user costs of capital may influence the households' decision to invest. Additionally, they find the value to wait increases when volatility of the spread is high. Their empirical results from the American Housing Survey strongly support the real option model.

Extending the study by Downing and Wallace, we can treat the option to improve and the option to move in a competing framework. Yet the findings from the study by Littlewood and Munro (1997) imply that we cannot do so. The families may adopt the strategies of moving after improving or improving after moving. The ambit of competing choices should consist of all strategies that the families can utilize to maximize the total benefits they can enjoy.

Consider the strategy of improving and moving. Assuming that the investment is financed by equity alone and is fixed at I, per unit of housing. Family i can either improve their current dwelling at time1 or time 2. I further let the user costs, excluding interest payments, incurred by family i for consuming the housing good, to be capitalized within the investment costs.

At time 1, the family can improve their current dwelling and sell it to purchase a better dwelling. The amount of housing it will consume is derived in equation (29). Alternatively, it can improve the dwelling first, and delay to move till time 2. Whether the family moves depends on the possible price appreciation and additional cost of debt at time 2. The cost of debt may increase because of higher consumption of housing, and higher interest costs at time 2. Exhibit 4.4 further depicts the simple binomial tree for the computation of the option, and the other parameters are as defined earlier.

[Insert Exhibit 4.4 here]

Thus, if the family has made the investment at time 1, it should delay its decision to move till time 2 if the option premium,

$$\left[\left(p_u V_{in,u} + p_d V_{in,d}\right)e^{-\lambda} - \left(P(1+H_{investment}) - (1+r)K_i\right)\right], \qquad (31)$$

is positive. An important insight from (33) and Exhibit 4 is that households' decision to move at time 2 is not affected by the improvements, from this aspect. The amount of housing to be consumed is thus $\frac{V_{in}}{\gamma}$ at time 1.

Besides selling the dwelling after improving it, the household can move to a moderate dwelling that offers less housing services than $H_{i,1}$ but more than 1. The household then uses the savings to improve the moderate dwelling. If the household moves to the moderate dwelling at time 1, it will have to further decide whether to improve now or later. The household may delay its improvement decision because of the fluctuation costs of improvement over the two periods; it is likely that the improvement costs are cheaper at time 2. Alternatively, the family may wish to take advantage of the fluctuation of savings rate by delaying the decision to improve. We first have a generic model, which includes both the factors.

At time 1, family *i* has the choice to move to consume $H^{-}_{i,1}$ units of housing. If the family decides to move at time 1, it has to further decide whether to improve the housing the family bought at time 1 or to delay the improvement works till time 2. The payoffs and the choices are further provided in Exhibit 4.5.

[Insert Exhibit 4.5 here]

In this context, we assume $J = \frac{(1+s)}{I}$ to follow a geometric Brownian motion, where

$$dJ = \alpha_J Jdt + \sigma_J Jdz_j \, , \tag{32}$$

where α_J is the expected change in *J*, σ_J is the volatility of *J* and dz_j follows a Wiener process, independent of *dz*.

Following Cox, Ross and Rubinstein (1979) again, *J* follows a symmetrical binomial intertemporal price process defined by an up (u) and a down (d) path,

$$u = e^{\sigma_J \sqrt{dt}}; \qquad d = e^{-\sigma_J \sqrt{dt}} . \tag{33}$$

where *dt* is the discrete time interval. The probability that *P* will move up can be written as the following:

$$p_u = \frac{a-d}{u-d}, \tag{34}$$

where $a = e^{r_{f_j}\delta t}$ and r_{f_1} is the risk free rate at period 1. The probability that *P* will move down is $1 - p_u$.

The option to delay the improvement of the new dwelling, $Option_{improvement}$, is hence,

$$Option_{improvement} = \left[\left(p_u V_{imp,u} + p_d H_{imp} \right) e^{-\lambda} - \frac{P(H - \gamma H^-) - K_i}{I} \right]. \tag{35}$$

It is viable to move and delay improvement if the option is positive.

Besides improving after moving at time 1, the family can also move at time 2 and make the necessary renovation works subsequently around the same time. Unlike the former case, the determining factors that influence the households' decision to move and improve lie with the volatility of price and investment costs. Hence, the premium to move at time two can be further derived by Exhibit 4.6.

[Insert Exhibit 4.6 here]

In this case, we let $Q = f(P, I)$, and assume it follows a Geometric Brownian Process, where

$$dQ = \alpha_Q Q dt + \sigma_Q Q dz_Q, \tag{36}$$

where α_Q is the expected change in Q, σ_Q is the volatility of Q and dz_Q follows a Wiener process, independent of dz and dz_j.

Q, hence, follows a symmetrical binomial intertemporal price process defined by an up (u) and a down (d) path,

$$u = e^{\sigma_Q \sqrt{dt}}; \qquad d = e^{-\sigma_Q \sqrt{dt}}. \tag{37}$$

where dt is the discrete time interval. The probability that Q will move up can be written as the following:

$$Q_u = \frac{a - d}{u - d}, \tag{38}$$

where $a = e^{r_{f_j} \delta t}$ and r_{f_1} is the risk free rate at period 1. The probability that Q will move down is $1 - p_u$. The option premium to move and improve at time 2 is further derived as

$$Option = \left(p_u V_u + p_d V_d\right)e^{-\lambda} - \frac{P(H - \gamma H^-) - (1 + r)K_i}{I}. \tag{39}$$

Comparing all the strategies that are available to the family and letting *Hsg* be the optimal amount of housing services consumed by a household, the choice depends on the following criterion:

$$Hsg = \max\left\{\begin{array}{l} H_{i,1}, \dfrac{(1+\eta)P-(1+r)^2 K_i}{\gamma(1+\eta)P}, \\ \dfrac{P(1+H_{investment})-(1+r)K_i - IH_{invesment}}{\gamma P}, \dfrac{\left(p_u V_u + p_d V_d\right)e^{-\lambda} - I}{\gamma P} \\ H_{i,1}^{-} + H'_{investment}, \left(p_u H_{imp,u}' + p_d H_{imp,d}'\right)e^{-\lambda} \\ + H^{-}, H^{-} + \left(p_u H_{imp,u} + p_d H_{imp,d}\right)e^{-\lambda} \end{array}\right\}, \qquad (40)$$

given that $Hsg \leq H^*$, and $H^* - Hsg$ is minimized.

It is noted that we have excluded the households' decision to improve only and their option to delay the improvement works as alternative strategies. The reason lies in the substitutability of the households' current dwelling and new dwelling. Given our context, the household can only borrow or use its labor income to finance any renovation on their current dwelling. If the family decides to improve their current dwelling, the savings from not moving -lower debt costs- can be utilized to improve the housing. In other words, the housing consumed by the household is

$$H_{io} = 1 + \frac{((1-\gamma)PH_{i,1}) - K_i}{I}, \qquad (41)$$

where $H_{i,1}$ is the amount of housing that the household would consume, if it had moved.

Whether the household would move or improve depends on the cost of improvements, and how much the improvements are valued in the market. If the improvements are not much valued by the market, households are unlikely to improve, and would rather study the strategies that involve movement. The only exception is when the housing households are consuming is close to H^*, and they do not want to over consume housing services. If such circumstances arise, these households will only consider improvement of the dwelling and the decision to do so largely depends on the spread between the rental income and user costs as postulated by Downing and Wallace (2000). Nevertheless, the omission of this group of households is unlikely to affect our result, since the excessive demand and the effect of real options are largely caused by households who only want to move.

Studying the payoffs of the different strategies stated above, the strategy of moving at time 2 after improving the current dwelling at time 1 may supercede the strategy of waiting to move at time 2, given that price volatility is high. If this happens, the ability to improve at time 1 only serves to amplify the effect of the waiting option. However, the effect of the option to move is likely to be eroded if the household adopts the strategy of moving to a moderate housing at time 1 and improving at time 2. They will occur for 2 likely reasons.

First, if the volatility of saving rates and improvement costs are much higher than that of price, and the quality of the moderate dwelling, which is less than $H_{i,1}$ but more than 1, is not very far off from *IH**, it is likely that the families adopt the strategy of moving to the moderate housing at time 1. Second, if the market valuation of the improvement exceeds the costs, i.e. the cost of improvements is subsidized; it is also likely that the families adopt such a strategy. In the context of Singapore market, as stated in chapter 3, the Main Upgrading Sites were completed by 1995, and residents can sell the completed flats then. The second reason may explain the sustenance of the excess demand and speculation in private and public housing market in 1995.

The last strategy of delaying the move to a moderate dwelling and improving it subsequently is unlikely to be dominant. When price volatility is high and the investment costs are sufficiently high, the household may choose to purchase the new housing that maximizes his utility instead of delaying his move to a moderate dwelling and subsequently improving it. This is because the improved housing is unlikely to be better than the new dwelling. Alternatively, if the investment costs are heavily subsidized, the household will move first to utilize the savings rate.

4.3 Collective Improvement: Voting to Improve- Abstaining by moving

4.3.1 Minimization of disutility

A large proportion of the home improvement literature treats the families' decision to improve as an individual decision, rather than a collective decision. In Singapore and many Asian cities, most people live in multi-family units and major renovation works require the consensus of all the residents living in the same block. Ben-Shahar and Sulganik (2003) provide the first study in understanding the residents' collective decision to improve. They model the households' choice of voting rules, given the households' specific voting rules. As mentioned in the literature review, they implicitly assumed that these households will choose to minimize their disutility.

In their model, they consider a group of *N* individuals that will make a decision by voting on a future proposal that affects the members of the group. Each voter's decision is driven by individual preferences and that the decision upon the proposal is obtained by a vote of all *N* members of the group. Ben-Shahar and Sulganik (2003) further denote the number of voters who will vote supporting (S) by the discrete random variable $\tilde{l}$. In addition, the existing voting rule is denoted $l \geq X^*$, where l is the realization of $\tilde{l}$ and X^* $(0 \leq X^* \leq N)$ is some fixed integer representing a threshold level agreed upon *ex ante* by the members of the group. If the voting rule is satisfied, then the proposal is accepted. By specifying the amount of disutility the voter would receive given an unfavorable outcome , and the voter's *ex ante* subjective assessment of the probabilities other voters' choice, Ben-Shahar and Sulganik (2003) further derive X^* by minimizing the disutility of those who support or oppose the proposal. They further vary the weights assigned by each voter to the outcome in which he does not want, and the *ex ante* probabilities, which also serves to identify the homogeneity of voters, to analyze how the optimal decision rule changes.

The above study offers several interesting insights, which can be linked to our study. Our previous section explains how the possibility of improving the current dwelling affects the families' option to move. Yet in a multi-family housing development, such improvement decisions are collective decisions. We need to compute the probability of non-performance of the improvement proposal, so that we can accurately capture the effect of the improvement decision on the mobility decision. Nevertheless, the probability cannot be deduced from the voting rule as shown by Ben-Shahar and Sulganik (2003) and have to be determined by other means. Additionally, Ben-Shahar and Sulganik (2003) assumes that the voter's choice relies on their need to minimize disutility, whereas our earlier analysis on households' decisions centers on the maximization of utility. In other words, the voters will behave more conservatively than the families we discussed earlier.

4.3.2 Bounded Rationality Model and Abstaining from the decision to improve by moving

While Ben-Shahar and Sulganik (2003) offer an insight on the families' choice of voting rule, they assume no abstention on the families' part. Additionally, these families are rational. Extending their model and incorporating the bounded rational model proposed by Sieg and Schulz (1995), we relax the above assumptions to study the decision making process of households.

In Sieg and Schulz's model, the voter is a learning individual- he does not solve decision problems, but learns how to operate. The voters learn which strategies are good by observing what has worked well for them in the past and what has worked well for other people. The objective of the voter is to improve his or her social position, which is proxied by the ratio of the payoff of the voter with that for other voters. Let $i \in \{1,...,\overline{M+N}\}$ be an element of the index set of players who can vote among alternative outcomes, A_1, for A_2, or moving. The additive utility function of voter *i* is U_i, and if $U_i(A_1) > U_i(A_2)$, the strategy vote for A_1 dominates the strategy of vote A_2. We further let $T_1 = \{1,...,M\}$ be the index set of voters with $U_i(A_1) > U_i(A_2)$, and $T_2 = \{M+1,...,M+N\}$ be the index set of voters with $U_i(A_2) > U_i(A_1)$. The *M*+*N* voters have *M*+*N* strategy sets which consists of pure strategies $s_i \in \{1,0\}$ and mixed strategies $q_i \in \{0,1\}$. The following notations are further defined,

q_i	Strategy of voter $i \in T_1 \cup T_2$
π_i	$\pi_i(q_1,...,q_{M+N})$: expected payoff for a voter $i \in T_1 \cup T_2$ with strategy q_i
π^A	$\pi^A(q_1,...,q_{M+N})$ :: average expected payoff for a non deviant voter.
${}_iE$	${}_iE(p) = {}_i\,E(q_1,...,q_{j-1},p,q_{j+1},...,q_{M+N})$: expected revenue for a voter in T_1 with strategy *p*
$({}_i\pi^A), {}_i\pi$	Average expected payoff for a voter in T_1
$({}_i\pi^D)$	${}_i\pi^D(p) = {}_i\,\pi_D(q_1,...,q_{j-1},p,q_{j+1},...,q_{M+N})$: expected payoff for a

deviant $j \in T_i$ with strategy $p \in \{0,1\}$.

A deviant player is one that learns and applies a strategy that is a relative response, rather than one that applies a strategy that leads to a Nash equilibrium. He will have the added incentive to learn a new strategy and apply it in the future if he can increase his relative success by changing his strategy. Hence, a voter is able to learn a new strategy if this strategy increases his social position. It is noted that that only the change in relative success is important. A voter with strategy $q_i \in \{0,1\}$ is able to learn strategy $p \in \{0,1\}$ if

$$\pi_i^D(p) - \pi^A(s_1,...,s_{i-1},p,s_{i+1},...,s_{M+N}) \geq \pi_i^D(q) - \pi^A(s_1,...,s_{i-1},q,s_{i+1},...,s_{M+N}). \quad (42)$$

In intuitive terms, Equation (42) states that relative voter payoff for choosing strategy *p* is higher than the relative payoff for choosing strategy *q*.An evolutionary voting equilibrium is reached 'whenever no other strategy can increase the relative payoff and thus no other strategy can be learned.

In our context, a voter *i* will have to decide whether he supports the scheme to upgrade the current dwelling or not. As in the case of Singapore's Main Upgrading Programme, the voter can only vote for or against the scheme, which is consistent with the assumption made Ben-Shahar and Sulganik (2003). The dominance of the strategy to support over a strategy of not supporting depends on the likely payoffs, which is a function of the household's intentions in the earlier section. Yet the voter can actually abstain by moving to another property, since the resident can give up the right to vote by surrendering his ownership rights to his buyer. Unlike the example of voter turnout as described by Sieg and Schulz (1995), the voter, however, replaces himself with a buyer that supports the scheme which the voter opposed[2].

In Singapore context, residents living flats that are at least 18 years old are likely to receive an offer to improve their dwellings via the Main Upgrading Programme. Although the residents do know the decision rules for the voting decision in our context, their knowledge of voting costs and potential quantity of the preference groups is not obtainable; their decisions may not appear rational. Hence, instead of assuming the rational voter, we assume that the voters are learning individuals as explained above.

They have to learn, either from past experience, or from the experiences of others[3] who have undergone upgrading. Whether they learn depends on the satisfaction of Equation (32), the costs of voting, which includes the cost of improvements, and the respective payoffs from the deviant strategy, and other strategies. For instance, some households may find moving less affordable than upgrading, despite their opposition to upgrading. Hence, they have no incentive to learn the deviant strategy of abstaining by moving.

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[2] We assume that the buyer knows about the vote for improvement works and the expected results, else he will not buy the dwelling. In other words, possible regulatory constraints against new owners and asymmetry information are not considered.

[3] They could learn the experiences of households who have undergone the upgrading program via word of mouth, mass media and the government authorities. Here we do not consider the bias of the source of information.

The question is then how to capture such learning phenomenon. The uniqueness of Singapore's main upgrading programme allows us to do so. As mentioned earlier, when their flats become 18 years old or older, the owners will be offered a chance to upgrade, depending on the authorities' list of priority and the timing of the implementation of the policy. Thus, some flats will be upgraded when they are over 20 years old, while others get to upgrade when their flats are newer. Assuming there are *M*+*N* residents, who are entitled to vote, in the affected precinct. The *M* residents who support the upgrading belong to T_1 and the other *N* residents who are against the upgrading belong to T_2. We try to identify the households in both T_1 and T_2 by the difference between the housing services that can be consumed after MUP is completed, H^{MUP}, and H^*, the desired amount of housing family *i* wants to consume. In other words,

$$P(\text{support MUP}) = \min(|H^* - H^{MUP} + C|, |H^* - H^c|), \qquad (43)$$

where H^c is the amount of housing services the resident is currently enjoying, H^* is determined by the life-cycle stage the household is in, and C is the cost of upgrading. It is noted that H^{MUP} can be higher than H^* because the upgrading works may create more space than the resident desires. The excess space may create disutility to the households who are in the latter stages of life-cycle, where their household size is small or expected to decline in the future.

Yet, as seen from the results of our survey and the findings by Littlewood and Munro(1997), the owners may improve the current dwelling, so that they can obtain a higher capital gain in the resale market and afford the down payments for their desired housing. In addition, owners may improve their current dwelling and down grade to a cheaper unit, so that they can enjoy the increase in wealth. Hence, equation (43) can be further expanded

$$P(\text{support MUP}) = \min(| H^{*} - H^{MUP} + C |, (H^{*} - H^{New} + C_{transaction}) - W \times downgrade, | H^{*} - H^{c} |) \quad ,(44)$$

where $C_{transaction}$ is the transaction costs incurred purchasing the new flat,

H^{New} represents the amount of new consumption services received from the new flat purchased,

and *W* represents the gain in wealth from the transaction if the owner downgrades.

It is noted that the second term, unlike the third and fourth terms, can be negative because of the wealth component. We also assume that households that wish to move up their housing career will use every cent from the sale proceeds to purchase the new dwelling. Hence, the wealth component only applies to households who intend to downgrade to cheaper dwellings.

Additionally, those households who wish to move up their housing career will support *MUP* if H^{New} is maximized by selling the upgraded dwelling. In other words,

$$H^{New} = \left(PH - Loan - C \times MUP\right) \times \frac{1}{\gamma P}, \quad (45)$$

where *P* is the price per unit of housing, *Loan* is the outstanding loan payable, *MUP* is a dummy variable and takes the value 1 if *MUP* is completed and γ is the proportion of property price required for down payment. Alternatively, we modify the function by including a wealth component if the households wish to downgrade, as shown in Equation (46).

$$H^{New} + W \times downgrade = \left(PH - Loan - C \times MUP\right) \times \frac{1}{\gamma P}. \tag{46}$$

As mentioned earlier, residents living in public housing face a window period from eligibility to polling because of the institutional setup. This window can be viewed as an immediacy or urgency factor that acts as a catalyst for the household to decide whether moving strategy is better than the strategy of staying and voting for their desired outcome. Following Sieg and Schulz (1995), we replicate equation (42) except *p* refers to the household's strategy of moving during the window and *q* refers to the households' strategy of staying and voting for its desired outcome. Unlike Sieg and Schulz, we do not specifically include a deviant voter where other voters can learn the deviant strategy of abstaining. Rather, we assume the voters learn the payoffs of moving from studying the price trends and the probability of the favorable outcome being voted.

From equation (44), we observe that households support the upgrading for several reasons. First, some households support the upgrading because they want to increase their housing consumption and they are financially constrained to move. As time passed, we postulate that households learn the price trends and the possible payoffs of moving before the polling takes place. Rather than waiting for the polling and the completion of the upgrading works, these households may find the relative payoffs are higher than those that remain in the precinct. Thus we expect the affordability measure to be significant for these households during the window period. Second, some households who support MUP to increase their consumption of housing services face prohibitive social costs to move. Since households who live in the area longer tend to have higher social costs, we utilize the Weibull model in our duration tests in Chapter 7 to isolate the effects. The Weibull model allows the hazard rate to follow a concave distribution. Third, some households support MUP so that they can use the sale proceeds of the upgraded dwelling to purchase a better one. Yet, over the course of time during the window, the households may learn about increase in price, which encourages them to upgrade. In addition, the household may now find that the returns from sale exceed what is required for the purchase of the new dwelling. Hence, household may be encouraged by the excess returns to move. Fourth, some households may want to downgrade to cheaper dwellings, but they support MUP because of the higher wealth that can be obtained from the sale proceeds of the upgraded dwelling, as shown in Equation (46). Like previous examples, the learning of price trends may induce the households to downgrade first, especially if the returns are attractive.

On the other hand, households may oppose to upgrading because of affordability problems and small household size. When the window opens, these households are subject to an urgency to decide whether the moving strategy is better than the opposing strategy. Such a strategy depends on the likelihood of having majority support for upgrading, and changes in price. Increase in price may induce households to down grade to cheaper dwelling before the upgrading takes place. Hence, we expect the households to react to changes in price and their level of affordability if households learn the strategy during the window, regardless of households' reasons support for or against MUP.

Chapter 5 Preliminary Tests and Results

In this chapter, we attempt to analyze housing price movements in Singapore housing market and seek some preliminary evidence to support the real option model. In addition, we also conduct some tests on the assumptions that we employ in our model, using the macroeconomic data that is publicly available in the government publications. The results from the preliminary tests provide some empirical support to our hypotheses on the real option model.

One of the key implications from our earlier analysis is the relationship between price change and volatility. When price increases, the reinforcing effects of the down payment further fan demand for new dwellings. The price volatility increase until it reaches a point, where the households will put their option to move on hold. According to the real options theory, we expect the households to find the option to wait more attractive, especially if the price volatility is high. The collective behavior of home owners delaying their option will be in the slow down in demand, and any new supply initiated by the developers will further result a fall in price.

Using the price indices of the Housing Development Board (HDB) flats derived from the transactions in the resale market, we compute the volatility of returns of HDB resale flats and plot it against the price indices as shown in Exhibit 5.1. The volatility is computed over a four-year window period. Exhibit 5.2 also depicts a similar relationship between the price index of private housing (condominium) and the volatility of the returns of private housing. Volatility of housing price returns is computed using the formula,

$$\frac{\sum_{i=1}^{16}(r_i - \bar{r})^2}{16},$$

where $\bar{r}$ is the mean return over the sixteen quarters, and r_i is the return for each year considered.

[Insert Exhibit 5.1]

[Insert Exhibit 5.2]

The graphical depictions of the volatility of returns against resale flat and private property price indices offer some interesting insights. The volatility of the returns of both type of housing tends to bottom out when the market is at the bottom of the cycle and peak after the price cycle reaches its apex. In addition, the volatility of the returns tends to jump sharply, when a recovery starts to set in and falls steeply when the demand no longer supports the supply. The visual relationship between the movements of price and its volatility supports the implication of the real option hypothesis we set earlier.

The real options model expressed in the earlier chapter also implies that the volume of transactions is closely related to housing return volatility. Exhibit 5.3 shows the graphical depiction of the number of resale applications and the volatility of returns of HDB flat.

[Insert Exhibit 5.3]

The number of resale applications moves in tandem with the volatility of returns, and the number of application peaks right after the volatility of HDB price returns hit the highest point. We further run a simple ordinary least squares regression, with the number of applications as the dependent variable and the volatility of returns of HDB apartments and its square as the independent variables. The results, as seen in Exhibit 5.4, show that the square of the volatility of returns of HDB flats is negatively related to the number of applications for resale units. [4]

[Insert Exhibit 5.4].

Although the above preliminary analyses provides some support of the model we postulated, several key assumptions must be satisfied for the theory to work - whether households are forward looking, and whether the theory of loss aversion and equity constraints work in the subject housing market we are testing. As mentioned earlier, the Singapore housing market is chosen because of the clear demarcation of the housing market into public and private sectors. The segmentation of the market, coupled with the availability of a resale market for public housing, allows us to make our test more tractable.

We further conduct more preliminary tests on the assumptions made in the model. The rationale and the results of the tests are provided in the table below:

[4] It is acknowledged that a time-series model will be more appropriate. However, given the limited data, we are unable to run time-series analysis.

Tests	**Rationale**	**Results**
Whether Households are forward looking?	We assume the households to form rational expectations because the option component in our model assumes that price follows a Geometric Brownian Motion.	The test shows that households hold rational expectation of future return of public housing.
Does equity constraints affect price?	Our model adopted many similar specifications from Stein's model. In other words, we assume debt to generate self-reinforcing effects on changes in price.	The test shows that an increase in affordability will trigger households' decision to move. This implies that debt will generate the required self-reinforcing effects due to changes in prices.
Does loss aversion effects affect price?	Although we did not explicitly incorporate this effect in the model, loss aversion effects may dominate the equity constraint effect when price falls. Given that our model relies heavily on the Stein's model, it is important that his model is still valid after incorporating loss aversion effects.	The test shows that households do exhibit loss aversion, but equity constraints still play an important role in their decisions to move.

Source: Author

5.1 Data

In our subsequent preliminary tests of the assumptions, we use a sample of households obtained from a Housing Development Board branch office. The data pertains to only one constituency. This chosen constituency is one of the earliest HDB estates built in Singapore, and many improvement works and rebuilding activities have been undergoing since 1996. The majority of the flats in the chosen estate are more than ten years old and the resale market for these flats is very active, given its central location. From a total stock of 37,000 units in the estate, a sample of 594 resale mortgages spanning a period from 1982 to 2000 is collected. For each loan, we were further given the borrower characteristics, property characteristics and loan amount, and the date of purchase and sale of property. The descriptive statistics of the sample and the respective denotations are further provided in Exhibit 5.6. It is noted that we do not include a dummy variable to capture the effect of Interim Upgrading Program, which is discussed in Chapter 3. This is because the authorities have no intentions to start interim upgrading program in the constituency. Exhibit 5.6a further provides the definitions of the variables considered.

[Insert Exhibits 5.5 and 5.6]

One of the problems I faced when I was using this sample is that the selection of the subject constituency may generate bias in our results. Nevertheless, the HDB apartments are similar in design and the amenities in each neighborhood are similar. I try to ensure consistency by comparing the socioeconomic characteristics of the sample with those of the population. We found that the data reflects the resale market well; the proportion of transactions made for each type of public housing reflects that in the market shown in Exhibit 5.5. About 54% of the households surveyed lived in the 3-room flat, 34% of those surveyed lived in 4-room flats and the rest of the households lived in 5-room apartments. In addition, the racial composition of the sample is consistent with that of the population.

As observed in Exhibit 5.6 , the average income level of households surveyed is below the national average income level. This is reasonable because the housing provided by HDB is of poorer quality and is lower in price. Hence, most of the households who lived in HDB apartments belong to the lower income group. Nevertheless, given that the resale market does not restrict rich households from entering the market, we also observe that some of our sampled households have higher than average income. In addition, the difference in quality between 5-room HDB apartments and private apartments is small, and the households staying in these 5-room HDB flats have higher household income. Hence, this attributed to the high standard deviation in income.

The purchase price of housing ranges from $20,000 to $800,000. The lower bound of the purchase price can be attributed to the transactions completed in the early 1980s. Alternatively, the upper bound of the purchase price can be attributed to the speculation and continuous rise in price from 1990 to 1995. Because some sampled households have returned the flats to HDB due to foreclosure, we observe that the lower bound of the selling price is 0. What is interesting to note from the descriptive statistics is that the premium for housing is extremely high. On average, each buyer pays a price 51.3% higher than the valuation of the apartment. This phenomenon is resulted from the speculation during the 1990s.

A summary of the results, rationale and the objective of our tests are further provided in Exhibit 5.6b.

[Insert Exhibit 5.6b]

5.2 Forward-looking households

The appropriateness of our hypothesis of the market relies on our assumption of households' behavior; they are forward looking, rational individuals. We compute the option premium backwards, considering that the prospective buyers are able to foresee the future. In other words, we have to test whether the expectations formed by households are rational, myopic or exogenous.

5.2.1 Methodology

Following past studies, we utilize survival duration models-parametric and non parametric- to test the above assumption. The hazard rate used in this study is the mobility rate of households living in Housing Development Board (HDB) flats. In other words, the hazard rate is the instantaneous rate of a move, conditional upon the property having survived move up till that time. The duration of time between the purchase of property and sale for i^{th} property is denoted as T_i.

The probability distribution of duration can be specified by the distribution function

$$F(t) = \Pr(T < t)\,, \qquad (47)$$

which specifies the probability that the random variable T is less than some value *t*. The corresponding density function is

$$f(t) = \frac{dF(t)}{dt}. \tag{48}$$

In studying duration data, it is also useful to study the survivor function where

$$\begin{aligned} S(t) &= 1 - F(t) \\ &= \Pr(T \geq t), \end{aligned} \tag{49}$$

which is the probability that the random variable T will equal or exceed the value t. The hazard function is then

$$\lambda(t) = \frac{f(t)}{S(t)}. \tag{50}$$

In this study, we employ two approaches to study the effect of postulated covariates on the mobility rate- the non-parametric and the parametric duration models.

5.2.1.1 Non-parametric duration model

The sample survivor function for a sample of n observations with no censoring is

$$S(t) = n^{-1} \text{ (No. of sample points} \geq t), \tag{51}$$

where the empirical cumulative distribution is turned around. Censoring occurs when the observation could not be made as the start point or the ending point is out of the study period. The life table approach of Cutler and Ederer (1958) will be used for the non-parametric analysis, allowing for censored observations (Kiefer, 1988). Observations that are censored are borrowers who have not moved as at end of June 2000.

Suppose the completed durations in the sample are ordered from the smallest to largest, $t_1 < t_2 < t_3 < \ldots < t_k$. The number of completed durations of K is less than n because of censoring and because of ties. Ties occur when two or more observations have the same duration. Let h_j be the total number of moves at duration t_j, for $j = 1, \ldots, K$. In the absence of ties, the h_j are equal to one. Let m_j be the number of observations with durations greater than t_j, the longest complete duration. The hazard rate at duration t_j for $j = 1$ to K, is the probability of a prepayment at duration t_j, conditional upon the property have survived being sold up till t_j. Thus the hazard rate will be

$$\lambda(t_j) = \frac{h_j}{n_j}, \tag{52}$$

where

$$n_j = \sum_{i \geq j}^{K} (m_i + h_i), \tag{53}$$

n_j being the number of mortgages that were neither prepaid nor censored before duration t_j. The corresponding estimator for the survivor function is

$$S(t_j) = \prod_{i=1}^{j} \frac{(n_i - h_i)}{n_i} = \prod_{i=1}^{j} (1 - \lambda_i) , \tag{54}$$

which is the Kaplan-Mier or product limit estimator for j= 1 to K.

The time line is split up into fixed intervals in the tabulation of the life table. A survival rate is then calculated for each interval. Let λ_i be the probability of prepay at the *ith* interval. The acturial estimator adjusts for censoring by subtracting one-half of the number of observations censored during the *ith* interval from the number entering the interval in calculating the fraction of completed spells.

5.2.1.2 Parametric duration model

The Weibull distribution is selected with the hazard function *h(t)* to be

$$h(t) = \lambda p(\lambda t)^{p-1} \tag{55}$$

and the Survivor function *S(t)* to be

$$S(t) = \exp(-\lambda t)^{p} . \tag{56}$$

The Weibull distribution is proposed for the study, since it allows for duration dependence captured by the parameter p. Duration dependence means that the hazard rate can be increasing or decreasing. If the duration dependence factor p =1, the duration follows an exponential distribution where the likelihood to move is constant with time.

The hazard rate is defined as an exponential function of covariates

$$\lambda(t) = \exp(-\beta' x_i). \tag{57}$$

The hazard function can be further transformed such that,

$$y_i = \ln T_i = \sigma w_i + \beta, \tag{58}$$

where

$$w = (\ln T - \beta) / \sigma, \tag{59}$$

$\lambda = e^{-\beta}$ and $\sigma = \frac{1}{p}$. Allowing for censoring due to incomplete spells observed at the last date of our sample period, the likelihood function is

$$L = \prod_{i=1}^{N} [\sigma^{-1} \exp(w - e^{w})]^{\delta_i} [\exp(-e^{w})]^{-\delta_i} \ , \tag{60}$$

where δ_i is the censoring indicator (1 if complete and 0 if censored). The expected duration is simply the reciprocal of the hazard rate,

$$E[t] = \frac{1}{\lambda(t)} = \exp(\beta' x_i). \tag{61}$$

5.2.2 Variables

We model the motivation to move against four categories of independent variables, borrower, property, loan and the macroeconomic explanatory variables. Most of the variables included in the model are motivated by previous studies on household mobility, which will be elaborated at a later section. We further include the different returns computed under the above theories in the model.

The expected returns of private and public housing are generated at the time of sale or censored date, using the adaptive, rational and exogenous expectations methodology. The returns of private housing are included because findings in the research of Tu et al (2002) and Ong and Sing (1999) imply the households' upward mobility from public housing to private housing. Under the adaptive expectation methodology, the expectation of the price in the next quarter is formulated as follows:

$$MYOPTE\_5_t = \frac{1}{5} \times \left(\begin{array}{l} \frac{RPI_{t-1} - RPI_{t-2}}{RPI_{t-2}} + \frac{RPI_{t-2} - RPI_{t-3}}{RPI_{t-3}} + \frac{RPI_{t-3} - RPI_{t-4}}{RPI_{t-4}} + \\ \frac{RPI_{t-4} - RPI_{t-5}}{RPI_{t-5}} + \frac{RPI_{t-5} - RPI_{t-6}}{RPI_{t-6}} \end{array} \right) \tag{62}$$

and

$$MYOPUB\_5_t = \frac{1}{5} \times \left(\begin{array}{l} \frac{HDBPR_{t-1} - HDBPR_{t-2}}{HDBPR_{t-2}} + \frac{HDBPR_{t-2} - HDBPR_{t-3}}{HDBPR_{t-3}} + \\ \frac{HDBPR_{t-3} - HDBPR_{t-4}}{HDBPR_{t-4}} + \\ \frac{HDBPR_{t-4} - HDBPR_{t-5}}{HDBPR_{t-5}} + \frac{HDBPR_{t-5} - HDBPR_{t-6}}{HDBPR_{t-6}} \end{array} \right), \qquad (63)$$

where $MYOPTE\_5_t$ is the expected return of the private housing in quarter *t* and $MYOPUB\_5_t$ is the expected return of public housing at quarter *t*. The choice of using the average expected returns over 6 quarters is motivated by Tu and Wong (2001), who found that there are no significant differences between the different user cost measurements differentiated by the different quarters (from 2 quarters to 6 quarters) considered to form the price expectation[5]. On the other hand, the expected return from both public and private housing is the inflation rate at the time of sale or prepay or the censored dated, represented by *EXO_1*. The rational price expectation of HDB return *(RATPUB)* and *(RATPTE)* in quarter *t* are obtained by the following:

where

$$RATPTE_t = \frac{(RPI_{t+1} - RPI_t)}{RPI_t} \qquad (64)$$

and

[5] The results remained unchanged when average expected returns over 5 and 4 quarters are used.

$$RATPUB_t = \frac{(HDBPR_{t+1} - HDBPR_t)}{HDBPR_t}. \tag{65}$$

5.2.3 Results

From the above non-parametric methodology, we derive the graphs for the hazard rates and survival rates. Exhibit 5.7 shows the Cutler and Ederer life table estimation of the duration (DUR). The table shows that the most moves occur between 23 and 47 months (1.91 years[6] to 3.91 years). This is due to the resale restriction policy for two and half years by HDB. The hazard rate reaches a maximum at 0.99% between 94 months to 118 months (7.83 years to 9.83 years). Exhibit 5.8 and Exhibit 5.9 show the graphical depiction of the estimated survival function and the Kaplan-Meier Hazard function. The graph shows that the majority of the prepayment occurs at the 150 months, which is approximately 12.5 years, and the hazard rate is expected to peak at the end.

Going one step further, we conduct four parametric tests separately to analyse the impact of the expected prices formed by the each methodology. The actual realised return is included in the model in the first test, Test 1, so that we can compare its results with those of other tests that utilise the respective expected return variables. For the completed sales data, the actual return realised from sale of property is

[6] Although there is a stipulation that households can only relocate after two and a half years, there are households who are forced to move due to persistent default of loan commitments and carrying out of unlawful activities in their HDB dwellings. Such instances are, however, rare because of the purpose of the provision of public housing.

$$ACTGAIN = \frac{\text{(Purchase Price} - \text{Sale Price)}}{\text{Purchase Price}}. \quad (66)$$

For households who have not sold their dwellings within the test period, we use the change in HDB price index to proxy the realized gains accrue to them at the censored date.

In Test 2, the average expected returns over the past 6 quarters are computed using the adaptive methodology, as motivated by Tu (2001). In Test 3, the expected returns are computed over a quarter, using the rational methodology. In the final test, Test 4, the expected returns of housing are assumed to be formed independent of the housing market past performances; the inflation rate is used to proxy the expected returns of housing.

The results are presented in Exhibit 5.10. Using the Likelihood ratio test, we found that at least one variable in all the four tests are significant and improved the performance of the model. It is also observed that the average hazard rate is about 0.9% for all tests except test four and is significantly different from zero. In other words, there is a 0.9% probability that prepayment will occur in a particular month. All the parametric tests show that the data exhibits a significant positive dependence ($p>1$), showing that the Weibull model is appropriate. The estimated survival function plotted in Exhibit 5.11 also resembles that in Exhibit 5.8. The Kaplan Mier hazard function in Exhibit 5.9 appears to be an increasing function, which is similar to the estimated hazard rate function depicted in Exhibit 5.12.

After running Tests 2, 3 and 4, the results show that the adaptive and the rational expected return for public and private housing have the same signs in the tests. Under the adaptive expectations assumptions, the returns from the mortgagors' dwelling are positively related to their length of stay. Alternatively, the expected returns from the private housing market are negatively related to borrowers' length of stay. The results are interesting because they imply that the supply of resale flats will fall when the returns from the resale flats are relatively high in the past quarter, assuming all other variables remained unchanged. In addition, the significant relationship between expected returns from the private sector and the length of stay also implies that both public and private housing markets are related, which is consistent with previous studies on the co-integration between private and public markets (Ong and Sing, 2002).

The results under the rational expectation assumptions are mixed. On the one hand, the rational expected returns from public housing sector are significant at 5% level of significance. This is an interesting finding, given that the expected returns based upon the assumption of adaptive expectation are also significant. In addition, the expected returns under both rational and adaptive assumptions have a relatively low correlation of 0.238. A possible explanation for the finding is that expectations formed using past prices affect the households' decision to move and the households' decision to move is further reflected in the price.

On the other hand, the rational expected returns from private housing sector are insignificant. It is not surprising that the expected private returns, using the rational expectation assumptions, are insignificant because real estate market is inefficient. However, the results offer an interesting contrast to the relationship between public market returns and the households' length of stay. The results imply that both private and public housing market mechanisms are different and both markets are in different levels of efficiencies. Nevertheless, the results of the above study lend support to our assumptions for our model as a whole.

5.3 Equity Constraints

In our model postulated earlier, we borrow Stein's concept on large price swings, and the findings by Chan (2001), Stein and Lamont (1999) support Stein's model. In order to test Stein's hypothesis whether households consume more housing given increased affordability, we need to identify the mobility patterns to capture the increase in consumption, and discover a measure for affordability. The Singapore housing market is a good choice because we can easily identify the upward movement from public housing to private housing and use it as a starting point for our test. Exhibit 5.13(i) shows the cross tabulation between the capital gains households received when they moved prior to June 2000 and the loan-to-value ratios they undertaken when they purchase their original flats. It is observed that most households experience gains when they move. Alternatively, Exhibit 5.13(ii) shows that about 36% of the households who undertook a mortgage of more than 60% loan-to-value ratio did not move by June 2000. This proportion is much higher than that of households who borrowed less. Although we observe that the majority of households who borrowed less than 60% loan-to-value ratio experience gains as computed from change in HDB price index, the proportion is less than that for households who moved prior to June 2000. On the whole, 104 households out of the 594 households experience losses, while 490 households experience some gains as shown in Exhibit 5.13(iii).

5.3.1 Methodology.

The more applicable measures for our study are the measure of accessibility of homebuyers defined by ANHS (1991) and the affordability index defined by Keare and Jimenez (1983). The homebuyers' accessibility to new housing (ANHS, 1991) is determined by the households' ability to afford the down payment. Given that the average homebuyers' wealth is made up by the value of their current housing, the homebuyers' affordability of the house greatly depends on the capital gains obtained from the sale of their current housing. On the other hand, the affordability index proposed by Keare and Jimenz (1983) captures the buyers' affordability in terms of mortgage payments.

Although the affordability measures above provide a good basis to analyse the homebuyers' upgrading behaviour (Tu et al, 2002), the measures cannot adequately explain the upgrading process. This is because the interactions between the two measures cannot be observed and monitored. There are many households who may pass one of the affordability measure but not the other measure. In addition, we cannot determine which factor is dominant if we utilise both measures jointly.

Linneman and Wachter (1989) also used similar measures as above to estimate the extent by which the desired purchase price exceed the maximum allowed under industry borrowing standards. They came up with size constraint measures: three each for income and wealth. Hendershott, LaFayette, and Haurin (1997) further extends the study by allowing households to select the loan-to-value ratio and mortgage product that minimize the impact of the constraint. Haurin, Hendershott and Wachter (1997) further improve the measures by having a fuller consideration of the endogeniety of wealth and income.

For our study, we will adopt the Threshold Upgradability Index, or TUI, (Ong and Sing, 1999), which follows the spirit of Haurin, Hendershott and Wachter (1997). The TUI incorporates both effects and is a suitable measure of would-be movers' ability to upgrade. Ong (2000) further empirically tested the model to evaluate the theoretical underpinning as well as the ability of the model to predict private property price and found the model to be robust and a good predictor of private property price.

The index is derived from the concept of the "threshold upgrader". The threshold upgrader is the owner of a HDB flat who is just able to upgrade to a private property prior to a decline in values (Ong and Sing, 1999). The threshold upgrader relies entirely or partially on cash proceeds from the sale of HDB flat to pay the required down payment of the private property. The threshold upgrader, moreover, can just barely afford the servicing of the mortgage.

The TUI is obtained by deriving the minimum of two prices; each constrained by different conditions and is derived at the point of sale. The TUI at the point of sale is chosen because we are trying to find out the level of TUI that will induce the sale. The first price is constrained by the price of HDB, proxied using the HDB resale index. At t=1, HDB resale prices move to H_i. In order for the threshold upgrader to upgrade, the private property price must be P_1^{R4} such that

$$P_1^{R4} = \frac{(H_1 - H_0)}{0.245} + P_0 \ . \tag{67}$$

The 0.245 denominator is due to the minimum cash requirements of the purchase of the unit[7]. The other price is constrained by the change in mortgage rate and income. If the threshold buyer's income is to increase to Y_i when the mortgage rate changes to i_i, and assuming that the loan-value ratio and the payment-income ratio remain constant after the changes and all other factors unchanged, the new private property price P_1^A that can be afforded by the threshold buyer is

$$P_1^A = \frac{Y_i MC_{i_0,n,12}}{Y_0 MC_{i,n,12}} P_0 \ . \tag{68}$$

Hence, the threshold private property price that will allow households to upgrade is

[7] Before May 1996, the minimum down payment required for the purchase of private housing is 10% of sale price. The minimum down payment required is, however, raised to 20% of sale price on May 1996 as a measure to curb speculation. In this case, the TUI is adjusted accordingly to reflect the change in policies. As at Sep 2002, buyers can use their Central Provident Fund to pay 10% of the sale price as down payment in the latest changes.

$$TPP_t = \min\left[P_t^{R4}, P_t^{A}\right] \,, \tag{69}$$

since the threshold buyer is subject to both constraints. The TUI is computed as a ratio of the threshold private property price over the actual property price at time t. The year 1990 is used as a base year as it is free of economic shocks. Hence TUI_t is computed as follows:

$$TUI_t = 100\frac{TPP_t}{P_t} \,. \tag{70}$$

The higher the TUI implies the greater the affordability to upgrade. The TUI over the years is shown in Exhibit 5.13.

The variables included in our test are the same as before, except for the Threshold Upgradability Index. Following the literature, borrower specific characteristics such as race, household size and age of buyer are included in the model. The gross household income (*GHHINC*) is also included, since it determines the ability of the borrower to move (Pickles and Davis, 1991). In our study, we use the household income level, instead of the gross household income, so that we can account for inflation and the relative changes in income over the study period. Household income level (*INCLEV*) is the ratio of the annual gross household income adjusted for inflation to the average household income of the country at the point of purchase, which is represented by

$$INCLEV = \frac{GHHINC_n}{AVEHHINC_n} \tag{71}$$

where $GHHINC_n$ is the real annual household income at year n and $AVEHHINC_n$ is the average household income in year n, derived from the annual GDP at the point of purchase.

The property specific data cover the description of the property including the type of flat, the floor-level and the age of flat. In addition, the market premium (*PREMIUM*) paid by the buyer is also included in the model and is defined as the difference between price and valuation of property divided by the valuation. The higher the premium paid implies the greater the demand for the unit since any premium must be paid in cash.

Loan specific information includes the loan-value ratio (*LV*), loan outstanding at prepayment date (*OUTLOAN*) and initial payment-to-income ratio (*PAYINC*). *LV* is computed by dividing the loan amount by the appraised value or purchase price whichever is lower. It is assumed the valuation is equal to the price transacted when no valuation is available.[8] The maximum loan-to-value ratio is 80% and the purchaser can at most take a loan up to 80% of the purchase price or valuation whichever is the lower. The date of origination (*PDATE*) is added too and coded in terms of the year. Another variable that is incorporated is the spread between the public interest rate and the private housing loan rate for 15 years (*INTDIFF*). It is defined as the difference between the 2 rates at the point of prepayment or at the censored date.

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[8] This is especially in the earlier years when valuation is not required. The assumption is valid as flats of same classification are resold at similar prices and the market is very stable during the earlier period.

Next, we specify the set of macroeconomic variables to capture the changes in the environment. These include the return on public residential market (*CHDBPR*) obtained from the HDB Resale Price Index, the public mortgage rate at the point of prepayment (*SHDBINT*) and the change in GDP per household (*CGDP*). The change of HDB Resale Price Index is used to proxy capital gains over the holding period, which is from the date that the owner first purchased the dwelling to the date that he sells the house, or June 2000, the censored date, whichever is later. The change in GDP per household enables us proxy the change in income over the holding period. From the literature reviewed earlier, these three variables are not only important in our tests for mobility decisions (Ioannides,1987; Ioannides & Kan,1996), but also critical in shaping Stein's model (1995).

The change in SES index (*CSES*) is incorporated in the model because it helps us to capture borrowers' expectations of the housing market, since property market tends to lag stock market. Furthermore, this variable allows us to capture how changes in the return of other assets affect the households' mobility decision and their prepayment decision (Zorn and Lea, 1989).

Additionally, we include the volatility of private mortgage rate (*SMORTVOL*) in the model. Although the volatility of the mortgage rate is not tested in the empirical analysis of mobility decisions, we expect that greater volatility of mortgage rates will discourage buyers because the buyers are taking adjustable rate mortgages and will be subject to greater interest rate risk. The volatility is measured by the standard deviation over a 4-year rolling window.

5.3.2 Results

We employ the time-varying parametric duration and probit models to analyze the relationship between the TUI and the length of stay of households. The time-varying parametric duration model is like the parametric duration model in the earlier test, except that some variables are allowed to vary over time. More about the time-varying parametric duration test is further discussed in the subsequent chapter. Besides the type of dwelling the subject household is staying, the race of the subject household, its household size, income level, floor level, we let all other independent variables vary over time. The results are tabulated in Table 5.15a. In this test, we omit some variables that are tested in the subsequent probit tests, like the date of purchase, and payment-to-income ratio. This is because the date of purchase is reflected in the dependent variable and the payment income ratio over time is partially derived from the change in GDP index over time and is related to the time varying loan-to-value. Both the loan-to-value ratios and the change in GDP index are included in the model, and we would face multi-collinearity problems if payment- to-income ratio were included. The results show that the threshold upgradeability index is negatively and significantly related to the households' length of stay.

We further conduct probit test to verify our earlier results. The households' decision to move and prepay is tested using the probit test in the following: Model A, Model B and Model C. In this case, we use the probit model instead. In Model A, the TUI variable is included to test the households' likelihood to prepay. However, as seen in Exhibit 5.15b, we have chosen to omit several variables in Model A in our test. Macroeconomic variables such as changes in HDB prices and private prices, volatility of returns of HDB and private dwellings and difference between the public and private rates are not considered because these variables are used jointly to derive TUI and may lead to erroneous results. Nevertheless, although variables such as the change in income and volatility of market mortgage are derived using the same variables- mortgage rate and GDP- in deriving TUI, these variables are included because the treatment of the inputs in deriving the mortgage volatility and change in income is different. Furthermore, as shown in (68), the movements of GDP and mortgage rate may offset each other in the derivation of the overall TUI. In addition, several property specific variables such as floor level are omitted because they are highly insignificant.

In Models B and C, we replace TUI with the variables omitted earlier. In addition, we include another variable, the relative price difference between private housing and public housing (*RELPI*), in the probit model to analyse whether HDB mortgagor is more likely to prepay when the price differential has decreased. The relative price differential is obtained by dividing the private property price index by the residential price index, with the base year for both indices fixed at 1990. Hence, the larger the value of *RELPI* is, the greater the price differential between HDB and private residential properties. The difference between Model B and C is that the households' mobility decisions are tested against the public HDB rate in Model B whereas their decisions are tested against the difference between the public and market rates in Model C. All the results are summarised in Exhibit 5.15b. Using the Likelihood ratio test, we found that at least one variable in all the three tests are significant and improved the performance of the model.

The TUI is found to be positively related to the probability that the household will move and prepay. In other words, households are induced to move when their level of affordability improves. Hence, Stein's implicit assumption that the households will move to consume more of the housing good when they able to do so is empirically supported.

In order to ensure the robustness of the earlier test, two further tests on the households' decision to move and prepay are carried out by excluding TUI and including other variables that are omitted earlier. Models B and C provide a good fit with Log likelihood of – 39.78 and -41.46 respectively. Most of the variables tested exhibit similar relationship, except payment-to-income ratio, which becomes insignificant. A likely reason is due to the inclusion of the public mortgage rate as a test variable. Conversely, the property specific variables, which were omitted previously, exhibit similar relationship as that in the preliminary test we did earlier in Model A.

5.4 Loss Aversion

The prospect theory, which were introduced by Englehardt (2003) and Mayer and Genosove (2001) to real estate literature, hypothesizes that households tend to hold out by listing higher prices during market downturn, because of their aversion to nominal losses. Both Englehardt (2003) and Mayer and Genosove (2001) hypothesize that the effect of Stein's equity constraints model during a downturn may be over stated, if the effect of loss aversion was not captured. Englehardt (2003), and Mayer and Genosove (2001) themselves, and Seslen (2003) further tested the prospect theory, and find that the loss aversion effect is more influential than that of equity constraint variables. We further extend the test of loss aversion in Singapore's market; the effect maybe different. The households may view housing differently and the regulations that are in place may prevent the way the prospect theory postulates to be.

5.4.1 Methodology and Results

Further to our earlier tests, we further include variables to capture the loss aversion effect, following Englehardt's equation. From Equation 61, we extend the right hand side to the following,

$$E(t) = \exp\begin{pmatrix} X'_{it}\alpha + \phi LTV + \tau(D_{Loss} \times Loss) + \upsilon(LTV \times D_{loss} \times Loss) \\ + \delta(D_{Gain} \times GAIN) + \xi(LTV \times D_{Gain} \times Gain) \end{pmatrix}. \tag{72}$$

The first term, X, includes all our previous explanatory variables, except the expected returns of HDB housing. The second term includes the loan-to-value ratio. The third term makes up of two components: D_{Loss}, a dummy variable that is one if the household has experienced a nominal loss in house price in current period *t* relative to the initial purchase period, and *Loss*, which measures the nominal loss in percentage terms. *Loss* is expressed as a positive number. The fourth term is an interaction term of the *Loss* variable with the *HLTV* variable. The *HLTV* variable takes the value one if the loan is more than 0.6 of the value[9]. *Loss* and *Gain* for each household are derived from the HDB residential price index. The value of *Loss* for each household is the same as that of *CHDBPR*, if *CHDBPR* is negative, else zero. The value of *Gain* is computed similarly, except that the value of *Gain* takes that of *CHDBPR* only if *CHDBPR* is positive.

The initial loan-to-value ratio is included because it is likely to have an effect on mobility independent of equity constraints. The υ parameter represents the differential effect of having a high initial loan-to-value on mobility and experienced a nominal loss in housing. In other words, the parameter υ measures the impact of equity constraints. By filtering the effects of equity constraints, τ measures the impact of loss aversion. Consequently, the D_{Gain} is a dummy variable if the household has experienced a nominal gain in house price in excess of moving costs in current period *t* relative to initial period 0, *Gain* measures the nominal gain in percentage. Therefore, ξ measures the differential effect of having a high LTV and experienced a nominal gain. δ, on the other hand, measures the pure effect of nominal gains on mobility for

[9] This is lower than that used in Englehardt's study because of the minimum loan limit stipulated in the banking regulations in Singapore.

households not expect to be equity constrained. We further test the variables using the parametric duration tests, The results are further provided in Exhibit 5.16.

[Insert Exhibit 5.16]

Exhibit 5.16 shows that the parameters of initial loan, loss aversion and equity constraints are positively related to the length of stay. The loss aversion effect is, however, less pronounced than that of equity constraints. Nominal gains also encourage both constrained and non-constrained households to move. The results support both the loss aversion and equity constraints hypothesis. But unlike the findings of Englehardt and Mayer and Genosove, the effect of equity constraints is much stronger that that of loss aversion.

Chapter 6 Empirical Test on Real Option Hypothesis

6.1 Computing the Real Option

In order to test the real option hypothesis, we need to identify a market where we can observe the households' upward movement of their housing career. The clear segmentation of Singapore housing market into private and pubic housing sectors enables us to do so. Yet, the adjustable rate mortgages are the dominant form of mortgages in Singapore. There are two implications: (1) the quarterly adjustment of mortgage rates, coupled with the subsidized rates, causes the reduction of borrowers' motivation to prepay when market rates fall, and (2) the periodic changes in mortgage rate have to be accounted as dividends in our real option model. Applying the real options model, we attempt to find the option premium that the owner is enjoying at each period. We further try to operationalize the model we proposed in Chapter 4.

The proposed model is only for repeat would-be movers. This model assumes that the household can afford the mortgage payments. The household's maximum length of stay is defined as n, and the owner will not move after n because the cost of moving will outweigh any benefits of moving. In addition, we further assume that n is less than or equal to the mortgage term N. If n is greater than N, the owner, who accumulates sufficient capital through the amortization of the housing loan will exercise his option at *N*, unless the sale price of the current housing depreciates below the down payment required.[10]

Assuming the would-be movers will not incur transaction and moving costs if they decide to move. The household will move as long as the following equality is satisfied;

$$P(X)_j - L_x / V_x P(X)_0 \prod_{k=1}^{j} \left(MC_{i_{k-1}, N-k+1} PVAF_{i_{k-1}, N-k} \right) \geq (1 - L_y / V_y) P(Y)_j \,, \tag{73}$$

where

X refers to the current dwelling of the household,

Y refers to desired dwelling of the household,

$P(X)_j$ is the price of the household's current dwelling at period *j*,

$MC_{i_{k-1}, N-k+1}$ is mortgage constant for the computation of mortgage payments in period *k-1*,

$PVAF_{i_{k-1}, N-k}$ is the present value factor for the computation of mortgage balance outstanding at period *k*, where *j*>*k*,

i_j is the mortgage rates at *j*.

[10] If this assumption does not hold, the value of the option is zero because the homeowner cannot afford to move. Nevertheless, the homeowner has the option to default. See Appendices on the option to default.

$P(Y)_j$ is the price of the household's desired dwelling at period *j* and *L/V* is the loan to value ratio for the loan to be taken to purchase the household's desired dwelling.

The second term at the left hand side of the equation is the household's mortgage balance at the end of period *k*. Rearranging the above inequality gives us

$$D \geq L/VP(X)_0 \prod_{k=1}^{j} \left(MC_{i_{k-1},N-k+1} PVAF_{i_{k-1},N-k} \right), \tag{74}$$

where $D = P(X)_j - (1 - L/V)P(Y)_j$.

At each time step, the homeowner will have to repay the loan payment for its current dwelling, if he or she does not exercise his or her option. Moreover, given that housing is a consumption asset, the household will enjoy services from its current dwelling. Hence, the households will receive benefits from their current dwelling if they do not exercise their option to move. However, the dwellings desired by the households also provide housing services, which are equivalent to the convenience yield enjoyed by manager if he exercises the option. Yet, the households will have to repay its mortgage payments to finance his purchase of their desired dwelling and current dwellings. Thus the benefits accrued to the household if it exercises its option can be written as follow,

$$CF_j = R(Y)_j - PMT(Y)_j - \lfloor R(X)_j - PMT(X)_j \rfloor. \tag{75}$$

where

CF_j is the benefits accrued to homeowner at period *j* if he or she exercises the option,

$R(Y)_j$ is the services accrued to household if he or she purchases house *Y* at period *j*,

$PMT(Y)_j$ is the mortgage payments that the household will pay if the homeowner purchased his or her desired house at period *j* , which can be written as

$$PMT(Y)_j = P(Y)_j MC_{i_j,N} . \tag{76}$$

$R(X)_j$ can be defined as the services accrued to household if he or she stays in house *X* at period *j*, and $PMT(X)_j$ defines the mortgage payments that the household will pay if the homeowner continues to stay at his or her current dwelling at period *j*. $PMT(X)_j$ can also be written in the following,

$$PMT(X)_j = P(X)_0 \prod_{k=1}^{j} MC_{i_{k-1},N-k+1} PVAF_{i_{k-1},N-k} MC_{i_k,N-k} . \tag{77}$$

R_j can be assumed as a percentage of the property price and is synonymous to the rental yield of residential properties. Furthermore, it is assumed that the receipt of *CF* is between two consecutive time steps. In other words, the benefits are deducted off the spot value *V* at each time step.

From the above, the strike price is the outstanding mortgage balance at the end of the period, which can be written as follows,

$$S = P(X)_0 \prod_{k=1}^{j} MC_{i_{k-1},N-k+1} PVAF_{i_{k-1},N-k} \ . \tag{78}$$

The mortgage balance is subject to movements in the mortgage rates. Following Ong and Tan (2000) and Tse (1998), we use the Vasicek model to represent the stochastic process. The usual stochastic model used to represent the interest rate movements is generally in the form of a mean reverting process:

$$dr = \beta(\alpha - r)dt + \sigma_r r^{\gamma} dW \ , \tag{79}$$

where *W* is the standard Brownian Motion, *r* is the risk-free rate, α is the equilibrium risk-free rate to which rates will tend to return (the long-term interest rate), β is a non-negative reversion parameter that describes the intensity at which risk-free rates will return to the equilibrium rate. σ_r is the volatility of risk-free rates and γ is the parameter that determines the sensitivity of the volatility with respect to interest rate level. γ take the value 0 in the Vasicek model. Although the Cox, Ingersoll and Ross (CIR) model is the most appropriate form to describe interest rates, the Vasicek model is less complex. The parameter estimates obtained by Tse (1998) over period 1975 to 1993 for the Vasicek model will be used, where

β=0.0069,

α=5.1682%, and

σ_r=0.3208.

These values, however, were computed on a weekly basis. Given that this study discretised time into annual basis, so

$$r_{t+1} - r_t = \beta'(\alpha - r_t) + \varepsilon_{t+1},$$

where ε_{t+1} follows $N(0, \sigma_r)$; β=0.3312, and σ_r=2.2225%.

The risk free rate, r, is assumed to lie within the range 1% to 9%, since historic data shows that the 3-month inter-bank rate lies within the range of 1% to 9%. The mortgage rate is also assumed to change by a magnitude of 0.25% in each adjustment because mortgage rates adjustments tend to be 0.25%. The margin between the mortgage rate and the risk free rate is taken to be between 2.5% and 5.5%. Although Board rates are usually pegged to the interbank rates by a margin of 3.5% to 5.5%, the lower boundary appears to be breached on numerous occasions. In addition, it is assumed that there are no transaction costs and there are no restrictions to prepayment in the mortgage arrangements.

The market prices of the households' current dwelling and their desired housing are assumed to follow the geometric Brownian motion. In other words,

$$\frac{dP(X)}{P(X)} = \mu_x dt + \sigma_x \varepsilon \sqrt{dt} \text{ and,} \tag{80}$$

$$\frac{dP(Y)}{P(Y)} = \mu_y dt + \sigma_y \varepsilon \sqrt{dt} , \tag{81}$$

where μ_x is the drift of P(X),

μ_x is the drift of P(Y),

σ_x is the variance of P(X),

σ_y is the variance of P(Y),

ε is the random drawing from a standardized normal distribution, N(0,1), for P(X) and P(Y).

Given that *D*= $P(X)_j - (1 - L/V)P(Y)_j$, the variance for *V* can be written as

$$\sigma_V^2 = \sigma_x^2 + (1 - L/V)^2 \sigma_y^2 - 2(1 - L/V)\rho_{x,y}\sigma_x\sigma_y, \tag{82}$$

where ρ_{xy} is the correlation between *P(X)* and *P(Y)*. The stochastic process representing the movements of *D* can be further defined as follows,

$$\frac{dD}{D} = (\mu_x - (1 - L_y / V_y)\mu_y)dt + \sigma_D \varepsilon \sqrt{dt}. \tag{83}$$

Following Cox, Ross and Rubinstein (1979), *V* follows a symmetrical binomial intertemporal price process defined by an up (u) and a down (d) path,

$$u = e^{\sigma_v \sqrt{dt}}; \qquad d = e^{-\sigma_v \sqrt{dt}}. \tag{84}$$

where *dt* is the discrete time interval. For an option matures in *n*, the option life can be divided into *h* number of *dt* intervals, i.e.*h* =*n*/*dt* and that probability that *V* will move up or down can be written as the following:

$$p = \frac{a-d}{u-d}, \tag{85}$$

where $a = e^{r_{f_j}\delta t}$ and r_{f_j} is the risk free rate at period *j*.

The value of the call option to move is, hence,

$$C_t = \max\left(0, \left[D_t - CF_t - P(X)_0 \prod_{k=1}^{j} \left(MC_{i_{k-1},N-k+1} PVAF_{i_{k-1},N-k}\right)\right], E(C_{t+1})\right). \tag{86}$$

The option to move is similar to a compound option (Geske, 1979; Carr, 1988), where the premiums of the options in the later period are contingent upon the premiums of the earlier periods. Implicitly, we assumed that the mortgage rate is independent of the housing prices. The assumption is reasonable because the correlation between 3-months interbank rate and property return derived from the private property price index is -0.29 for the period from 1988 to 1998.

The base case is shown in the following Exhibit 6.1. In the base case, we assume that the buyers will take up maximum loan available, which is 80% of the property price. The maximum period of stay is assumed to be 5 years. Nevertheless, we expect that that the changes in maximum length of stay will not affect our analysis and result. The mortgage rate is assumed to be 3% above the risk free rate, which is assumed to follow the above stochastic process. We also assume that the mortgage rate is the same, regardless of the type of housing purchased by the owner.

The housing return volatility for current dwelling is obtained from the Housing Development Board (HDB)[11] price index from 1990 to 2000 and the return volatility is obtained from the Urban Redevelopment Authority (URA) private price index[12] from the same time period. The correlation between the desired dwelling and current dwelling of households in the base case is also derived from HDB and URA. The housing prices for the desired dwelling and the current dwelling are assumed to follow the stochastic process in (79) and (80). The current rental yield for desired and current dwelling is set at 6% and 3% in the base case. The benefits or CF_j were deducted at every time step.

[Insert Exhibit 6.1]

[11] The HDB Price Index is based on the quarterly average resale price of HDB flats by date of registration.

[12] The URA Price Index is based the price of private properties, obtained from caveats lodged with "Option exercised" as grounds of claim. The price of properties excludes stamp duties, legal & agency fees and other professional fees. It is the agreed purchase price of the property between the purchaser and the vendor as entered in the caveat form. En bloc sales are not included because the prices of en bloc sales are usually higher than normal.

Using the @Risk package, which let the user perform Monte Carlo simulations, we simulate the movements of the risk-free rate and the prices for current and desired dwellings together to determine the option value. A simulation of 1,000 iterations was conducted and the option value is shown in Exhibit 6.2. The value of the options is positively skewed as shown in Exhibit 6.2. The mean option value is about $55,436, which is about one sixth of the value of the household's current dwelling. The mode option value is much lower, at $39,445.

[Insert Exhibit 6.2]

It was also found that higher volatility of mortgage rates will result higher average option values. In addition, the option value also has a positive relationship with the volatilities of the prices of the households' current dwellings and their desired homes. An interesting finding is that a lower correlation in the prices of current dwellings and the desired dwellings will result a higher option value. In addition, it is found that the greater the difference between the prices of the current and desired dwellings, the greater the value of the option to move.

Alternatively, by dividing equation (74) by the price of the current dwelling at period *j*, $P(X)_j$, equation (74) can be rewritten as follows:

$$Z \geq L/V\left(\frac{P(X_0)}{P(X_j)}\right)\prod_{k=1}^{j}\left(MC_{i_{k-1},N-k+1}PVAF_{i_{k-1},N-k}\right), \tag{87}$$

where $Z = 1 - (1 - L/V)\dfrac{P(Y_j)}{P(X_j)}$. In other words, the value of the option can also be written as

$$C_t = \max\left(0, \left[Z_t - \frac{CF_t}{P(X_j)} - L/V\left(\frac{P(X_0)}{P(X_j)}\right)\prod_{k=1}^{j}\left(MC_{i_{k-1},N-k+1}PVAF_{i_{k-1},N-k}\right)\right], E(C_{t+1})\right). \quad (88)$$

Implicitly, equations (87) and (88) imply that the greater the capital gain, the higher the value of the option, and, hence, the less likely the homeowner will move. In addition, the smaller the difference between the price of the household current dwelling and desired dwelling, the higher the option price and the less likely homeowners will move.

6.2 Volatility and Spread Test

Using the same sample, we further carried a parametric duration test (non-time varying) on the volatility of returns of HDB and private apartments. The parameter estimates are provided in Exhibit 6.3. The results show that the household's duration of stay will be longer if higher price volatility for HDB flats and private properties exists and this relationship is significant at 5% level of significance. In addition, most of the variables are consistent in both tests except *SHDBINT*, which may be due to collinearity errors. The presence of the mortgage volatility variable may distort the significance of *SHDBINT*. Since the real options model suggests that higher price volatility increases option premium to wait, the empirical results suggests that the real options model can explain the households' mobility decisions. The private mortgage volatility is also positively and significantly related to the households' duration of stay. This result is similar to the sensitivity analysis of the option value with respect to the mortgage volatility.

[Insert Exhibit 6.3]

6.3 Option premium and time-varying covariates

6.3.1 Methodology

By substituting the relevant values in equation (86) and let *n* be 10 years, we further formulate a 10 year binomial tree to compute the option premium. There are several reasons why we use 10 years as our benchmark. First, by the tenth year, the household is qualified to purchase a new HDB flat at the subsidized rate, with subsidized mortgage rates. Hence, those living in the smaller flats could upgrade to bigger public flats, without a levy. Second, since given that the average amortizing period is 18 years, the borrower is likely to build up sufficient capital by paying the loan over the 10 years period, and become less constrained by the down payment requirement at the end of the 10^{th} year.

In addition, instead of computing the option premium for those upgrading from a HDB flat to a private apartment, we also compute the option premium to delay moving from a small HDB flat to a bigger one. We obtain the average valuation of each type of flat from the HDB annual reports and use them for our start values. In addition, we assume the different types of HDB flats have the same volatility as that reflected in the HDB price index. Using a separate sample of 14,436 HDB flat resale transactions spanning from 1997 to 2000, we further compute a hedonic regression and obtain the price indices for the 3 room, 4 room, and 5 room flats.[13] We further compute the correlation of returns between the different types of dwellings. One possible problem is that the variance of returns of the different types of housing may be different. In the appendices, we show that the price movement is similar for all types of HDB housing from 1997 and 2000.

Another key variable that is required for our computation of option premium is rent for HDB housing. The rental transactions for HDB housing are not recorded and are arranged in an ad-hoc manner. The only published rents for public housing are rents for one and two room flats. I interviewed several agencies and managed to obtain the current rent for HDB flats in the targeted constituency. From the interviews made, the rent is estimated about $800 for a 3 to 4 room flat and $1000 for 5-room flats. With the given current rents, I further work backwards the rents using the private rental index, assuming that public and private rents move in tandem. Private rents, on the other hand, are obtained via REALIS database. The mortgage rates used are based on the housing loan rates of financing companies, which can be obtained from the TRENDS database. Alternatively, the public rates are obtained from Housing Development Board. After obtaining the data, we compute the option premium to delay, *Option*, using equation (86) for each year, each stage of payment and each type

[13] The computation of the hedonic regression is provided in the appendix.

of housing to which the household will upgrade to. In our context, we assume that households will upgrade from three-room flat to four-room flat, from four-room flat to five-room flat, from five-room flat to private apartments.

Nevertheless, we found that the above duration analysis largely assumes that the covariates are constant, which may not be reasonable. We further attempt to adopt the time-varying covariates duration model. We let the interval 0 to t_i be divided into k exhaustive, nonoverlapping intervals, $t_0 < t_2 < t_3 .. < t_{(k-1)} < t_k$, where t_0=0 and t_k=t_i. The covariates are assumed to stay constant within each of the k intervals, but may change from one interval to the next. Let

$$h_{(t \times x_k)} = \text{hazard function from } t_{k-1} \text{ to } t_k,$$

since within that interval, the covariates are constant.

The hazard function and survival rate can be written as the following,

$$h_t = \frac{d \ln S(t)}{dt}, \text{ and} \tag{89}$$

$$\Pr ob\left[T \geq t_j \mid T \geq t_{j-1}\right] = \exp\left\{-\int_{t_{i-1}}^{t_i} h(s \mid x_j) ds\right\} \text{ respectively.} \tag{90}$$

The survival function for duration of t_k is changed to

$$S(t_k \mid x_k) = \prod_{j=1}^{k} \Pr ob\left[T \geq t_j \mid T \geq t_{j-1}\right]. \tag{91}$$

Finally, the density at t_k is

$$f(t_k \mid x_k) = h(t_k \mid x_k) + \ln S(t_k). \tag{92}$$

The log-likelihood function for one observation is

$$\ln L_i = \delta_i \ln h(t_k \mid x_k) + \ln S(t_k)\ . \qquad (93)$$

Thus, each observation contributes the survivor function to the log-likelihood function. For noncensored observations, we add the density, evaluated at the terminal point. Therefore,

$$\ln L_i = \delta_i \ln h(t_k \mid x_k) - \sum_{j=1}^{k} \int_{t_{j-1}}^{t_j} h(s \mid x) ds\ . \qquad (94)$$

In other words, the hazard function is modeled as a step function, with different values of the covariates through several intervals between t=0 and t=T, the terminal value in the observation, at which either censoring or exit takes place.

Besides the usual variables and the option premium, *Option*, we include several variables. We include the two dummy variables, *AMUP* and *MUP*. The former takes the value one when the households' current dwelling qualifies for Main Upgrading Program, while the latter takes the value of one when the households' current dwelling has been confirmed to undergo the upgrading program. In addition, not all variables are time-varying. *R3*, *R4*, *MAL*, *JOINT*, *HHOLD* and *PDATE* are time-invariant variables. Intuitively, the type of housing the households live in, the race of households and the year they purchase the house will not change over time. Nevertheless, the household size and the type of ownership may change over time. We, however, do not have access to the changes in these two variables and can only test these variables at the origination date with respect to the households' length of stay. The time varying variables are *MUP, AMUP, Option, BLDGAGE, INCLEV, BUYERAGE, CGDP* and *CSES.*

6.3.2 Results

We first conduct three tests. In the first test, we include all observations spanning from 1982 to 2000. In the second test, we omit observations where purchases are made before 1990. This is because the market conditions for the resale housing market are very stable and volatility is zero before 1990. Under such circumstances, the premium to wait has no value. As shown in Exhibit 6.4, the option premium is positively related to the duration of stay, whether the pre 1990 observations are included or not. Nevertheless, the effect of option premium is weakly significant when the pre 1990 observations are included, as compared to when it is not. The results generally support our hypothesis of real option model. The log likelihood also shows that the test is robust; at least one variable in the model is significant at 5% level of significance. The relationship between the rest of the variables and length of stay remains consistent with our earlier analysis.

We also observe that both *MUP* and *AMUP* are significant. The positive coefficients of *MUP* and *AMUP* show that the advent of the upgrading program will entice the household to lengthen its stay in its current dwelling. The presence of *MUP* and *AMUP* also help ensure that the effect of *OPTION* is isolated. We further include an interaction variable between *AMUP and OPTION*, in the third test. The inclusion of the interaction variable is to determine whether households' decision to delay moving is affected by the advent of upgrading. If the interaction variable is insignificant, it implies that one's decision to delay moving is affected by his improvement decisions. The results show that the interaction is negatively related to households' length of stay, but insignificant. According to our model, we show that such insignificance arises when the household decides to cash in the difference between the market valuation and the actual cost of improvements.

Yet, interestingly, we observe that such relationship is inconsistent when we test the relationship between the value of option to delay moving after MUP and the household length of stay. We introduced another variable *MUPOP* by multiplying the variables *MUP* and *OPTION* together. This variable captures the changes in the option premium after the upgrading is completed. Conducting the same test again except omitting *MUP*, we find that the regression coefficient of this variable is positive. The result offers some empirical support that the voting and uncertainty influence dilutes the real option effect. I suspect that the unique institution setup of the upgrading programme may cause the inconsistency. It is likely that the uncertainty surrounding the date of carrying out upgrading and the support of the improvements further dilutes the households' option to move.

[Insert Exhibit 6.4]

One of our hypotheses surmises that the effects of loss aversion and equity constraint lose its influence on the prospective buyer's decision to purchase their desired dwelling when house price volatility declines. Following the loss aversion and equity constraints theories, the transaction volume of housing will fall when a negative shock causes the housing price to decline. The continued fall in transaction volume after the negative shock reduces the price volatility, which also reduces the household option premium to wait.

To test our hypothesis, we have to test whether the influence of loss aversion and equity constraints is significant when it is favorable to exercise the option to move. We introduce two dummy variables to equation (71): *POPT*, which takes the value 1 if the option premium to wait is positive, and *ZOPT*, which takes the value of 1 if the option premium to wait is zero. We further multiply the above dummy variables on the equity constraint and loss aversion terms in equation (71), and analyze whether the parameters remain significant. Yet, by including the two dummy variables in equation (71), we realize that too many zeros are created, and this led to multicollinearity among the different variables.

In order to resolve the problems stated above, we let these two variables interact with the relative change in Threshold Upgradability Index, *TUI*, and housing returns over the households' length of stay instead. The independent variables include the following:

$$\begin{aligned}\beta Z_{,it} = X_{i,t}^{'}\alpha &+ \phi_{POPT}\left(POPT \times LOSS \times CHDBPR\right) + \varphi_{POPT}\left(POPT \times PTUI \times CTUI\right)\\ &+ \gamma_{POPT}\left(POPT \times GAIN \times CHDBPR\right) + \eta_{POPT}\left(POPT \times NTUI \times CTUI\right)\\ &+ \phi_{ZOPT}\left(ZOPT \times LOSS \times CHDBPR\right) + \varphi_{ZOPT}\left(ZOPT \times PTUI \times CTUI\right)\\ &\gamma_{ZOPT}\left(ZOPT \times GAIN \times CHDBPR\right) + \eta_{ZOPT}\left(ZOPT \times NTUI \times CTUI\right)\end{aligned},$$

(95)

where *LOSS* is a dummy variable and takes the value 1 if *CHDBPR* is less than 0,

GAIN is a dummy variable and takes the value 1 if *CHDBPR* is more than 1,

POPT is a dummy variable and takes the value 1 if the option premium to wait is more than zero,

ZOPT is a dummy variable and takes the value 1 if the option premium to wait is zero,

NTUI is a dummy variable and takes the value 1 if the relative *TUI* over the length of stay drops,

PTUI is a dummy variable and takes the value 1 if the relative *TUI* over the length of stay rises,

CTUI is the relative change in TUI over the length of stay.

The first term on the right hand side of the equation captures the households' loss aversion effect when the option premium to wait is positive and the fifth term captures the same effect when the option premium to wait is zero. We expect the parameter of the first term to be significant and positive, since the presence of the option premium to wait will reinforce the effect of loss aversion. Alternatively, if the parameter of the fifth term is significant, we cannot conclude that whether the real option is indeed present. Yet, if this parameter is insignificant, the hypothesis that the real option effect overcoming the loss aversion at the trough is supported. This is because that offers evidence of the counteracting effects of the two forces.

The third term on the right hand side of the equation accounts for the effect of capital gains on the length of stay when the option premium to wait is positive, and the seventh term captures the same effect except that the option premium has no value. Unlike the first and fifth term, we expect the parameter of the seventh term to be significant and negative, and that of the third term to be insignificant. With higher gains for household to receive from sale and no incentive for the household to wait, we expect the household to exercise his option. Nevertheless, the effect of capital gains is less clear when the option premium is positive, and we cannot draw conclusions on our hypothesis unless the parameter of the third variable is insignificant.

The remaining variables measure the influence of equity constraints when the option premium is positive and zero. The inclusion of these variables helps us to isolate the equity constraints and the loss aversion effects. We do not include any interactive variables in this case because the derivation of the threshold upgradeability index incorporates the change in housing price. The second and the sixth term measure the effects of reduced equity constraints on the households' length of stay when the option to delay is favorable and unfavorable respectively. Following our hypothesis, we expect the parameter of the second term to be insignificant, and the parameter of the six term to be negative and significant. The remaining fourth and eighth terms measure the impact of increased equity constraints on households' mobility decisions, when it is more favorable or unfavorable to delay the decision to a later date. The theory suggests that the parameter of the eighth term to be insignificant because of counteracting effects of equity and real option effects. However, we expect the parameter of the fourth term to be significant and positive.

The results are further tabulated in Exhibit 6.4a. The findings show that the loss aversion effects are not significant when the option premium to delay is nil; the variable *ZOPT*LOSS*CHDBPR* is insignificant. Similarly, the effect of equity constraint is also shown to be insignificant when the option premium to wait is not valuable. The results also reveal that the relationship between capital gains and households' length of stay is insignificant. Alternatively, we found that positive capital gains, together with low option premium, will encourage households to move. Thus the results lend support to our earlier hypothesis on the turning point.

Chapter 7 Collective decisions and voting for upgrading program

7.1 Methodology and Test

Although the advent of Main Upgrading Program may influence the households' decision to move, the decision to carry out the upgrading works is made collectively, not individually. Even though the household may want to improve its dwelling, the final decision may go against its favor. In the earlier chapter, we also observe that the effect of real option is diluted when the dwelling enters the window eligible for upgrading. A possible way to incorporate the voting for the upward movement our earlier test is to make use of the voting rule. Yet Ben-Shahur and Sulganik (2003) notes the voting rule alone cannot answer how the voters vote. Assuming that voters are rational, and they seek to minimize disutility, Ben-Shahur and Sulganik (2003) predict that voters belonging to different camps may choose the same voting rule. However, in our mobility and improvement model, we assume that households maximize the utility. Since adopting either criterion may draw different conclusions, we attempt to test whether the households seek disutility. In addition, we also test whether households actually 'learn' the deviant strategy of abstaining by moving. This is especially so if the households realize that the general consensus will be unfavorable.

We surveyed 872 households and their votes for or against the Main Upgrading Program (MUP). These 872 households are from two constituencies; 378

households are from Clementi Avenue 4 and the rest from Pandan Gardens, West Coast. Both constituencies are in close proximity to each other, and the polling for MUP was held in the same year, 2003. Hence, there should be little differences in H^* and information sets for the two constituencies. During the sampling process, I initially targeted respondents from other sites that have undergone MUP in the past to obtain a panel data set. Yet, I found that some of the actual voters have moved after MUP is carried out and the responses are likely to be biased. Hence, select the two constituencies to investigate the voting model from the cross-sectional perspective.

The main reason for the choice of both constituencies is largely because of the different outcomes of the polls in both areas. The majority of the residents in Pandan Gardens have polled against MUP, and those in Clementi Ave 4 have voted for it. This offers us the opportunity to test and measure whether disutility plays a part in household decision making process. We try to capture the households' disutility by asking those households who obtained an outcome that they were against, and how much they were willing to pay to overrule the decision. At the same time, we also try to observe how voter demographic and economic characteristics influence their choices.

[Insert Exhibit 7.1]

Exhibit 7.1 lists the reasons that households vote against the Main Upgrading Program. The most commonly cited reasons are the inconvenience cause by the upgrading works and the high costs involved. In addition, about 26% of the households who vote against MUP find that the additions do not increase the value of their properties substantially. Alternatively, most households that support the upgrading program cite neighborhood requiring major facelift as the reason, as shown in Exhibit 7.2. Interestingly, 22% of those who support the upgrading works believe that the improved amenities will increase the value of their dwellings substantially and 26 % find MUP is value for money, which contrasts with the perceptions of those oppose. Exhibit 7.2 also reveals that 30% of respondents who support the upgrading works vote for MUP because they are attached to the neighborhood and would like to improve the neighborhood.

[Insert Exhibits 7.2 and 7.3]

We further adopt a probit model to test our hypothesis on the households' voting decisions. We examine the probability to vote for the upgrading by assigning the dependent variable, $\boldsymbol{y_i}$ to be either 0 (against) or 1 (for). The vote is then modelled on a set of independent variables denoted as $\boldsymbol{x_i}$. Generally, the probability to vote for the program can be specified as

$$\Pr(y_i = 1) = F(\beta x_i) \quad , \tag{96}$$

where F is an appropriate distribution function.

Many empirical analyses have either utilized the logit or the probit model to understand discrete choices of respondents. Given that the choice of either model does not affect the results, we use the probit model. The probit model is chosen instead of the normal linear model because using the normal linear model will lead to specification bias. The cumulative distribution curve of the probit model is a S shape, bounded in the interval (0,1) and such that $E(\boldsymbol{Y_i}) \to 0$ when $\boldsymbol{X_i} \to -\infty$ and $E(\boldsymbol{Y_i}) \to 1$ when $\boldsymbol{X_i} \to \infty$.

The probit model can be expressed as

$$\Phi(x) = \int_{-\infty}^{\beta' x} (2\pi)^{-1/2} \exp(-\frac{1}{2} t^2) dt \quad . \tag{97}$$

As both functions are non-linear, we cannot use the familiar Ordinary Least Squares (OLS) procedure to estimate our parameters. Hence it is accepted that the probit model can be estimated by maximizing the likelihood function, where

$$L = \prod_{i=1}^{N} [F(\beta' x_i)]^{y_i} [1 - F(\beta' x_i)]^{1-y_i} \quad . \tag{98}$$

The variables are further described in Exhibit 7.3 and the descriptive statistics are provided in Exhibit 7.4.

7.2 Results

The results are tabulated in Exhibit 7.5. We conduct 6 tests. We exclude the households' income and the job status of owner in the first test, the education level of owner and households' income in the second test and the job status and education level of owner in the third test. For Test 4, we substitute household size with marriage status. In tests 5 and 6, we further incorporate the disutility factors. The log likelihood tests are significant for all three tests. Generally, household income and job status of owner have insignificant effects on the households' decision to vote for MUP. Alternatively, it is found that the voters with tertiary education-having at least a university degree- tend not to vote for MUP, as compared to those with primary education. Since the employment status of owner and its income are insignificant, we believe that highly educated voters vote against MUP not because of affordability reasons. It is likely that these highly educated voters have better knowledge of the costs of MUP than those with poorer education. Or they could have higher specific costs associated with MUP.

The results also show that *AREA*, which takes the value of 1 if the household interviewed is located in Pandan Gardens, is negatively related to the households' likelihood to support MUP. In other words, households living at Pandan Gardens are more likely to vote against MUP than those in Clementi precinct. The HDB precinct in Pandan Gardens, compared to that in Clementi Avenue 4, has poorer access to the Mass Rapid Transit and other forms of public transport. In addition, there are fewer amenities in Pandan Garden than in Clementi Avenue 4. As stated earlier, many residents that oppose the upgrading claimed that the upgrading do not increase their property values, and it is likely that this is especially so in Pandan Gardens where the location is poorer than that in Clementi.

Three other variables that are significant in influencing households decision to vote; the age of owner, the type of flat and the size of household. The older the owner is, the more likely he is to vote against MUP. From the interviews conducted, most of the older owners are adamant on the need for MUP. They felt the money can be safeguarded for other purposes. Incidentally, we also found that the heads of households at Pandan Gardens, where MUP is rejected, are predominantly more than 50 years old. On the other hand, we find larger households are more pro-MUP than smaller households. This is because they need more room to accommodate the family and MUP usually offers the addition of one room or an increase in floor area. Interestingly, we observe that the residents living in 5-room flats are more likely to vote against MUP than those living in 3 room flats. The residents living in the 5-room flats interviewed told us that there was no need to, as the space they had was sufficient.

We further incorporate the variables that capture the amount of money the households are willing to pay to get what they want in our test. These variables are used as proxies for the disutility if the households face an unfavorable outcome. We further splintered the amount of money payable into four categories, with the category of minimal disutility as our basic variable. Test 5 of Exhibit 7.5 shows that the likelihood to support the upgrading program is positively and significantly related to the variable *11_20*. This means that households receiving a disutility of 11-20% of the total upgrading costs are more likely to support the upgrading program as compared to those who receive disutility of less than 10% of the upgrading costs. Yet, households receiving a disutility of more than 30% of the upgrading costs have a greater likelihood to oppose the upgrading works as compared to those who receive lower utility costs. This implies that households with low disutility tend to vote for MUP and those with highest disutility tend to vote against MUP. In other words, those households that vote against MUP tend to have higher disutility than those who support MUP. Nevertheless, the costs are hypothetical and are not enforceable. Additionally, the costs are not relative to family wealth or income. We try to circumvent the problem by multiplying the variables with the disutility factors, whereby

$$\begin{aligned}\beta x_i = \phi Z_i + \alpha HI \times ("11\_20"+"21\_30"+">30") + \\ \rho LOW("11\_20"+"21\_30"+">30")\end{aligned} \quad ,(99)$$

where x_i represents all the independent variables and β represents the parameters of

x_i;

Z_i represents the property and buyer independent variables that affect households' decision to move and ϕ is the related parameters,

HI takes the value one if the household is higher than the average household income computed from GDP per capita and national average household size,

LOW takes the value one if the household is lower than the average household income computed from GDP per capita and national average household size, and "11_20", "21_30", ">30" represent the percentage of upgrading costs the owner is willing to pay to overturn the decision.

The results for low income reflect those of Test 5, but high income owners who receive disutility of 21-30% of upgrading costs are more likely to support upgrading as compared to those receiving disutility of less than 10% of upgrading costs. The results of Test 6 imply that high income owners are willing to pay more to support MUP.

A possible criticism to the above result is that households when surveyed may provide extreme views. For instance, a household who does not want MUP will desire maximum compensation, while a household who wants MUP will go for minimum compensation. We try to overcome the problem by spacing out the questions during the interview. For instance, we asked the respondent who rejected MUP whether they would vote for MUP if they were to receive a discount of 5% of the total costs. After asking this question, we would follow up with other questions before asking them the same question, but quoting a higher discount. We did a trial survey and found that this method prevented the respondents from giving extreme values.

One interesting result from the above test is the insignificance of *RETURN*, on the probability to vote for MUP. Coupled with the significance of the disutility variables, it appears that the households disregard the possible monetary return that they are likely to make, when deciding to vote for or against upgrading. Yet, the use of the cross-sectional data may prevent us from making the above conclusions. It is likely, as postulated in the learning model, that the households who are against the MUP move before they vote against it.

In order to test whether the households learn the deviant strategies, we introduce a third set of variables to the sample, which we used to test the real option hypothesis. As mentioned previously, the returns of housing may form the impetus of households' decision to support MUP. Hence, the household will only learn of the deviant strategy to move before voting if the returns excess of what are required to move to a better housing is significant. In this subsequent test, we adopt the time-varying parametric duration test, because households' income, house prices, and buyers' age change over time. In addition, we let *AMUP* and *MUP* to be time-varying variables. *AMUP* took the value of 1 if the observed property is eligible for upgrading at the subject point of time, else 0. Similarly, *MUP* takes the value of 1 if the authorities announced polling for upgrading of the observed property at each point in time, else zero.

We conduct 5 tests. In the first test, we use the parameters obtained in our earlier probit test 3 of Exhibit 7.5 and substitute the relevant values of the observations in our second sample to obtain each household's probability of voting for upgrading. The use of test 3 results is due to the lack of information on the educational level of the residents. Given that the precincts the households in the earlier sample are located in are similar to that in Clementi, we let *AREA* took the value of 0. We also introduce two more variables; *AMUPPROB* and *MUPPROB*. *AMUPPROB* captures the probability that the owner will vote for upgrading when his dwelling is eligible for improvement, and is a time varying variable in our model. *MUPPROB*, which is also a time varying variable, captures the probability that the owner will vote for upgrading when the authorities announced the polling for Main Upgrading. In other words,

$$\beta x_i = \phi Z_i + \gamma AMUPPROB + \eta MUPPROB, \qquad (100)$$

where x_i represents all the independent variables and β represents the parameters of x_i;

Z_i represents the property and buyer independent variables that affect households' decision to move and ϕ is the related parameters

γ represents the parameter for *AMUPPROB* and η represents the parameter for *MUPPROB.*

The results are tabulated in Exhibit 7.6 and they show that *AMUPPROB* and *MUPPROB* are positively related to the households' length of stay in their current dwelling. However, *AMUPPROB* is found to be insignificant, whereas *MUPPROB* is strongly significant. The results imply that households that are against upgrading do not consider the strategy of moving. Yet over time, these households may find that their opposition is futile, and learn and subsequently apply the strategy of moving. These findings support the hypothesis that households are learning individuals, and those who are against the upgrading learn the deviant strategy of moving.

In Test 2, we further test whether the household level of affordability and changes in price induces them to learn and apply the strategies of moving. The independent variables included are shown as follows:

$$\beta x_i = \phi Z_i + \kappa AMUPTUI + \varpi AMUPCHDBPR, \qquad (101)$$

where κ and ϖ are the respective parameters of *AMUPTUI* and *AMUPCHDBPR*. The first variable, *AMUPTUI*, captures the change in threshold upgradeability index or the affordability of households' ability to upgrade during the window period. The second variable, *AMUPCHDBPR*, captures the return of the HDB dwelling during the window period. It is noted that an increase in HDB price will also increase TUI, because the owner can sell at a higher price, as shown in Equation (67). Thus the presence of TUI removed the derived effect of a change in affordability caused by change in price and vice versa. Test 2 of Exhibit 7.6 shows that *AMUPTUI* and *AMUPCHDBPR* are negatively and significantly related to the duration of households' stay. The results support our hypothesis that households learn to appreciate the payoffs of moving and apply the strategy of moving as opposed to voting when the payoffs are higher.

We further conduct a test with both the probability measures in Equation (100) and measures of affordability and gains shown in (101). By doing so, we not only can isolate the marginal effect of *AMUP* on *TUI*, we can also evaluate the effect if changes in gains influence the decision to vote. Exhibit 7.6 shows that the signs for the variables for probability to support upgrading, affordability and gains are the same as earlier tests. Nevertheless, we notice that *AMUPPROB* becomes significant. This implies that the variables for affordability and gains affect the households' decision to support during the window.

It is noted that the households may downgrade to a cheaper housing, and the wealth component is not readily observable. We try to filter the downgrading cases by excluding the observations with owners who are more than 50 years old. We also try to filter the downgrading phenomenon by excluding observations with owners who live in 4 and 5 room flats. This is because the 3-room flats are low-end housing, and owners are unlikely to downgrade further. The results remain consistent.

One possible criticism to the results garnered in Exhibit 7.6 is that households only act when the upgrading is announced, and are apathetic to whether their dwellings are eligible for the upgrading program. This is unlikely in our context. The households in both samples do not belong to the first or demonstration batch for Main Upgrading program, and the residents are likely to know the policy. In addition, the Upgrading Program is used as part of the election agenda, and is one of the key reasons that gave the ruling party the legitimacy of governance of Singapore. The residents are being informed consistently of the eligibility of the upgrading program by the town council and the ruling party, especially when elections draw near. Thus, it is unlikely that the residents only plan when the authorities announce the upgrading program. When *AMUP*= 1, it increases the immediacy or urgency for the household to decide.

Chapter 8 Conclusion

We first set out to discover the causes of the turning point of cycles. Many studies have attributed the turning point of house price cycle to supply lags. Yet what makes the demand to fall such that supply become in excess remains unstudied, especially since the effects of down payments will reinforce the price fluctuations. Borrowing from the real option theory, we postulate that households have the option to defer its move. Building on theory by Stein (1995), we surmise that a positive exogenous shock will swing the households to move up their housing career. The down payment requirements further reinforce the effects and the number of transactions increase. Yet the increase in transactions and price volatility entice households to wait for possible increase in price in future. The waiting phenomenon further dampens the demand. Together with possible new supply, price starts to fall. The effects of loss aversion and equity constraints set in and the number of transactions and price volatility fall, until some point when it is beneficial to exercise the option.

We first conduct several preliminary tests to check the assumptions of our model. The option component of our model assumes that price follows a Geometric Brownian Motion, which is a memoryless process. In other words, we assume that households hold rational expectations on house price. Our duration test shows that households' decision to move depend on the rational expectations of future price and this result supports our assumption.

Our second preliminary test aimed to study the importance of equity constraints. Our model draws upon the specifications and assumptions of Stein's model. In other words, we assume that equity constraints play an important role in generating reinforcement effects from price to demand. In order to test whether the assumption is reasonable, we further incorporate the Threshold Upgrader Index (TUI) in our duration test. The TUI encompasses the changes in households' level of affordability to purchase a private apartment resulting from changes in price, income and mortgage rates. We found that an increase in affordability of private housing will increase the households' likelihood to move. This result supports Stein's hypothesis.

Our third preliminary test further check whether loss aversion effects overwhelm the effects of equity constraints. If the loss aversion effects render the equity constraint effects insignificant, we will need to redefine the model when price declines. Following the example of Genosove and Mayer (2003), we generated the loss aversion and equity constraints using a mix of interacting variables between the extent of mortgage borrowed and the gain in each year. The results show that both loss aversion effects and equity constraints effects are significant.

After verifying our assumptions of our model, we further test the real option hypotheses. We first compute the option premium for each household and each year of their stay. We further include this option premium in a time-varying duration test. The results supported our model. First, the value of the households' option is increasing with the households' length of stay in their existing accommodations.

Second, it is shown that the households' length of stay is lower if the value of the option is low and capital gains are high.

We further extend the above analysis by analyzing how improvement decisions are included into the equation. Improvements, as observed by Munro and Littlewood (1997), can be carried out before or after the move, so that the household can consume its desired amount of housing at the particular stage of life cycle. Following our modeling, we found that the households' decision to delay their move is unlikely to be influenced with the added option to improve, provided that the households' intention is to improve and move. Nevertheless, the households may not delay his move even if the option premium is positive. This will occur when the market valuation of the improvement exceeds the costs. In our tests, we further use the Main Upgrading Programme (MUP) as a proxy to households' improvements. Interestingly, we found that the relationship between the value of option to delay moving and the households' length of stay when MUP is announced and that when MUP is completed is different under different scenarios. I attribute the inconsistency of the results to the unique institution setup of the upgrading programme. More specifically, the collective decision making process of upgrading may affect the relationship between value of households' option to delay moving and their length of stay. As shown in Chapter 7, we found that the way people votes changes as they learn their strategies. Hence, such changes in strategies will reduce the impact of the value of option to delay moving.

We further test the model postulated by Ben Shahar and Sulganik (2003) whether households make their votes based on minimizing disutility. In addition, we further test whether households do learn new strategies to abstain, or move over time, especially if they find the new strategy is more optimal. In order to test our hypothesis, we identify the Singapore housing market because of its unique regulatory framework and clear segmentation of the housing sector into private and private. From our tests, we find that the households' option premium to defer payment do influence their decision to move; the higher the option premium the greater the likelihood they move. In addition, even with upgrading program, the option premium remains significant.

In our second part, we further test the assumptions of Ben-Shahur and Sulganik's model (2003). We find that the household do take into consideration of disutility in their vote. In addition, using the longitudinal data, we further found that most households learn the strategy to move and apply the deviant strategy.

8.1 Limitations

There are several limitations in our test. First, our sample is not large, despite a lot of data about the resident is known. Second, for our test of collective decision, we are unable to obtain how the decisions change over time and over different stages of economic cycle. Third, we cannot directly observe the characteristics of households that move before the vote. Fourth, our assumptions of rental of HDB flats and its growth are based on informal sources and there may be bias. A better database will allow us to better test our hypothesis.

8.2 Extensions

A possible extension of the real option theory portion is to use the least square approach (Longstaff and Schwartz, 2001) to value the option premium. The approach involves using a least squares analysis to determine the best-fit relationship between the value of continuing and the values of relevant variables at each time an early decision has to be made.

Alternatively, we can further the collective decision making process by empirically testing the assumptions in the using surveys from the private households. Given that the households are more homogenous in demography, the results may differ.

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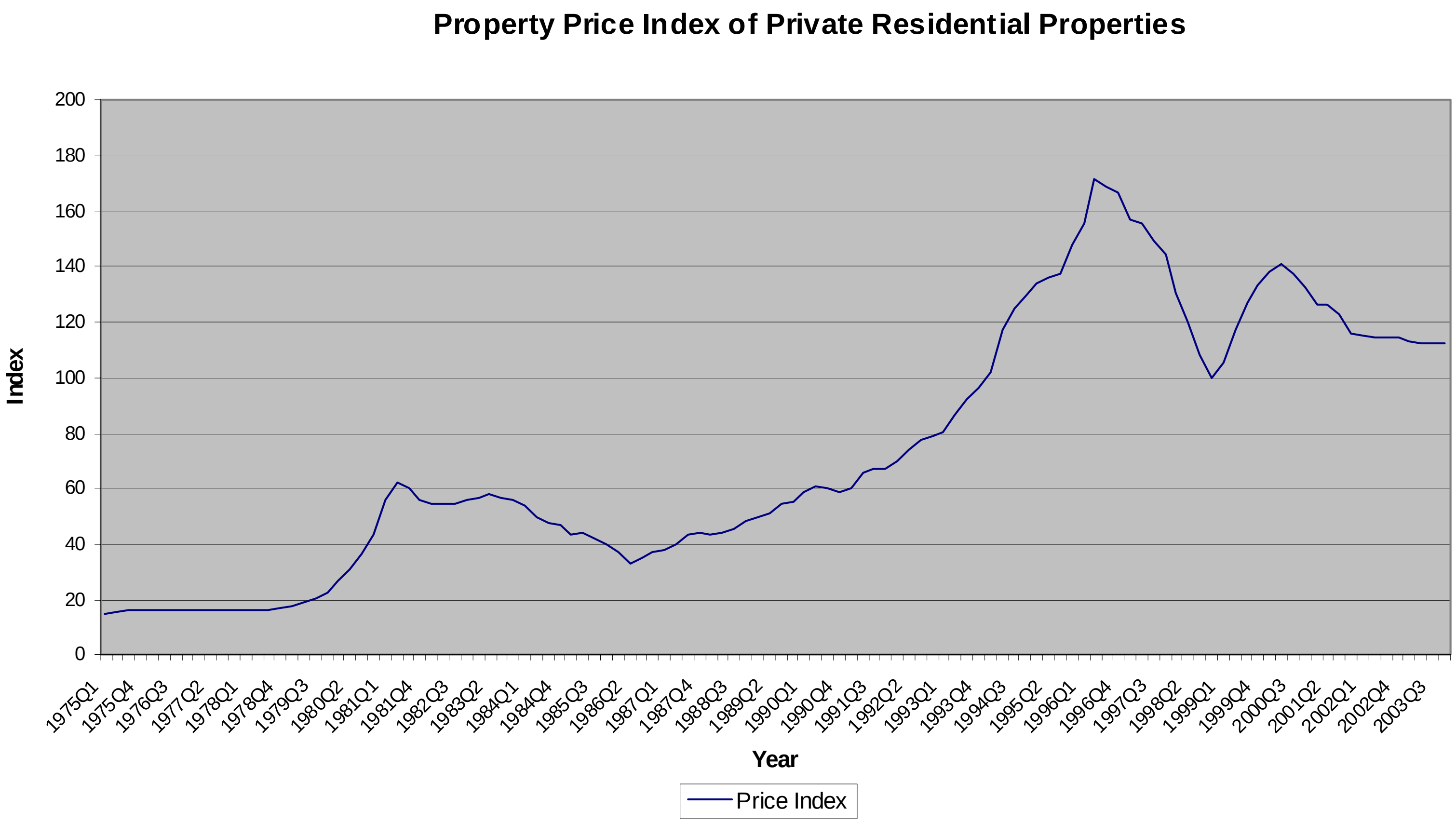
Exhibits

Exhibit 3.1

Source: HDB

Exhibit 3.2



Source: URA

Exhibit 4.1

Time 1

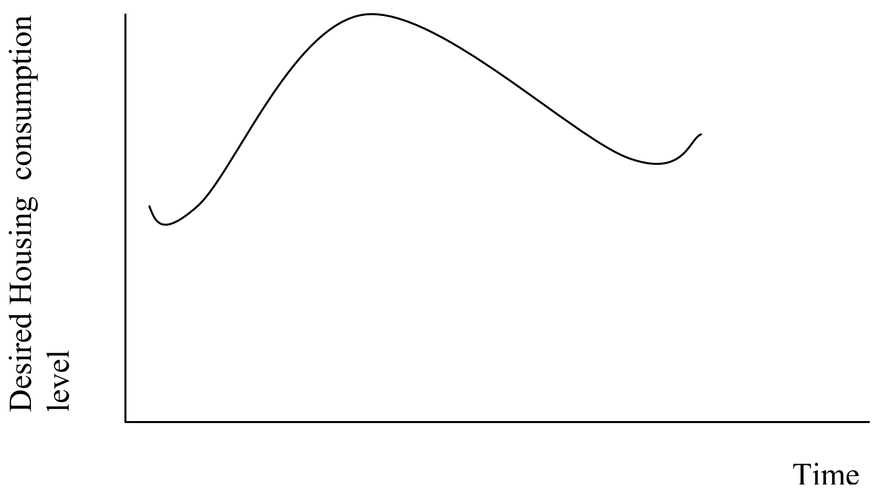
$$V = \max\left[P - (1+r)K_i, \left(p_u V_u + p_d V_d\right)e^{-\lambda}\right]$$

Time 2

$$V_u = \max(uP - (1+r)^2 K_i - c_{Debt2}, 0)$$

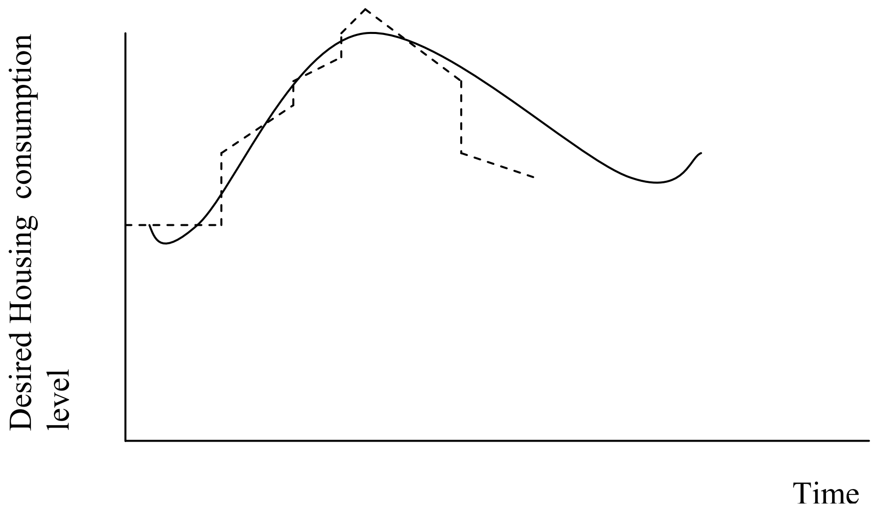
$$V_d = \max(dP - (1+r)^2 K_i - c_{debt2}, 0)$$

Exhibit 4.2



Notes: Housing demand typically increases during child-rearing stage of the life cycle towards a 'peak' of housing consumption, before diminishing towards a lower life cycle.

Exhibit 4.3



Notes: In order to match more closely to the continuously adjusting demand equilibrium, households adopt the strategy of moving and improving, as shown by the dotted line.

Exhibit 4.4

Time 1

Time 2

$$V_{in,u} = \max(uP(1+H_{investment}) - (1+r)^2 K_i - c_{Debt2}, 0)$$

$$V_{in} = \max\left[P(1+H_{investment}) - I - (1+r)K_i, \left(p_u V_u + p_d V_d\right)e^{-\lambda} - I\right]$$

$$V_{in,d} = \max(dP(1+H_{investment}) - (1+r)^2 K_i - c_{debt2}, 0)$$

Exhibit 4.5

Time 1

$$H_{imp} = \max\left[\frac{P(H-\gamma H^{-}) - (1+r)K_i}{I}, \left(p_u H_{imp} + p_d H_{imp}\right)e^{-\lambda} \right]$$

Time 2

$$H_{imp} = \max(u\left\{ \frac{\left[P(H-\gamma H^{-}) - (1+r)K_i\right](1+s)}{I} \right\},0)$$

$$H_{imp} = \max(d\left\{ \frac{\left[P(H-\gamma H^{-}) - (1+r)K_i\right](1+s)}{I} \right\},0)$$

Exhibit 4.6

Time 1

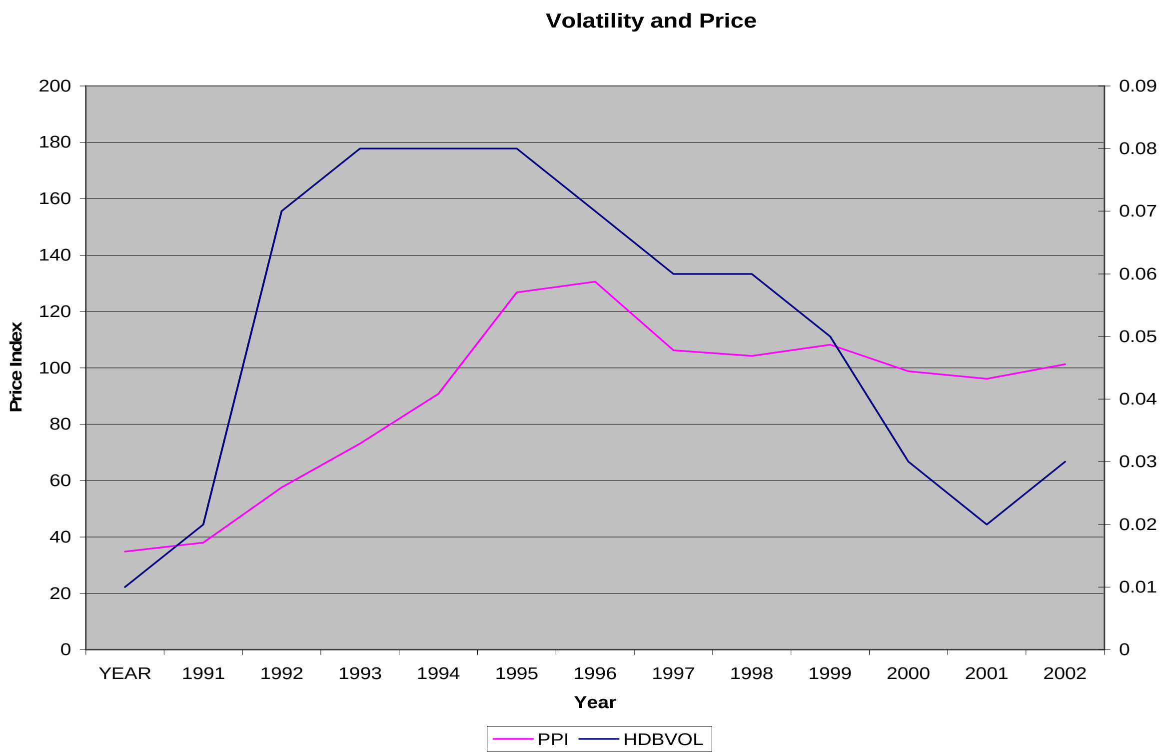
$$H_{imp} = \max\left[\frac{P(H-\gamma H^{-}) - (1+r)K_i}{I}, \left(p_u H_{imp,u}' + p_d H_{imp,} \right.\right.$$

Time 2

$$H_{imp,u}' = \max(u\left\{ \frac{\left[P(H-\gamma H^{-}) - (1+r)^2 K_i\right]}{I} \right\},0)$$

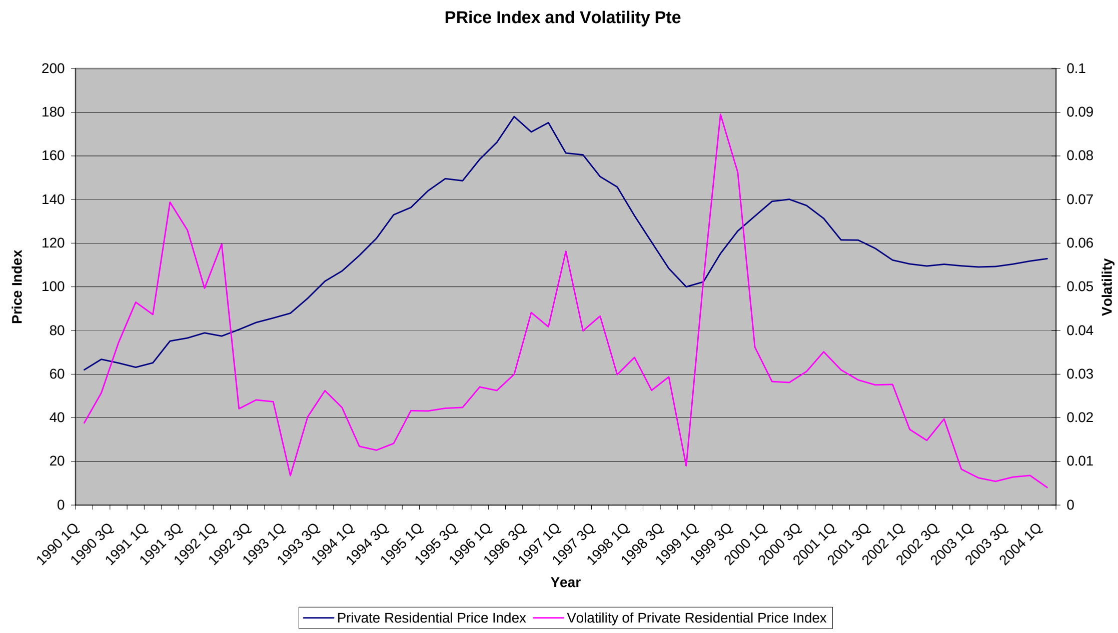
$$H_{imp,d}' = \max(d\left\{ \frac{\left[P(H-\gamma H^{-}) - (1+r)^2 K_i\right]}{I} \right\},0)$$

Exhibit 5.1 Relationship between Private Property Price Index and Volatility of Returns of HDB flat



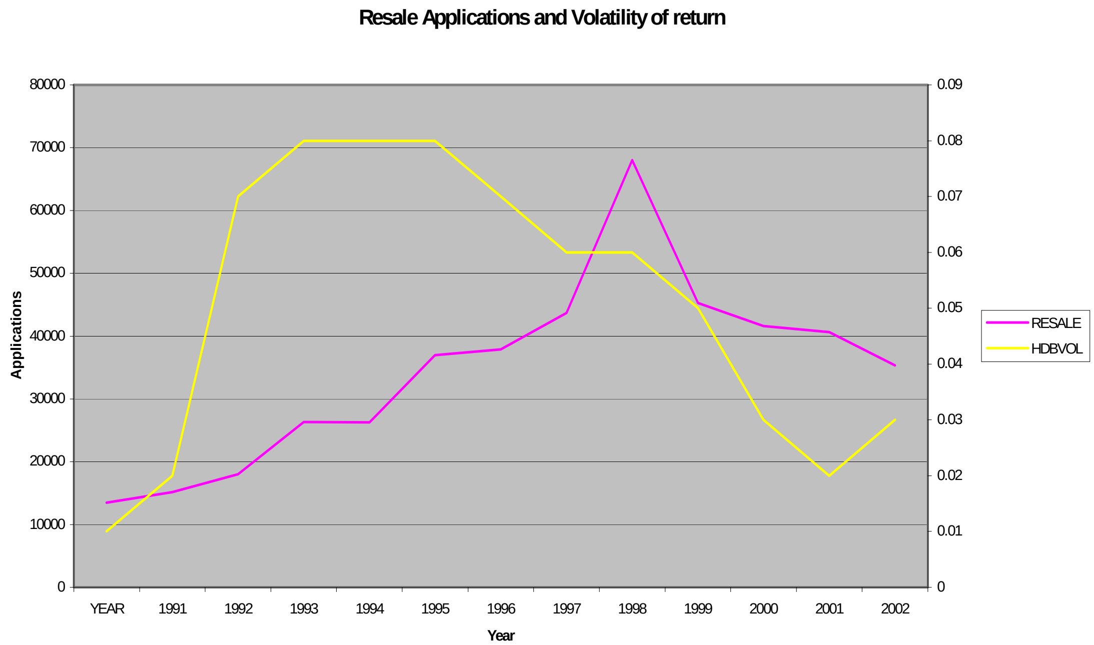
Source HDB, URA and Author's Computation

Exhibit 5.2 Relationship between Private Property Price Index and Volatility of Private Residential Price Index



Source HDB, URA and Author's Computation

Exhibit 5.3 Resale Applications and Volatility of returns of HDB flat



Source HDB, URA and Author's Computation

Exhibit 5.4: Regression between Volatility of Returns of HDB Housing and Resale Price

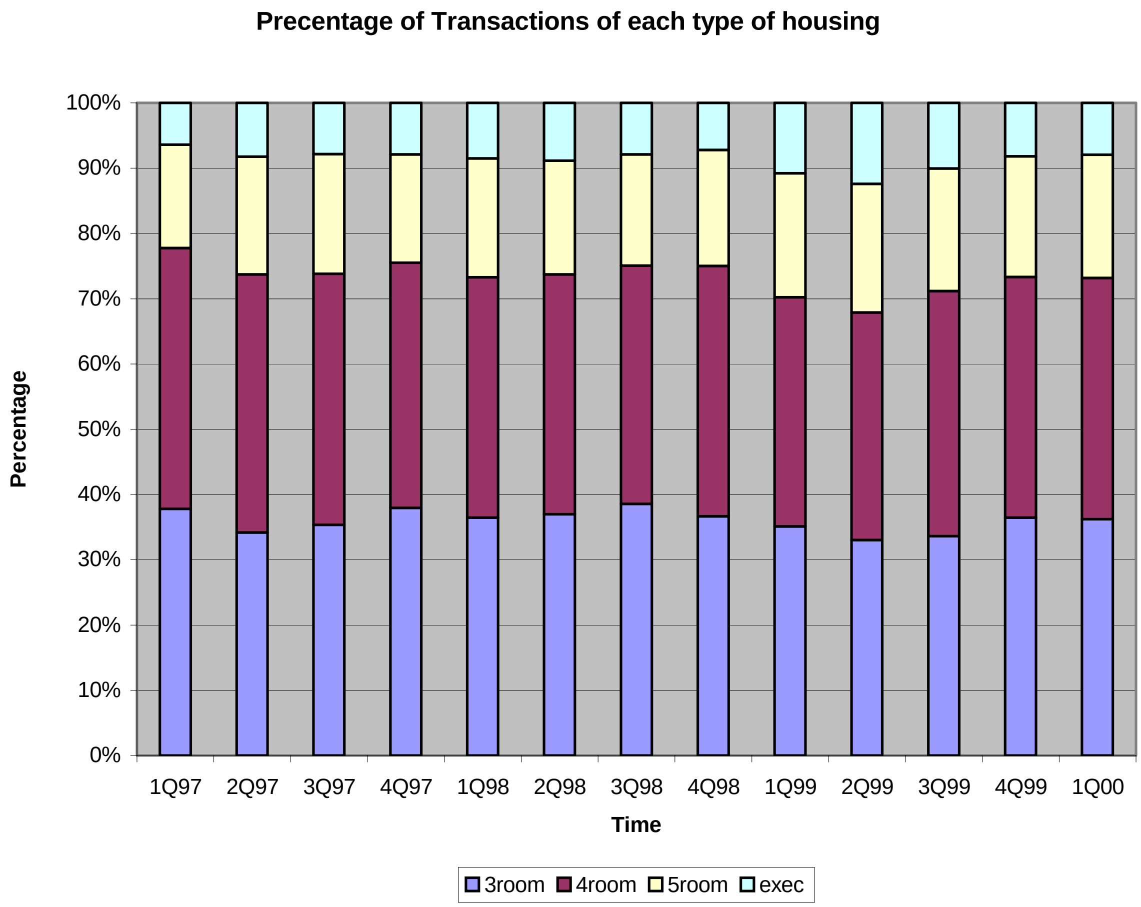
Dependent variable *RESAPLL*

Independent Variables	Coefficients	Sig
Constant	-5033.229	.662
HDBVOL	1979693.2	.003
HDBVOL2	-19003965	.005

R-Square= 0.594

Notes: HDBVOL refers to the volatility of returns of HDB flats, *HDBVOL2* refers to the square of *HDBVOL*, and *RESAPLL* refers to the number of applications

Exhibit 5.5: Percentage of Transactions of Each Type of Housing



Source: HDB

Exhibit 5.6 Descriptive Statistics

VARIABLE	MEAN	STD. DEV.	MINIMUM	MAXIMUM
FLOOR	8.65	5.48	1	25
R3	.539	.499	0	1
R4	.335	.472	0	1
BUYERAGE	38.48	10.98	21	79
MAL	.138	.345	0	1
IND	.488	.216	0	1
OTHERS	.505	.709	0	1
JOINT	.786	.41	0	1
HHOLD	3.133	1.45	1	7
INCLEV	.770	.522	0	3.93
PPRICE($)	115423	89735	20000	800000
SPRICE($)	97261	126100	0	750000
LOAN ($)	63401	56516.7	1800	328000
LV (%)	57.3	21.4	22.9	90
OUTSTAND($)	21525.29	37206.96	0	287346
PREMIUM (%)	51.3	10.11	-28.9	56
MUP	.318	.466	0	1
BLDGAGE	24.213	4.909	8.75	33
SMORTVOL(%)	.556	.202	.19	1.55
HDBVOL	43.498	17.455	0	80.6
SHDBINT(%)	2.219	1.183	.43	4.51
CSES	.375	.549	-.554	2.289
CGDP	.721	.580	-.321	2.917
CHDBPR	1.071	1.009	-.2117	3.062
CHDBMR	2.926	2.409	-.561	9.488
INTDIFF(%)	4.299	1.297	2.09	9.69
CAPGAIN	.728	1.407	-1	18.4805
TUI	99.3705	6.5294	69.9	114.1

Notes: The data for this study were provided from Housing Development Board (HDB) Branch Office of Singapore. A sample of 594 resale mortgages spanning a period from 1982 to 2000 is observed. The buyer characteristics are the age of the buyer *(BUYERAGE)*, the dummy variables for Malay *(MAL),* Indians (*IND*) and others (*OTHERS*). Other buyer characteristics include size of household (*HHOLD)*, and the household income level (*INCLEV)*. The household income level is computed by normalizing the reported household income with the overall household income adjusted to 1990 prices. The property related variables include dummy variables of 3-room (R3) and 4-room (R4), age of unit *(BLDGAGE)* and dummy variable for Main Upgrading Programme (*MUP*). The loan characteristics are loan- to- value ratio (LV), the outstanding balance (*OUTSTAND*) and the payment- to- income ratio (*PAYINC*). Other variables include the purchase price (*PPRICE*), the selling price (*SPRICE)*, the premium which is the amount paid above valuation and the date of originations and prepayments.The macroeconomic factors include the change in SES index (*CSES*), change in GDP (*CGDP*), change in HDB mortgage rate (*CHDBMR*), change in HDB index (*CHDBPR*), the HDB public rate at point of sale (*SHDBINT*), the HDB price volatility *(HDBVOL*), the private mortgage volatility rate at point of sale (*SPMORTVOL*) and the spread between the public and private rates (*INTDIFF*). The households' ability to upgrade is represented by the threshold upgradability index (*TUI*). The price of dwelling, in GDP and SES may be 200% higher than that when the household first bought the flat. This is because the price, GDP and SES has increased over the past 10 years continuously, and this is especially so for households that have lived very long in these flats.

5.6a Definition of Variables

VARIABLE	DEFINITION
FLOOR	This is a discrete variable that indicate the floor level the households stayed in.
R3	This is a dummy variable that indicates whether the household stayed in a 3-room apartment or not.
R4	This is a dummy variable that indicates whether the household stayed in a 4-room apartment or not.
BUYERAGE	This variable indicates the age of the buyer. If the property is jointly purchased by two buyers, the age of the older buyer would be recorded.
MAL	This is a dummy variable that indicates whether the household's ethnic group is Malay or not. For inter-racial marriages, we will adopt the ethnic group of the head of household.
IND	This is a dummy variable that indicates whether the household's ethnic group is Indian or not. For inter-racial marriages, we will adopt the ethnic group of the head of household.
OTHERS	This is a dummy variable that indicates 1 if the household's ethnic group is neither Malay nor Indian. For inter-racial marriages, we will adopt the ethnic group of the head of household.

JOINT	This is a dummy variable that indicates whether the housing is jointly purchased or not.
HHOLD	This is a discrete variable that indicates the size of the household.
INCLEV	This variable captures the relative income level of the household with respect to the national household income.
PPRICE($)	Purchase price of housing
SPRICE($)	Selling price of housing.
LOAN ($)	Amount of loan taken
LV (%)	Loan to value ratio
OUTSTAND($)	Amount of Outstanding Loan
PREMIUM (%)	Percentage paid above the apartment's valuation.
MUP	This variable is a dummy variable that captures whether Main Upgrading Programme is carried out.
BLDGAGE	This variable is a discrete variable that indicates the age of the apartment
SMORTVOL(%)	Mortgage Volatility
HDBVOL	Volatility of HDB price
SHDBINT(%)	HDB mortgage rate at the point of sale
CSES	Change in Singapore Stock Exchange Index over the period of stay
CGDP	Change in GDP over the period of stay
CHDBPR	Change in HDB residential price Index over the period of stay
CHDBMR	Change in HDB mortgage rate over the period of stay
INTDIFF(%)	Difference between HDB mortgage rate and market rate

CAPGAIN	Capital gains earned over the period of Stay
TUI	Threshold Upgradability Index

Source: Author

Exhibit 5.7: Cutler and Ederer life table estimation of the duration

Survival		Enter	Censored	At Risk	Exit	Survival rate		Hazard Rate	
.0-	23.5	594	0	594	6	1.0000	(.000)	.004	(.000)
23.5-	47.0	588	54	561	107	.9899	(.004)	.0090	(.001)
47.0-	70.5	427	74	390	73	.8011	(.017)	.0088	(.001)
70.5-	94.0	280	51	254	47	.6511	(.021)	.0087	(.001)
94.0-	117.5	182	28	168	35	.5309	(.023)	.0099	(.002)
117.5-	141.0	119	26	106	12	.4209	(.025)	.0051	(.001)
141.0-	164.5	81	30	66	12	.3727	(.026)	.0085	(.002)
164.5-	188.0	39	30	24	1	.3049	(.027)	.0018	(.002)
188.0-	211.5	8	7	4	0	.2922	(.029)	.0000	(.000)
211.5-	235.0	1	1	0	0	.2922	(.029)	.0000	(.000)

Source: Author's computation

Exhibit 5.8:Estimated Survival Function

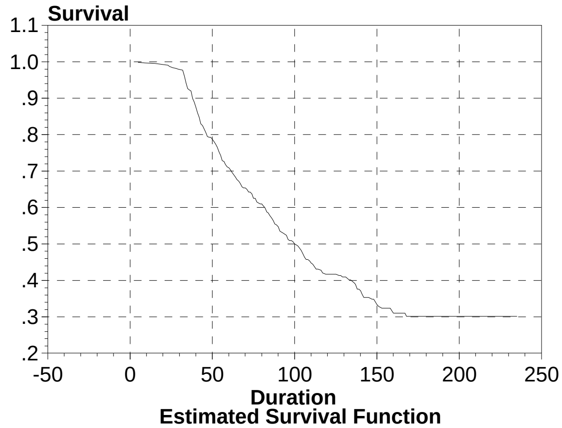


Exhibit 5.9: Kaplan-Meier Hazard Function

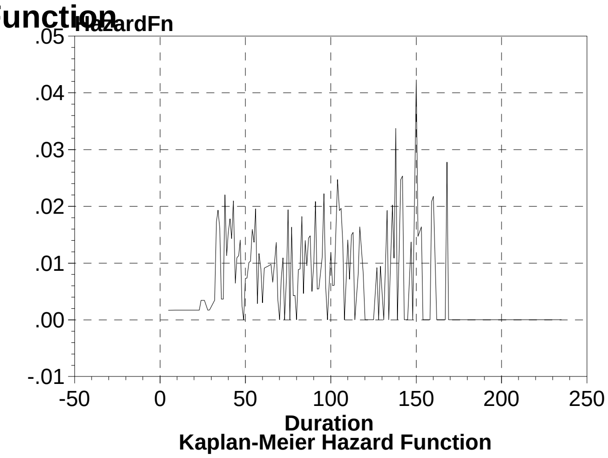


Exhibit 5.11: Estimated survival function

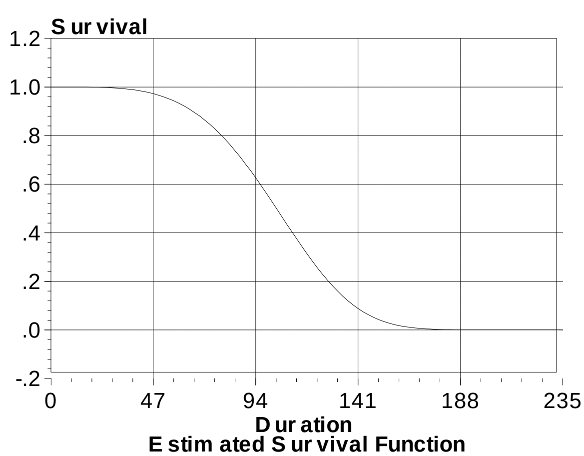
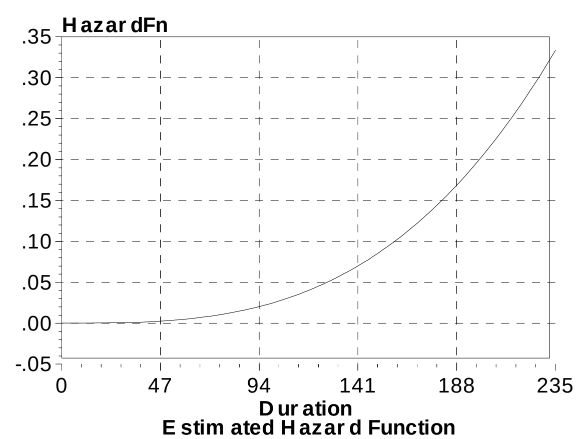


Exhibit 5.12 : Estimated Hazard function



Source: Author's computation

Exhibit 5.10 Parametric Duration test on Expectations (Non- Time Varying)

Dependent Variable: Log(Duration of Stay)

	TEST 1 (Using Actual Returns)		TEST 2 (Using Adaptive Expectation methodology)		TEST 3 (Using Rational Expectation methodology)		TEST 4 (Using Exogenous expectation methodology)		Test 5 (Includes TUI and excludes returns)	
	Coefficient	P	Coefficient	P	Coefficient	P	Coefficient	P	Coefficient	P
Constant	2.1870	.0000	2.0481	.0000	2.1744	.0000	1.7614	.0000	2.2821	.0000
BUYERAGE	- 0.3104	.9868	- 0.6361	.7310	- 0.6142	.7516	- 0.6878	.8085	- 0.2772	.8843
MAL	- 0.1007	.1592	- 0.8821	.1249	- 0.7417	.1867	- 0.3511	.2012	- 0.9678	.0701*
IND	- 0.5986	.3275	- 0.6805	.2850	- 0.4573	.4786	- 0.7696	.4228	- 0.7070	.2462
JOINT	- 0.2980	.0000*	- 0.2934	.0000*	- 0.3079	.0000*	- 0.2473	.0070*	- 0.2917	.0000*
HHOLD	- 0.1734	.2554	- 0.1422	.3710	- 0.6232	.6853	- 0.9061	.3027	- 0.1456	.3629
INCLEV	- 0.8084	.0430**	- 0.6925	.0877**	- 0.9227	.0162*	- 0.1505	.0027*	- 0.8601	.0375*
PREMIUM	- 0.2602	.1388	- 0.2821	.1249	- 0.1592	.3757	- 1.6126	.0001*	- 0.2560	.1119
LV	- 0.9465	.3906	- 0.1170	.2992	- 0.1739	.1108	- 0.6424	.0001*	0.1306	.5664
INTDIFF	0.1953	.0000*	0.1962	.0000*	0.1775	.0000*	0.3287	.0000*	0.1898	.0000*
SMORTVOL	1.4863	.0000*	1.5923	.0000*	1.5487	.0000*	1.6281	.0000*	1.6548	.0000*
R3	- 0.1438	.1354	- 0.7517	.2778	- 0.1148	.1871	- 0.3576	.0001*	- 0.1197	.0854*
R4	- 0.3701	.5611	- 0.4021	.9491	- 0.1029	.8733	- 0.1364	.1188	- 0.1143	.8599
BLDGAGE	0.1430	.0005*	0.1288	.0063*	0.1331	.0010*	0.3485	.0000*	0.1368	.0011*
SPRICEVOL	0.1239	.0000*	0.1030	.0000*	0.1344	.0000*	0.2902	.0000*	0.1347	.0000*
CSES	- 0.1071	.1456	- 0.7133	.2748	- 0.7894	.1347	-	-	- 0.8311	.1173
CGDP	1.0870	.0000*	1.0228	.0000*	1.0473	.0000*	-	-	1.0462	.0000*
TUI	-	-	-	-	-	-	-	-	- 0.3584	.0153*
RELPI	0.5746	.0641**	-	-	-	-	-	-	-	-
ACTGAIN	- 0.2417	.0002**	-	-	-	-	-	-	-	-
MYOPTE_5	-	-	- 3.6967	.0001*	-	-	-	-	-	-
MYOPUB_5	-	-	3.0805	.0006*	-	-	-	-	-	-
RATPTE	-	-	-	-	- 1.2067	.3123	-	-	-	-
RATPUB	-	-	-	-	0.3414	.0015*	-	-	-	-
EXO_1	-	-	-	-	-	-	11.1554	.2313	-	-

Source: Author’s computation

Notes:

* Indicates significance at 5 per cent level and ** indicates significance at 10 percent significance level

The data for this study were provided from a Housing Development Board (HDB) Branch Office of Singapore. From a total of 37,000 units in a constituency, a sample of 594 resale mortgages spanning a period from 1982 to 2000 is observed. The buyer characteristics are the age of the buyer (BUYERAGE), the dummy variables for Malay (MAL), Indians (IND). Other buyer characteristics include size of household (*HHOLD)*, and the household income level (*INCLEV)*. The household income level is computed by normalizing the reported household income with the overall household income adjusted to 1990 prices. The property related variables include dummy variables of 3-room (R3) and 4-room (R4), age of unit *(BLDGAGE)*. The loan characteristics are loan- to- value ratio (LV) and the payment- to- income ratio (*PAYINC*). Other variables include the date of originations (*PDATE*) and the amount paid over the valuation (*PREMIUM)*. The macroeconomic factors include the change in SES index (*CSES*), change in GDP (*CGDP*), change in HDB mortgage rate (*CHDBMR*), change in HDB index (*CHDBPR*), the HDB public rate at point of sale (*SHDBINT*), the change in private residential price index (*CRPI*), the private mortgage volatility rate at point of sale (*SPMORTVOL*). *RATPTE* and *RATPUB* represent the expected returns of private and public housing using rational expectations methodology. *MYOPTE_5* and *MYOPUB_5* represent the expected returns of private and public housing using rational expectations methodology. *EXO_1* represent the expected returns of private and public housing using exogenous expectations methodology.

The hazard rate is

$$h(t) = \lambda p(\lambda t)^{p-1}$$

where

$$\lambda(t) = \exp(-\beta' x_i).$$

	TEST 1 (Using Actual Returns)	TEST 2 (Using Adaptive Expectation methodology)	TEST 3 (Using Rational Expectation methodology)	TEST 4 (Using Exogenous expectation methodology)	Test 5 (Includes TUI and excludes returns)
Lambda	0.00897	0.00902	0.00890	0.00752	0.00901
P	4.03332	4.12865	4.04179	2.38059	3.99223
Log-likelihood without variables on expected returns	144.8824	144.8824	144.8824	144.8824	NA
Log-Likelihood	-136.8495	-126.7102	-134.2864	-331.7604	-144.2287
Sig at 5% level of significance	Yes	Yes	Yes	No	Yes

Notes: The log-likelihood for a model without coefficients is -547.7889. Hence, the likelihood ratio test shows that at least one variable is significant.

Source: Author’s computation

Exhibit 5.13

Cross Tabulation between Loan-to-Value ratio and Change in Price (Capital Gains)

i) For Households who have moved before June 2000

		Loan-To-Value Ratio			Total
		0-40%	41%-60%	>60%	
Capital Gains	<0%	7	13	13	33
	0-20%	6	6	18	30
	21%-50%	3	6	26	35
	51-70%	5	1	10	16
	>70%	33	75	71	179
Total		54	101	138	293

ii) For Households who have not moved by June 2000

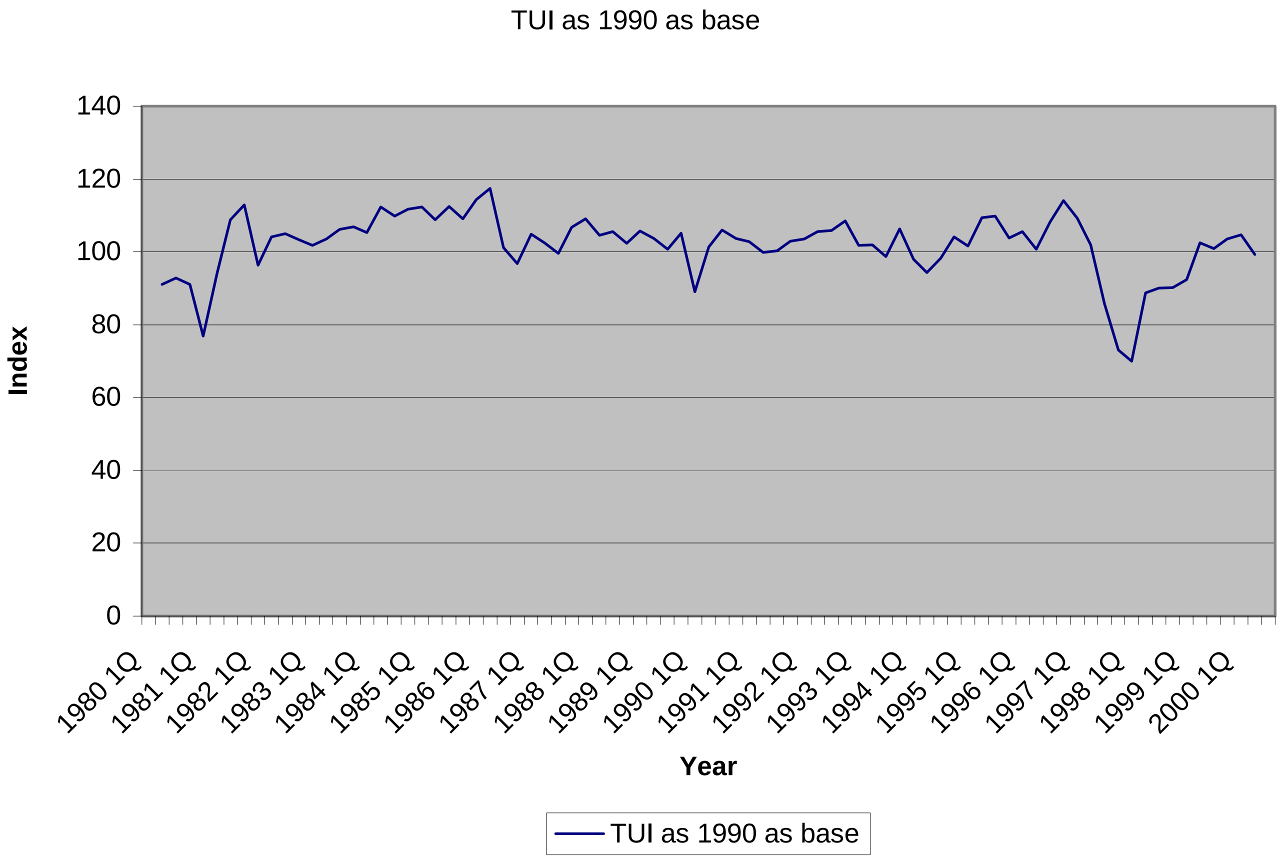
		Loan-To-Value Ratio			Total
		0-40%	41%-60%	>60%	
Change in HDB Price Index	<0%	13	13	53	79
	0-20%	3	5	16	24
	21%-50%	5	2	18	25
	51-70%	11	8	18	37
	>70%	51	45	40	136
Total		83	73	145	301

iii) For the whole sample

		Loan-To-Value Ratio			Total
		0-40%	41%-60%	>60%	
Change in HDB Price Index	<0%	16	19	69	104
	0-20%	13	17	46	76
	21%-50%	9	6	43	58
	51-70%	20	12	24	56
	>70%	79	120	101	300
Total		137	174	283	594

Source: Author's computation

Exhibit 5.14 Threshold Upgradability Index



Source: Author's computation

Exhibit 5.15a

Time-varying Parametric Duration test

Dependent variable: Log Duration

	Coefficient	P
Constant	4.2559**	0.0000
BUYERAGE	0.8626**	0.0044
MAL	-0.4406**	0.0000
IND	-0.4709**	0.0003
JOINT	-0.3472**	0.0006
HHOLD	0.1307**	0.0000
INCLEV	-0.1960**	0.0012
BLDGAGE	-0.3037**	0.0012
FLOOR	0.4804	0.4286
R3	-0.1236	0.3179
R4	-0.7440	0.4654
MUP	0.1824**	0.0490
AMUP	0.3605**	0.0000
LV	-0.9645**	0.0000
INTDIFF	0.1156	0.5604
SMORTVOL	0.2550	0.1219
CSES	-0.9566	0.8629
CGDP	2.4260	0.5890
TUI	-0.1745**	0.0009
LAMBDA	0.08402	
P	2,04090	
Log Likelihood	-914.6188	

Notes: *: 10% level of significance, **: 5% level of significance

R3 and R4 are dummy variables; *R3* takes the value of 1 if the current dwelling is 3 room and *R4* takes the value of 1 if the dwelling is 4-room flat. *BUYERAGE* represents the age of the head of household and varies over time. *MAL* takes the value 1if the buyer is malay, else 0. *JOINT* takes the value 1 if the dwelling is under joint ownership, else 0. *HHOLD* captures the household size. *BLDGAGE* represents the age of dwelling. *INCLEV* represents the income level of household over the years, *SMORTVOL* represents the mortgage volatility, *TUI* refers to the threshold upgradeability index, *CSES* captures the change is Singapore Stock Exchange Index, *CGDP* represents the change in *GDP* for each year. *MUP* is a dummy variable, and it takes the value 1 if the unit has undergone upgrading. *AMUP* is a dummy variable, and it takes the value 1 if the unit is eligible for upgrading.

Source: Author's computation

Exhibit 5.15b Statistical Results: Test For Equity Constraints

Dependent Variable: Log(Duration of Stay)

	Coefficients		
Variable	Model A	Model B (original)	Model C (Substitute *SHDBINT* with *INTDIFF*)
CONSTANT	5236.2433 (.0000)	6180.0000 (.0000)	6306.4419 (.0000)
Borrower Specific Variables			
BUYERAGE	0.2011 (.8873)	0.5600 (.9734)	- 0.3678 (.9830)
MAL	1.6789* (.0011)	1.6840* (.0035)	1.6191* (.0039)
IND	-0.2551 (.7355)	- 0.6061 (0.5443)	- 0.5436 (.5159)
JOINT	0.8000 ** (.0657)	0.8097** (.0753)	0.7411** (.0950)
HHOLD	-0.5787 (.6520)	- 0.2147 (.1811)	- 0.1909 (.2165)
INCLEV	0.2333 (.5709)	0.9698 (.8464)	0.6062 (.9028)
Property Specific Variables			
PDATE	-2.6265 * (.0000)	- 3.077* (.0000)	- 6.316* (.0000)
PREMIUM	1.2263 (.3663)	1.5991 (.3043)	1.6022 (.2970)
BLDGAGE	0.8441** (.0793)	0.1365** (.0599)	0.1384* (.0455)
FLOOR	NA	- 0.1358 (.6868)	- 0.2121 (.5261)
R3	0.4823 (.9305)	- 0.1335 (.8546)	- 0.1811 (.7952)
R4	-0.6195 (.2640)	- 0.5014 (.4707)	- 0.5488 (.4142)
MUPB4SAL	NA	- 0.2802 (.5147)	- 0.3085 (0.4647)
Mortgage specific variables			
LV	1.2904 (.1316)	1.5873 (.1383)	1.6596 (.1087)

INTDIFF	NA	NA	- 0.2705 (0.7611)
SHDBINT	NA	2.295* (.0386)	NA
PAYINC	0.7038 * (.0046)	0.1699 (0.6238)	0.2075 (.5387)
SMORTVOL	-27.3566* (.0000)	-38.8025* (.0000)	-36.3303* (.0000)
Macroeconomic specific variables			
CSES	2.8011* (.0031)	3.1348* (.0053)	2.7925* (.0151)
CGDP	-18.8748* (.0000)	-27.823* (.0000)	-27.8606* (.0000)
CRPI	NA	5.8705* (.0005)	6.6037* (.0003)
CHDBPR	NA	- 2.4190* (.0015)	- 2.6393* (.0005)
HDBVOL	NA	- 0.2808* (.0152)	-0.1062 (.2656)
TUI	0.2350 (.0005)	NA	NA
RELPI	NA	- 7.9365* (.0005)	-8.1827* (.0002)
Log likelihood	-46.74350*	-39.77867*	-41.45977*

Predicted									
	Model A			Model B			Model C		
Actual	0	1	Total	0	1	Total	0	1	Total
0	299	2	301	299	2	301	299	2	301
1	8	285	293	9	284	293	9	284	293
Total	8	285	594	308	286	594	308	286	594

Notes*:* * Indicates significance at 5 per cent level and ** indicates 10 per cent level

The data for this study were provided from Housing Development Board (HDB) Branch Office of Singapore. A sample of 594 resale mortgages spanning a period from 1982 to 2000 is observed. 3 tests have been carried out. In Model A, The threshold upgradability index (*TUI)* is included. However, the HDB mortgage rate at the point of sale (*SHDBINT*), change in private residential price index over the years of occupation (*CRPI*), price volatility of HDB housing *(HDBVOL*) and change in HDB price *(CHDBPR*) are omitted. The buyer characteristics are the age of the buyer *(BUYERAGE)*, the dummy variables for Malay *(MAL),* Indians (*IND*) and others (*OTHERS*). Other buyer characteristics include size of household (*HHOLD)*, and the household income level (*INCLEV)*. The property related variables include dummy variables of 3-room (R3) and 4-room (R4), age of unit *(BLDGAGE)* and dummy variable for Main Upgrading Programme (*MUP*). Some of the property characteristics are omitted in Model A because they are highly insignificant. The loan characteristics are loan- to- value ratio (LV) and the payment- to- income ratio (*PAYINC*). Other variables include the date of originations (*PDATE*) and the amount paid over the valuation (*PREMIUM)*. The macroeconomic factors include the change in SES index (*CSES*), change in GDP (*CGDP*). In model B and C, the *TUI* is replaced by the omitted variables. In model B, the change in HDB mortgage rate is used (*SHDBINT*) and the difference between private mortgage rate and public mortgage rate (*INTDIFF)* is used in model C. Actual capital gains (*CAPGAINS*) is included in models B and C to test the appropriateness of *CHDBPR* as a proxy of capital gains ,and is the difference between the selling and the purchase price and divided by the latter. The relative price of private property to the price of HDB flats is represented by (*RELPI*). The Log likelihood ratio test shows that at least one variable is significant in all 3 models at 5% level of significance. The restricted log-likelihood is -411.6756.

Source: Author's computation

Exhibit 5.16: Test for loss aversion effects

Dependent Variable: Log(Duration of Stay)

Variable	Coefficient	Significance
Constant	4.442**	0.0000
R3	- 0.9072*	0.0998
R4	- 0.2468	0.9630
BUYERAGE	0.1728	0.2623
MAL	- 0.1194**	0.0031
JOINT	- 0.2263**	0.0000
HHOLD	0.5365	0.6700
PREMIUM	0.1504	0.4045
BLDGAGE	0.1167**	0.0001
INCLEV	- 0.6862*	0.0505
CSES	- 0.3145**	0.0000
CGDP	1.3890**	0.0000
SHDBINT	- 0.2366**	0.0000
LTV	0.1189**	0.0078
$LTV \times LOSS \times D_{loss}$	4.6642**	0.0001
$LOSS \times D_{loss}$	3.7417**	0.0000
$LTV \times Gains \times D_{Gainss}$	- 0.4683*	0.0583
$Gains \times D_{Gains}$	- 0.7243**	0.0252
Lambda 0.00929 P 4.33661 Log Likelihood –133.4559		

** Indicates significance at 5 per cent level and * indicates 10 per cent level

Notes: *LTV*, loan-to-value ratio, can take values of 1 and 0, and helps to identify the effect of initial *LTV* on mobility independent of equity constraints. $LTV \times LOSS \times D_{loss}$ allows us to identify the effect of equity constraints and $LOSS \times D_{loss}$ let us test whether loss aversion does affect mobility of households. $Gains \times D_{Gains}$ let us test the effect of nominal gains, without equity constraints, on mobility and $LTV \times Gains \times D_{Gainss}$ allows us to test the differential effect of high LTV and nominal gains on mobility.

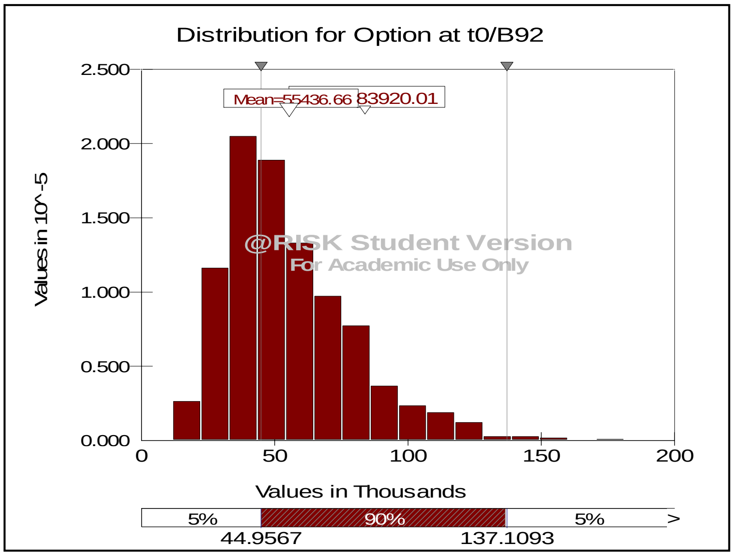
Source: Author's computation

Exhibit 6.1: Base Case Values

Variable	Base Case Value
Initial price of current dwelling	$300,000
Initial price of desired dwelling	$500,000
Loan to value ratio	0.8
Loan term, *N*	15
N	5
Length of each time step	1
Initial mortgage rate	5.5%
Initial risk free rate	2.5%
Reversion parameter	0.3312
Equilibrium interest rate	5.1682% p.a
Interest rate volatility	2.2257% pa
Rental Yield for desired housing	6%
Rental yield for current dwelling	3%
Housing return volatility for desired housing (std dev)	6.09%
Housing return volatility for current dwelling (std dev)	6.49%
Correlation between desired housing and current dwelling	0.89

Source: Author's computation

Exhibit 6.2: Simulation of Option



Source: Author's computation

Exhibit 6.3: Parametric Model: Test of Volatility

Dependent Variable: Log Duration

	Test A Excluding CHDBPR and SPRICEVO			*Test B* Excluding CRPI and HDBVOL		
Variable	Coefficient	t statistic	p-value	Coefficient	t-stat	p-value
CONSTANT	2.7992	13.392	.0000	2.8413	15.392	.0000
MAL	-.1427**	-2.195	.0282	-.1045*	-1.773	.0609
IND	-.8713	-1.272	.2033	-.8114	-.177	.8596
R3	-.1333*	-1.786	.0740	-.1178*	-1.843	.0609
R4	-.1905	-0.026	.9792	-.1045	-.177	.8596
JOINT	-.3608**	-7.720	.0000	-.3406**	-7.567	.0000
BUYERAGE	-.4361	-0.228	.8193	.1890	.101	.9198
HHOLD	-.6856	-.396	.6921	-.1408	-.888	.3747
INCLEV	-.1131**	-2.643	.0082	-.6888**	-2.115	.0345
LV	-.5007	-.424	.6714	-.1751	-1.628	.1036
PREMIUM	-.1110	-.628	.5300	-.2621	-1.598	.1101
SHDBINT	-.5597**	-1.975	0.0483	.2474	1.261	.2072
BLDGAGE	.2128**	4.726	.0000	.1600**	3.353	.0008
SMORTVOL	1.729**	12.707	.0000	1.1851**	12.166	.0000
HDBVOL	.7612**	4.318	.0000	-	-	-
SPRICEVO	-	-	.-	.1381**	7.611	.0000
CSES	-.1232	-1.613	.1067	-.8426	-1.351	.1766
CGDP	1.2389**	9.605	.0000	1.196	11.103	.0000
CHDBPR	-	-	-	-.9153**	-2.308	.0210
PAYINC	-.6005**	-1.641	.1007	-.3060	-1.020	.3077
CRPI	-.5853	-1.004	.3125	-	-	-
Lambda	.009040*			.00914*		
P	3.670813*			.87675*		
Log likelihood	-195.1843			-167.5428		

Notes: * *Indicates significance at 5 per cent level and * indicates significance at 10 per cent level

The data for this study were provided from a Housing Development Board (HDB) Branch Office of Singapore. From a total of 37,000 units in a constituency, a sample of 594 resale mortgages spanning a period from 1982 to 2000 is observed. The buyer characteristics are the age of the buyer *(BUYERAGE)*, the dummy variables for Malay *(MAL),* Indians (*IND*). Other buyer characteristics include size of household (*HHOLD)*, and the household income level (*INCLEV)*. The household income level is computed by normalizing the reported household income with the overall household income adjusted to 1990 prices. The property related variables include dummy variables of 3-room (R3) and 4-room (R4), age of unit *(BLDGAGE)*. The loan characteristics are loan- to- value ratio (LV) and the payment- to- income ratio (*PAYINC*). Other variables include the date of originations (*PDATE*) and the amount paid over the valuation (*PREMIUM)*. The macroeconomic factors include the change in SES index (*CSES*), change in GDP (*CGDP*), change in HDB mortgage rate (*CHDBMR*), change in HDB index (*CHDBPR*), the HDB public rate at point of sale (*SHDBINT*), the change in private residential price index (*CRPI*), the private mortgage volatility rate at point of sale (*SPMORTVOL*). Most importantly *HDBVOL* and *SPRICEVO* are defined as the price volatilities o f public and private housing. The *HDBVOL* and *SPRICEVO* are individually tested because the correlation between both variables is relatively high, at 0.61. In addition, the change in private price index and residential price index over the occupation period are not tested together with the relevant price volatilities because it may cause compounding errors.

The hazard rate is

$$h(t) = \lambda p(\lambda t)^{p-1}$$

where

$$\lambda(t) = \exp(-\beta' x_i).$$

Source: Author’s computation

Exhibit 6.4: Test on Option

Time-Varying Parametric Test
Dependent Variable: Log Duration

	TEST 1 (Includes all observations)		TEST 2 (Excludes observations where purchases are made before 1990)		TEST 3 (Excludes observations where purchases are made before 1990 and includes the *AMUP*OPTION* variable)		TEST 4 (Excludes observations where purchases are made before 1990 and includes the *MUP*OPTION* variable)	
	Coefficient	P	Coefficient	P	Coefficient	P	Coefficient	P
Constant	175.6789	0.0000	159.3337	0.0000	163.8686	.0000	157.1218	0.0000
R3	-0.1654*	0.0985	-0.2370*	0.0544	-0.2218*	.0623	-0.2043*	0.0918
R4	-0.1378	0.8740	-0.9675	0.3745	-0.9913	0.3519	-0.9766	0.3698
BUYERAGE	-0.9170**	0.0003	-0.799388**	0.0144	0.7530**	0.0198	0.8228	0.1270
MAL	-0.4064**	0.0000	-0.5016**	0.0000	-0.4810**	0.0000	-0.5335**	0.0000
JOINT	-0.3275**	0.0000	-0.4665**	0.0000	-0.4511**	0.0000	-0.4720**	0.0000
HHOLD	-0.8432**	0.0003	-0.1086**	0.0005	0.1059**	0.0006	0.1084**	0.0006
BLDGAGE	0.1216	0.8760	0.4760	0.5502	0.1017	0.1707	0.3588	0.6543
INCLEV	-0.1482**	0.0085	-0.1264**	0.0341	-0.1105*	0.0526	-0.1237	0.306
CSES	-0.4618	0.2471	-0.3382	0.9406	0.9777	0.9825	0.4572	0.9921
CGDP	-10.3875**	0.0042	-9.9712**	0.0162	-9.9898**	0.0145	-11.0900**	0.0074
MUP	0.2425**	0.0015	0.1269*	0.0998	0.1864**	0.0119	-	-
AMUP	0.2663**	0.0001	0.1966*	0.0950	-	-	0.1233	0.1124
OPTION	0.3983	0.1022	0.4003*	0.0560	-	-	-	-
INITIAL YEAR	-0.8718**	0.0000	-0.7898**	0.0000	-0.8128**	0.0000	-0.7784**	0.0000
*AMUP*OPTION*	-	-	-	-	0.1587	0.4487	-	-
*MUP*OPTION*	-	-	-	-	-	-	0.2726**	0.0117
LAMBDA	0.10723		0.13555		0.13628		0.13556	
P	2.33229		2.79316		2.8168		2.7740	
Log Likelihood	-918.1023		-449.0650		-451.6100		-450.2036	

Notes: *R3* takes the value of 1 if the household currently lives in a 3-room flat, else 0. *R4* takes the value of 1 if the household currently lives in a 4-room flat, else 0. *BUYERAGE* represent the buyer's age. *MAL* takes the value 1 if the household is Malay. *JOINT* takes the value 1 if the dwelling is jointly owned. *HHOLD* records the values of the number of members in the household. *BLDGAGE* refers to the age of the HDB dwelling, *INCLEV* refers to the income level of the household as compared to the average household in Singapore at the subject time, *CSES* and *CGDP* refers to the change in stock exchange index and change in GDP per capita. *AMUP* takes the value 1 if the housing is eligible for MUP. *MUP* takes the value 1 if the housing is confirmed to undergo upgrading. *Option* refers to the option premium derived in (81). *INITIAL YEAR* takes the value of the year when the current dwelling is purchased. *AMUP*OPTION* is the interactive variable between *AMUP* and *OPTION*, whereas *MUP*OPTION is the interactive variable between MUP* and *OPTION*. It is noted that we omit *MUP* and *OPTION* for the last test and *AMUP* and *OPTION* for the third test, because of collinearity problems.
*-10% significance level
**- 5% significance level

Source: Author's computation

Exhibit 6.4 (a): Test on interaction between the influence of option and loss aversion/ Equity influences

Dependent Variable :Log Duration
Test: Time Varying Parametric (Weibull) Duration Model

	Coefficient	P
Constant	321.13	.0000
R3	-0.4721	.1483
R4	-0.2982	.6447
BUYERAGE	-0.1443*	.0819
MAL	-0.5055*	.0992
JOINT	-0.1251**	.0390
HHOLD	-0.3892**	.0483
BLDGAGE	0.7964	.1360
INCLEV	-0.3305*	.0640
CSES	-0.5988	.1099
CGDP	-18.8276**	.0000
MUP	0.1289**	.0191
AMUP	0.2712*	.0551
INITIAL YEAR	-0.1599**	.0191
*POPT*LOSS*CHDBPR*	9.9509**	.0000
*POPT*GAIN*CHDBPR*	-5.3055	.8002
*POPT*NTUI*CHDBPR*	0.3497**	.0000
*POPT*PTUI*CTUI*	-0.1653	.1350
*ZOPT*NTUI*CTUI*	-0.1300	.4430
*ZOPT*PTUI*CTUI*	-0.2608**	.0135
*ZOPT*LOSS*CHDBPR*	4.9589	.3214
*ZOPT*GAIN*CHDBPR*	-4.9965**	.0000
LAMBDA	0.1130	
P	5.02028	
Log Likelihood	-290.3845	

Notes:
5% level of significance: **
10% level of significance:*
LOSS is a dummy variable and takes the value 1 if *CHDBPR* is less than 0, and *GAIN* is a dummy variable and takes the value 1 if CHDBPR is more than 1. *POPT* is a dummy variable and takes the value 1 if the option premium to wait is more than zero. *ZOPT* is a dummy variable and takes the value 1 if the option premium to wait is zero. *NTUI* is a dummy variable and takes the value 1 if the relative TUI over the length of stay drops. *PTUI* is a dummy variable and takes the value 1 if the relative TUI over the length of stay rises. *CTUI* captures the relative change in TUI over the length of stay.

Source: Author's computation

Exhibit 7.1 :Reasons Against MUP (420 respondents voted against MUP)

Reason	Frequency	Percentage
High Costs	209	49.7%
Moving in the future	24	5.7%
Does not substantially increase dwelling's value	109	26%
Have renovated the apartment recently	103	24.5%
Very Inconvenient	179	42.6%
Happy with the current conditions	85	20.0%
Bad Design	26	6.2%
Unemployed	5	1.2%
Takes a long time to finish development	14	3.3%

Source: Author's survey

Exhibit 7.2 :Reasons for MUP (452 respondents voted for MUP)

Reason	Frequency	Percentage
Increase value of dwelling	100	22.2%
Neighborhood requires major facelift	261	57.7%
It is a cheaper alternative than moving	51	11.28%
Attachment to neighborhood	136	30%
Improved amenities	119	26.3%
Good value for money	7	1.55%
Following Government direction	8	1.76%

Source: Author's survey

Exhibit 7.3: Variables

Variable	Definition
11_20	Takes value 1if the owner is willing to pay/receive 11-20% of costs to overturn any unfavorable outcome
20_30	Takes value1 if the owner is willing to pay/receive 21-30% of costs to overturn any unfavorable outcome
>_30	Takes value 1 if the owner is willing to pay/receive >30% of costs to overturn any unfavorable outcome

AGE	Age of Owner
AREA	Takes value 1 if at owner lives in Pandan Garden
HHOLD	Household size
TIER	Takes value 1 if the owner received tertiary education
INTERMEDIATE	Takes value 1 if the owner received intermediate education
MALAY	Takes value 1 if the owner is Malay
INDIAN	Takes value 1 if the owner is INDIAN
PDATE	Date of purchase of flat
TYPE	Type of flat
RETURN	Nominal Return
SELFEMPL	Take value of 1 if the owner is Self-employed
UNEMPL	Take value of 1 if the owner is Unemployed
PROFF	Take value of 1 if the owner is Profession
GSKILL	Take value of 1 if the owner is General-skilled workers
HHOLDINC	Household Income
MARRIED	Take value of 1 if the owner is married
R4	Take value 1 if owner lives in 4 room
R5	Take value 1 if owner lives in 5 room

Exhibit 7.4: Descriptive Statistics of Households interviewed

Variable	Mean	Std Deviation	Minimum	Maximum
11_20	0.57	0.23	0	1
20_30	0.27	0.16	0	1
>_30	0.53	0.22	0	1
AGE	48.38	10.762	22	87
HHOLD	3.82	1.234	1	8
TIER	0.1	0.301	0	1
INTERMEDIATE	0.633	0.482	0	1
MALAY	0.163	0.3704	0	1
INDIAN	0.090	0.28	0	1
PDATE	1989	8.8827	1968	2004
RETURN	1.1134	1.008	-0.202	2.05
SELFEMPL	0.1502	0.3759	0	1
UNEMPL	0.2465	0.4312	0	1
PROFF	0.2947	0.4561	0	1
GSKILL	0.3084	0.4621	0	1
HHOLDINC	2858	1755	0	8000
MARRIED	0.899	0.3759	0	1
R4	0.27	0.4439	0	1
R5	0.44	0.4971	0	1

Source: Author's survey

Exhibit 7.5: Test for Disutility and voting decisions

Probit model: Dependent Variable: For MUP

Variable	Test 1 Exclude household income and status of employment	Test 2 Exclude education level and income level	Test 3 Exclude education level and employment status	Test 4 Substitute Household with Marriage	Test 5 Include disutility factors	Test 6 Include disutility factors interacting with income level
Constant	1.800	4.607	1.2673	3.2953	7.3917	6.3882
R4	-0.2182	-0.2435	-0.2489	-0.1518	-0.2421	-0.2782*
R5	-0.4399**	-0.4583**	-0.4738**	-0.3341*	-0.4028*	-0.4519**
AGE	-0.1256**	-0.7991	-0.1039*	-0.1311**	-0.1320**	-0.1236**
AREA	-0.8476**	-0.8292**	-0.7994**	-0.8768**	-0.9818**	-0.9667**
HHOLD	0.9761**	0.1002**	0.9643**	-	0.8787**	0.8467**
TIER	-0.4303**	-	-	-0.4756**	0.5250**	-0.4844**
INTERMEDIATE	0.8092	-	-	0.6137	0.9034	0.9700
MALAY	0.2490	0.7729	0.8293	0.9053	0.5691	0.4248
INDIAN	0.6253	0.8407	0.8817	0.1091	0.1393	0.1160
PDATE	-0.4399	-0.1956	-0.2394	-0.1028	-0.3129	-0.2632
RETURN	0.1994	0.4153	0.4866	0.1994	0.13633	0.1838
SELFEMPL	-	-0.6016	-	-	-	-
UNEMPL	-	-0.1613	-	-	-	-
PROFF	-	0.2180	-	-	-	-
HHOLDINC	-	-	0.4937	-	-	-
MARRIED	-	0.7138	-	0.1045	-	-
11_20	-	-	-	-	0.703**	-
21_30	-	-	-	-	-0.393	-
>_30	-	-	-	-	-1.140**	-

11_20(HI)	-	-	-	-	-	0.3803
21_30(HI)	-	-	-	-	-	0.7119**
>_30(HI)	-	-	-	-	-	-0.8189**
11_20(LOW)	-	-	-	-	-	1.1186**
21_30(LOW)	-	-	-	-	-	-0.3805
>_30(LOW)	-	-	-	-	-	-1.4625**
Log-likelihood	-519.3743	-523.2853	-523.6696	-521.9574	-106.9307	-490.4979

*-10% sig level** 5 significance level

Notes: We add one additional test to observe whether owners who are married would vote for the project. The result shows that whether households are married or not does not influence the households' decision to vote. 11_20(HI), 21_30(HI), >30(HI) represents the disutility or amount an owner would receive or pay to overrule the decision. 11_20(LOW), 21_30(LOW), >30(LOW) represents the disutility or amount a rich owner would receive or pay to overrule the decision. TYPE represents the type of housing.

Source: Author's survey

Exhibit 7.6: Parametric Duration Test

Dependent Variable: Log (Duration of Stay)

	TEST1 (To test whether the probability to vote for MUP changes and affect decision to vote)		TEST2 (To test whether CHDBPR when AMUP=1 is significant when TUI is also included)		TEST3 (Include probability variables and Affordability and property gain variables)		TEST 4 (Exclude observations with owners more than 50 years old)		Test 5 (Exclude observations with owners living in 4 and 5 room flats	
	Coefficient	P	Coefficient	P	Coefficient	P	Coefficient	P	Coefficient	P
Constant	4.6066**	.0000	3.1101**	.0000	5.3050**	.0000	4.073**	.0000	5.3050**	.0000
R3	-	-	0.8074	.4687	-	-	-	-		
R4	-	-	-0.8267	.9355	-	-	-	-		
BUYERAGE	-	-	0.1115**	.0003	-	-	-	-		
MAL	-0.4504**	.0000	-0.4375**	.0000	-0.6382**	.0000	-0.4914**	.0000	-0.6382**	.0000
IND	-0.4362**	.0007	-0.4354**	.0006	-0.9027**	.0000	-0.4381**	.0038	-0.9027**	.0000
JOINT	-0.4544**	.0000	-0.4019**	.0001	-0.3354**	.0119	-0.3816**	.0012	-0.3354**	.0119
HHOLD	-0.1290**	.0000	0.1159**	.0000	-	-	-	-		
BLDGAGE	-0.1198	.1198	-0.7468	.3901	-0.4321**	.0021	-0.1307**	.1513	-0.4321**	.0021
INCLEV	-	-	-0.2328**	.0009	-	-	-	-		
SHDBINT	4.0979*	.6614	-13.1117*	.0697	-18.1762*	.0928	-13.7662	.1117	-18.1762	.0928
CSES	-0.2208	.6453	-0.6242	.1924	-0.5861	.4454	-0.8471	.1357	-0.5861	.4454
CGDP	10.1717	.1082	-1.8758	.7142	-9.4624	.2802	-6.3894	.2792	-9.4624	.2802
*AMUP*TUI*	-	-	-5.7018**	.0330	-5.2132*	.0834	-5.4368	.0739	-5.2133	.0834
*AMUP*CHDBPR*	-	-	-252.15**	.0012	-302.54**	.0013	-382.8857	.0001	-302.5440	.0013
TUI	-0.1788**	.0005	-	-	-	-	-	-		
AMUPPROB	0.3541	.1394	-	-	0.5416*	.0789	0.5482	.0532	0.5416	.0789
MUPPROB	0.1383**	.0277	-	-	0.3894*	.0858	0.4070	.0011	0.3894	.0852
HDBVOL	-3.4438**	.0002	-4.8316**	.0000	-4.2674**	.0009	-4.7000	.0000	-4.3674	.0009
LV	-1.0351**	.0000	-0.7570**	.0000	-1.042**	.0000	-0.7570	.0000	-1.0429	.0000
LAMBDA	0.08074		0.08962		0.08791		0.08981		0.08791	
P	1.96659		1.94104		1.73292		1.76249		1.73292	
Log Likelihood	-941.2537		-937.7676		-472.3609		-818.4321		-472.3609	

*: 10% level of significance **: 5% level of significance

Notes: *AMUP*CHDBPR* refers to the change in housing price during the period where *MUP* is likely to be announced. *AMUP*TUI* refers to the upgradability index during the subject period. *AMUPPROB* is the probability that household will vote for MUP after the 18 year benchmark but before the announcement. The probability is computed by substituting the significant parameters derived in Exhibit 23 and values of this sample. *MUPPROB* is the probability that households will vote for *MUP* when it is announced. As shown in the second test, the relationship of the probability to vote actually becomes significant at the point of MUP. This implies that most of the households who were against the upgrading has left by the time MUP has be announced. It is likely that households, who oppose the program, learn of the strategy of moving, and the probability of winning. The new knowledge gained over time convince them to leave.

Source: Author’s computation

Appendices

1.1 Option to default and move

We omitted the households' right to default because of the institutional setup in Singapore- the government tolerance for delinquent payments. Assuming a different setup, we surmise that the households' decision to default is unlikely to affect our model, if most mortgages undertaken are adjustable rate mortgages. Similar to the households' flexibility to move, households also have the option to default their mortgage. The finance literature view mortgage default as a put option; borrowers have the right to demand that lenders purchase their properties in exchange for the elimination of their non-recourse mortgage. The key idea of these option based models is that the likelihood of default increases as the market value of equity declines. This happens when property values declines or mortgage value increases (Kau *et al*, 1995). Thus, the movements of local property prices, interest rates, along with the related vitalities, are the main variables explaining default.

Nevertheless, the competing risks models (Deng, 1997; Hilliard, Kau and Slawson, 1998), which postulate that prepayment and default are competing risks. Since the mortgage rates are adjusted frequently, the motivation to refinance to take advantage of the lower market rates is weak, and the decision to prepay is synonymous to the households' decision to move. Furthermore, given that capital gains are critical to the constrained households to move up, we expect the movements of housing returns to play an important role in the households' decision to move. In this case, the risk to default may not be 'competing' with the risk to prepay or move, assuming that the borrowers can afford the income payments.

Assuming that mortgage payments are affordable, a borrower will default its mortgage, the capitalized value of its interest and principal repayments must be more than the value of property and the transaction costs, i.e.

$$V_{Def} = \left(L/VP_0 MC_{i_k,n} \sum_{j=0}^{n} \frac{\prod_{k=1}^{j} P_0 MC_{i_k,n-k} PVAF_{i_k,n-k}}{(1+r_j)^j} \right) - \left(P_j + C_j\right), \qquad (1)$$

where

V_{Def} is the value of defaulting the mortgage,

L/V is the loan to value ratio,

$MC_{i_k,n}$ is the mortgage constant with interest *i*, and term *n*,

$PVAF_{i_k,n-k}$ is the present value annuity factor at interest i_k, and term *n-k*,

r_j is the discount rate at time *j*,

P_j is the price at time *j*,

C_j is the transaction cost involved in default at time *j*,

P_0 is the purchase price of the current dwelling.

As shown in (1), the higher the mortgage rate, the less the principal payments, and the slower the erosion of the mortgage loan.[14] This implies that default risk is more likely if mortgage rates are high, because much of the loan has yet to be amortised. Alternatively, a higher house price is likely to discourage households from defaulting their homes. Borrowing the real option concept, we expect the households to delay the option to default if the mortgage volatility and the housing price volatility to be high.

The empirical findings on households' decision to default have been mixed. On the one hand, Clauretie (1987), Zorn and Lea (1989), Canner et. al. (1991), Gabriel and Rosenthal (1991) and Kau et. al. (1994) found that house price volatility to be negatively and significantly related to the foreclosure rate. On the other hand, Schwartz and Torus (1993) found otherwise and Vanderhoff (1989) found the variable not significant in explaining foreclosure. Yet, besides the study by Zorn and Lea (1989), the rest centered their analysis on fixed rate mortgages. The payment to income effect may reduce the importance of house price volatility. Hence, following Zorn and Lea (1989), we believe that the higher the house price volatility, the less likely the borrowers will default their mortgage. Using the real option framework, higher price volatility will induce households to defer their decision to default because there is a high chance that the price will increase in the next period. Our model on option to move will not be affected with the added option to default.

[14] If we include the income effect, the impact of the decrease in amortization rate because of higher mortgage rate is likely to be insignificant.

1.2 Hedonic Regression

One of the problems we faced was the lack of price indices for different types of HDB flats. Without the price indices, we assume the price volatility for each type of public housing is the same, but this may not be true. In addition we cannot determine whether the price of each type of housing perfectly correlated. In order to overcome the problem, we create the price indices for the three types of housing, 3 room, 4 room and 5 room flats by using hedonic regression. Our sample consists of 14, 399 HDB transactions, and spanned from Jan 1997 to June 2000. Although the three year period is short for our hedonic regression, the price derived from the data helps indicate whether our assumption is reasonable and offers us the correlation among the prices for different types of HDB housing.

Hedonic equations provide one way to decompose expenditures on housing into measurable prices and quantities so that the prices for different dwellings or for identical dwellings in different places can be predicted (Green and Malpezzi, 2003). The individual characteristics of the dwelling are represented as independent variables at the right hand side of the equation, with the price on the left. The regression coefficients can be further transferred into estimates of the implicit prices of the characteristic. Following past literature, the fundamental regression equation can be denoted as follows:

$$V = f(S, N, L, C, T),$$

where

V= value,

S= structural characteristics,

N=neighborhood characteristics,

L= location within market,

C=contract conditions,

T= time value is observed.

Although there is no strong theoretical basis for choosing any specific functional form for a hedonic regression (Halvorsen and Pollakowski,1981, Rosen, 1974), most studies use the log-linear form for five reasons (Malpezzi, 2003). First, the semi-log model allows for variation in the dollar value of a particular characteristic so that price of one component depends in part on the house's other characteristics. Second, the coefficients of a semi-log model have a simple and appealing interpretation. Third the semi-log form often mitigates the common heteroskedasticity problem. Fourth, the semi-log models are computationally simple and last, it is possible to build specification flexibility into the right hand side, using dummy variables or splines.

As shown in the review by Malpezzi (2003), the following independent variables are usually included:

- Rooms, in the aggregate, and by type
- Floor area of the unit

- Structure type (single family, multi-family, number of units, number of floors,)
- Age of unit
- Structural features
- Type of cooling systems
- Structural materials and qualities of finish
- Neighborhood variables- school, socio-economic characteristics of the neighborhood,
- Distance to the central business district, sub-centres; access to shopping and other important amenities
- Characteristics of the tenant that affect prices: length of tenure, utilities
- Date of data completion.

In addition to above independent variables, we include dummy variables to capture the influence of main upgrading works. As mentioned in the Chapter 3, the upgrading is likely to increase the value of the flat, because of the subsidy.

The regression equation is further described in the following equation

$$Log(\Pr ice) = X_t^{'}\alpha + \sum \beta_{\text{period, type}} TYPE_i \times PERIOD,$$

where

$X_t^{'}$ is the vector of housing attributes,

$\alpha +$ is the vector of regression coefficients of the housing attributes,

$\beta_{\text{period, type}}$ captures the price changes over time for each type of housing,

$TYPE_i$ consists of dummy variables representing the different types of housing

and $PERIOD$ consists of dummy variables representing the period the housing is transacted.

The index is further obtained by the following

$$PI_{type,period} = e^{\beta_{type,period} - \beta_{3,98Q4}} \times 100\% ,$$

where the 3-room is the base case and 4th quarter 1998 is the base quarter.

The results of the regression are further shown in Exhibits A1 and the price indices of the different types of housing are plotted in Exhibit A2. The correlation between the prices of 3 room and 4 room is 0.58 and the correlation between that of 3 room and 5 room apartments is 0.5. The movements for the different types of housing appear to be synchronized and the volatility of the price should be similar.

Exhibit A1

Dependent Variable : Log Price

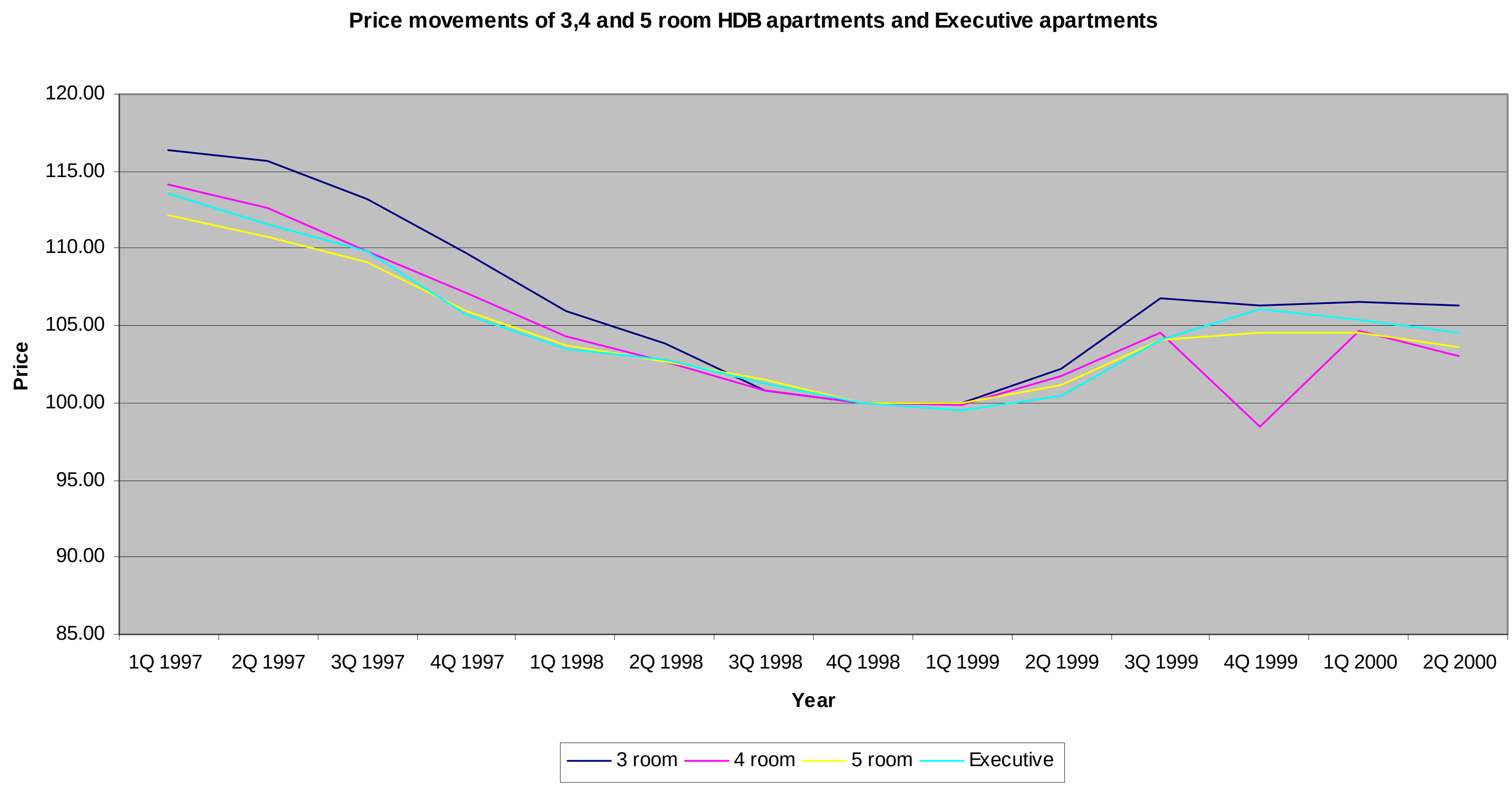
Variables	Coefficients	**Prob**
(Constant)	2.817	.000
log_age	-.066	.000
log_area	1.330	.000
poll	.008	.010
prog	-.001	.875
mup	.018	.000
amk	.014	.000
bedok	.007	.000
bishan	.078	.000
bbatok	-.049	.000
bmerah	.069	.000
bpanjang	-.084	.000
cck	-.051	.000
clementi	.017	.000
geylang	.021	.000
hougang	-.016	.000
je	-.040	.000
jw	-.089	.000
kw	.051	.000
pasir	-.015	.000
qtown	.058	.000
sbwang	-.163	.000
sengkang	-.137	.000
sr	.013	.000
tpayoh	.059	.000
wl	-.084	.000
yishun	-.051	.000
btimah	.023	.000
mp	.156	.000
ptehsg	-.002	.048
expway	-.008	.000
mrtstn	.014	.000
busint	.012	.000
primary	.001	.405
shopctr	.002	.047
industr	-.007	.000
q1_97rm12	.019	.239
q2_97rm12	.042	.002
q3_97rm12	.127	.000
q4_97rm12	-.022	.196
q1_98rm12	-.044	.001

q2_98rm12	-.021	.057
q3_98rm12	-.018	.425
q1_99rm12	-.056	.005
q2_99rm12	-.063	.005
q3_99rm12	.100	.000
q4_99rm12	.120	.000
q1_00rm12	.235	.000
q1_97r4	.132	.000
q2_97R4	.117	.000
q3_97r4	.093	.000
q4_97r4	.067	.000
q1_98r4	.041	.000
q2_98r4	.025	.000
q3_98r4	.006	.004
q1_99r4	-.003	.267
q2_99r4	.015	.000
q3_99r4	.043	.000
q4_99r4	.042	.000
q1_00r4	.045	.000
q2_00r4	.028	.000
q1_97r5	.125	.000
q2_97r5	.112	.000
q3_97r5	.101	.000
q4_97r5	.071	.000
q1_98r5	.048	.000
q2_98r5	.035	.000
q3_98r5	.026	.000
q1_99r5	.010	.001
q2_99r5	.018	.000
q3_99r5	.052	.000
q4_99r5	.054	.000
q1_00r5	.055	.000
q2_00r5	.046	.000
q1_97exe	.162	.000
q2_97exe	.138	.000
q3_97exe	.126	.000
q4_97exe	.088	.000
q1_98exe	.067	.000
q2_98exe	.059	.000
q3_98exe	.046	.000
q1_99exe	.027	.000
q2_99exe	.036	.000
q3_99exe	.070	.000
q4_99exe	.091	.000
q1_00exe	.085	.000
q2_00exe	.080	.000

q1_97rm3	.136	.000
q2_97rm3	.129	.000
q3_97rm3	.107	.000
q4_97rm3	.075	.000
q1_98rm3	.041	.000
q2_98rm3	.021	.000
q3_98rm3	-.010	.000
q1_99rm3	-.017	.000
q2_99rm3	.004	.221
q3_99rm3	.049	.000
q4_99rm3	.044	.000
q1_00rm3	.046	.000
q2_00rm3	.044	.000

R- Square: 0.944
Adjusted R-Square: 0.943
Notes: *log_age* represents the age of the dwelling in its log function and *log_area* represents the floor area of the dwelling in its log function. *poll* is a dummy variable and takes the value one if the dwelling is undergoing polling for MUP. *prog* is a dummy variable and takes the value one if the dwelling is undergoing through the improvement process. *mup* takes the value 1 if the dwelling has undergone MUP. We also include 24 dummy variables representing the town which the dwelling is located in. The 24 towns are Ang Mo Kio (*amk*), Bedok(*bedok*), Bishan (*bishan*), Bukit Batok (*bbatok*), Bukit Merah (*bmerah*), Bukit Panjang (*bpanjang*), Chao Chu Kang (*cck*), Clementi (*clementi*), Geylang (*geylang*), Hougang (*hougang*), Jurong East (*je*), Jurong West (*jw*), Kallang/Whampoa (kw), Pasir Ris (pasir), Queenstown (qtown), Sembawang (sbwang), Seng Kang (*sengkang*), Serangoon (*sr*), Toa Payoh (*tp*), Woodlands (*wl*), Yishun (*yishun*), Bukit Timah (*btimah*), and Marine Parade (*mp*). *ptehsg* takes the value 1 if the dwelling is within 300 metres to a private residential estate else 0. *expway* takes the value 1 if the dwelling is within 300 metres to an expressway else 0. *mrtstn* takes the value 1 if the dwelling is within 300 metres to a MRT station else 0. *busint* takes the value 1 if the dwelling if the dwelling is within 300 metres to a bus interchange else 0. *primary* if the dwelling is within 300 metres to a primary school else 0. *shopctr* takes the value 1 if the dwelling is within 300 metres to a shopping center else 0. *industry* takes the value 1 if the dwelling is if the dwelling is within 300 metres to an industrial estate else 0. The remaining variables capture the changes in market values. *q* stands for quarter, and the following number represents the quarter the dwelling is sold. The subsequent two digits represent the year the dwelling is transacted. *rm12* stands for 1-2 room apartments, *rm3* stands for 3-room apartments, *r4* stands for 4-room apartments, *r5* stands for 5-room apartments and *exec* stands for executive apartments.

Exhibit A2


Price movements of 3,4 and 5 room HDB apartments and Executive apartments
Price
120.00
115.00
110.00
105.00
100.00
95.00
90.00
85.00
1Q 1997
2Q 1997
3Q 1997
4Q 1997
1Q 1998
2Q 1998
3Q 1998
4Q 1998
1Q 1999
2Q 1999
3Q 1999
4Q 1999
1Q 2000
2Q 2000
Year
3 room
4 room
5 room
Executive