Asymmetrical limits of arbitrage: micro evidences from the Singapore private housing market and policy implications

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Abstract

This article studies the impacts of anti-speculation policies as limits of arbitrage (LOA) on investors in the Singapore private housing market. It finds that these policies act as additional market frictions may limit arbitrage asymmetrically (less at buying side and more at selling side), and as a result act as a trap that lets the investors buy while hampers their selling. The asymmetrical LOA explains the distorted price-volume relationship as well as the decreasing cap-rate in the Singapore private housing market.

Besides, by comparing the policy impacts in countries (or regions) which adopt different anti-speculation strategies, it demonstrates that collecting sellers' stamp duty on short-term property holders creates stronger asymmetry in LOA.

It makes the following contributions. Firstly, it adds to the understanding of LOA by providing micro evidences for LOA and by revealing that additional market frictions limit arbitrage asymmetrically (less at buying side and more at selling side) which is ignored by the existing studies. Secondly, the asymmetrical LOA has important implications for governments' market interventions.

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1 Introduction

The limits of arbitrage (LOA) is theoretically well established for understanding market mis-pricing in both financial and housing markets (Fama et al., 1969[18]; Gromb & Vayanos, 2010[29]; Glaeser& Nathanson, 2014[28]; Poterba, 1984[44]; et al.). Empirically, the LOA has well explained the anomalies of the efficient market hypothesis (EMH) such as momentum, predictable returns at aggregate level, and the failure of no-arbitrage condition in both financial market (Malkiel and Fama, 1970[41]; Schwert, 2003[52]; et al.) and housing market(Meese & Wallace, 1994[43]; Glaeser, Gyourko & Saiz, 2008[27]; Ling, Naranjo and Scheick, 2014[37]; Fu & Qian, 2014[21], et al.), while few has adopted the LOA to understand market mis-pricing at disaggregate level. Thus, the LOA lacks of empirical underpinnings at micro level.

LOA is an important framework for understanding market operation, especially for understanding how governments' policies impact on market (Stiglitz, 1989[59]; Fu, Qian & Yeung, 2013[22], Deng, Liu & Wei, 2014[15], et al.). However, as a result of short of micro empirical foundation, one possible concern is that the current level of understanding about LOA, that is, additional market friction limits arbitrage by forcing the potential buyers to see more under-price before buying (taking long position) and to see more over-price before selling (taking short position), is not sufficient for serving the above mentioned purposes. For example, when government imposing transaction taxes to remove speculators to stabilize a housing market, the current understanding about LOA cannot tell whether the government should directly tax the investors by raising transaction taxes (adopted in mainland China, UK, some period in Singapore, et al) or impose transaction taxes (sellers' stamp duty) on short-term holders (adopted in mainland China, Singapore, and Hong Kong, et al). The above motivates this paper.

In the past decade, the Singapore private housing market has experienced two rounds of housing cycles (as shown in Figure 1). The first housing cycle happened between 2006 and 2008. This cycle was driven by the 2007 sub-prime crisis. The impacts of the crisis on the Singapore housing market is short lived and ended at the end of 2008. The year of 2009 witnessed a rapid economy rebound (see the nominal GDP growth rate in Figure 1) and a housing price escalation in its private housing market. The Singapore government issued 9 rounds of anti-speculation housing policies to stabilize the private housing market dynamics between the 3rd Quarter of 2009 (the vertical line in Figure 1) and 2013. Three major components of the policies are to increase sellers' stamp duty (taxing on short-term property holders), to lower loan-to-value ratio, and to raise additional buyer's stamp duty for second home buyers (see Section 3 for details).

Figure 1 illustrates the tardy effects of policies carried out after 2009, as well as a distorted relationship between housing prices and transaction volumes. Before 2009, the price indexe and the transaction volume were highly and positively correlated, which are well explained by several factors, including the loss aversion approach (Genesove & Mayer, 2001[25]), the approach of down-

payment constraints (Stein, 1995[58]), and others (Leung & Feng, 2005[36]; Clayton, Miller & Peng, 2010[13], et al). After 2009, housing price and housing transaction volume significantly drifted apart. Housing price escalations were stabilized after 2012, when 4 rounds of increasingly stronger housing policies had been carried out. Although the price still remained high, housing transaction volume declined sharply. The literature has offered few studies to explain the observed phenomena after 2009, however, we believe they are likely to be resulted from the government anti-speculation policies which target at short-term property holders (speculators), multi property investors and foreigners.

Together with the distorted price-volume relationship, the market cap-rate decreased consistently, as shown in Figure 2. Since the anti-speculation policies were carried out after 2009, the Singapore government is trapped by the policies. Housing demands are curbed by the policies while accumulate as economy is sound. Many prospect buyers are now waiting for the government to lift the curbs. Once the curbs are lifted, the housing prices are expected to shoot up; while if the curbs are not lifted, the market freezes, the government cannot gain tax revenues, the developers face severe financial problem, and buyers cannot move on.

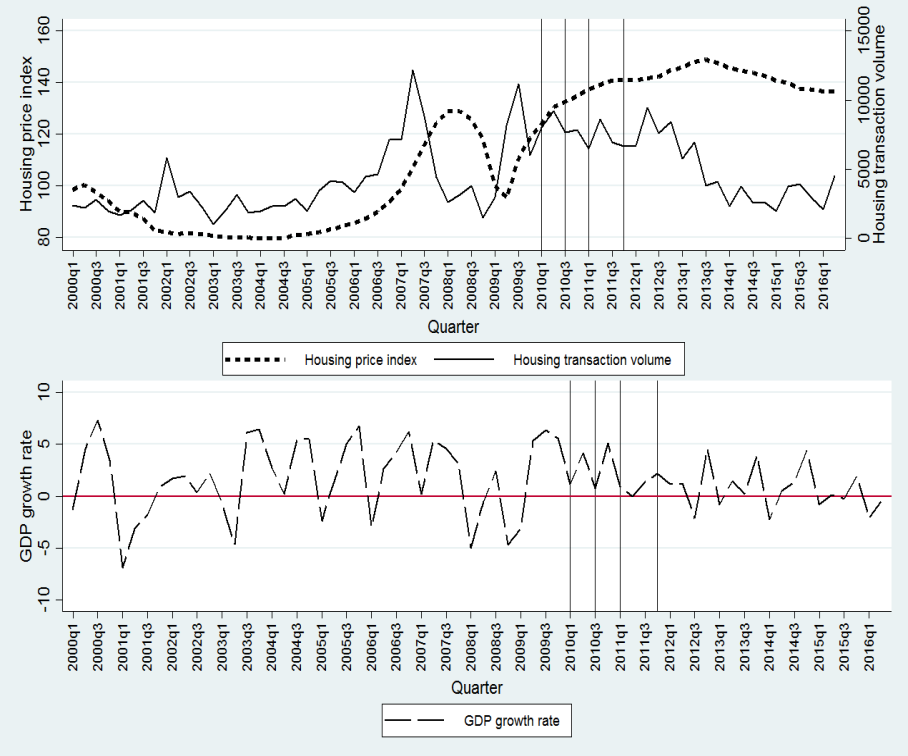

Figure 1: The divert of price index from sales transaction volume due to policies: Q1 2000-Q1 2016

Note: Price index in the Figure is the index for private non-landed residential properties, which is calculated use hedonic method and released by URA (Urban Redevelopment Board) of Singapore, Q1 2009=100. The Volume in the Figure is calculated by the authors based on REALIS database, it includes the sales transaction volume of non-landed private residential properties (Condo and Apartment) in Singapore. GDP is the nominal quarter-on-quarter growth rate, calculated with data from Singstat. This Figure with data from URA, REALIS and Singstat is consistent with the our composed dataset, which is shown in Appendix.

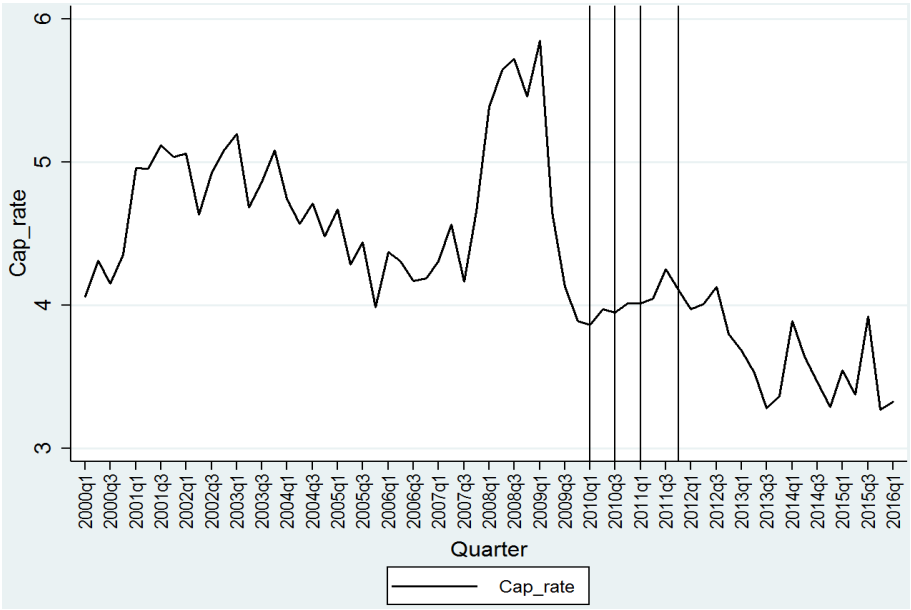

Figure 2: Market cap-rate in Singapore, in %: Q1 2000-Q1 2016

Note: The market cap-rate is calculated based on median rent rate and median price of non-landed properties released by URA (Urban Redevelopment Board) of Singapore.

We believe that the asymmetrical limits of arbitrage (LOA) results in the above phenomena in the Singapore private housing market. In this article, we firstly demonstrate that the Singapore private housing market is inefficient with arbitrage opportunities. Compared to owner occupiers, investors require and are able to realize higher cap-rates when buying and lower cap-rates when selling. Secondly, we demonstrate that the arbitrage of the investors is asymmetrically limited by the anti-speculation policies. We demonstrate that the arbitrage of the investors at the buying side is not very limited by the policies, while the arbitrage at selling side of this same group of investors is limited, they are forced to hold the properties for a longer time of period, to rent out in the space market even facing lower cap-rates. This asymmetrical LOA can be explained by human irrationality, including such as loss aversion (Tversky and Kahneman, 1991[61]; Genesove and Mayer, 2001[25], et al), heterogeneous risk attitudes (Fellner and Maciejovsky, 2007[19]), over confidence (Scheinkman and Xiong, 2003[51], et al.), and backward looking & positive feedback (De Long, et al., 1990[14], et al.).

The anti-speculation policies imposed asymmetrical LOA on investors during the upward period in the Singapore private housing market, which explains the tardy policy effects, the distorted price-volume correlation and the decreasing market cap-rate. The policies limited the arbitrage of investors at the buying side less than their arbitrage at the selling side. This explains why the housing prices kept surging even after the policies were carried out. While the buying of investors was not limited that much, the policies imposed strong selling constraint which limited the arbitrage of investors when selling and forced them to hold the rent out properties in the space market. As a result, the downward adjustment of market prices in face with negative policy information was hampered (Diamond and Verrecchia, 1987[16]) and the price was upheld at a high level, distorting the price-volume correlation. Simultaneously, as these limited investors were

forced to rent out in the space market which reduced the market rent rate and cap-rate.

Besides, we argue that the policy strategy that collecting sellers' stamp duty on short-term property holders has creates stronger asymmetry in LOA. This strategy creates a possibility that if the investor holds a property for a time long enough, he can avoid the additional stamp duty. It actually encourage risk seeking investors to keep entering into the market, under-estimating the potential cost brought by the policy; when it is time to sell, the stamp duty as selling constraint is certain (no longer acts as risk) and forces the investors to hold the properties for a longer time of period. We demonstrate the above argument by comparing the policy impacts in countries (or regions) which adopt the strategy that collecting sellers' stamp duty on short-term holders (Singapore and Hong Kong) to that in countries which simply imposing buying transaction taxes(the Great Britain).

This article makes two major contributions. Firstly, it adds to the understanding of limits of arbitrage theory (LOA) by zooming into micro scope and revealing that additional market frictions may limit arbitrage asymmetrically (less at buying side and more at selling side). Secondly, the asymmetrical LOA provides understandings on the impacts of governments' market interventions.

The remaining of the article is arranged as follows. Section 2 provides a literature review on the LOA in finance and housing literature. Section 3 introduces the institutional background of the Singapore private residential housing market and makes 2 predictions in terms of the arbitrage behaviors of housing market participants. Section 4 presents the dataset, as well as the identification of housing market participants. Section 5 provides the empirical design and Section 6 discusses the empirical results. Section 7 summarizes and discusses the empirical results and policy implications. Section 8 concludes.

2 Insufficient understandings about the LOA

The efficient market hypothesis (EMH) and the LOA are theoretically developed for understanding market prices and mis-pricing in both financial and housing markets, with the latter providing an explanation to the anomalies inherent in the EMH, such as momentum, predictable returns, and failure of housing rent-user-cost relationship in the short-term. All the existing literature related to the above anomalies are discussed at market level, while discussion at micro level is insufficient. In this regard, the LOA is short of micro foundation. As a result, one possible concern is that whether the common understandings about LOA, that is, additional market friction limits arbitrage by forcing the potential buyers to see more under-priced before buying (take long position) and to see more over-priced before selling (take short position), is sufficient. The above motivates this paper.

Arbitrage corrects market mis-pricing and drives a market towards fundamental. It plays a critical role in the efficient market hypothesis (EMH). The EMH is proposed by Fama et al. (1969)[18], Malkiel and Fama (1970)[41] and Samuelson (1965)[50], in general hypothesizing that individual investors form expectations rationally, a market can aggregate information efficiently, equilibrium prices incorporate all available information instantaneously, and any mis-pricing will be arbitraged away[1]. The EMH (Fama, 1965[17]) models arbitrage as a large number of arbitrageurs who take infinitesimal positions against market mis-pricing, drive the prices towards fundamentals. In particular, arbitrage in finance literature is defined as "the simultaneous purchase and short-sale of the same, or essentially similar, security in two different markets for advantageously different prices" (Sharpe & Alexander, 1990[53]), for example, arbitrage requires no capital preparation and realizes returns free of risk (Shleifer & Vishny, 1997[56]).

The LOA is developed to explain the anomalies inherent in the EMH, such as predictable price dynamics and price momentum[2]. Gromb & Vayanos (2010)[29] reviews the LOA literature and summarizes the factors that may reduce market efficiency and limit arbitrage behaviors. The following factors may prevent the arbitrageurs from trading the asset price towards fundamentals and from providing liquidity to outside investors after an exogenous demand shock. Firstly, lower market liquidity reduces information efficiency and raises information costs, which deters arbitrage. Secondly, non-fundamental risk reduces the correlation between the two assets (or one asset of different time periods) and deters the arbitrage, and this is especially true when the arbitrageur holds a short horizon. Thirdly, holding costs and transaction costs deter arbitrage. The above three factors impose additional costs for prospect arbitrageurs, and a prospect arbitrageur needs to see a price discrepancy large enough to cover the additional costs or risk before taking his position. As a result, the price deviation from the fundamental will be larger and the market will be more volatile. Besides, leverage constraints and constraints on equity capital lower the ability of arbitrageurs to eliminate price discrepancies. Other factors also include short-selling constraints (Diamond and Verrecchia, 1987[16]) and agency problems[3].

Both EMH and LOA are applied to a housing market. Compared to the finance definition of arbitrage which is buying the under-priced and short-selling the over-priced simultaneously to earn risk-free returns, the arbitrage in a housing market is essentially considered as constrained arbitrage because short-selling in a housing market is constrained and market participants face more additional market frictions such as higher transaction costs, higher searching costs and lower liquidity (Glaeser& Nathanson, 2014[28]). As a result, the arbitrage in a housing market needs capital preparation and does not ensure risk-free returns.

[1]The asset pricing models (such as Marsh and Merton, 1986[42], Black and Scholes, 1973[6], Lucas, 1978[38], Grossman and Shiller, 1981[30] and Shiller, 1984[54]) and the empirical tests on the implications of EMH theories (Campbell et al., 1997[8], Poterba and Summers, 1988[46], Brock, Lakonishok and LeBaron, 1992[7], Hansen and Hodrick, 1980[31], et al.) make up the two major streams of literature stemming from EMH.

[2]If the market is efficient, price and risk-adjusted return dynamics should be random as the dynamics reflects the random variation in information (Samuelson (1965)[50]).

[3]Shleifer & Vishny (1997)[56] also mentions the agency problems those large institutional arbitrageurs face, which make them avoid the "extremely volatile arbitrage positions".

In housing literature, there are a few alternative definitions for arbitrage, and we list several of them as follows. One is the arbitrage between investing in housing or in other assets. It stems from the "financial no-arbitrage condition" defined by studies such as Case & Shiller (1990) [11] and Poterba, Weil & Shiller (1991)[47]. It states that investors earn equal risk-adjusted returns by investing in housing or other assets. The second one is arbitrage between renting and owning a home proposed by Poterba (1984)[44] and Henderson & Ioannides (1983)[33], et al. It indicates that the costs of owning a home should be equal to renting a home. The third one is spatial arbitrage. The spatial no arbitrage condition requires that individuals receive similar net benefits from owning a property in different places (Alonso, 1964[1]; Rosen, 1979[49]). Also, arbitrage is described as simply buying the under-priced or selling the over-priced (Fu, Qian & Yeung, 2013[22]; Chinco & Mayer, 2014[12]). The arbitrage of developers is defined as supplying more in the over-priced period and supplying less during the under-priced period (Capozza, Hendershott, Mack & Mayer, 2002[10]).

Arbitrage between owning and renting as well as the financial no-arbitrage condition are two theories for understanding behaviors of owner-occupiers and investors in a housing market, respectively. As proposed by Poterba (1984)[44] and Poterba (1992)[45], et al. and adopted by studies like Glaeser & Gyourko (2007)[26], et al., the one-period arbitrage condition for a prospect owner-occupier is that the user cost of owning a property equals to the cost of renting a property.

$$R = P \times \omega \tag{1}$$

R is the current rent rate of a property; $P \times \omega$ is the user cost of owning the property, where P is the current price of the property and ω is the cost rate. The cost of owning a property $(P \times \omega)$ can be specified as follows.

$$P \times \omega = i \times P + \tau \times P + (m + \delta) \times P + \beta \times P - \pi \times P \tag{2}$$

i is interest rate when a prospect owner-occupier buys the property with 100 percent home loan, or is a risk-free return as the opportunity cost when a prospect owner-occupier buys the property using his own money; τ is property tax rate, m and δ are maintenance cost rate and depreciation rate of the property, respectively; β is risk premium of owning the property, π is the (expected) nominal price appreciation. By rearranging the two equations, the arbitrage condition can be specified as follows.

$$\frac{R}{P} = i + \tau + (m + \delta) + (\beta - \pi) \tag{3}$$

Equation 3 also applies to the decision of a prospect investor who arbitrages between investing in housing or an alternative asset. This is the "financial no-arbitrage condition" as proposed by

Case & Shiller (1990) [11] and Poterba, Weil & Shiller (1991)[47] (Detail discussion are provided in Appendix).

Equation 3, as a typical implication of EMH in a housing market, is empirically demonstrated to be not valid in the short term but valid in the long term. LOA is adopted to explain the failure of Equation 3. However, similar to the situation in the general LOA literature, micro foundation of LOA as an explanation to the failure of Equation 3 in a housing market is absent.

The LOA explains the failure of the EMH at housing market level. Meese & Wallace (1994)[43] finds that the long-run relation between housing price and present value stands while the short-run relationship is not due to the existence of transaction costs which limit the arbitrage. Ling, Naranjo and Scheick (2014)[37] argues that, compared to more liquid public markets, private markets have substantial information asymmetries, illiquidity, short-sale constraints and lack of continuous price revelation; the inability to short-sell in the periods of over-valuation and the limited access to credit in the periods of under-valuation deter arbitrageurs, as a result, the mis-pricing (measured as continuous market returns) induced by sentiment is prolonged in private commercial real estate market. Glaeser, Gyourko & Saiz (2008) [27] states that the very high transaction costs and more difficult short-selling in housing market make it difficult to arbitrage away the price deviation from fundamental, which raises housing bubbles. As a summary, lower market efficiency deters the arbitrage behaviors and raises housing market volatility (Barkham & Geltner, 1996[3]; Capozza, Hendershott & Mack, 2004[9]; Fu & Qian, 2014[21]).

Fu, Qian & Yeung (2013)[22] distinguishes the flippers from other housing buyers, finds that the withdrawal of stamp duty payment deferral raises price volatility by deterring informed flippers more while noisy flippers less[4]. This conclusion is implicitly based on the assumption that the informed flippers are more likely to behave as arbitrageurs who find the under-priced housing properties and stabilize the market. Similarly, Chinco & Mayer (2014)[12] studies the impacts of informed speculators and the non-informed speculators on the market mis-pricing of single family housing markets of US Metropolitan Statistical Areas[5]. Chinco & Mayer (2014)[12] finds that increase in the mis-informed speculative buyers predicts the increase in future house prices and the implied-to-actual rent ratio's appreciation rate (a higher implied-to-actual rent ratio implies a higher excess return in addition to rental income, and thus more deviation of price away from the fundamental). Both Fu, Qian & Yeung (2013)[22] and Chinco & Mayer (2014)[12] study the impacts of housing investors at individual transaction level. However, they arbitrarily take the informed investors as arbitrageurs and the non-informed as non-arbitrageurs, without specifying the buying side and selling side of arbitrage behaviors in a housing market.[6]

[4] Flippers are defined as those who sell properties before project completion. This identification is based on the institutional background of Singapore: in the pre-sale market, housing units have not been handed over to the buyers and the buyers have very low holding costs. In addition, the flippers are further specified into the informed and the non-informed.

[5] Chinco & Mayer (2014)[12] defines the second-property buyers as speculators; among which, the local ones are informed and the out-of-town ones are not informed, based on the assumption that the local have information advantage.

[6] Market microstructure theory (Spulber, 1996[57]; Garman, 1976[23]; Madhavan, 2000[40]; Biais, Glosten & Spatt, 2005[5]) is an alternative to the EMH and LOA to study individual behaviors in housing market, but to our best knowledge, Bayer, Geissler & Roberts

It is insufficient for understanding LOA by studying at market level or studying at micro level but without specifying the buying and selling side of arbitrage in a housing market. Fu, Qian & Yeung (2013)[22] only considers the buying of arbitrageurs as well as how their buying is deterred. Chinco & Mayer (2014)[12] does not specify the buying and selling of market players as arbitrage behaviors.In the LOA literature, it is common understanding that additional market friction limits arbitrage by forcing the potential buyers to see more under-priced before buying and to see more over-priced before selling. The LOA at the buying and selling sides is implicitly taken as symmetry or this issue is generally ignored (Glaeser, Gyourko & Saiz (2008) [27]; Samuelson (1965)[50]; Gromb & Vayanos (2010)[29]; et al.).

We believe that, human irrationality, including such as loss aversion (Tversky and Kahneman, 1991[61]; Genesove and Mayer, 2001[25], et al), heterogeneous risk attitudes (Fellner and Maciejovsky, 2007[19]), over confidence (Scheinkman and Xiong, 2003[51], et al.), and backward looking & positive feedback (De Long, et al., 1990[14], et al.), make LOA at buying side and selling side asymmetrical. For example, during the upward period, if investors are backward looking, risk seeking and loss averse, they may keep buying as they expect the housing prices to keep growing while under-estimate the risk and overlook the additional costs brought by governments' anti-speculation policies; while when they plan to sell their properties, the policy-induced additional costs may force them to hold the properties for a longer time of period until realizing a higher capital gain.

As a summary, although the LOA can theoretically explain the anomalies of the EMH such as momentum and predictable returns at market level in both financial and housing markets, few empirical studies have adopted the LOA theory to understand market mis-pricing from individual transaction perspective. While among the several micro-level studies on housing market, the asymmetry between the LOA at the buying side and that at the selling side is ignored.

3 How does LOA happen in a housing market at micro level?

Section 3.1 introduces the institutional background of the Singapore private housing market as well as the four studied housing policies. Section 3.2 analyzes the arbitrage conditions of the 5 types of transactions, discusses how the policies influence their arbitrage by entering into their arbitrage conditions, and proposes 2 predictions based on the arbitrage conditions in housing market as well as the LOA. Section 3.3 summarizes the predictions and explains the housing policy trap in Singapore using the 2 predictions.

(2013)[4] is the only study that adopts this theory. Bayer, Geissler & Roberts (2013)[4] distinguishes the flippers from the owner-occupiers and investors and further specifies the flippers into the middlemen (the experienced) and the speculator (the inexperienced). They find that the informed flippers are middlemen whose motivation is to fetch purchasing discount and selling premium, and the middlemen can stabilize the market. However, we will only focus on the discussion of arbitrage and LOA, as the market microstructure theory, unlike EMH and LOA, has not formed a well established framework which clearly links the relationship between market friction, efficiency, participants' behaviors and market mis-pricing.

3.1 The Singapore private housing market: housing participants and policies

The Singapore private housing market houses upper-middle class and above Singaporeans[7], permanent residents as well as some foreigners. Newly constructed properties are often launched for presales that are developer sales before a Temporary Occupation Permit (TOP) is issued. TOP is the date that a property development project is completed and home buyers can move in. New housing sales in Singapore includes presales, sub-sales which are repeated sales before a TOP and sales by a developer after a TOP (post TOP sales). Resales are defined as the properties sold by individuals after TOP. It is important to differentiate new housing sales from resales as the former does not incur any maintenance costs, insurance costs or have building depreciations. It is noted that a property development project is typically launched two to four years before its TOP. Both presale home buyers' and developers' defaults in Singapore are uncommon.

The Singapore private housing market consists of an asset market where properties are transacted and a space market where properties are rented out. Condominiums and apartments are the two dominant property types. The following figure gives an overall picture of the relationship between the 5 types of transactions in the two markets.

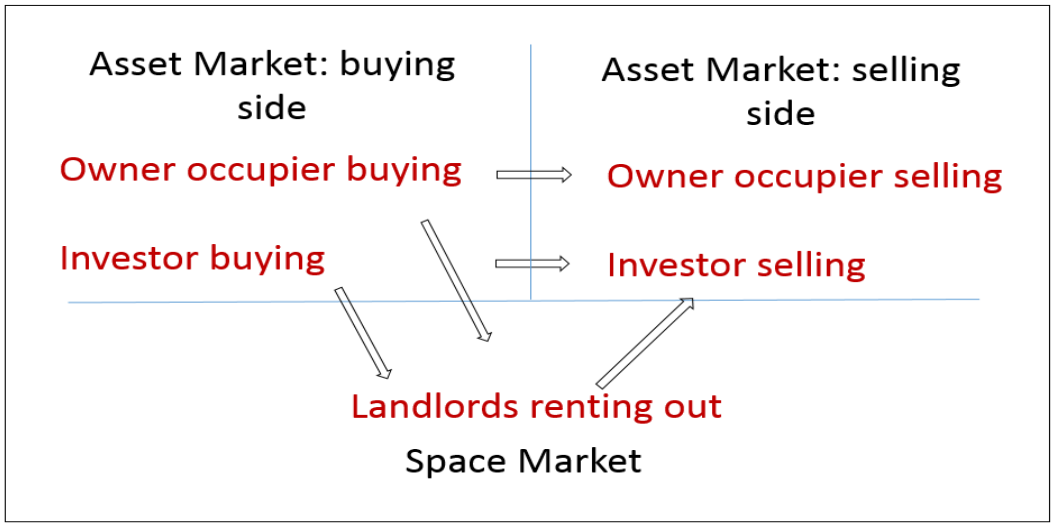

Figure 3: The 5 types of transactions in the asset and space market of Singapore private housing market

In an asset market (the asset market in this paper indicates the sales housing market where properties are transacted), there are two types of participants as buyers. One is an owner occupier (Own_Occup_B), who buys a property for living into it; the other is an investor ($Invest\_B$), who buys a property for investing (not for living).

The space market, which is the Singapore private rental housing market, is dominated by individual property owners as landlords ($Landlord$). Both Own_Occup_B and $Invest\_B$ who buy in

[7] According to Singapore Department of Statistics, in 2015, 13.9% of Singaporeans are living in private properties.

the asset market can be landlords in the space market. For an Own_Occup_B, he may rent out his property when he no longer needs to live in it, probably moving to another property. For an $Invest\_B$, he rents out the property for reducing holding costs and intend to hold the property for a longer time of period. The space market is a nearly free housing market with limited government interventions.

Similar to the buying side, in asset market, there are also two types of selling transactions, i.e., sold by owner occupiers (Own_Occup_S) or by investors ($Invest\_S$). Specifically, only these owner-occupiers who buy and sell the property without renting it out are taken as investor sellers [8]. As once an owner occupier move out and rent out the property, he actually becomes an investor and also a landlord in the space market.

The 5 types of transactions are identified in the Singapore private housing market, and the identification strategy is introduced in Section 4. According to the housing arbitrage condition as discussed by Case & Shiller (1990) [11] and Poterba, Weil & Shiller (1991)[47], et al., each of the 5 types of transactions is an arbitrage decision, which we will discuss in 3.2.

To stabilize the Singapore private housing market escalation, the government issued nine rounds of anti-speculation policies between 2009 and 2013 (see the Appendix for details). We will focus on only the 4 consecutive rounds of policies as follows because the market showed the sign of stabilization after the 4th round and also due to data limitation.

Policy Round 1: The first round of anti-speculation policy was Imposed on the 19th Feb 19th, 2010 and took effect in the following day. It implements additional stamp duty on sellers (SSD) who buy and sell residential properties within 1 year, and lowers the limit of loan-to-value ratio (LTV) of all home buyers from 90% to 80% (the taxation and LTV adjustment are listed in the following Table). This policy raises the transaction cost of short-term traders (who buy and sell within 1 year).

Table 1: LTV ratio and the taxation of sellers' stamp duty imposed in Policy Round 1

1) SSD for buying and selling a property within 1 year	
1%	for the first $180,000 of the consideration;
2%	for the next $180,000;
3%	for the balance.
2) LTV lowered from 90% to 80%;	

Policy Round 2: The second round of anti-speculation policy was imposed on the 29th August 2010 and takes effect in the following day. It further extends the SSD to

[8]Here we ignore the cases that an owner-occupier temporarily moves out the property and rents the property out. We take the above cases as that the owner-occupier converts to investors and landlords. This actually will not influence our empirical results, only makes our results more conservative.

3 years, lowers the LTV limits from 80% to 70% and raises the minimum cash down payment[9] from 5% to 10% for the buyers who have 1 or more outstanding loans. This policy further raises the cash requirement of all investors (second-home-loan takers tend to be investors) and raises the transaction costs of investors who buy and sell within 2 or 3 years. Besides, since 30th August, 2010, private property owners who buy HDB flats need to sell the owned private properties within 6 months from the date of purchasing the HDB flat (HDB flat is the public housing in Singapore, details about the policy are introduced in Table 17 in Appendix. C). The details of the Policy 2 is summarized in Table 2.

Table 2: LTV ratio and the taxation of sellers' stamp duty imposed in Policy Round 2

1) Increasing holding period for SSD from 1 year to 3 years.
1.1 for within 1 year: 1% for the first $180,000 of the consideration; 2% for the next $180,000; 3% for the balance. 1.2 for sold within 2 years: 2/3 of the full SSD; 1.3 for sold within 2-3 years: 1/3 of the full SSD;
2) LTV lowered from 80% to 70% for whom have 1 or more outstanding housing loans;
3) Minimum cash payment raised from 5% to 10% for whom have 1 or more outstanding housing loans.
4) Disallow concurrently owning an HDB flat and private residential property.

Policy Round 3: The third round of anti-speculation policy was imposed on 14th Jan 2011 and took effect in the following date. The Policy dramatically raises the rate of SSD and extends it to 4 years, lowers the LTV limit from 70% to 60% for buyers who have 1 or more outstanding loans, and lower the LTV limit to 50% for non-individual buyers. This policy substantially raises the transaction costs for investors intending to sell within 4 years, further raises the down-payment requirement for all investors and non-individual investors. The details of the policy are summarized in Table 3. Besides, Since 2011, the governments revise the owner-occupier's concessionary tax rate of 4% to be Progressive Property Tax Regime (PPTR), which raises the property tax for private properties as a whole (Refer to Appendix for details). It is important to note that, in the rest of the paper, we describe the policy strategy of SSD imposed in Policy 2 and Policy 3 as "strategy of taxing short-term holder" for short.

Policy Round 4: The fourth round of anti-speculation policy was imposed on the 7th Dec, 2011 and took effect on the 8th Dec, 2011. It charges additional buyers' stamp duty (ABSD) for the buyers who are foreigners, non-individuals, as well as second-home buyers who are Singaporeans and permanent residents. The details of the policy are summarized in the following Table. This policy symbolizes the turning point of the market, significantly stabilizing housing market escalation. The following rounds of policies simply further strengthen the effect.

[9]In Singapore, a prospect home buyer can pay the down payment with CPF and cash, where CPF is "a mandatory social security savings scheme funded by contributions from employers and employees to meet retirement, housing and health care needs". Details are provided by the Singapore government at: http://www.mom.gov.sg/employment-practices/central-provident-fund/what-is-cpf.

Table 3: LTV ratio and the taxation of sellers' stamp duty imposed in Policy Round 3

1) Increasing holding period for SSD from 3 year to 4 years.	
16%	Sold with 1 year after buying;
12%	Sold in the second year after buying;
8%	Sold in the third year after buying;
4%	Sold in the fourth year after buying.
2) LTV of 50% for housing loan to non-individual buyers;	
3) LTV lowered from 70% to 60% for whom have 1 or more outstanding housing loans;	
4) Owner occupiers' concessionary tax rate of 4% is revised to be a Progressive Property Tax Regime (PPTR).	

Table 4: The ABSD scheme imposed by Policy Round 4

1) ABSD	
10%	for foreigners and non-individuals;
3%	for Singaporeans and PRs buying second residential property;
Note: the existing BSD is:	
1\%	on first \$180,000 of purchase consideration;
2\%	on the next \$180,000;
3\%	for the remainder.

3.2 An analysis of arbitrage behaviors in the Singapore private housing market

In Section 3.2, we will firstly analyze the arbitrage condition of the 5 types of transactions and provide the Prediction 1 based on the arbitrage condition (In Section 3.2.1). Secondly, we analyze how housing policies as additional market frictions asymmetrically limit the arbitrage of investors, which is Prediction 2 (in Section 3.2.2).

3.2.1 The arbitrage condition of the 5 types of transactions and Prediction 1

Each of the 5 types of transactions, i.e., *Own_Occup_B*, *Invest_B*, *Landlord*, *Own_Occup_S* and *Invest_S*, is essentially an arbitrage decision. For a prospect owner-occupier buyer who is going to buy (*Own_Occup_B*) in asset market, his arbitrage condition is a choice between renting or buying a property, i.e., if the rent rate is higher than user cost, he will by and owner-occupy the property, vice versa. For a prospect investor who is going to buy (*Invest_B*) in the asset market, his arbitrage condition is a choice between investing in a housing market or investing in other assets, i.e., if the return in a housing market is higher than the return from other assets, he will buy the property, vice versa.

For a landlord who is going to rent out a property (*Landlord*) in the space market, his arbitrage condition before renting out the property is a choice between keep investing in the housing market (keep and renting out a property) or cashing out the property and investing in other assets. If the return from a housing market is higher than the return from other assets, he will keep and rent the property out, vice versa. Similarly, for a prospect selling by an investor (*Invest_S*) or owner occupier *Own_Occup_S*, the home owner faces an arbitrage decision between holding and renting out the property or cashing out the property. In practice in a housing market, the above

mentioned arbitrage behaviors can also be conducted through rescheduling their trading (Glaeser & Gyourko, 2007[26]).

The arbitrage decisions behind the 5 types of transactions can be explained by the same arbitrage condition as in Equation (3) which is discussed in Section 2.

$$\frac{R}{P} = i + \tau + (m + \delta) + (\beta - \pi) \tag{3}$$

In Singapore, buying properties in the asset market needs to pay buyers' stamp duty (BSD for short), which acts as transaction tax paid by the buyer. The existing BSD is close to 3% of the contract price (Refer to "the existing BSD" in Table 4). In addition, the studied four rounds of government policies (as introduced in Section 3.1) raises the transaction tax of different types of transactions. The transaction taxes actually also enter into the user cost of buyers in the asset market. Thus, we bring transaction tax c into Equation 3, which leads to Equation 4.

The transaction tax c varies across different transactions. It mainly happens for the buying or selling of owner occupiers and investors in asset market. It is also influenced by the holding period. A home owner holds the property for a longer period of time, his annualized transaction tax is lower. That is why transaction tax can to some extent deter the short-term traders (Stiglitz, 1989[59]; Fu & Qian, 2014[21]; Deng, Liu & Wei, 2014[15]) and force the owners to hold the property for a longer time of period. In addition, the anti-speculation policies in Singapore impose additional transaction taxes on sellers who sell their properties within a certain time of period after purchases,

$$\frac{R}{P} = i + \tau + (m + \delta) + (\beta - \pi) + c \tag{4}$$

Prediction 1 According to the arbitrage condition, the required cap-rate of a prospect owner occupier buying in the asset market (Own_Occup_B) will be lower than the buying of investor ($Invest\_B$); the required cap-rate of a prospect owner occupier selling in the asset market (Own_Occup_S) will be higher than the selling of investor ($Invest\_S$). They can realized their different cap-rates due to market inefficiency.

Three reasons lead to the lower required cap rate of owner occupiers buying in the asset market. Firstly, the buying of owner occupiers in asset market should be less cap-rate driven than the other three types of transactions. This is because an owner occupier buying a property not only for consuming housing services but also for many other motivations like gaining higher social status as a home owner than a renter (Arrondel & Lefebvre, 2001[2]; Yang, 2005[63]; Flavin & Yamashita,2008[20]; Flavin & Nakagawa (2008)[20]; Lustig & Van, 2005[39]; Hung and So, 2012 [34]; Tu, Zhang & Deng, 2016[60]). Secondly, the depreciation and maintenance costs ($m+\delta$) of an owner-occupied property is lower than that of the property used by tenants (Glaeser & Gyourko,

2007[26]). Thirdly, although the buying of owner occupiers in asset market faces transaction tax c, the owner occupiers tend to hold the properties for a longer time of period and thus the annualized transaction tax is very low. Thus the expected user cost of an owner occupiers is lower and he will require a lower cap-rate.

The last but the most important reason is that, housing market is a segmented market and is with a lot of market frictions (Glaeser & Gyourko, 2007[26], Genesove and Han, 2012[24]), the market inefficiency results in that different participants facing different arbitrage conditions can realize different cap-rates when they enter the market.

The same three reasons also lead to the higher cap rate of owner occupiers than investors when selling in the asset market. The selling decision of owner occupiers is also not a pure arbitrage decision, and owner occupiers are less cap rate driven. In the inefficient housing market, owner occupiers tend to realize higher cap rate (lower housing prices) when selling than investors.

3.2.2 Additional market frictions brought by anti-speculation policies limit arbitrage at buying side and selling side asymmetrically

Prediction 2 The arbitrage of investors buying in the asset market ($Invest\_B$) is not as limited as their selling in the asset market during the upward market period. Specifically, the additional market frictions may not deter the investors from buying in asset market (making them requiring a larger under-price and thus higher cap rate before buying), while they will stop the selling of investors and force them to hold properties for a longer period, until realizing higher capital gain (lower cap-rate). Another evidence of policies forcing investors to hold the properties until realizing lower cap-rate is that investors who are constraint by the policies will hold the properties for a longer time of period, and they accept lower cap-rate when renting out in the space market.

At the buying side (taking long position in the asset market)

Table 5 reveals how each round of policy impacts on the two types of buying transactions by entering their arbitrage conditions, without considering irrationality of market participants. Firstly as shown in Column (6), as a response to Policy 1, a prospect owner occupier buying in asset market (Own_Occup_B) will require "+1" higher of cap-rate ($\frac{R}{P}$), and a prospect investor who buys in asset market ($Invest\_B$) after Policy 1 will require "+3" higher of cap-rate.

Policy 1 has little impact on the transaction cost (c) of Own_Occup_B because an owner occupier typically stays in a property for more than one year. It is reflected by "Nil" in Table 5. However, Policy 1 may send a negative signal to owner occupiers that the government intends to decelerate housing price appreciation, which reduces the expected appreciation rate of the property (π). It is reflected by "+1" under the "Nega Infor" in Table 5. Policy 1 does not influence the holding

cost ($i + \tau + (m + \delta)$) faced by *Own_Occup_B*. In addition, Policy 1 lowers the LTV for all home buyers from 90% to 80%, which removes some prospect home buyers. It is reflected by "+1" for a prospect owner occupier under "Borr Constr" in Table 5. Among the factors listed in Table 5, only "User Cost" related factors, including c, $i + \tau + (m + \delta)$ and π, come into the arbitrage condition (while borrowing constraint doesn't). Thus, for a prospect owner-occupier, Policy 1 raises his user cost by "+1" and therefore the required cap-rate (the Column (5) in Table 5) of a prospect owner-occupier buying after the Policy 1 should be "+1" higher. As Policy 1 is the first studied policy, its net impact on the required cap-rate of *Own_Occup_B* is also "+1" as shown in Column (6).

For a prospect investor who buys in the asset market (*Invest_B*), Policy 1 may raise his transaction cost (c) if he decides to sell the property within 1 year after buying it, but this additional transaction cost can be avoided just by keeping the property for longer than 1 year. Thus, we assign "+2" under "Trans Cost/ Sel constr" (c) for a prospect investor. Similarly, Policy 1 may send a negative signal to that the government intends to decelerate housing price appreciation. It is reflected by "+1" under the "Nega Infor" (π). As a whole, Policy 1 raises his user cost by "+3" and therefore the required cap-rate (the Column (5) in Table 5) of a prospect investor buying after the Policy 1 should be "+3" higher.

As Policy 1 is the first policy studied in the paper, the net change in required cap-rate induced by Policy 1 (in Column (6)) is equivalent to the cumulative change in the required cap-rate (in Column (5)) for each of the 2 types of transactions.

We take Policy 3 as another example. Policy 3 has some impact on the transaction cost of a prospect owner occupier who buys in the asset market (*Own_Occup_B*). Although an owner occupier typically stays in a property for several years, he might sell the property and upgrade within 4 years which will be taxed by the aggressive SSD raised by Policy 3. It is reflected by "+3" under "Trans Cost/ Sel constr" (c) in Table 5. Policy 3 slightly raises the property tax burden (which comes into the holding cost) for owner-occupied private properties, and we assign "+1" for *Own_Occup_B* under "Hold Cost" ($i+\tau+(m+\delta)$). Policy 3 may also send a strong negative signal to owner occupiers to dampen his expected price appreciation, as this is the third and very strong signal sent by the government to cool the market down. It is reflected by "+3" under the "Nega Infor" (π) in Table 5. Besides, Policy 3 further lowers the LTV from 70% to 60% for buyers who have 1 or more outstanding housing loans, which will probably impose more borrowing constraint on owner occupiers as home up-graders. We assign "+3" under "Borr Constr" for *Own_Occup_B*. Thus, the cumulative impacts of Policy 1-3 on the user cost of a prospect owner occupier who buys after Policy 3 will be raised by "+7" (which is the sum of c, $i + \tau + (m + \delta)$ and π) and the cumulative change in the required cap-rate when buying by an owner occupier is "+7" as implied by arbitrage condition, as shown in Column (5). Compared to the cumulative impacts of Policy 1 & 2 on an owner occupier, which is "+4" as shown in Column (5) for *Own_Occup_B* after

Policy 2, the net impact of Policy 3 on a prospect owner occupier buying in asset market is "+3" ("+7" − "+4") as shown under Column (6) for *Own_Occup* after Policy 3.

As shown in Table 5, the "Trans Cost/ Sel constr" (c) is the major contributor to the changes in the required cap-rate of the four types of participants. The impacts of "Trans Cost/ Sel constr" (c) can also be understood as the partial removal of resale option, as it raises the transaction cost if resale within a relatively short time of period. Existing literature has well recognized the fact that buyers pay a premium for the resale option (Hayunga & Lung, 2011[32]; Qian, 2013[48]; et al.). Removing the resale option reduces price premium a prospect home buyer would like to pay and raises his required cap-rate. In this regard, the removal of a resale option acts the same role as adding transaction cost (as discussed above) in influencing the required cap-rate of the transactions (those Own_Occup_B and $Invest\_B$ in the asset market).

In the above discussion, we take "Trans Cost/ Sel constr" (c) as a factor of user cost, i.e., it enters the fundamental each transaction type faces. Alternatively, it can also be understood as transaction cost or (Tobin's Tax) as a factor that limits arbitrage. As the arbitrageurs facing additional transaction costs need to see larger price discrepancy from the fundamental before arbitraging to compensate the transaction cost (Gromb & Vayanos, 2010[29]; Deng, Liu & Wei, 2014[15]; et al.). This understanding of how transaction cost limits arbitrage essentially is consistent with the implication we made based on the arbitrage condition,as shown in Column (6) of Table 5, the mare targeted participants require higher cap-rate for entering the housing market.

In the Column (6) of Table 5, we reveal the net impact of each policy on the 2 types of transactions (without considering the irrationality issues) in terms of the changes in their required cap-rate ($\Delta\frac{R}{P}$). As a whole, we can see that, the policy strength increases from Policy 1 to Policy 4. In Appendix D, we summarize the impacts of each policy expected by the public reported by the Strait Times Singapore. The news reports are consistent with our discussion as shown in Table 5. Each policy targets at a prospect investor ($Invest\_B$) buying a property in the asset market more than that on a prospect owner occupier (Own_Occup_B) buying in the asset market. As implied by the arbitrage condition, for taking a long position in the housing market, a prospect investor ($Invest\_B$) should requires higher cap-rate increment as a response to each policy compared to an Own_Occup_B.

The irrationality housing market participants may lead to asymmetrical LOA as policy impacts, and this asymmetry is enlarged by the policy strategy which collecting additional sellers' stamp duty from investors who hold the property for a relatively short time of period (we use the "strategy of taxing short-term holder" for simplicity in the rest of the article), details of the policy strategy is discussed in Section 3.1.

Although when buying in the asset market (taking a long position), a prospect investor ($Invest\_B$) should requires higher cap-rate increment as a response to each policy compared to an Own_Occup_B, we believe that, human irrationality, including such as loss aversion (Tversky and Kahneman, 1991[61]; Genesove and Mayer, 2001[25], et al), heterogenous risk attitude (Fellner and Maciejovsky, 2007[19]), over confidence (Scheinkman and Xiong, 2003[51], et al.), and backward looking & positive feedback (De Long, et al., 1990[14], et al.), make the arbitrage at the buying side less limited. In other words, a prospect investor buying in asset market may not require a higher cap-rate before buying. [10]

Besides, we believe this asymmetry is enlarged by the strategy of taxing short-term holder (details of the policy strategy is discussed in Section 3.1.). This strategy creates a possibility that if the investor holds a property for a time long enough, he can avoid the additional stamp duty. It actually encourage risk seeking investors to keep entering into the market, under-estimating the potential cost brought by the policy; when it is time to sell, the stamp duty as selling constraint will force the investors to hold the properties for a longer time of period.

At the selling side in asset market and in space market (taking short position)

The anti-speculation policies not only limit arbitrage at the buying side, but also limit arbitrage at the selling side by imposing short-term selling constraints. The selling constraint imposed by each policy is summarized in Column (1) in Table 6. We take Policy 1 and Policy 3 as examples to discuss in details how the selling constraint limits arbitrage. Policy 1 does not impose selling constraint on an $Invest\_S$ who bought the property before Policy 1. So the selling constraint the Policy 1 imposes on this transaction is "Nil", i.e., $Invest\_S$ who bought before Policy 1 can relatively freely arbitrage between renting out the property or selling it. In contrast, an $Invest\_S$ who buys the property after Policy 1 has to hold the property for at least 1 year otherwise he has to pay an additional sellers' stamp duty (Refer to Table 1 for the tax rate). But this constraint is not strong as it is easy for an investor to hold the property for longer than 1 year, as a typical rental lease in Singapore is 1 year. Thus, we assign "Very Weak" for the selling constraint imposed by Policy 1 on an $Invest\_S$ who bought after the Policy.

The selling constraint imposed by Policy 3 charges a very aggressive sellers' stamp duty (SSD) for those participants who buy after Policy 3 and sell within the subsequent 4 years (Refer to Table 3 for details of the policy, strategy of taxing short-term holder). It is much stronger than that by Policy 1. For an $Invest\_S$ who bought the property after Policy 3, he is forced to keep and

[10] An alternative explanation to the above is that the Singapore private housing market might be very efficient and there is no arbitrage opportunity in the market. As a result, the different types of transactions facing with different user costs caused by the policies cannot realize different cap-rates (without considering the non-fundamental risks created by the policies). This alternative explanation does not hold. Housing market is a typical inefficient market with high transaction costs, lower liquidity and information efficiency (Glaeser & Gyourko (2007)[26]; Glaeser, Gyourko & Saiz, 2008[27]; Glaeser& Nathanson, 2014[28]; et al.), and so is the Singapore private housing market (Fu, Qian & Yeung, 2013[22]; Fu & Qian, 2014[21]; et al.). Tu, Zhang & Deng, (2016)[60] find that the three types of housing participants can realize different buying and selling prices in the Singapore private housing market due to their different trading abilities, which also indicates that the Singapore market is not efficient as the "law of one price does not hold".

Table 5: The cumulative and net impacts of each cooling measure on arbitrage behaviors of two types of buying transactions in asset market without considering irrationality

	(1)	(2)	(3)	(4)	(5)	(6)
	User Cost					
	Trans Cost/ Sel constr	**Hold Cost**	**Nega Infor**	**Borr Constr**	**Cumu Chan in Requ Cap Impl by Arbit**	**Net Chan in Requ Cap Impl by Arbit**
	c	$i+\tau+(m+\delta)$	π			$\Delta\frac{R}{P}$
Policy 1: Policy Feb 20th, 2010						
Own_Occup_B	Nil	Nil	+1	+1	+1	+1
Invest_B	+2 (Easily avoidable)	Nil	+1	+1	+3	+3
Policy 2: Policy Aug 30th, 2010						
Own_Occup_B	+2	Nil	+2	+2	+4	+3
Invest_B	+4	Nil	+2	+2	+5	+3
Policy 3: Policy Jan 2011						
Own_Occup_B	+3	+1	+3	+3	+7	+3
Invest_B	+7	Nil	+3	+3	+10	+5
Policy 4: Policy Dec 8th, 2011						
Own_Occup_B	+5	+1	+8	+3	+17	+8
Invest_B	+10	Nil	+8	+3	+21	+11

Note: This table presents only the impact of the policy in a short period after the policy; "+number" measures the magnitude of the effect, a larger number means a larger effect, i.e., larger increase in required cap-rate, and the scale is assigned just for comparison.
Specifically, "Trans" is short for "Transaction", "Constr" is short for "Constraint", "Borr" is short for "Borrowing" and "Nega Infor" is short for "Negative Information". "Cumu Chan in Requ Cap Impl by Arbitra" is the short for "The cumulative changes in required cap-rate implied by arbitrage condition".
In addition, "User cost" includes transaction cost, holding cost and the negative information which reduces expected price appreciation.

rent out the property within the next 4 years, otherwise he needs to pay a high SSD. So we assign "Strong" for his selling constraint. For an *Invest_S* who bought the property before Policy 3, his selling is constraint by Policy 2 which is "Weak" in strength.

Thus, as predicted by arbitrage condition, at the selling side in the asset market, an *Invest_S* who bought the property after a Policy has to face a lower cap-rate than an *Invest_S* who bought the property before the Policy because his arbitrage (selling) is constraint and he cannot sell his property until realizing a lower cap-rate (higher capital gain). Besides, this effect is increasingly stronger from Policy 1 to Policy 4.

The limited arbitrage at the selling side by each policy can also be reflected by the space market, as investors whose selling is constraint have to hold the properties and rent them out in the space market even facing with lower cap-rate.

How is selling constraint limiting arbitrage reflected in the space market? Taking the constraint proposed by Policy 3 as an example, a participant who is limited by the constraint have to hold the property and keep renting it out for 4 years, otherwise he needs to pay additional transaction costs. According to the arbitrage condition (Equation 4), he needs to see a cap-rate low enough (or price high enough) to compensate the additional transaction cost before selling the property. Thus, for an *Landlord* who bought the property after Policy 3, he has to accept lower cap-rate in the space market. Thus, as predicted by arbitrage condition, in the space market, a *Landlord* who bought the property after Policy 3 have to face a lower cap-rate than a *Landlord* who bought the property before Policy 3 because his arbitrage (selling) is constraint and he cannot sell his property even facing with a lower cap-rate.

Table 6: The cumulative selling constraint of each policy on investor and owner-occupiers who buy after the policy

	(1)	(2)
	Selling constraint (by Transaction Tax), c	**The Changes in Cap-rate, $\Delta\frac{R}{P}$**
Policy 1		
Invest_S buying before this policy	Nil	0
Invest_S buying after this policy	Very Weak	-1
Policy 2		
Invest_S buying before this policy	Very Weak	-1
Invest_S buying after this policy	Weak	-2
Policy 3		
Invest_S buying before this policy	Weak	-2
Invest_S buying after this policy	Strong	-6
Policy 4		
Invest_S buying before this policy	Strong	-6
Invest_S buying after this policy	Strong	-8

Note: "+number" measures the magnitude of the effect, larger number means larger effect, and the scale is assigned just for comparison.

3.3 Summary and how the 2 predictions explain housing policy trap in Singapore

We make the 2 predictions on the LOA in a housing market at micro level. Firstly, Prediction 1, according to the arbitrage condition, the required cap-rate of a prospect owner occupier buying in the asset market (Own_Occup_B) will be lower than the buying of investor ($Invest\_B$); the required cap-rate of a prospect owner occupier selling in the asset market (Own_Occup_S) will be higher than the selling of investor ($Invest\_S$). Secondly, Prediction 2, The arbitrage of investors buying in the asset market ($Invest\_B$) is not as limited as their selling in the asset market during the upward market period.

The asymmetrical limits of arbitrage during the upward housing market caused by the policies explain the tardy policy effects, the distorted price-volume correlation, and the policy trap the Singapore government faces. The policies do not stop investors' buying as much as investors' selling. This explains why the housing prices kept surging after the early policies (Policy 1 and Policy 2) were carried out. Secondly, the later very strong policies (Policy 3 and Policy 4) imposed strong selling constraint which limited the arbitrage of investors when selling and force them to hold the rent out properties in the space market. As a result, the speed of the downward adjustment of market prices in face with negative policy information was reduced (Diamond and Verrecchia, 1987[16]) and the price was upheld at a high level, distorting the price-volume correlation, and reducing the cap-rate.

4 Data and identification

We construct our working dataset based on the following data sources: StreetSine, PowerSearch, REALIS, Datastream and URA[11] and HDB[12] News Release. Datastream provides the time series data for Singapore such as the 10-year government bond yield and housing loan interest, and the URA and HDB NEWs Release provide the information about Singapore housing-related policies.

The composed dataset includes comprehensive sale and rental transaction records for the private housing market, and provides hedonic attributes such as size, floor and property age for each transacted property. There are generally 6 types of private housing properties in Singapore, condominium, apartment, EC (executive condominium), the detached, the semi-detached and terrace, while transactions of condominiums and apartments are very active due to their relatively low total price and higher liquidity, and the two account for around 90% of total private housing transactions. Thus, in our dataset, we only include the condominiums and the apartments.

[11]The Urban Development Board of Authority of Singapore, which provides mainly the private housing information: http://www.ura.gov.sg/

[12]Housing & Development Board, which is Singapore's public housing authority, mainly provides information on public housing: http://www.hdb.gov.sg/

Based on the constructed dataset, we identify the 5 types of transactions, i.e., sales transactions in the asset market where owner occupiers as buyers (Own_Occup_B) and as sellers (Own_Occup_S), investors as buyers ($Invest\_B$), as well as the space market where landlords ($Landlord$) rent out their properties. The identification follows the 3 specific principles. Firstly, an Own_Occup_B is the transaction bought by an owner occupier who lives into the property; an Own_Occup_S is the transaction sold by an owner occupier after when he moves out of the property. Secondly, an $Invest\_B$ is the transaction bought by an investor who does not live into the property, he can buy and hold the property empty and then sell the property within a short time of period, or buy and immediately rent out the property if the property construction is finished; an $Invest\_S$ is the transaction sold by an investor. Thirdly, all rental transactions in the space market are taken as transactions rented out by landlord ($Landlord$). No matter the landlord acted as an owner-occupier or investor when he bought the property, we take him as an investor after when he rents out his property. Thus, if a property has been rented out, and then sold, the seller in the sales transaction is identified as $Invest\_S$.

We use a threshold of 2 years to judge whether the buyer really moves into the property, i.e., after purchasing the property. If since the property construction is finished, the buyer keeps the property for longer than 2 years and does not rent out it during this 2-year holding period, then the buyer is an owner occupier, and the property is bought by the owner-occupier (Own_Occup_B); otherwise the property is bought by an investor ($Invest\_B$). We set this 2 year threshold based on the fact that it might take several months for a buyer to really get the property after when the contact is signed (the contract date in our dataset), and get prepared to move in; besides, before moving out, it takes him (now becomes the home owner) another several months to get prepared. Thus, the 2-year threshold should be conservative for judging whether the buyer is an owner-occupier or investor. An investor is unlikely to keep the property empty for a long time because of the holding cost (mortgage, property tax and maintenance costs). Detailed explanation to the identification strategy is provided in the Appendix E.

We take the historical transaction records of a housing unit (as shown in Table 7) as an example to show how the transactions are identified. Record No.1 is identified as the sales transaction bought by an investor $Invest\_B$. The construction of the property is finished in 2006, and buyer buys the property in Aug 2003 and sells it in Sep 2006. Which indicates that the buyer does not really moves into the property before he sells it. Thus, the buyer in the asset market is an investor. The seller of transaction No.1 is either unobserved or developer, so we cannot identify whether this transaction is sold by an investor or by an owner occupier. Thus, for No.1 under "Identi", we mark "$Invest\_B$ & N.A.".

For Record No.2, the buyer in Record No.2 rents out the property in Dec 2007 and sells it in Sep 2009. Although he holds the property for 3 years and 4 days before cashing it out, he rents out the property (as Record 3) just 1 year and 3 months after he buys the property, which indicates

that he probably does not move into the property. Thus, the record No.2 is bought by an investor ($Invest\_B$), as the buyer in record No.1 is identified to be an investor and he is also the seller in No.2, thus No.2 is identified to be sold by an investor ($Invest\_S$). Thus, for No.2 under "Identi", we mark "$Invest\_B$ & $Invest\_S$".

We take Record 3 and Record 8 as another two examples. Record 3 is the renting out by a landlord in space market, it is identified as *Landlord*. Record 8 is identified as bought by an owner-occupier in the asset market (Own_Occup_B). This is because the buyer in Record 8 buys the property in July 2010 and rents out the property more than 5 year later and the property construction has already been finished in 2006. During these 5 years the buyer is probably living in the property.

Table 7: Examples for identification

No.	Full Address	Market	Rent/Sale	TOP	Contract date	Holding Interval	Identi
1	1 ESSEX * #**-02	Asset	Sale	2006	8/29/2003	3 years 28 days	$Invest\_B\&N.A.$
2	1 ESSEX * #**-02	Asset	Sale	2006	9/25/2006	3 years 4 days	$Invest\_B\&Invest\_S$
3	1 ESSEX * #**-02	Space	Rent	2006	12/26/2007		*Landlord*
4	1 ESSEX * #**-02	Space	Rent	2006	12/16/2008		*Landlord*
5	1 ESSEX * #**-02	Asset	Sale	2006	9/28/2009	303 days	$Invest\_B\&Invest\_S$
6	1 ESSEX * #**-02	Space	Rent	2006	1/4/2010		*Landlord*
7	1 ESSEX * #**-02	Space	Rent	2006	6/18/2010		*Landlord*
8	1 ESSEX * #**-02	Asset	Sale	2006	7/28/2010	5 years 159 days+	$Own\_Occup\_B\&Invest\_S$
9	1 ESSEX * #**-02	Space	Rent	2006	1/2/2016		*Landlord*

Note: For the Full Address of the records, we have the address inform while cover it for confidentiality consideration.
Under "Identi", if the transaction record is a sales transaction (in asset market), we identify both the buyer and seller of the transaction record, represented as "Buyer & Seller"; if the record is a rental transaction in space market, then it is renting out by a *Landlord*. "N.A." means the transaction cannot be identified.

The detailed explanation to the identification strategy is provided in the Appendix. In addition, it is important to link the buying, renting and selling transactions of a property together. In the empirical design part, we will use this linkage to decide whether the selling or renting out transactions are under the constraint of a certain anti-speculation policy in Singapore, as each policy only targets at properties which are bought after the policy. Table 8 summarizes the definition of the variables.

Table 8: The definitions for all variables

Variables	Definition
$Invest\_B$	Dummy variable, 1 if the buyer of the transaction record is a rental housing investor, 0 otherwise.
Own_Occup_B	Dummy variable, 1 if the buyer of the transaction record is an owner occupier, 0 otherwise.
$Landlord$	Dummy variable, 1 if the transaction is a rental transaction, 0 otherwise.
$Invest\_S$	Dummy variable, 1 if the seller of the transaction record is an investor, 0 otherwise.
Own_Occup_S	Dummy variable, 1 if the seller of the transaction record is an owner occupier, 0 otherwise.
$Cap_{i,j,t}$	The implied cap-rate at which a property is transacted, calculated as $\frac{Rent \times 12}{Price} \times 100$ [1].
$Size$	The size of a housing unit, measured in Square foot.
$Floor$	The floor level that a housing unit is located.
$TenureD$	A dummy variable representing property tenure, with 1 indicating that it is leasehold property with maximum tenure of 99 years and 0 if it is a freehold or a tenure of 999 years.
$Propertytype\_Dummy$	A dummy variable with 1 indicating a Condo and 0 indicating an apartment.
Age	The age of a housing unit when it is transacted, measured by year (contract date minus TOP date).
$Resale$	A dummy variable with 1 indicating the transacted property is a new property, 0 otherwise.
$MonthDummy$	Dummy variables indicating the Month when the transaction happens.
$ProjectDummy$	Dummy variables indicating the property project development where the transacted property locates.

Note 1: For rental transactions, the cap-rate is calculated with the actual monthly rent rate and the implied housing price; for sales transactions, the cap-rate is calculated with the implied monthly rent rate and the actual housing transaction price.

5 Empirical design and variable selection

This section introduces the empirical design to test the predictions raised in Section 3, with Section 5.1 testing prediction 1, and Section 5.2 testing Prediction 2.

5.1 Testing Prediction 1

Prediction 1 states that the required cap-rate of a prospect owner occupier buying in the asset market (Own_Occup_B) is lower than that of the buying of an investor ($Invest\_B$); the required cap-rate of a prospect owner occupier selling in the asset market (Own_Occup_S) will be higher than the that of the selling of an investor ($Invest\_S$).

Firstly, for the buying side, we estimate Hedonic models whose depend variable is cap-rate and in which $Invest\_B$ and Own_Occup_B are measured by dummy variables and enter the models as explanatory variables, as shown by Equation 5.

$$Cap_{i,j,t} = \alpha \mathbf{D_j} + \mathbf{f X_{i,j,t}} + \varepsilon_{i,j,t} \tag{5}$$

Cap is the implied cap-rate realized by the transaction.

i indicates the i^{th} property.

j indicates the 2 types of buying transactions,i.e., bought by owner occupiers (Own_Occup_S) or bought by investors ($Invest\_B$), separately.

t indicates the different Months when a transaction happens.

α and $\mathbf{f}$ are coefficients.

ε are residuals.

$\mathbf{D_j}$ is a vector of dummy variables, including Own_Occup_B and $Invest\_B$. To avoid multicollinearity, we take Own_Occup_B as the base and include only $Invest\_B$ into the model.

$\mathbf{X_{i,j,t}}$ is a vector of hedonic variables of property i, transacted by j type of market participant at time period t.

Based on Equation 5, we estimate 2 models covering a sample period between July 2006 and Sep 2009 when anti-speculation policies have not been carried out yet. In Model 1, we include all new housing sale and resale samples; in Model 2, we only include new-housing samples, in order to remove the concern that the high implied cap-rate realized by investor buyers is because they buy properties with poor indoor maintenance (at lower price). Table 9 presents the summary statistics for the variables of studied samples for Model 1 (Panel A) and Model 2 (Panel B), respectively.

Table 9: Sample at buying side, Sample Period: July 2006-Sep 2009

Panel A: Both new housing and resale housing units							
	Oservations	**Caprate**	**Resale**	**Age**	**Floor**	**Size**	**Property Type Dummy**
Own_Occup_B	33,087	4.330	0.673	5.903	8.324	1,406.382	0.714
		(1.163)	(0.469)	(7.556)	(7.279)	(595.399)	(0.452)
Invest_B	23,026	4.418	0.401	2.753	8.762	1,291.281	0.666
		(1.215)	(0.490)	(7.378)	(7.816)	(573.603)	(0.472)
Panel B: Only new housing units							
	Oservations	**Caprate**	**Resale**	**Age**	**Floor**	**Size**	**Property Type Dummy**
Own_Occup_B	10,804	4.377	N.A.	-0.973	9.469	1,362.665	0.662
		(1.209)	N.A.	(1.867)	(8.703)	(603.922)	(0.473)
Invest_B	13,790	4.450	N.A.	-1.872	9.247	1,251.738	0.627
		(1.258)	N.A.	(1.500)	(8.406)	(566.547)	(0.484)

Secondly, we also run against Equation 5 for the selling side. But the sample construction method is different and $\mathbf{D_j}$ is different. Here, $\mathbf{D_j^k}$ is a vector of dummy variables, including Own_Occup_S and $Invest\_S$. To avoid multicollinearity, we take Own_Occup_S as the base and include only $Invest\_S$ into the model.

As mentioned in Section 3.1, each of the policies only target at those property buyers who buy after the policy. Therefore, in order to avoid the influence of the anti-speculation policies on our results, we select these selling transactions which are not constraint by the policies, i.e., these selling transactions whose sellers bought the properties before Sep 14th, 2009, But their selling happen throughout the whole period of July 2006-April 2014. We summarize the studied sample in Table 10.

Against Equation 5, we estimate Model 1-3 based on different samples. We only focus on resale housing properties, as there is no owner occupiers as sellers in the new housing market. Model 2-3

narrow down the sample properties to be young properties, to remove the possible bias caused by indoor maintenance as an unobserved variable. Typically, private properties within 5 years or even 10 years in Singapore does not need major renovation. Table 10 presents the summary statistics for the variables of studied samples for Model 1 (Panel A), Model 2 (Panel B) and Model 3 (Panel C), respectively.

Table 10: Sample at selling side, Sample Period: July 2006-April 2014

Panel A: All Resale housing units						
	Oservations	**Caprate**	**Age**	**Floor**	**Size**	**Property Type Dummy**
Owner Occupier	27,978	3.960	11.203	7.160	1,373.676	0.735
		(0.977)	(6.827)	(6.113)	(532.656)	(0.441)
Investor	12,549	3.946	7.430	8.175	1,330.002	0.696
		(0.961)	(7.228)	(7.173)	(589.792)	(0.460)
Panel B: Resale housing units with Age<=5						
	Oservations	**Caprate**	**Age**	**Floor**	**Size**	**Property Type Dummy**
Owner Occupier	5,569	4.123	3.962	7.554	1,285.699	0.699
		(0.856)	(0.864)	(6.689)	(460.622)	(0.459)
Investor	6,746	3.992	2.353	8.462	1,254.672	0.680
		(0.871)	(1.291)	(7.611)	(503.176)	(0.467)
Panel C: Resale housing units with Age<=10						
	Oservations	**Caprate**	**Age**	**Floor**	**Size**	**Property Type Dummy**
Owner Occupier	15,453	4.159	6.579	7.138	1,311.440	0.740
		(0.925)	(2.321)	(6.118)	(452.210)	(0.438)
Investor	9,251	4.027	3.878	8.211	1,273.429	0.694
		(0.901)	(2.837)	(7.249)	(508.651)	(0.461)

5.2 Testing Prediction 2

Prediction 2 states that the arbitrage of investors buying in the asset market ($Invest\_B$) is not as limited as their selling ($Invest\_S$) in the asset market during the upward market period. For Prediction 2, we carry out two parts of empirical analysis. In Step 1, we split the whole sample period into pre-policy period (July 2006-Sep 2009) and post-policy period (Sep 2009-April 2014). In Step 2, we zoom in and study the impacts of each round of anti-speculations one by one.

5.2.1 Step 1: only consider the pre-policy and post-policy period

Firstly, for the buying side, we adopt a Difference-In-Difference method (DID) to model the responses of the 2 types of buying transactions (Own_Occup_B and $Invest\_B$) to each policy. As the policies target at investors more than at owner occupiers, as implied by the arbitrage condition, the gap between the required cap-rates by the $Invest\_B$ and Own_Occup_B during the post policy period should be larger than that during the pre-policy period. In other words, the investors buying properties in the post-policy period are more cautious and require a larger price discount. However, if the arbitrage at the buying side is not very limited, this change may not be significant. The DID model is set up as Equation 6.

$$
\begin{aligned}
&Cap_{i,j,t} \\
&= \beta_1 \times Pol + \beta_2 \times Invest\_B_{i,j,t} + \beta_3 \times Pol \times Invest\_B_{i,j,t} \\
&+ \eta \times \mathbf{X}_{i,j,t} + Con_{i,j,t} + \varepsilon_{i,j,t}
\end{aligned} \tag{6}
$$

$Cap_{i,j,t}$ denotes the cap-rate realized by each transaction.

Pol is a dummy variable, with 0 indicating the transaction happens during the pre-policy period, and 1 indicating that the transaction happens during the post-policy period.

$Invest\_B_{i,j,t}$ is a dummy variable with 1 indicating the transaction is bought by an investor, 0 indicating it is bought by an owner-occupier; its coefficient β_2 reveals the difference between cap-rate realized by an investor buyer and that realized by an owner-occupier buyer.

$Pol \times Invest\_B_{i,j,t}$ is the interaction term between Pol and $Invest\_B_{i,j,t}$; its coefficient β_3 reveals the difference between the response of an investor and that of an owner-occupier to the policies in terms of their realized cap-rates.

Against Equation 6, we estimate 2 models. In Model 1, we include all new housing sale and resale samples; in Model 2, we only include new-housing samples, in order to remove the concern that the high implied cap-rate realized by investor buyers is because they buy properties with poor indoor maintenance (at lower price). Figure 4 shows the average realized cap-rate of owner occupiers and investors when buying during the pre-policy period and post-policy period. The Figure shows that the anti-speculation policies slightly change the difference in average cap-rate between Own_Occup_B and $Invest\_B$, which indicates that the policies which target at investors more might limits their arbitrage at buying side. But this effect seems not strong.

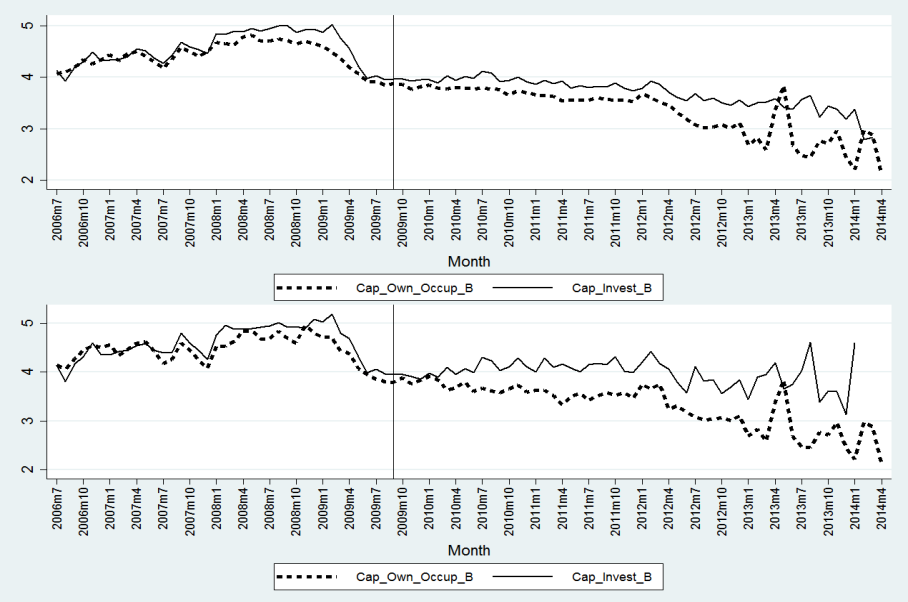

Figure 4: The average realized cap-rate of owner occupiers and investors when buying (Whole sample in the up panel and new housing sample in the down panel)

Secondly, for the selling side, we further identify the selling transactions by investors who buy during the pre-policy period ($Invest\_S\_Bef\_Policy$) and the selling transactions by investors who buy during the post-policy period ($Invest\_S\_Aft\_Policy$), and construct the sample of selling transactions $Invest\_S\_Bef\_Policy$, $Invest\_S\_Aft\_Policy$ and Own_Occup_S, as summarized in Table 11.

Table 11: Sample at selling side, Sample Period: Sep 2009-April 2014

Panel A: All Resale housing units						
	Oservations	**Caprate**	**Age**	**Floor**	**Size**	**Property Type Dummy**
Owner Occupier	17,428	3.620	11.731	7.265	1,347.564	0.725
		(0.709)	(6.958)	(6.221)	(500.901)	(0.446)
Investor bef	6,669	3.717	6.921	8.406	1,256.489	0.668
		(0.711)	(6.916)	(7.464)	(519.585)	(0.471)
Investor aft	3,059	3.609	9.472	8.030	1,209.319	0.651
		(0.667)	(7.612)	(7.047)	(470.212)	(0.477)
Panel B: Resale housing units with Age<=5						
	Oservations	**Caprate**	**Age**	**Floor**	**Size**	**Property Type Dummy**
Owner Occupier	3,126	3.742	3.996	8.185	1,241.441	0.647
		(0.634)	(0.826)	(7.457)	(444.784)	(0.478)
Investor bef	3,789	3.721	2.331	8.940	1,219.857	0.626
		(0.692)	(1.284)	(8.125)	(492.765)	(0.484)
Investor aft	1,141	3.685	2.422	9.101	1,106.245	0.583
		(0.687)	(1.372)	(8.185)	(512.344)	(0.493)
Panel C: Resale housing units with Age<=10						
	Oservations	**Caprate**	**Age**	**Floor**	**Size**	**Property Type Dummy**
Owner Occupier	8,462	3.741	6.478	7.683	1,294.145	0.723
		(0.626)	(2.266)	(6.634)	(448.503)	(0.448)
Investor bef	4,981	3.749	3.598	8.728	1,228.006	0.654
		(0.671)	(2.612)	(7.767)	(475.465)	(0.476)
Investor aft	1,825	3.695	4.462	8.804	1,150.716	0.628
		(0.631)	(2.971)	(7.687)	(465.703)	(0.483)

We adopt the same model as shown by Equation 5 (in Section 5.1), we estimate Hedonic models whose depend variable is cap-rate and in which $Invest\_S\_Bef\_Policy$, $Invest\_S\_Aft\_Policy$ and Own_Occup_S are measured by dummy variables and enter the models as explanatory variables. We estimate 3 Models against Equation 5 where $\mathbf{D_j}$ is a vector of dummy variables, including $Invest\_S\_Bef\_Policy$, $Invest\_S\_Aft\_Policy$ and Own_Occup_S, we take $Invest\_S\_Bef\_Policy$ as the base and include only the rest of the two dummy variables into the model.

Against Equation 5, we estimate Model 1-3 based on different samples. We only focus on resale housing properties, as there is no owner occupiers as sellers in the new housing market. Model 2-3 narrow down the sample properties to be young properties, to remove the possible bias caused by indoor maintenance as an unobserved variable. Typically, private properties within 5 years or even 10 years in Singapore does not need major renovation. Table 10 presents the summary statistics for the variables of studied samples for Model 1 (Panel A), Model 2 (Panel B) and Model 3 (Panel C), respectively.

5.2.2 Step 2: zoom into the impacts of each anti-speculation policy

One possible concern arises in terms of method in Step 1. That is, some of the investors who buy during the pre-policy period might buy at the market bottom (as shown in Figure 1) and sell during the post-polity period, they have a higher chance to earn a higher capital gain than those who buy during the post-policy period. As a result, as implied by loss aversion theory (Genesove & Mayer, 2001[25], et al.), they are more willing to accept relatively lower selling prices (higher cap-rates) than those who buy during the post-policy period. To avoid this concern, in Step 2, we repeat the same empirical strategy as in Step 1, but instead of simply cut the sample into pre-policy period and post-policy period, we zoom into the impact of specific policies.

Firstly, for the buying side, we adopt the similar DID method as that in Step 1, as shown in Equation 7. The only difference is that, in Equation 6, Pol is a dummy variable, with 0 indicating the transaction happens during the pre-policy period, and 1 indicating that the transaction happens during the post-policy period; while in Equation 7, Pol_k indicates each specific round of anti-speculation policy, with k indicating Policy 1-4.

$$\begin{aligned} &Cap_{i,j,t} \\ &= \beta_1 \times Pol_k + \beta_2 \times Invest\_B_{i,j,t} + \beta_3 \times Pol_k \times Invest\_B_{i,j,t} \\ &+ \eta \times \mathbf{X}_{i,j,t} + Con_{i,j,t} + \varepsilon_{i,j,t} \end{aligned} \tag{7}$$

For studying the impact of each policy, we take a 2-month threshold before and after each policy[13]. A description of how each policy influences the cap-rates of buying transactions by investors compared to owner occupiers is presented in Figure 5.

We repeat the DID procedure for the new housing sample, to avoid the influence of indoor maintenance as unobservable variable, and a description of the impacts of each policy is presented in Figure 6. According to the two figures, we find that the policies do not really make the investors require higher cap-rates when buying, compared to owner occupiers, which indicates that the arbitrage of investor buyers may not be limited.

[13] We remove sample transactions happen during the period of 14 days immediately after each policy. Because in a typical transaction process in Singapore, the contract price we observe is determined approximately 14 days ago, i.e., before signing the contract, the prospect buyer has a period of up to 14 days to reconsider the deal. Thus, the contracts signed during the period of 14 days immediately after each policy may not be really affected by the policy.

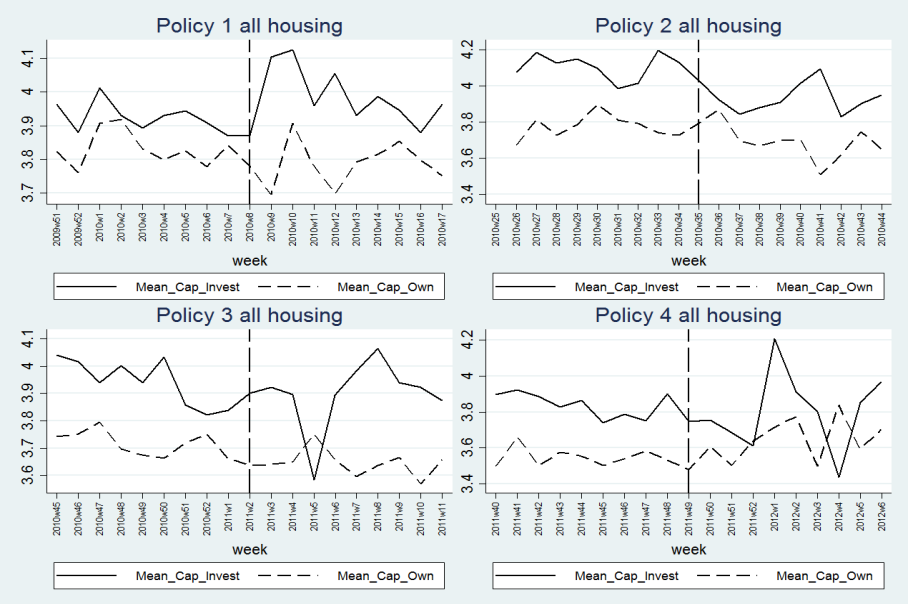

Figure 5: The average realized cap-rate of owner occupiers and investors when buying (Whole sample, 2 month threshold and the vertical line represents policy)

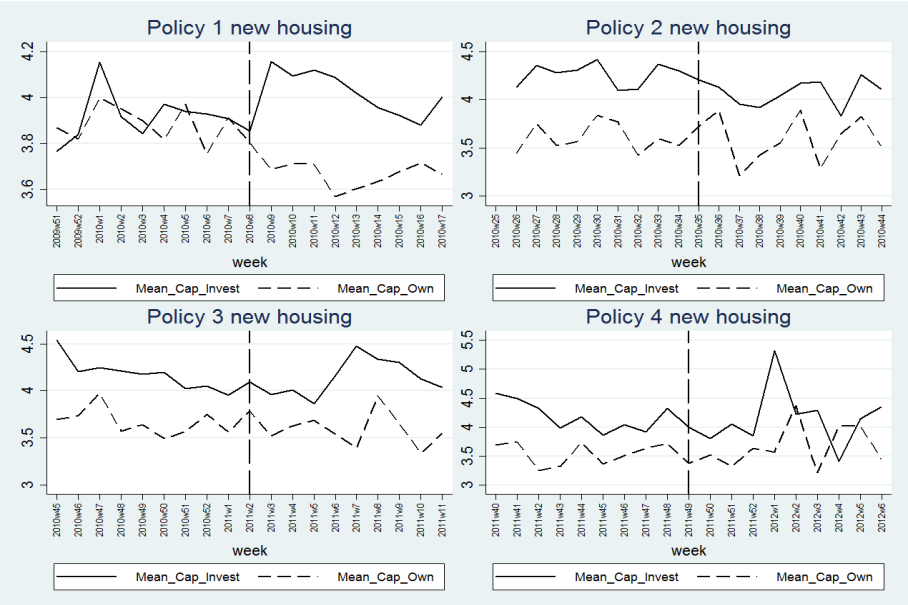

Figure 6: The average realized cap-rate of owner occupiers and investors when buying (new housing sample, 2 month threshold and the vertical line represents policy)

For the selling side, we expect to adopt the same method as that for studying the selling side in Step 1. However, the empirical analysis on the selling side suffers from insufficient sample observations, due to the limitation of our dataset. Our dataset only covers the period before April 2014, while the studied policies are carried out between 2009 and 2012. Especially, after Policy 3 (carried out in Jan 2011), which is strongest policy in terms of its constraint on selling, very few selling observations are observed, because most investors are forced to hold and rent out the properties to avoid the aggressive sellers' stamp duty. Therefore, we further study the renting behaviors of investors in space market, to see how anti-speculation policies force the investors to hold the properties and limit their arbitrage at the selling side.

Table 12 summarizes the observations of selling transactions by investors who buy during the 2-month threshold period before and after each policy, as well as their average holding periods. We can see that, the number of selling transactions by investors who buy after Policy 2 is substantially reduced compared to that by investors who buy before policy 2, and the reduction is even more substantial for the Policy 3. In terms of meaning holding period, the numbers in Table 12 actually can demonstrate that investors' holding periods in average are prolonged by each policy. Our dataset is truncated at April 2014, the average holding period in Table 12 is calculated based on only these observed selling transactions. As the substantial proportions of sellings by investors who buy after policy 2 and 3 are not observed, the seemingly very close holding periods before and after each of the policies actually show that each of the policies much prolongs investors holding periods, constraint their selling.

Table 12: Observed selling volumes by investors and and their observed holding periods

	Observations	**Mean Holding Period**
Selling by Investors who buy Before Policy 1	752	655.981
Selling by Investors who buy After Policy 1	677	715.049
Selling by Investors who buy Before Policy 2	588	698.100
Selling by Investors who buy After Policy 2	299	695.254
Selling by Investors who buy Before Policy 3	352	664.355
Selling by Investors who buy After Policy 3	36	650.000
Selling by Investors who buy Before Policy 4	28	392.500
Selling by Investors who buy After Policy 4	10	400.800

In order to demonstrate how each of the Policies limits arbitrage at the selling side, we focus on the rental transactions on the space market, and compare the realized cap-rate of rental transactions by invstor owners who buy after policy k ($Invest\_Rent\_Aft\_Poilcy_k$) to that by invstor owners who buy before policy k ($Invest\_Rent\_Bef\_Poilcy_k$).

We adopt the same model as shown by Equation 5 (in Section 5.1), we estimate Hedonic models whose depend variable is cap-rate and in which $Invest\_Rent\_Aft\_Poilcy_k$ and ($Invest\_Rent\_Bef\_Poilcy_k$) are measured by dummy variables and enter the models as explanatory variables. To avoid multi-

collinearity, we take $Invest\_S\_Bef\_Policy$ as the base and include only $Invest\_Rent\_Aft\_Poilcy_k$ into the model. We estimate the Model 1-4 for each of the 4 studied policies respectively.

Table 13 presents the sample periods and summary statistics for the studied samples in space market for study the impacts of each policy. We can see that, Policy 3 and Policy 4 impose very strong constraint on investors' selling, as the average realized cap-rate by investors who buy after Policy 3 (Policy 4) in the space market is lower than that by investors who buy before the policy. This indicates that the arbitrage of investors at the selling side is limited by the policy, otherwise they should have cashed out.

Table 13: Summary statistics for the studied sample in space market for each policy

Panel A- Policy 1, with period of rental observation between Oct 2010-April 2014						
	Oservations	**Caprate**	**Age**	**Floor**	**Size**	**Property Type Dummy**
Invest_Rent_Bef_Policy	1,298	3.676	7.181	8.636	1,191.778	0.685
		(1.054)	(7.346)	(7.391)	(526.077)	(0.465)
Invest_Rent_Aft_Policy	1,523	3.675	7.496	8.815	1,193.810	0.681
		(1.003)	(7.969)	(7.446)	(582.402)	(0.466)
Panel B- Policy 2, with period of rental observation between April 2011-April 2014						
	Oservations	**Caprate**	**Age**	**Floor**	**Size**	**Property Type Dummy**
Invest_Rent_Bef_Policy	1,213	3.619	7.492	8.257	1,087.423	0.622
		(0.862)	(7.862)	(7.378)	(460.992)	(0.485)
Invest_Rent_Aft_Policy	1,028	3.639	7.346	8.406	1,103.496	0.683
		(0.865)	(7.388)	(7.310)	(451.970)	(0.466)
Panel C- Policy 3, with period of rental observation between July 2011-April 2014						
	Oservations	**Caprate**	**Age**	**Floor**	**Size**	**Property Type Dummy**
Invest_Rent_Bef_Policy	1,279	3.630	7.709	8.751	1,114.339	0.615
		(0.830)	(7.998)	(7.668)	(519.950)	(0.487)
Invest_Rent_Aft_Policy	777	3.618	7.629	8.071	1,124.335	0.676
		(0.850)	(7.547)	(6.998)	(493.081)	(0.468)
Panel D- Policy 4, with period of rental observation between July 2012-April 2014						
	Oservations	**Caprate**	**Age**	**Floor**	**Size**	**Property Type Dummy**
Invest_Rent_Bef_Policy	509	3.533	8.026	8.904	1,099.532	0.609
		(0.915)	(7.340)	(7.420)	(509.510)	(0.488)
Invest_Rent_Aft_Policy	221	3.494	7.222	8.023	1,081.652	0.638
		(1.027)	(7.471)	(6.794)	(470.086)	(0.482)

6 Empirical Results

This section presents the empirical results. For demonstrating Prediction 1, the results are discussed in Section 6.1. We take two steps to demonstrate Prediction 2. In Step 1, we study the policy impacts simply specifying the sample period into pre-policy period and post-policy period, as discussed in Section 6.2; In Step 2, we zoom into the impacts of each of the 4 anti-speculation policies, which is discussed in Section 6.3.

6.1 Prediction 1: Inefficient housing market with arbitrage opportunities

For testing Prediction 1, in Section 6.1, we run 2 models with sample at the buying side and another 3 models with sample at the selling side, to demonstrate that housing investors, compared to owner occupiers, require and can realize higher cap-rate when entering into the market and lower cap-rate when cashing out housing properties, which implies that housing market is an inefficient market.

As shown in Table 14, in both Model (1) and Model (2), the key variable of special interest, $Invest\_B$, has expected coefficients and are generally significant at 1% level. The important controlled variables *size* and $Floor$ are significant at 1% level, both models have satisfying R-Squares which are around 0.7. The results in Table 12 reveal that, compared to owner occupiers, investors buying in the asset market realize higher cap-rates.

In Model (1), with both new housing and resale housing properties, the coefficient of $Invest\_B$ is 0.114 and significant at 1% level, which indicates that the investors are able to realize cap-rates that are in average 0.114 higher than that realized by owner occupiers when buying in the asset market. To avoid the concern that indoor maintenance as an unobserved variable might bias the results, Model (2) only contains new housing properties where indoor renovation is done standardly by developers. The coefficient of $Invest\_B$ is 0.104 and significant at 1% level, which is consistent with that in Model (1).

Table 14: Investors realize higher cap-rates when buying

	(1)	(2)
	Whole Market	New-housing sample
Dependent Variable:	**Cap-rate**	
Invest_B	0.114***	0.104***
	(0.007)	(0.009)
Size	-0.000271***	-0.000536***
	(0.000)	(0.000)
Floor	-0.00968***	-0.00923***
	(0.001)	(0.001)
Propertytype_Dummy	-0.0614	-0.173
	(0.120)	(0.153)
Resale_Dummy	-0.275***	
	(0.018)	
Age	-0.0475***	-0.0524***
	(0.008)	(0.009)
Month Dummy	Controlled	Controlled
Project Dummy	Controlled	Controlled
Constant	Controlled	Controlled
Observations	56,113	24,594
R-squared	0.704	0.75

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 15 reveals the results for the selling side. In both Model (1) and Model (3), the key variable of special interest, $Invest\_S$, has expected coefficients and are significant at 1% level, while in Model (2), the coefficient is not significant. The important controlled variables *size* and *Floor* are significant at 1% level, all the three models have satisfying R-Squares which are around 0.73. The results in Table 13 generally support our prediction that, compared to owner occupiers, investors selling in the asset market realize lower cap-rates.

Model (1) estimates on resale housing properties of all property ages, the coefficient of $Invest\_S$ is -0.0485 and significant at 1% level, which indicates that the investors are able to realize cap-rates that are in average 0.0485 lower than that realized by owner occupiers when selling in the asset market. To avoid the concern that indoor maintenance as an unobserved variable might bias the results, Model (2) only contains young housing properties (within 10 years after TOP) where indoor renovation is not that necessary. The coefficient of $Invest\_S$ is -0.0375 and significant at 1% level, which is consistent with that in Model (1).

However, when we further narrow down the sample to resale properties that are within 5 years after TOP, as shown under Model (2), the coefficient for $Invest\_S$ is not significant, which seems to support our concern that investors are able to sell at lower cap-rates (or higher prices) because they tend to do more renovation than owner occupiers. But this is not the case. For properties within 5 years after TOP, indoor renovation is not needed. The insignificant coefficient might indicate that investors are not able to sell at a lower cap-rate than owner occupiers. We believe this is not the case. Firstly, when major renovation is not needed, owner occupiers tend to do better indoor maintenance than that of investors (Wang, Grissom, et al., 1991[62]), which may lead to a higher selling price and lower cap-rate. This implies that an insignificant coefficient still can demonstrate that investors are able to sell at lower cap-rates (higher prices). Secondly, it is probable that our identification strategy takes some of the investors to be owner occupiers, and these identified owner occupiers who sell very young properties are more likely to be actual investors.

In summary, the above results prove Prediction 1, which is, according to the arbitrage condition, the required and realized cap-rate of a prospect owner occupier buying in the asset market (Own_Occup_B) is lower than that of the buying of an investor ($Invest\_B$); the required and realized cap-rate of a prospect owner occupier selling in the asset market (Own_Occup_S) is higher than that of the selling of an investor ($Invest\_S$). They can realize their different cap-rates due to market inefficiency. The above findings are consistent with the existing studies which take a housing market as a segmented and inefficient market (Glaeser& Nathanson, 2014[28]; Glaeser, Gyourko & Saiz, 2008[27]; Ling, Naranjo and Scheick, 2014[37]; et al.).

Table 15: Investors realize lower cap-rates when selling

	(1)	(2)	(3)
	All	Property Age<=5	Property Age<=10
Dependent Variable:	**Cap-rate**		
Invest_S	-0.0485***	0.0176	-0.0375***
	(0.007)	(0.011)	(0.008)
Size	-0.000227***	-0.000457***	-0.000367***
	(0.000)	(0.000)	(0.000)
Floor	-0.00560***	-0.00308***	-0.00477***
	(0.001)	(0.001)	(0.001)
Propertytype_Dummy	-0.239***	0.0483	-0.149
	(0.069)	(0.102)	(0.130)
Age	-0.00581	0.0268	0.0282
	(0.007)	(0.038)	(0.023)
Month Dummy	Controlled	Controlled	Controlled
Project Dummy	Controlled	Controlled	Controlled
Constant	Controlled	Controlled	Controlled
Observations	40,527	12,315	24,704
R-squared	0.726	0.73	0.738

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6.2 Prediction 2-Step 1: anti-speculation policies limit arbitrage at buying side less than that at selling side

We take two steps to test Prediction 2 which says that anti-speculation policies asymmetrically limit the arbitrage of housing investors. Specifically, we argue that the arbitrage of housing investors at the buying side is less limited while that at the selling side is relatively more limited. For Step 1, in Section 6.2, we run 2 models with sample at the buying side to demonstrate that anti-speculation policies do not make the remaining investors who buy after the policies require higher cap-rate, which indicates that the policies do not very limit the arbitrage of housing investors at the buying side. We run another 3 models with sample at the selling side, to demonstrate that investors who are constraint by the anti-speculation policies indeed require lower cap-rate when selling, which indicates that their arbitrage when selling is relatively more limited.

As shown in Table 16, in both Model (1) and Model (2), the coefficients of the key variable of special interest, $Invest\_B \times Policy$, as expected, are insignificant. The important controlled variables *size* and *Floor* are significant at 1% level, both models have satisfying R-Squares which are above 0.7. The results in Table 16 reveal that, the anti-speculation policies does not make the remaining housing investors who buy during the post-policy period require higher cap-rate, which indicates that the arbitrage of these investors are not very limited.

In both Model (1) and (2), the coefficients of $Invest\_B$ are positive and significant at 1% level, which indicates that the investors are able to realize higher cap-rates when buying in the asset market. The coefficients for $Invest\_B \times Policy$, as expected, are insignificant, which indicates that the arbitrage of remaining housing investors who buy during the post-policy period is not very limited. This finding is consistent with some existing studies which explain it from different

angles. For example, Fu, Qian, and Yeung (2013)[22] argues that the anti-speculation policies remove the informed investors and the remaining investors who keep buying are the non-informed. In addition, this can also be explained to be that the remaining investors are more risk seeking or more over-confident (Fellner and Maciejovsky, 2007[19]; Scheinkman and Xiong, 2003[51]; et al.), as the impact of anti-speculation policies are not direct but only imposes a risk, as long as the investors can hold the properties for a longer time of period, they can avoid paying the additional sellers' stamp duty.

Table 16: Anti-speculation policies do not very limit arbitrage at the buying side

	(1) Whole Market	(2) New-housing sample
Dependent Variable:	**Cap-rate**	
Invest_B	0.0904***	0.105***
	(0.006)	(0.009)
Policy	0.00365	0.0126
	(0.021)	(0.041)
Invest_B × Policy	-0.00692	0.0117
	(0.008)	(0.015)
Size	-0.000290***	-0.000490***
	(0.000)	(0.000)
Floor	-0.00790***	-0.00882***
	(0.000)	(0.001)
Propertytype_Dummy	-0.0778	-0.087
	(0.054)	(0.123)
Age	-0.0357***	-0.0466***
	(0.006)	(0.007)
Resale_Dummy	-0.117***	
	(0.009)	
Month Dummy	Controlled	Controlled
Project Dummy	Controlled	Controlled
Constant	Controlled	Controlled
Observations	103,508	38,004
R-squared	0.705	0.759

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Although the arbitrage of the remaining investors who buy during the post-policy period are not very limited, the selling of this same group of people is indeed limited by the policies. As shown in Table 17, in Models (1) - (3), the coefficients of the key variable of special interest, $Invest\_S\_Aft\_Policy$, as expected, are significant at 1% level. All models have satisfying R-Squares which are above 0.67. The results in Table 17 reveal that, the anti-speculation policies limit that arbitrage of investors who buy during the post-policy period in terms of their selling.

In Model (1), where all resale housing properties are considered, the coefficients of $Invest\_S\_Aft\_Policy$ is -0.0473, as expected and is significant at 1% level. It indicates that compared to the selling by investors who buy during the pre-policy period, the selling of these investors who buy during the post-policy period require lower cap-rates, i.e., their arbitrage in terms of selling is limited. This is because, investors buying after the anti-speculation policies face additional sellers' stamp duty

if they need to sell within a relatively short holding period. They tend to wait until higher prices (lower cap-rate) or hold the properties for a period longer enough to avoid the additional taxes. The results in Model (2) and Model (3) are consistent.

Table 17: Anti-speculation policies limit arbitrage of investors at the selling side

	(1)	(2)	(3)
	All	Property Age<=5	Property Age<=10
Dependent Variable: Cap-rate			
Own_sell	-0.0317***	-0.0630***	-0.0394***
	(0.008)	(0.012)	(0.008)
Invest_S_Aft_Policy	-0.0473***	-0.0390**	-0.0436***
	(0.010)	(0.016)	(0.012)
Size	-0.000288***	-0.000574***	-0.000419***
	(0.000)	(0.000)	(0.000)
Floor	-0.00274***	0.000931	-0.000857
	(0.001)	(0.001)	(0.001)
Propertytype_Dummy	-0.0687**	0.0474	0.000876
	(0.030)	(0.092)	(0.075)
Age	-0.00286	0.0381	0.037
	(0.008)	(0.038)	(0.024)
Month Dummy	Controlled	Controlled	Controlled
Project Dummy	Controlled	Controlled	Controlled
Constant	Controlled	Controlled	Controlled
Observations	27,156	8,056	15,268
R-squared	0.71	0.683	0.675

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6.3 Prediction 2-Step 2: anti-speculation policies limit arbitrage at buying side less than that at selling side

As mentioned in Section 5.2.2., there is one possible concern in terms of method in Step 1. That is, some of the investors who buy during the pre-policy period have a higher chance to earn a higher capital gain than those who buy during the post-policy period. As a result, the pre-policy buyers are more willing to accept a relatively lower price (high cap-rate) than those who buy during the post-policy period. To avoid this concern, in Step 2, we zoom into the impact of specific policies.

In this section, for the buying side, we run 8 models with sample at the buying side to demonstrate that anti-speculation policies do not make the remaining investors who buy after the policies require higher cap-rate, which indicates that the policies do not very limit the arbitrage of housing investors at the buying side. At the selling side, we run 4 models with sample of rental transactions, to demonstrate that investors who are constraint by the anti-speculation policies indeed are forced to hold and rent out the properties, to indirectly demonstrate that their arbitrage when selling is limited.

In Panel A of Table 18, in all of the 4 models with both resale and new housing sample, the coefficients of key variable of special interest, $Invest\_B \times Policy$, as expected, are insignificant. The important controlled variables *size* and *Floor* are significant at 1% level, all models have

satisfying R-Squares which are above 0.78. The insignificant coefficients for $Invest\_B \times Policy$ reveal that, non of the anti-speculation policies make the remaining housing investors who buy during the post-policy period require higher cap-rates, which indicates that the arbitrage of these investors are not very limited. In Panel B of Table 18, in all of the 4 models with new housing sample, we obtain consistent results as in Panel A. As a whole, the results in Table 18 are consistent with those in Table 16, demonstrating that anti-speculation policies do not limit the arbitrage of the remaining buyers at buying side who buy after when policies are carried out.

Table 19 presents the results for limits of arbitrage at the selling side. Consistent with the conclusion in Section 6.2, we find that, although the arbitrage of the remaining investors who buy during the post-policy period are not very limited at the buying side, the selling of this same group of investors is indeed limited by the policies. Due to the limitation of selling observations, as discussed in Section 5.2.2, we instead use the rental behaviors of investors in the space market to demonstrate how their selling as arbitrage is limited by the policies and are forced to hold the properties and rent out in the space market.

As shown in Table 19, in Models (1) - (4), the coefficients of key variable of special interest, $Invest\_Rent\_Aft\_Policy$, are as expected. All models have satisfying R-Squares which are above 0.73. The results in Table 18 reveal that, the anti-speculation policies limit that arbitrage of investors who buy after the policies in terms of their selling and force them to rent out properties in the space market.

Model (1) reveals the impacts of Policy 1 on the renting out of the investors. The coefficient of $Invest\_Rent\_Aft\_Policy$ is 0.0026 but not significant. This result does not support the argument that Policy 1 limits the arbitrage of investors who buy after Policy 1 in terms of their selling. In Model 2, the coefficient of $Invest\_Rent\_Aft\_Policy$ is -0.00494 and also not significant. As discussed in Section 3.2.2, the selling constraint imposed by Policy 1 and Policy 2 is actually not strong, as the additional sellers' stamp duty is low and easily avoidable. This may explain why the results for in Model 1 and Model 2 are not significant.

Model (3) reveals the impacts of Policy 3 on the renting out of the investors. The coefficient of $Invest\_Rent\_Aft\_Policy$ is -0.0766 and significant at 5% level, which indicates that, compared to investors who buy before Policy 3, the investors who buy after Policy 3 realize cap-rates of 0.0766 lower in the space market. In other words, compared to investors who buy before Policy 3, the selling (arbitrage at selling side) of investors who buy after Policy 3 is limited, and these investors are forced to hold and rent out their properties in the space market. In Model (4), the coefficient of $Invest\_Rent\_Aft\_Policy$ is negative (-0.154) but not significant, this insignificance may be caused by insufficient number of observations due to the limitation of our dataset.

Table 18: Non of the anti-speculation policies very limit arbitrage at the buying side

Panel A: all resale and new housing sample				
	(1)	(2)	(3)	(4)
	Policy 1	Policy 2	Policy 3	Policy 4
Dependent Variable: Cap-rate				
Invest_B	0.0886***	0.0823***	0.0669***	0.107***
	(0.016)	(0.020)	(0.018)	(0.026)
Policy	0.0713***	-0.103***	-0.0312	-0.0508
	(0.023)	(0.023)	(0.034)	(0.054)
Invest_B × _Policy	0.000433	-0.0272	-0.0474	-0.0229
	(0.020)	(0.027)	(0.030)	(0.049)
Size	-0.000431***	-0.000269**	-0.000298**	-0.000401***
	(0.000)	(0.000)	(0.000)	(0.000)
Floor	-0.00525***	-0.00662***	-0.00600***	-0.00587***
	(0.001)	(0.002)	(0.002)	(0.002)
Propertytype_Dummy	0.101	-0.178	0.177	-0.796*
	(0.066)	(0.207)	(0.225)	(0.419)
Age	-0.0380***	-0.0191	0.0156	0.0324
	(0.009)	(0.013)	(0.026)	(0.033)
Month Dummy	Controlled	Controlled	Controlled	Controlled
Project Dummy	Controlled	Controlled	Controlled	Controlled
Constant	Controlled	Controlled	Controlled	Controlled
Observations	8,069	5,917	5,436	2,629
R-squared	0.819	0.82	0.787	0.835

Panel B: new housing sample				
	(1)	(2)	(3)	(4)
	Policy 1	Policy 2	Policy 3	Policy 4
Dependent Variable: Cap-rate				
Invest_B	0.0975***	0.163**	0.0667*	0.0602
	(0.029)	(0.067)	(0.038)	(0.074)
Policy	-0.0735	-0.0289	0.00391	-0.186
	(0.051)	(0.050)	(0.073)	(0.137)
Invest_B × _Policy	0.0496	-0.136	-0.0489	0.12
	(0.038)	(0.088)	(0.057)	(0.094)
Size	-0.000547***	-0.00031	-0.000468***	-0.000788***
	(0.000)	(0.000)	(0.000)	(0.000)
Floor	-0.00982***	-0.00237	-0.00431	-0.0143***
	(0.002)	(0.004)	(0.003)	(0.004)
Propertytype_Dummy	0.141	-1.634*	0.754***	-1.253***
	(0.112)	(0.989)	(0.154)	(0.262)
Age	-0.0528***	-0.00952	-0.0183	-0.257***
	(0.004)	(0.038)	(0.027)	(0.004)
Month Dummy	Controlled	Controlled	Controlled	Controlled
Project Dummy	Controlled	Controlled	Controlled	Controlled
Constant	Controlled	Controlled	Controlled	Controlled
Observations	2,549	1,769	1,488	526
R-squared	0.824	0.826	0.852	0.891

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 19: Anti-speculation policies limit the arbitrage of investors at selling side

	(1) Policy 1	(2) Policy 2	(3) Policy 3	(4) Policy 4
Dependent Variable: Cap-rate				
Invest_Rent_Aft_Policy	0.0026	-0.00494	-0.0766**	-0.154
	(0.029)	(0.038)	(0.038)	(0.103)
Size	-0.000128***	6.41E-05	-0.000129*	-0.00019
	(0.000)	(0.000)	(0.000)	(0.000)
Floor	-0.00913***	-0.00996***	-0.00542**	-0.00418
	(0.003)	(0.003)	(0.003)	(0.011)
Propertytype_Dummy	-0.147**	-0.17	-0.129	0.0442
	(0.063)	(0.128)	(0.086)	(0.289)
Age	0.00906	0.152	0.157	-0.922
	(0.117)	(0.115)	(0.133)	(0.657)
Month Dummy	Controlled	Controlled	Controlled	Controlled
Project Dummy	Controlled	Controlled	Controlled	Controlled
Constant	Controlled	Controlled	Controlled	Controlled
Observations	2,821	2,241	2,056	730
R-squared	0.818	0.738	0.763	0.827

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

As a short summary, results in Table 18 demonstrate that anti-speculation policies do not limit the arbitrage of the remaining buyers at buying the side who buy after when policies are carried out; while at the same time, results in Table 19 demonstrate that the anti-speculation policies, especially the Policy 3 which imposes the strongest selling constraint, limits the investors' arbitrage when selling in the asset market, and force them to hold the properties and rent out in the space market. The above results together demonstrate that the arbitrage of investors is asymmetrically limited, with selling side more limited than the buying side.

7 A summary of empirical results and discussion on policy implications

In this section, we firstly summarize the empirical results (in Section 7.1), and then discuss the policy implications (in Section 7.2). We argue that human irrationality causes the asymmetrical limits of arbitrage, and the policy strategy of taxing short-term holders adds to this asymmetry compared to directly imposing transaction taxes on all investors.

7.1 A summary of empirical results

In Section 6.1, we demonstrate that the Singapore private housing market is inefficient with arbitrage opportunities. Compared to owner occupiers, investors require and are able to realize higher cap-rates when buying and lower cap-rates when selling. In Section 6.2, we demonstrate that the arbitrage of the investors who buy during the post-policy period is not limited at the

buying side, while the arbitrage at selling side of this same group of investors is limited by the anti-speculation policies. In Section 6.3, we obtain consistent conclusion as that in Section 6.2, and we find that, Policy 3, as the strongest policy in terms of its strategy of raising sellers' stamp duty to tax short-term holders, has significant constraint on the selling of investors, forcing them to hold the properties for a longer time of period, rent out in the space market and accept lower cap-rates.

Results in Section 6.2 and Section 6.3 demonstrate that anti-speculation policies as additional market frictions asymmetrically limit the arbitrage of investors, i.e., they limit the investors' arbitrage when selling more than that when buying. As discussed in 3.2.2, human irrationality, including such as loss aversion (Tversky and Kahneman, 1991[61]; Genesove and Mayer, 2001[25], et al), heterogenous risk attitude (Fellner and Maciejovsky, 2007[19]), over confidence (Scheinkman and Xiong, 2003[51], et al.), and backward looking & positive feedback (De Long, et al., 1990[14], et al.), can explain this asymmetry.

This pattern of asymmetrical limits of arbitrage is consistent with some of the findings of existing literature, but is actually ignored by them, probably because they only focus on the buying side while ignore the selling side. For example, Fu, Qian, and Yeung (2013)[22] argues that the anti-speculation policies remove the informed investors and the remaining investors who keep buying are the non-informed. They do observe that the remaining investors after anti-speculation policy keep buying in the asset market, and they take them as the non-informed and their buying disturb the market more. However, our findings demonstrate that, this same group of investors, their selling as arbitrage is actually limited, which further stops price correction. As they are forced to hold the properties and rent out in the space market even facing with lower cap-rate. As a result, the market price does not go down due to reduced supply (less selling) while rent rate in the space market keeps going down (more supply in space market) and a consistently decreasing market cap-rate. The above explains the current housing market situation in Singapore.

In addition, the asymmetrical limits of arbitrage can also be explained by that the remaining investors are more risk seeking or more over-confident (Fellner and Maciejovsky, 2007[19]; Scheinkman and Xiong, 2003[51]; et al.), as the impact of anti-speculation policies are not certain or acts simply as a risk, as long as the investors can hold the properties for a longer time of period, say 4 years, they can avoid paying the additional sellers' stamp duty.

7.2 Discussion on policy implications

As long as the above mentioned human irrationalities exist, we believe asymmetrical limits of arbitrage exist. In addition, the policy strategy of raising sellers' stamp duty to tax short-term holders adds to this asymmetry compared to directly imposing transaction taxes on investor buyers. Because the strategy of taxing short-term holders creates the possibility that the tax could

be avoided if the holders hold the properties for sufficient time of period, which may actually does not stop investors' buying (if they are risk seeking or have poor judgment on the future market) while definitely constraint their selling.

We examine several other countries (or regions) in addition to Singapore, to see how the above two different strategies of tax collection (anti-speculation policy) impact on housing markets. We find that housing markets such as Singapore and Hong Kong, who adopt similar strategy of taxing short-term property holders, share same market pattern, i.e., distorted price-volume correlation and decreasing market cap-rate. While housing markets like the Great Britain, which directly tax housing transactions, do not show this market pattern.

The market pattern and housing policies of Singapore private housing market are introduced in detail in Section 1 & 3. We now focus on the Hong Kong case. From Figure 7, we can see that the Hong Kong housing market shows similar pattern as the Singapore private housing market. Specifically, the two rounds of anti-speculation policies distorted the price-volume correlation, with housing market price high while housing transaction volume very low (shown in upper panel of Figure 7). At the same time, the market cap-rate consistently went down (shown in the down panel of Figure 7).

The anti-speculation policies imposed on Hong Kong housing market (the two vertical lines) share one important element as that in the Singapore case, that is, raising sellers' stamp duty to tax short-term property holders. Specifically, in November 2010, in order to deter speculators, the HK authorities increased the stamp duty to 15% for properties resold within six months of purchase, to 10% stamp duty for the holding period of more than 6 months but less than or for 12 months, and 5% stamp duty for the holding period of more than 12 months but less than or for 24 months.

We believe the policy strategy of taxing short-term property holders contributes to the asymmetrical limits of arbitrage and results in the distorted price-volume relationship and decreasing cap-rate. In comparison, the Great Britain also raised transaction tax to stabilize housing market: 1) from April 2010, the government imposed 5% stamp duty on for properties worth over GBP 1 million; 2) from March 2012, the government imposed the stamp duty of 7% for properties over GBP 2 million; 3) from April 2011, the government discontinued the exemption of stamp duty for properties priced between GBP 125,000 and GBP 250,000.

Different from the situation in Singapore and that in Hong Kong, we see that the policies in Great Britain immediately stabilized the housing price, while at the same time did not distort the price-volume relationship.

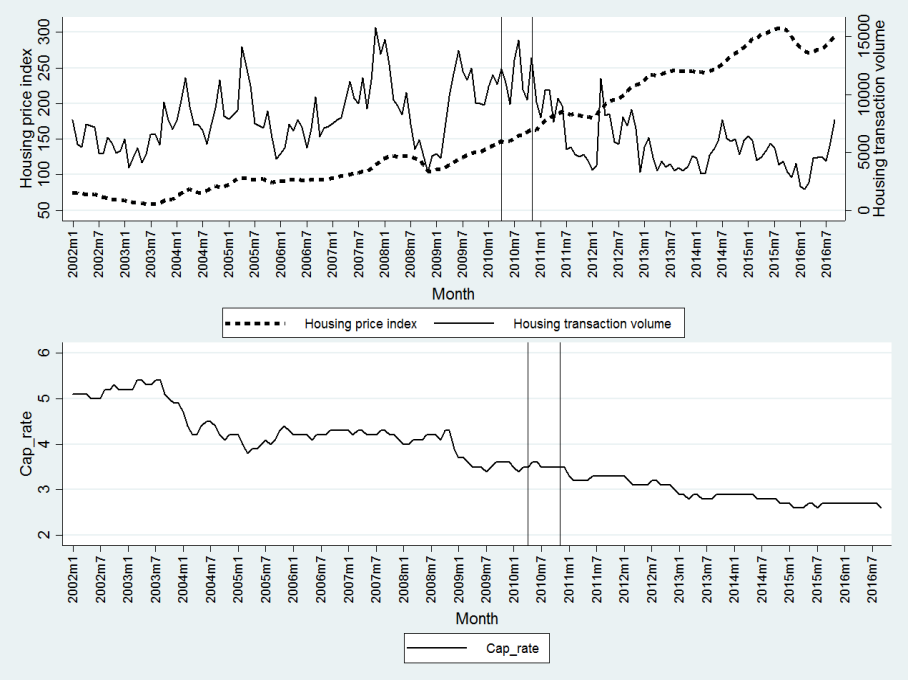

Figure 7: The price-volume relationship and market cap-rates of Hong Kong housing market

Note: The figure is based on data collected from PROPERTY MARKET STATISTICS, https://data.gov.hk. For the price index, the price of Dec 2008=100. The two vertical lines represents the two anti-speculation housing policies.

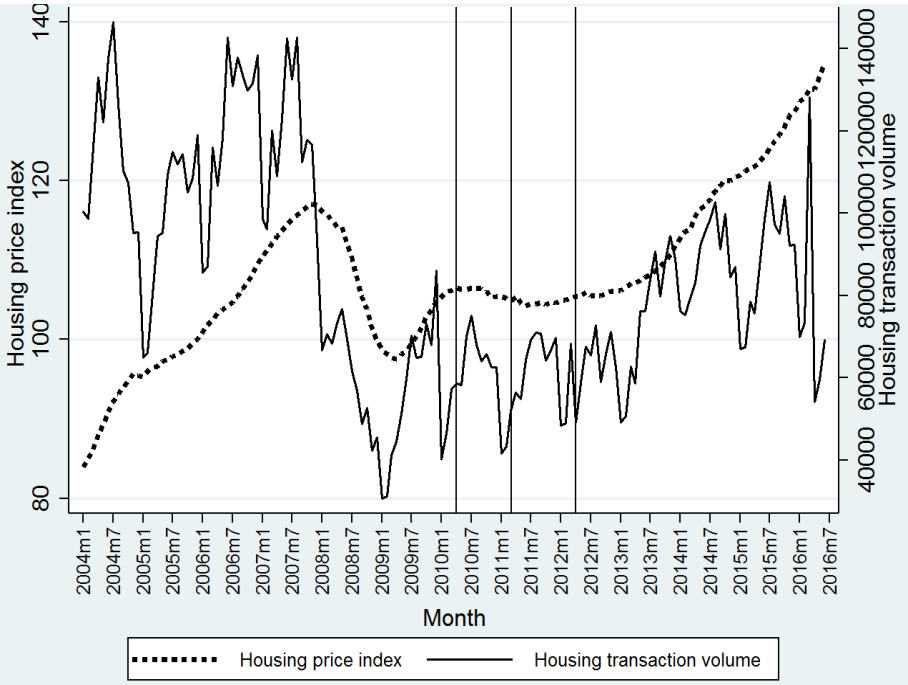

Figure 8: The price-volume relationship of housing market in the Great Britain

Note: The figure is based on data collected from Datastream database. For the price index, the price of Dec 2008=100. The three vertical lines represents the three housing policies adding to housing transaction taxes.

The strategy of raising sellers' stamp duty to tax short-term property holders is also adopted by the Chinese authorities, and a lot of other countries have adopted some kinds of transaction taxes to cool their housing market down. These policies and countries are summarized in the "Policy database" of Shim, Bogdanova, Shek and Subelyte (2013)[55] and discussed in Kuttner and Shim (2013)[35]. Due to data limitation, we are not able to provide discussion on policy impacts of the rest of the housing markets.

By comparing the impacts of different tax strategies adopted in Singapore, Hong Kong and Great Britain, also combining our conclusion on the asymmetrical limits of arbitrage, we believe that the strategy of taxing short-term property holders are more likely to result in asymmetrical limits of arbitrage.

How the governments should adopt transaction taxes to cool the housing market down? It depends on the governments' purpose. If the government wants to stabilize the market immediately or even decrease the housing price, the strategy of taxing short-term property holders is may not be a good choice. Instead, the governments should impose transaction taxes on investors, for example, imposing additional buyers' stamp duty on second home owners.

8 Conclusion and future study

By zooming into limits of arbitrage (LOA) at micro level and specifying the arbitrage at buying and selling side, we try to add to the understanding on the current LOA theory. We argue and demonstrate that additional market frictions limit arbitrage asymmetrically. Under the scenario that government carries out anti-speculation policies to deter speculators and stabilize housing market, we empirically demonstrate that, arbitrage at buying side is less limited while arbitrage at selling side is more limited, which can be explained by human irrationality.

With the above understanding, it is easy to understand that anti-speculation policy strategies like imposing sellers' stamp duty to tax short-term holders actually act like a trap, letting the investors into the market (buying) but limit their exiting (selling). The result of the trap is what we observe in the Singapore private housing market, i.e., the distorted price-volume relationship with transaction frozen but price upheld at high level, as well as decreasing cap-rate.

This paper is related to but different from the existing discussion on the effects of Tobin's tax on market stability. The existing criticisms on the effects of Tobin's tax include that Tobin's tax remove more informed investors (arbitrageurs) while the remaining are relatively non-informed and destabilize market (Fu, Qian & Yeung, 2013[22]), or weak Tobin's tax has limited impact due to overconfidence of market participants (Scheinkman and Xiong, 2003[51]). These existing

discussion does not specify what will happen after these so-called non-informed investors enter the market. Our results imply that, strong additional market frictions including strong Tobin's tax limit arbitrage and may not help stabilize the market. During the upward period of a market, additional transaction costs deter the selling more than buying, act as a trap and hamper market price correction (going down).

This is the very first draft. Due to data limitation, some of our empirical analysis suffer from insufficient observations. We are trying to get more updated dataset, expanding the sample period from April 2014 (the current version) to April 2016, we anticipate this will improve our results.

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Appendices

Appendix .A The figure for volume and index calculated based on our data sample

The figure for volume and index calculated based on our data sample is consistent with what we get from REALIS and URA.

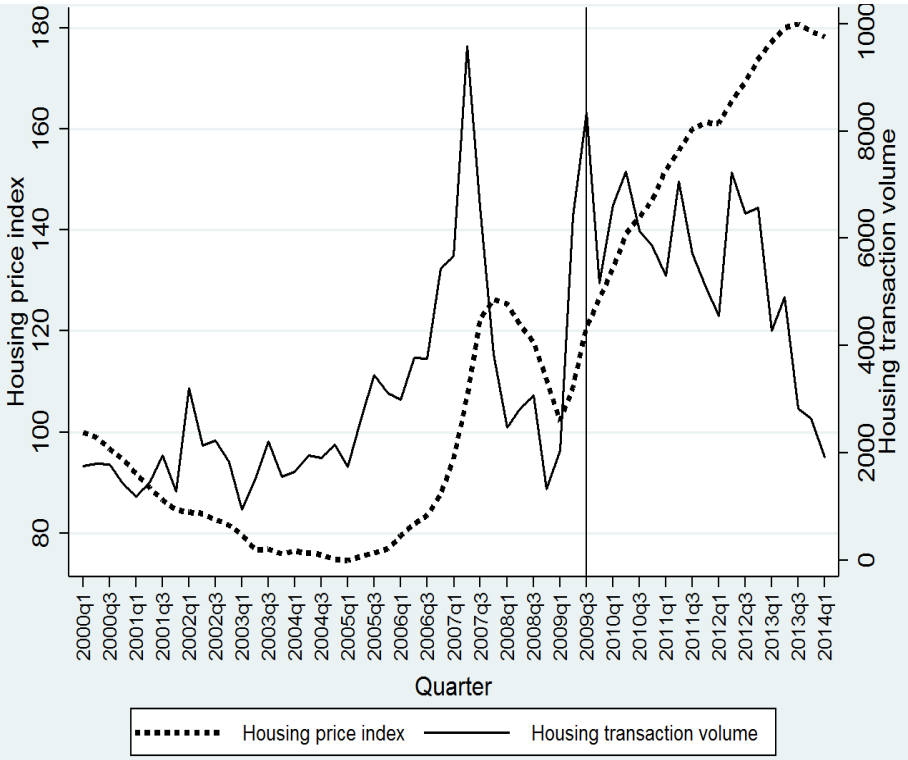

Figure 9: The divert of price index from sales transaction volume due to policies: 2000Q1-2014Q1

Appendix .B The "financial no-arbitrage condition for a prospect investors

As proposed by Case & Shiller (1990) [11] and Poterba, Weil & Shiller (1991)[47], in the short run, the arbitrage condition for a prospect investor is that the return from investing in a property is same as the return of investing in an alternative asset.

$$P \times i = R - P \times \omega \tag{8}$$

$P \times i$ is the return if investing the amount of money equivalent to housing price P to an alternative asset, and i is risk-free interest rate which is the risk-free return from the alternative asset; R is the current rent of the property; $P \times \omega$ is the user cost of owning the property, where P is the current price of the property and ω is the cost rate. (Note: Here we establish the discussion assuming

that the housing investor owns all the money and does not take mortgage, or assuming that the prospect investor can borrow or lend money at the same interest rate i.) The cost of owning a property ($P \times \omega$) can be specified as follows.

$$P \times \omega = \tau \times P + (m + \delta) \times P + \beta \times P - \pi \times P \tag{9}$$

τ is property tax rate, β is risk premium for owning the property, m and δ is maintenance cost rate and depreciation rate of the property, respectively; π is the expected nominal price appreciation. By rearranging the two equations, the "financial no-arbitrage condition for a prospect investor can be specified as the following Equation which is exactly the same as that for a prospect owner-occupier.

$$\frac{R}{P} = i + \tau + (m + \delta) + (\beta - \pi) \tag{10}$$

Appendix .C Other housing related policies like Property Tax Adjustments

1. 2006-2007 The Property Tax (Surcharge) Act was firstly enacted in 1974 to impose a surcharge, in addition to the property tax payable, for certain classes of properties held by foreign owners before 1 January 1974. The Act states that it will be in effect from 1 July 2006. On 22 January 2007, MOF repeals the Property Tax (Surcharge) Act.

2. Before Jan 2011 The tax rates for the owner-occupied properties and non-owner-occupied properties are as follows.

1. Owner-occupier's concessionary tax rate of 4%.
2. Non owner-occupied residential properties and other properties are taxed at 10%.

3. After Jan 2011 and Before Jan 2014 The government revises the tax scheme and adopt Progressive Property Tax Regime (PPTR) for owner-occupied properties.

Table 20: For 3. After Jan 2011 and Before Jan 2014

1) Progressive Property Tax Regime (PPTR) for owner-occupied properties	
0	First 6,000
4%	Next 59,000
6%	Above 65,000
2) Non owner-occupied residential properties and other properties are still taxed at 10\%	
3) Cessation of the 1994 GST Rebate	

4. From Jan 2014 The government revises the tax scheme and adopt Progressive Property Tax Regime (PPTR) for non-owner-occupied properties.

Table 21: For 4. From Jan 2014

1) Progressive Property Tax Rates For Non-Owner-Occupied Residential Properties		
Annual Value	Since Jan 1st 2014	Since Jan 1st 2015
First 30,000	10%	10%
Next 15,000	11%	12%
Next 15,000	13%	14%
Next 15,000	15%	16%
Next 15,000	17%	18%
Excess 90,000	19%	20%
Annual Value	Since Jan 1st 2014	Since Jan 1st 2015
First 8,000	0%	0%
Next 47,000	4%	4%
Next 5,000	5%	5%
Next 10,000	6%	6%
Next 15,000	7%	8%
Next 15,000	9%	10%
Next 15,000	11%	12%
Next 15,000	13%	14%
In excess of 130,000	15%	16%
2) Property tax refunds for unoccupied residential and non-residential properties will cease with effect from 1 January 2014.		

For policy round 2 Disallow co-currently owning an HDB flat and Private residential property.

Table 22: Disallow co-currently owning an HDB flat and Private residential property

	Before Aug 30th 2010	**Aug 30th 2010 Onwards**
Investment in Private Residential Property After Purchase of Non-Subsidised HDB Flat	No Restriction	5 Years of MOP
Disposal of Existing Private Residential Property After Purchase of Non-Subsidised HDB Flat	No Need	Within 6 months from Date of Purchase

Appendix .D A summary of the responses of the market immediately after each policy

The following Table summarizes the impacts of each policy expected by the public reported by the Strait Times Singapore. Most of reported policy expectations are from real estate specialists, few are from home buyers.

Table 23: The key words of news on each day immediately after each policy

News No.	Date of news	Key words
After Policy Feb 19th, 2010		
1	2/20/2010	Limited effect; small steps; tougher steps in the pipeline; unlikely significant effect on genuine buyers and investors;
2	2/21/2010	Prices to remain firm; prices to stablize;
3	2/21/2010	Prevent speculative bubble; do not target at genuine buyers and investors;
4	2/23/2010	Genuine demand not affected; Real estate stocks fall; heightens potential impact from future policies; negligible impact from the measures alone;
5	3/9/2010	Strong new home sales;
Policy Aug 29th, 2010		
1	8/31/2010	Rein in investors and speculators; prices soften; hit sentiment; price stablizes;
2	9/1/2010	Buying sentiment hard hit; waiting the policy effects to be more certain;
3	9/9/2010	Buyers are still keen; motivated by the policy to buy;
4	9/12/2010	Wait-and-see over property measures;
5	9/16/2010	Volume to fall
6	10/23/2010	Prices are likely to be fairly flat
7	11/23/2010	Additional steps will be taken
Policy Jan 14th, 2011		
1	1/14/2011	Effectively halt buying activity from property investors; drastic
2	1/15/2011	Harshest ever; buyers are forfeiting their 1 per cent booking fee; developers and property agents are cancelling their advertisements; price fall;
3	1/15/2011	Price to take a tumble; buyers have withdrawn offers or walked away; people worried;
4	1/28/2011	Volume to fall, not prices;
5	2/25/2011	Up to 5% fall in home prices
Policy Dec 8th, 2011		
1	12/8/2011	Unprecedented; toughest; price drop;
2	12/28/2011	Hurt economy;
3	12/29/2011	New property rules may go;
4	1/4/2012	Prices may have peaked
5	1/14/2012	Should sell quickly; panic selling is unlikely; sentiment on the ground is mixed; won't be a sharp drop in prices;

Note: In this table, the news are from the Strait Times Singapore, it is the highest-selling news paper in Singapore. We read through the news records related to Singapore housing market and selected key words as those which describe the expectation on the impacts of the housing policies. Most of the expectations about the policy impacts in the news are from real estate specialists. While, for Policy Aug 29th, 2010, there is one news which interviewed a home buyer, saying that he was motivated by the policy to buy.

Appendix .E Identification of 5 types of transactions

We identify 5 types of transactions, i.e., sales transactions in the asset market where owner occupiers as buyers (Own_Occup_B) and as sellers (Own_Occup_S), investors as buyers ($Invest\_B$), as well as the space market where landlords ($Landlord$) rent out their properties.

.E.1 Identifying a home buyer as an owner occupier or investor

Identifying an transaction to be bought by an investor: assuming that a home buyer buys a property (the first sales transaction observed), and sells it later (the second sales transaction observed). He is an investors if one of the following criteria is satisfied.

- If the second selling transaction is a sub-sale, the first sales transaction is bought by an investor.
- The first sales transaction is a presale (before TOP) and the second transaction is a resale. There is no rental transaction between the two transactions. If the interval between the second transaction and the TOP is no more than 2 years, then the first sales transaction is identified as bought by an investor.
- Both transactions are resales. The time interval between the two transactions is no more than 2 years and there is no rental transaction between the two transactions. Then the first sales transaction is bought by an investor.

Identifying an transaction to be bought by an investor: assuming that a home buyer buys a property, and rents it out later. The transaction is bought by an investor is the following criteria are satisfied:

- The first transaction is a presale (before TOP), the second transaction is a rental housing transaction. If the interval between the rental housing transaction and the TOP is less than 2 years, the sales transaction is identified as bought by an investor.
- For two consecutive transactions, the interval between the first sales transaction which is a resale and the subsequent rental transaction is no more than 2 years, then the sales transaction is bought by an investor.

Identifying a transaction is bought by an owner occupier: assuming that a home buyer buys a property, and sells it later if there are two sales' observations. The first transaction is identified as bought by an owner occupier is one of the following criteria is satisfied.

- For two consecutive sales' transactions, the first transaction is a presale (before TOP), the second transaction is a resale. There is no rental transaction between the two trades. If the interval between the second transaction and the TOP is larger than 2 years, the first sales transaction is identified to be bought by an owner occupier.

- For two consecutive transactions, the first transaction is a presale (before TOP), the second transaction is rental housing transaction. If the interval between the rental transaction and TOP is larger than 2 years, then the first sales transaction is identified to be bought by an owner occupier.
- For a housing unit, only one sale transaction is observed. The transaction is a presale (before TOP). If the interval between 2014 and the TOP is larger than 2 years, the first sales transaction is identified to be bought by an owner occupier.
- For a housing unit, two consecutive sales' transactions are observed. The first transaction is a resale, there is no rental housing transaction between the two trades, and the interval between the two trades is longer than 2 years. The first sales transaction is identified to be bought by an owner occupier.
- For a housing unit, two consecutive transactions are observed, the first sales transaction is a resale, the interval between the first sale's transaction and the subsequent rental housing transaction is longer than 2 years, the first sales transaction is identified to be bought by an owner occupier.
- For the last transaction of a housing unit, if it is a post-TOP new housing sale or a resale, and the interval between 31st April 2014 and the transaction date is longer than 2 years. This sales transaction is identified to be bought by an owner occupier.

It is important to note that, there are some transaction records unidentifiable:

- For a housing unit, this is the last transaction observed and it is a sale's transaction. The transaction is a presale (before TOP). If the interval between 2014 and TOP is shorter than or equal to 2 years, the home buyer is unidentifiable.
- For the last trade of a housing unit, if it is a post-TOP new housing sale or a resale, and the interval between 31 April 2014 and the trade is shorter than or equal to 2 years. The home buyer is unidentifiable. (This is because our dataset only covers the period before 31 April 2014)

.E.2 Identifying a home seller as an investor or an owner occupier

As mentioned in Section 3, all rental transactions in the space market are taken as transactions rented out by landlord. No matter the landlord acted as an owner-occupier or investor when he bought the property, we take him as an investor after when he rents out his property. Thus, if a property has been rented out, and then sold, the seller in the sales transaction is identified as investor.

In the two consecutive sales' transactions mentioned above, if the home buyer in the first transaction is identified as an investor, then the seller in the second sales transaction is investor, and the second sales transaction is identified to be sold by an investor. If the first sales transaction is identified to be bought by an owner occupier, and it has never been rented out during the holding period and then sold in the second sales transaction, the seller of the second sales transaction is an investor. The rest are those either sold by developers or cannot be identified.