

# Behavioural response to time notches in transaction tax: Evidence from stamp duty in Hong Kong and Singapore

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# Behavioural response to time notches in transaction tax: Evidence from stamp duty in Hong Kong and Singapore

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## Abstract

To moderate speculation in housing market, multiple Asian cities implemented transaction tax notches on holding period of property. Using administrative transaction record of property trading, this paper studies the behavioural response in the timing of transaction, tax incidence and selection of buyers using the policy changes in Hong Kong and Singapore. Tax notches on holding period generate significant tax avoidance bunching in the timing of transaction, and properties were less likely to be resold even one year after the tax last applies, suggesting plausible crowd out of transactions. I construct and use a new dataset on government estimated rental rate to estimate the tax incidence and find evidence that buyers bear significant tax burden even when tax-free alternatives are available in the market. Evidence shows that time notches on holding duration produce selection effect among buyers with different ex ante probability of trade in the taxable holding period. Estimates suggest that traders on average are willing to wait for 3-4 weeks to avoid 1% of transaction tax, and each week of delay in transaction would generate loss in the trading surplus at 0.3 % of property value.

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# 1 Introduction

Transaction tax on short holding duration of real estate properties has become a popular policy tool for governments in east and south east Asia since 2010. Hong Kong, Singapore, Macau, Taiwan and China introduced transaction tax with rates that vary with holding duration to deter speculation in the housing market.<sup>1</sup> Typically, residential property transactions are subject to an additional tax from 4-16% of the transaction price if the property is re-sold within 2 to 4 years. Moreover, the tax rate declines with the time seller holds the property. One intriguing feature of these tax instruments is that they have a flat tax rate for an extended period of time (e.g. 6 months), which then sharply decline once the time threshold is passed and thus constitute salient time notches. While transaction tax in the property market is present in many countries, there is very little evidence exist in the public finance literature for how would the market reacts to transaction tax and particularly those that are designed with objectives beyond raising tax revenue. This paper provide empirical evidence on understanding how the market react to transaction tax that have explicit inter-temporal design.

Is transaction tax on short holding duration an appropriate tool to stabilize the housing market? Speculators and middlemen re-sell faster than home-owners (Bayer et al., 2011), thus transaction tax on property with short holding duration may impose additional cost for speculators and create selection of buyers in the market. On the other hand, it distorts the trading behaviour for all traders including home-owners, by either the distinct tax avoidance incentives and the potential tax burden for new buyers. Recent studies in the UK shows that expected transaction tax increase of 1% in the property market could generate significant re-timing of transactions up to three weeks (Best and Kleven, 2015). The high transaction tax rate and sharp tax notches implemented in Asia may thus creates incentives for buyers and sellers to re-time their transaction, and discouraged welfare improving transactions if the cost of re-timing is too high.<sup>2</sup> In a way similar to the analysis of capital gain tax, properties could be “locked-in” by the tax, which could lead to equilibrium effect on transaction price where little is known empirically (Dai et al., 2008). Using comprehensive administrative record in property transactions of Hong Kong and Singapore, this paper analyses both the re-timing of transaction and

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<sup>1</sup>Hong Kong, Singapore introduced transaction tax that varies with holding duration in 2010; Macau and Taiwan had followed through in 2011.

<sup>2</sup>The design is similar to the long-term versus short-term capital gain tax in the U.S. (Shackelford and Verrecchia, 2002; Hurtt and Seida, 2004); Vermont had implemented capital gain tax on land with a similar declining tax rate with holding duration to deter speculation since 1970s. Daniels et al. (1986) argues that the capital gain tax on land had restricted supply and raise land price.; Ontario had implemented land speculation tax in April 1974 on gains on property transfer within a 10 year horizon, and as the a fixed percentage of exemption is applied every full year, it created tax notches each year same as the tax notches analysed in this paper. (Smith, 1976)

extensive margin crowd out that conceptually constitute the two main sources of welfare cost of transaction tax with differential tax rate on holding duration.

The government of Hong Kong introduced the “Special Stamp Duty” on 20th November 2010, in which for any residential properties purchased thereafter and resold within 2 years, transaction tax rates of 5-15% were applicable. Using the administrative record of property transaction in Hong Kong from 2009-2015, I construct the full transaction history of residential properties from 2009-2015. Comparing properties that are subject to the “Special Stamp Duty” to those that are not, I provide graphical evidence on significant bunching in property transactions when properties were held for exactly 2 years as the tax rate drop from 5% to 0%. With an regression discontinuity design, I find that properties subject to the tax are less likely to be traded in the first three years since purchase by 13 percentage points, taking into account of re-timing of transaction. This gives evidence to the significant reduction in transaction at the extensive margin generated by the tax even when tax avoidance is feasible, which implies non-trivial cost of transaction re-timing in the housing market.

Contrasting cash buyers versus buyers who took a mortgage, I first provide evidence that cash buyers on average are more likely to sell their property in the first year by 4.6% before the reform. Using an event study setup, I find the introduction of Special Stamp Duty increase the percentage of buyer with mortgage by 5.5%, suggesting the Special Stamp Duty creates selection among the new buyers. The tax distorts the trading behaviour on both type of buyers at the intensive margin regarding tax-avoidance behaviour, while the extensive margin crowd-out is much larger among the cash buyers.

To estimate the tax incidence, I use difference-in-differences strategy comparing transactions carried out under the taxable holding period (before 2 years) to those sold after the taxable period, as well as its counterpart for properties that are not subject to the Special Stamp Duty at all. This controls for time-varying factors in the housing market that may be correlated with the execution time of the tax. To control for property heterogeneity, I construct a new data set on government estimated rental rate for properties being traded in 2009-2015. This makes sure the tax incidence is identified by comparing properties observationally equivalent but subject to different tax liability, a methodology that is close to [Besley et al. \(2014\)](#). I find that with transaction tax rate of 5% the buyer bear 4% of the burden, but from that on every 5 % additional tax buyer only bear 1%. The significant burden on buyer in a market where tax-free alternative is available suggests that buyer’s property specific valuation is quantitatively important in housing transactions.

Under a simple search and match framework with Nash bargaining between buyer and seller with the option to re-time their transaction similar to that in [Slemrod et al.](#)

(2016), I apply the bunching estimation method in recent public finance literature (Best and Kleven, 2015; Chetty et al., 2011; Saez, 2010) to identify the time cost of deferring transaction. Exploiting both the time notches in the “Special Stamp Duty” and the “Seller’s Stamp Duty” introduced in Singapore at January 2011, where its design is highly similar to the “Special Stamp Duty” in Hong Kong, I provide estimates on the time traders are willing to wait to close the contract for tax saving purpose.

I find that traders on average are willing to wait for 3-4 weeks to avoid 1% of tax. The empirical estimates provide a way to quantify the welfare loss arising from delay in transactions, and it suggests that each week of delay in transaction would generate 0.3% loss of the average value of the property traded. It also provides quantitative benchmark for calibration in macroeconomic models that explicitly model dynamics in housing market with forward looking buyers and sellers, for example when the market thickness changes with seasonality or when moving decision is endogenous, that buyers and sellers have to decide to enter the market now or later (Ngai and Tenreyro, 2014; Ngai and Sheedy, 2016). Taking into account of both the extensive margin crowd out and the cost of re-timing transactions, I find that the “Special Stamp Duty” imposed 0.31% of welfare loss in terms of property values per holding.

The paper is divided as follows. The context of holding duration tax in Hong Kong and Singapore is described in Section 2. The data and empirical strategy are described in Sections 3 and 4 respectively, followed by results in Section 5. Section 6 presents the conceptual framework to understand the welfare effect of the tax. Section 7 present the estimate of delay cost using the framework. Section 8 conducts welfare analysis. Section 9 discuss some further implications of the tax instrument.

## 2 Transaction tax on holding duration: Context

Transaction tax on real estate properties are termed stamp duty tax in Hong Kong and Singapore. It is applicable to both residential and commercial properties, where the tax rates varies according to the bracket of the transaction price, with progressive marginal tax rate on price ranges from 1.5 % to 4.25%.<sup>3</sup> While the marginal tax rate in each price bracket differs, there are no notches in which the average tax rate changes at sharp price cutoffs (e.g. in contrast to that in the UK stamp tax system).

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<sup>3</sup>Figure A.3 plots the tax rate in Hong Kong as a function of price. Leung et al. (2015) studies the extent of tax avoidance to kinks in the static non-linear tax schedule.

## 2.1 Special Stamp duty tax - Hong Kong

With the aim to prohibit speculative purchases and make residential properties more affordable, the Hong Kong government introduced the Special Stamp Duty (SSD) for residential units on 20th November 2010.

The Special Stamp Duty regulates that for any residential properties obtained after 20th November 2010, an additional transaction tax would be levied if its next transaction occur within 24 months from its last transaction.<sup>4</sup> For units that are resold within 6 months a tax rate of 15% is charged, 10% for 6-12 months, and 5% for 12-24 months. At each of these cutoff date, average tax rate drop one day before and after the time notch.<sup>5</sup> On 27th October 2012 the government raised the tax rate and increased the holding duration where the tax is chargeable to 3 years. For properties resold within 6 months, tax rate of 20% is levied, while for those held for 6-12 months tax rate of 15% is charged. For properties in which the holding period were from 1 to 3 years, the tax rate become 10%. The tax schedule as a function of holding duration is plotted in Figure 1.

In principle, both buyer and seller are jointly liable for paying tax. In any efficient bargaining between buyer and seller, buyer paying the tax would maximize the total surplus of the transaction.<sup>6</sup> It is also a common practice in the housing market in Hong Kong for buyer to pay the stamp duty tax, therefore in the following analysis I implicitly assume that buyer is responsible for paying the tax.

The Special Stamp Duty was completely unanticipated by the market in both phases, and apply immediately to those properties traded thereafter.<sup>7</sup> Property obtained before the government announcement of the policy is not affected. Non-residential units are also not subject to the Special Stamp Duty.

## 2.2 Seller's Stamp duty tax - Singapore

Singapore first introduced the Seller's Stamp Duty on 20th February 2010. Under the Seller's Stamp Duty, residential properties sold within one year is taxed at 1-3% of the transaction prices, depending on the price bracket of the property. The exact tax rate

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<sup>4</sup>This tax is levied on top of the underlying tax schedule.

<sup>5</sup>The duration of holding is defined as the time lapse between two legal documents that are subject to stamp duty tax, which includes most provisional agreements signed

<sup>6</sup>Since this minimize the transaction price on paper and thus lower the amount of tax paid out of the joint surplus.

<sup>7</sup>There are conditions in which the tax could be exempted: 1. the property is transferred to close relatives; 2. re-selling by financial institutions under the condition of mortgage default 3. transfer of property to government/charitable organizations 4. mandated selling by the court 5. selling of inherited properties 6. selling under bankruptcy 6. transfer of residential properties between related corporate body <http://www.ird.gov.hk/chi/faq/ssd.htm>

is a function of the transaction price - which creates a tax structure similar to the one studied by [Slemrod et al. \(2016\)](#) in Washington D.C., where there is a simultaneous decision problem in bunching at price versus bunching in time. Properties sold with holding period beyond one year face 0% rate from the Seller's Stamp Duty.

For properties obtained between 30th Aug 2010 to 13th Jan 2011, the taxable holding duration were extended to 3 years. Moreover, notches were introduced in 1 and 2 year, where the average tax rate drop by 1/3 at the 1 and 2 years cutoff. Therefore the size of the tax notch varies with the price bracket, for example, for properties with price smaller than 180,000SGD, selling within the first year implies 1% of tax rate, and the time notches have reduction in average tax rate of 0.33% in both the 1 and 2 years cutoffs.

In 14 Jan 2011, the tax rate were raised to 16% for selling within the first year, 12% for property sold in 1-2 year, 8% for property traded in 2-3 year, and 4% for property traded between 3-4 year. This tax structure follow exactly the same as that in Hong Kong, with a smaller drop in average tax rate at size of 4%. Also, the period that subject to the tax is longer than that in Hong Kong.<sup>8</sup> The tax schedule of the Seller's Stamp Duty after 14 Jan 2011 is plotted in Figure 11.<sup>9</sup>

### 3 Data

This paper uses government administrative transaction record of properties in Hong Kong, covering 2009-2015. The data contains information of more than 3 million contracts that is filed at the Land Registry for registration of tax purposes and is titled Memorial Day Book. It contains sets of contracts signed and lodged to the Land Registry for formal registration, including provisional/formal agreements of sales and purchases, assignment of the properties and mortgage agreement. The agreement of sales and purchases for residential property provide information on the date, address, value of the transaction as well as stamp duty paid. For each property I observe the history of transaction from 2009, I could therefore construct the duration of holding before its next sold, a key variable for the analysis that follows. From 2009-2015 there are 480,351 residential transaction records.<sup>10</sup>

The holding duration where the Special Stamp Duty applies counts from the first agreement that is registered to the Land Registry, which could either be a formal or provisional agreement of sales and purchases. While provisional agreements were signed

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<sup>8</sup>Source: [Inland Revenue Authority of Singapore \(2011\)](#)

<sup>9</sup>The transition of the seller's stamp duty for properties worth less than 180,000 SGD is summarized in Figure 11

<sup>10</sup>See data appendix for more detailed description.

before the formal agreement as common practice, only those that had a significant lag between the two would require registration of the provisional agreements.<sup>11</sup> In the empirical analysis I correct for the date of purchases to the date of which the provisional agreement is signed, if such provisional agreement exist in the Land Registry record.

For each residential transaction, I match it with the mortgage record filed to the Land Registry, a common procedure for transaction where the property were purchased under mortgage. This allows for construction of an indicator for whether the buyer purchase the properties with cash or with mortgage.

I collect data on the rateable values, the government estimates of open market rents adjusted according to property specific characteristics, for each properties being bought and resold within the period 2009-2015, dated at October 2015. Rateable values are used for tax purpose, as property owner are liable to pay the rate for each property which is around 3-5 % of the rateable values, similar to the council tax in the UK. The Rating and Valuation department states that the value adjust for property characteristics, including age, size, location, floor, direction, transport facilities, amenities, quality of finishes, building maintenance/repair and property management.<sup>12</sup> This provides a single measure of observables of property to control for property heterogeneity in the empirical analysis. It is important to note that the assessment of the rateable value is not affected by any sales restrictions or ownership status of the property.

I also obtained administrative record for Singapore residential properties transaction record from the Real Estate Information System of the Urban Redevelopment Authority of Singapore, from 1995 to 2015, which consists of 431,359 records during the period.

## 4 Empirical Setup and Measure

### 4.1 Extensive margin response

I first use regression discontinuity design to estimate the effect of the Special Stamp Duty on the probability that a property is being resold before 2 years where the transaction is taxable and up to 3 years where the transaction is not taxed. This quantifies the extent in which the Special Stamp Duty change the trading pattern.

Specifically, I exploit the fact that for properties purchased one day before the 20th November 2010, there is no tax liability on all holding duration while those purchased right

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<sup>11</sup>Usually the provisional agreement had to be registered if its lapse with the formal agreement is more than 14 days

<sup>12</sup>It is published for the public every year from March to May upon search.



on the 20th November it is liable for the tax. By comparing the behaviour of purchaser before and after the application of the tax locally, who face almost identical demand condition in the market following the purchases, one could identify the behavioural response that comes from the side of seller. Moreover, with the assumption that purchaser who signed the agreement one day before and after the application of the tax are similar in their selling behaviour in the absence of tax conditional on observables, one could identify the treatment effect of the tax schedule on the trading pattern.

In particular, the Special Stamp Duty introduced on 20th November 2010 had taxable period of 2 years, and with distinct tax rate at transaction of holding period before and after the cutoff of 6 months, 1 year and 2 years. I thus construct indicator  $T_y$  of whether a property is traded within  $y$  years since last purchased, where  $y$  belongs to 6 months, 1 and 2 years.

To measure the extent of extensive margin response, one must take into account of the re-timing in transaction due to tax avoidance incentives. If transaction could be perfectly re-timed by incurring cost that is low relative to the surplus of the transaction, one would observe that the probability of a property being resold not to be affected at horizon after 2 years. However, if re-timing is costly and the magnitude of tax is large relative to the size of surplus, then the tax on holding duration could cause significant crowd out, which could in turn have first order impact in welfare. I thus further construct the indicator  $T_y$  for the 3 year horizon, allowing for one year of potential re-timing of transaction.

I estimate the following linear RDD regression for each property  $i$  and spell  $j$  around 20th November 2010,

$$T_{y,ij} = \alpha + \beta\tilde{t} + \rho D_t + \beta_2 D_t * \tilde{t} + \eta_{ij} \quad (1)$$

where  $t$  is measured in days.  $\tilde{t} = t - \hat{t}$  where  $\hat{t}$  represent 20th November 2010, thus  $\tilde{t}$  is the time difference in days from 20th November 2010.  $D_t$  is an indicator for  $t \geq \hat{t}$ .  $T_{y,ij}$  is an indicator if a property holding is resold within  $y$  years since its purchase.

The coefficient of interest is  $\rho$ , which capture the difference in probability of re-trade in  $y$  years locally between purchaser who are subject to the tax and those who are not.

## 4.2 Tax incidence

The reduced form effect of tax burden on buyers and seller could be estimated with the following equation

$$\ln P_{ijt} = \beta_1 * H_{ij,6} * post_{ij} + \beta_2 * H_{ij,6-12} * post_{ij} + \beta_3 * H_{ij,12-24} * post_{ij} + \sigma_s + \gamma_t \ln RV_i + \gamma_{t2} \ln RV_i^2 + \delta_t + \epsilon_{it} \quad (2)$$

where  $\ln P_{ijt}$  is pre-tax price for property  $i$  of spell  $j$  at time  $t$ .<sup>13</sup>  $H_{ijs}$  is an indicator for property  $i$  held for  $s$  months,  $post_{ij}$  is an indicator that equals 1 if Special Stamp Duty is applicable to the property spell  $ij$ , i.e. bought between 20th Nov 2010-27th Oct 2012.  $\sigma_s$  is month of holding FE at broad group category of 0-6 months, 6-12 months, 12-24 months and beyond 24 months.  $\delta_t$  is fixed effect for the time in which the transactions occur, this allows us to control for any changes in average buyer's valuation affected by the tax.

$\ln RV_i$  is rateable value of property  $i$  measured at Oct 2015. As described in the data section, this is the government estimated open market annual rental value in October 2015, which summarizes many property specific characteristics. This control for most relevant heterogeneity of the property. As rent-price ratio can varies in the long run (Gallin, 2008), I allow for arbitrary time variant fundamental relation between rental rate and transaction price by allowing  $\gamma_t$  and  $\gamma_{t2}$  to varies over time at month level. In general, I could include an polynomial of  $\ln RV_i$  at higher order level, but as shown as the robustness section, the inclusion of 3rd or higher order makes very little difference to the empirical results.

### 4.3 Transaction Re-timing

To capture the overall effect and discontinuity in probability of trade generated by the Special Stamp Duty, I estimate the following hazard function flexibly at week intervals:

$$T_{ijt} = \sum_{j=0}^J w_j I_j + \epsilon_{it} \quad (3)$$

where  $T_{ijt}$  is an indicator of whether a trade happen for property  $i$  at time  $t$  at the  $j$ th week since it was last purchased.  $I_j$  is a set of fully flexible dummy variables that capture the baseline hazard.<sup>14</sup> Equation 3 is estimated separately for residential properties in Hong Kong purchased in 3 periods: 1) 1st January 2009 - 20th November 2010 where there is no tax liability as function of holding duration; 2) between 20th November 2010-26th October 2012 where time notches are present in the 6, 12, 24 months and 3) on or after 27th October 2012 where time notches are present in 6, 12, 24, 36 months. As far as the data allows, I estimate equation 3 taking  $J$  up to 158 weeks. That allows one to capture any re-timing effect up to the third year.

The degree of re-timing would be captured by the estimate  $w_j$  where  $j$  equals the time of the notch. One would expect the probability of trade to be much higher right on the notch, and if there is any market friction that prevent trading happening exactly at time

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<sup>13</sup>A spell is defined as a holding that start since a transaction occurred

<sup>14</sup>Estimating Equation 3 by OLS is equivalent to the Kaplan-Meier estimator

$\bar{t}$ , one would also see that for the immediate weeks after the notch the estimate  $w_j$  would still be higher than the counter-factual  $w_j$  as estimated using properties without the tax liability. Correspondingly, one would observe  $w_j$  would be lower than counter factual for weeks immediately before the time notch.

Similarly for Singapore I estimate the hazard function of trade up to 5 years as the data allows, to capture any re-timing effect following the time notch at the 4 years since purchase.

#### 4.4 Type selection

To identify the selection effect of the Special Stamp Duty on new buyers, I estimate the proportion of transaction where mortgages are filed in each week before and after the introduction of the tax. I estimate the following event-study equation using transactions of residential properties that has price below HKD 6,800,000, a price range with minimal change in loan-to-value ratio limit in the mortgage market for period 3 months before and after 20 November 2010<sup>15</sup>

$$m_{it} = \beta + \beta_1 * \sum_{b=-24}^{24} w_b I_b + \mu_i + \gamma_{dm} + \epsilon_{it} \quad (4)$$

$m_{it} \in \{0, 1\}$  is an indicator equal to 1 if the property  $i$  at time  $t$  is purchased by mortgage buyer.  $I_b$  is an indicator of whether the transaction  $it$  occurred  $b$ th weeks before or after the application of Special Stamp Duty phase 1. To increase the power and control for seasonality, I estimate the following regression:

$$m_{it} = \beta + \beta_2 * \text{After}_{it} + \mu_i + \gamma_{dm} + \epsilon_{it}$$

further including district-month of the year fixed effect  $\gamma_{dm}$  by extending the sample from July 2009 to March 2011, and property fixed effect  $\mu_i$  to control for unobserved characteristics of the property.

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<sup>15</sup>If any of the exogenous reduction in loan-to-value ratio limit in this period have effect on mortgage demand, the estimate in this section provide a lower bound of the selection effect. See Figure A.4 for a graphical summary of change in loan-to-limit ratio since 2009 in various price range.

## 5 Results

### 5.1 Re-timing and extensive margin response

Figure 2 plots the RDD graphs on the probability of re-sale in different time horizon since purchase by the day of the property was being obtained. The outcome variables are accumulative in each of the panels in Figure 2, thus the probability of being resold in 3 years in panel (a) is by definition larger than the probability of being resold in 6 months in panel (d). It is clear from all the panels in Figure 2 that there is a sharp discontinuity on 20th November 2010. For purchasers who purchase one day after 20th November 2010, the probability of resold in 6 months, 1 year, 2 years and 3 years are all significantly lower than those before it.

Table 1 reports the RD estimate of equation 1. Column (1) shows the coefficient for the effect of the tax on probability of re-sold in 3 years, where the estimate for  $\rho$  is -0.133 and is highly statistically significant, suggesting that purchaser who are subject to the tax are less likely to trade in 3 years by 13 percentage point. The baseline probability of a property being resold in 3 years is 29 percentage point, in which the treatment effect suggest a very large drop in the transaction at extensive margin. On the other hand, the estimates for  $\rho$  in column (4) for probability of resold in 6 months is exceptionally large at -0.0743 in relation to its baseline mean which is 7.59 percentage point, suggesting that the Special Stamp Duty reduced trade at very short duration dramatically.

I further estimate equation 1 by the type of buyers with or without mortgage. The treatment effect for buyers on the chance of resold in 3 years, for those without any mortgage is 16.6 percentage point, and is bigger than those without mortgage, where the treatment effect is 11.6 percentage point. This provide evidence that the tax has a stronger extensive margin effect on purchaser who are more likely to re-trade in early period.

Table 3 report estimate of equation 1 for the holding duration conditional on a property holding is resold before 31st December 2015. Column (1) report the estimate for all property holdings, while the average holding duration conditional on sales is 733 days before the treatment, the Special Stamp Duty increase the holding duration conditional on sales by 334 days. Comparing column (2) and (3), the magnitude of the treatment effect is of the same order of magnitude for property holding that is associated with or without mortgages.

Table 4 reports estimate of equation 1 on the probability of a property being resold in 5 years for the effect of Seller's Stamp Duty Phase 3 on 14 Jan 2011, where the maximum taxable holding period is up to 4 years and therefore capture the extensive margin effect

taking potential re-timing of transaction into account. The coefficient estimate is -0.058, which suggest that property were less likely to be re-traded in 5 years by 5.8 percentage point. The related RDD graph is plotted in Figure A.7.

I also conduct the test on continuity of the density around the cutoff date as suggested by McCrary (2008). Panel (a) and (b) of Figure A.8 plot the density of trading day around 20th Nov 2010 for Hong Kong, and the graphs suggest that there is discontinuity in the density of trade around this period of time. The density mass of the transaction on the day the policy announced on 19 Nov 2010, which is a Friday, is not significantly higher than previous Friday, implying there is very little manipulation in the conventional sense. It suggest that the discontinuity is mainly driven by reduction in transaction after the application of the policy, which is by itself an outcome of the tax policy. The graphical evidences from Figure 2 display no discontinuous change in the outcomes to the left of the cutoff, again confirming that the RD estimate is unlikely to be confounded by manipulation.

## 5.2 Tax incidence

Table 5 shows the coefficient estimates for equation 2 for transaction price of residential properties sold in 2009-2015 in Hong Kong. Column (1) leaves out (log) rateable values as control while column (2) includes it. The coefficients of interest are *post\*sold 6m*, *post\*sold 6-12m* and *post \*sold 1-2year*. The estimate for *post\*sold 6m* is -0.0103 %, implying that property traded with 5% tax are associated with 1.03 % lower price for seller, and the buyer pay 3.97% higher price for the property that are observationally equivalent to property that are not subject to the tax in the same market. The coefficient *post\*sold 6-12m* is -0.0505 and statistically significant, suggesting that property that are subject to 10% special stamp duty were traded at price 5.05 % lower, and thus buyers are paying 4.95 % higher price for the property. For property that are sold within the first 6 months are sold on average 8.85 % lower seller price, where it is subject to tax rate of 15%. This suggest that buyer pays around 6.15% higher price.

The difference between the estimates for *post\*sold 6m*, *post\*sold 6-12m* is around 0.038 and the difference between *post\*sold 6-12m* and *post\*sold 1-2year* is around 0.04. For every additional increase in the tax rate from 5% to 10% and 10% to 15%, the buyer only bear around 1 % of the additional tax, while the seller receive price that is 4% lower.

Comparing column (1) and (2), there are significant selection in the value of properties being traded under high transaction tax. In column (1) where I did not include rateable value as control, the *post\*sold 6m* coefficient is positive, in line with the pattern

observed in Figure 15, in which the median transaction price is plotted against the holding duration. The coefficient become significantly negative once we control for rateable values, suggesting that selection on observables explains a large proportion of the positive coefficient in column (1). Similarly, the coefficient *post\*sold 6-12m* is not statistically significant and is close to zero in column (1), while it turns into negative and significant once I control for rateable value. This suggest that properties at a higher price range have a larger mass for having surplus beyond 10%.

Figure A.10 plot the relationship between the log price and log rateable values for the sample in 2009. It shows the log rateable value is highly correlated with transaction price in a stable manner. In Table 6 I examined whether second order polynomial is a good fit for Rateable value as control for observables in the transaction price. I estimate equation 2 using 1-4 order polynomials from column (2)-(5). Upon the 2nd order polynomial, the estimates are very robust to adding additional polynomial terms. This suggest that 2nd order polynomial is a very good fit for rateable value to predict transaction price.

### 5.3 Transaction re-timing

Figure 5 plots the coefficients of  $w_j$  in equation 3 for properties that are purchased between January 2009 to 19th November 2010 and from 20th November 2010 to 26th October 2012. There is significant re-timing for transaction, and sharp discontinuities are observed in each of the time notch. There are three salient patterns 1) the tax schedule unambiguously decrease the probability of trade within the first 2 years of purchases; 2) the probability of trade increase dramatically at exactly 2 year, the last tax notch where the tax rate drop to 0; 3) the excess probability of trade is decreasing gradually after the 2 year time notch. Pattern (2) and (3) together provide sound evidence that many trades in the market are intentionally shifting their trading time to avoid the 5% tax rate within the 1-2 year window of holding period.

The reduction in the probability of trade within the first 2 years is proportional to the magnitude of the tax. Within the first year, the decline in the probability of trade is around 0.2-0.4%, which is almost equal to the pre-treatment average. In the 1-2 year period, the treatment effect is around 0.15%, and the probability of trade after the application of Special Stamp Duty is decreasing as one approach the 2 year time notch.

Figure 8 plot both the hazard function of trade and the coefficients of  $week_j$  in equation 3 by whether the transaction has a affiliated mortgages. Panel (a) plotted the hazard function by type of buyers for properties obtained under period that is unaffected by the tax, which shows cash buyer are more likely to trade within the first year, while starting from the second year the difference diminished or even reversed. The treatment effect

of tax plotted from panel (b) shows that the Special Stamp Duty has a much stronger impact on cash buyer than buyer who filed mortgages, mainly due to the fact that cash buyer has a larger baseline probability of trading below 1 year. The probability of trade in the 1-2 years period on both type of buyers from 1-2 year period are indistinguishable after the application of the tax. And both exhibit similar degree of bunching towards the 2nd year time notch.

## 5.4 Selection of buyer

Figure 9 plot the estimates of coefficients of time  $t$  in equation 4. The base group is on the third week of November 2010. The coefficients are not statistically significant from zero before the introduction of Special Stamp Duty, and also exhibit no trends. The estimates of the time coefficients after third week of November 2012 are slightly positive and become statistically significant at around 0.05 percentage point after the 5th weeks.

Table 7 shows the estimation results of equation 4. Column (1) report the coefficient that cover sample of 2 months before and after the introduction of Special Stamp Duty. The estimates suggest that after the introduction of the special stamp duty tax, 1.7% of the buyer are buyers who would filed mortgage, compare to period in which the Special Stamp Duty was not in place. Column (2) and (3) extends the sample to 3 and 4 months before and after the Special Stamp Duty and the coefficient is largely similar in magnitude.

Column (4) extends the sample to July 2009 to March 2011, and control for district-month of the year fixed effect to control for seasonality in the last quarter of the year. The estimate become 2.92%, which is very close to estimates in column (1)-(3). Column (5) control for property fixed effects, and the coefficient become even bigger at magnitude of 5.52%. The evidence suggest that after the introduction of the Special Stamp Duty among the new buyer there is 2-5% more of those filed mortgages.

## 6 Conceptual framework

In this section I provide an empirically relevant framework to understand the welfare implication of transaction tax on holding duration. The market response and welfare cost of transaction tax with time notches largely depends on the time preferences of representative buyers and sellers. (Slemrod et al., 2016) If buyer and seller has low adjustment cost in transaction time, a time notch may generate significant bunching toward the side with lower average tax rate to avoid tax. (e.g. the right hand side of the time notch in Figure 1) This means the tax would shift the timing of transaction, but few matched transactions would be forgone. On the other hand if adjustment cost is high, there would

be limited tax avoidance behaviour, but transaction with low surplus would be crowded out from the market depending on the size of the tax rate.

Central to this, I present a stylized model on buyer and sellers simultaneous decision on transaction price and trading time, simplified from [Slemrod et al. \(2016\)](#). In the empirical section I would show that its prediction match the basic pattern of the market reaction, and argue that it provides a framework for identifying the adjustment cost in time for transaction. In the model, buyers and sellers explicitly prefer early trading date.<sup>16</sup> The trade-off in the optimal trading time at the intensive margin naturally features intertemporal decision between tax saving and disutility associated with delaying transaction.

Consider a pair of matched buyer and seller who value the property by  $H$  and  $u$  respectively, at time  $t$  counting from the seller last bought the house. The buyer and seller bargain over the price and trading time through Nash bargaining. A tax notch is set by the government, where the transaction is taxable at rate  $\bar{\tau}$  if the trade is executed at time  $T$  when  $T < \bar{t}$ , otherwise tax rate  $\underline{\tau}$  applies where  $\underline{\tau} < \bar{\tau}$ .

The seller's surplus in a transaction is

$$S_v = p - u - k_v(T - t)$$

where seller receive price  $p$  over losing the reservation value  $u$ .  $k_v(T - t)$  capture the time preference of the seller, and  $T - t$  is the time between the transaction and the match was first formed. Assume that  $k_v > 0$  so that the seller prefer trading earlier.  $k_v$  is thus the utility cost in delaying transaction *per unit of time*.  $k_v(T - t)$  could be considered as first order local approximation for a general function of  $T$  and  $t$ .

Similarly, the buyer's surplus is

$$S_b = H - p(1 + \tau) - k_b(T - t)$$

where the buyer get the valuation  $H$ , pay the price  $p$ , and are subject to tax rate  $\tau$ , where  $\tau \in \{\underline{\tau}, \bar{\tau}\}$ .  $k_b(T - t)$  capture the time preference of buyer, with  $k_b > 0$  so that the buyer also prefer to trade sooner than later.

The trading time  $T$  and price  $p$  is determined by Nash Bargaining that maximize the joint surplus, i.e.

$$\max_{T,p} (S_b)^{1-\theta} (S_v)^\theta$$

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<sup>16</sup>Where in [Slemrod et al. \(2016\)](#) it is modelled as buyer and seller having an ideal trade-date, a setup that is more relevant when considering an increase in tax rate after a fixed date



If trade happen at time  $T$ , transaction price would follow the first order condition  $(1 + \tau)(1 - \theta)S_v = \theta S_b$ , explicitly given by the following

$$p(T, t, H, u) = \begin{cases} \frac{\theta}{1+\bar{\tau}}H + (1 - \theta)u & \text{if } T = t \\ \frac{\theta}{1+\bar{\tau}}[H - k_b(\bar{t} - t)] + (1 - \theta)(u + k_v(\bar{t} - t)) & \text{if } T = \bar{t} \end{cases} \quad (5)$$

To maximize the joint-surplus, only  $T = \bar{t}$  and  $T = t$  would be chosen, therefore a match between of buyer and seller, depending on the respective size of  $H$  and  $u$ , would decide upon: 1) trade immediately at time  $T = t$ , 2) bunch at the time notch  $T = \bar{t}$ , or 3) no trade at all.

To understand better the trade-off, a pair of buyer and seller would choose to trade exactly at the time  $\bar{t}$  if

$$S_b(T = \bar{t}) + S_v(T = \bar{t}) > \max\{S_b(T = t) + S_v(T = t), 0\}$$

When  $\tau = 0$ , the condition in which the match would wait until  $\bar{t}$  to trade could be further reduced into

$$p(t, t, H, u)\Delta\tau_t > (k_b + k_v)(\bar{t} - t) \quad (6)$$

where  $\Delta\tau = \bar{\tau} - \tau$ . The left hand side of equation 6 is the tax saving of executing the transaction at time  $\bar{t}$  instead of time  $t$ , while the right hand side of the equation is the total utility cost of delaying the transaction by  $\bar{t} - t$  unit of time.<sup>17</sup>

**Proposition 1** *Assume that  $H$  and  $u$  follows some joint distribution of  $G(H, u)$ , if time preference for trade is weak, i.e.  $k_b + k_v$  is small, then more transactions would trade exactly at  $\bar{t}$ , less transactions are carried out at  $t < \bar{t}$*

Proposition 1 says that when time preference is weak, the buyer and seller has little to lost by delaying the trade date. This also implies that we may observe very few transactions realizing before  $\bar{t}$ . One thing to note is that the shifting in timing of transaction need not depends only on the time preference of the seller even if the tax is seller specific. In an economy where the seller has distinct characteristics than the buyer, in terms of demographics or economic wealth<sup>18</sup>, both the time preference for buyer and sellers affect how the market response to the tax.

<sup>17</sup>The general case where  $\tau \neq 0$  is  $p(t, t, H, u)\Delta\tau_t > (k_b + k_v)(\bar{t} - t) - \Delta p_{t\tau}$

<sup>18</sup>e.g. [Lawrance \(1991\)](#) finds that poorer households has higher rate of time preference

**Proposition 2** *At the notch of which  $\tau = 0$ , and some joint distribution of  $H$  and  $u$   $G(H, u)$*

1. *the probability of trading at time  $t$  decrease as  $t$  get closer to  $\bar{t}$ , for  $t < \bar{t}$*
2. *The observed reduction in probability of trade at  $t < \bar{t}$ , where the tax rate drop to 0 after  $\bar{t}$ , is larger than the case with a tax policy that applies tax rate  $\tau$  for all trading time  $t$*

When  $\tau = 0$ , the decision between trading immediately or delaying transactions depends on the relative rate of decline between the saving of tax with the utility lost of delaying. In general, the disutility decline with the rate  $k_b + k_v$  when one get closer to  $\bar{t}$ , while the savings by tax decrease by the rate  $((1 - \theta)k_v - \theta k_b)\Delta\tau_t < k_b + k_v$ . Thus the probability of trade at time  $t$  for  $t < \bar{t}$  is decreasing in  $t$ .

The condition in which the three decisions are determined are illustrated in Figure A.12. It plots the combination of different  $H$  and  $u$  with the relevant constraints when  $\tau = 0$ . In the absence of tax, trade would happen for  $H$  and  $u$  when surplus is strictly positive.

When a transaction tax  $\tau$  is introduced, only matches with surplus higher than  $\tau$  percent of the reservation value of seller are traded. However if a time notch in  $\bar{t}$  is present, some matches that would yield non-positive surplus under tax  $\tau$  would then have positive surplus by waiting until  $\bar{t}$  to trade (i.e. area B in Figure A.12).

The empirical prediction in Proposition 2 can be seen by conducting comparative static with respect to  $t$ . For matches formed far away from  $\bar{t}$  implies a higher  $(k_b + k_v)(\bar{t} - t)$ . The line  $H - u \geq k(t)$  and the downward sloping dotted line would both move to the right. The area  $B + W$  would unambiguously decrease, and the area  $T + A$  would increase. When matches are formed far away from the time notch  $\bar{t}$ , the probability of trading at time  $t$  thus increase.

Consider an exogenous increase in  $\tau$ . Less transactions have the surplus over reservation value ratio higher than the tax rate, but at the same time it lowers the cutoff of  $p_d$  in which it is worth trading exactly at  $\bar{t}$ .

## 6.1 Selection on buyers and effect on equilibrium price

The application of transaction tax with rates that decrease with holding duration could create selection on type of buyers and changes the outside option of buyer in the search process.

If buyers have predetermined characteristics  $\theta$  that could predict average trading time of the property in the future, buyers with different  $\theta$  would foresee to face a different tax rate in expectation. In particular, the valuation of a buyer at the time of buyer could be represented as

$$H = \phi(\theta)\underline{u}(\tau) + (1 - \phi(\theta))\bar{u} - z(\tau) \quad (7)$$

where  $\underline{u}(\tau)$  is the present discounted value of selling in period  $t < \bar{t}$ ,  $\bar{u}$  is the present discounted value of selling in period  $t > \bar{t}$ , as long as  $\underline{u} < \bar{u}$ , there would be more buyer in the market with characteristics  $\theta_h > \theta_l$  with  $\phi'(\theta) > 0$

Furthermore, by reducing the probability of buyer matched with seller with positive surplus, the tax can affect the outside option of the buyer in the bargaining process. For example, the outside option  $z(\tau)$  could be decreasing in  $\tau$  if the tax reduce the effective supply. On the other hand if the selection effect reduce the number of buyers in the market, it may increase the chance the buyer meeting another seller with positive surplus, in that case  $z(\tau)$  would be increasing in  $\tau$ . Formally endogenizing the outside option for buyer is beyond the scope of this paper.

## 7 Estimating waiting time and welfare cost of delayed transactions

To quantify the effect of the tax notch on trading time, I estimate the average waiting time for traders in the market  $\bar{t} - t(H, u)$ , where  $t(H, u)$  is defined by rewriting equation 8 in the following form for each pair of  $H$  and  $u$ :

$$p(H, u)\Delta\tau_t = (k_b + k_v)(\bar{t} - t(H, u)) \quad (8)$$

$t(H, u)$  could be interpreted as the cutoff trading time for a transaction with price  $p(H, u)$ . If the seller meet a buyer at time  $t$  where  $t \in \{t(H, u), \bar{t}\}$ , the optimal trading time would be at time  $\bar{t}$ . For a given tax notch  $\tau$ , expectation of the cutoff trading time and  $\bar{t}$  across all the potentially profitable trades,  $E(\bar{t} - t(H, u)|H - u > \tau u)$ , would be the average waiting time for which the market would be willing to delay the transactions to time  $\bar{t}$ .

Assume that the density of arrival time of matches is  $l(t)$ , and the density of trading time in the presence of tax  $\tau$  is  $g(t)$ , which could be estimated from the data, the excess mass  $B$  at  $\bar{t}$  could be represented as

$$B \approx \int_{H-u > \tau u} \int_{t(H, u)}^{\bar{t}} l(t) dt dG(H, u) = g(\bar{t})(E(\bar{t} - t(H, u)|H - u > \tau u)) \quad (9)$$

where  $G(H, u)$  is any joint distribution function of  $H$  and  $u$ .<sup>19</sup>

The approximation is more accurate if the extensive margin response near the time notch is negligible. Under existence of extensive margin response locally at the time notch, the bunching estimates could provide a upper/lower bound of the quantity of interest,  $(E(\bar{t} - t(H, u)|H - u > \tau u))$ , by scaling the excess bunching mass with the density of the counter-factual density with tax rate 0 or with tax rate  $\tau$ , which I provide more discussion on it in the appendix.<sup>20</sup> Following the existing literature as in [Best and Kleven \(2015\)](#) and [Chetty et al. \(2011\)](#), I estimate the counter-factual density  $g(t)$  using the following equation:

$$b_j = c(j) + \sum_{k=\bar{t}-R}^{k=\bar{t}+R} \delta_k \mathbb{I}[j = k] + \mu_j \quad (10)$$

where  $b_j$  is the bin count in holding duration for  $j$ th weeks,  $c(j)$  is a 7th order polynomial in terms of number of weeks, and  $\mathbb{I}[j = k]$  is a set of dummies for  $R$  week before and after the tax notch at  $\bar{t}$ .<sup>21</sup> The prediction of this equation,  $c(\bar{t})$ , is going to provide an estimate of the counterfactual density  $g(\bar{t})$ , conceptually by excluding the weeks immediately before/after  $\bar{t}$ . Thus we could compute the estimate using equation 9.

$$\hat{E}(\bar{t} - t(H, u)|H - u > \tau u) \approx \frac{\hat{B}}{g(\bar{t})}$$

where  $\hat{B}$  is computed using the observed excess bin count around  $\bar{t}$ .

The ratio of waiting time to tax bear an intuitive interpretation for estimating the utility cost of  $k_b + k_s$  as percentage of trading price, by taking appropriate expectation over equation 8 and rearranging terms:

$$\frac{\Delta\tau}{E(\bar{t} - t(H, u)|H - u > \tau u)} = \frac{k_b + k_s}{E(p|H - u > \tau u)} \quad (11)$$

## 7.1 Results

Figure 13 panel (a) plots the actual and estimated counter-factual density of the 2 years notch of the Special Stamp Duty, for properties purchased between 20 November 2010 to 26 October 2012. Using the gap between the actual density and the counter-factual to

<sup>19</sup>The estimate would be robust to the case where buyer and seller have exponential discounting with first order linearization, in that case  $k_b = H\rho_b$  and  $k_v = u\rho_v$ , where  $\rho_b$  and  $\rho_v$  are discount rates of the buyer and seller respectively

<sup>20</sup>In the case of there is significant extensive margin response in at time  $\bar{t}$ , the estimate provide a bounding on  $(E(\bar{t} - t(H, u)|H - u > \tau u))$ . A detailed discussion is presented in the section A.3.

<sup>21</sup>In practice I include the dummy variables for holding duration from 330 to 400 days to estimate the excess mass at 1 year notch, and 694 to 864 days for the 2 years notch.

calculate the excess mass, I find that on average the cutoff waiting time,  $E(\bar{t}-t(H, u)|H-u > \tau u)$ , is 17.39 week when the size of the notch is 5%.

Panel (b) plot the actual and estimated counter-factual density of the 4 years notch of the Seller's Stamp Duty, for properties purchased between 14 January 2011, in which the 3rd phase of the Seller's Stamp Duty begins, to those that are purchased before 14 January 2012. I restrict plotting the data to the one year windows because for those properties that are purchased in mid-2012 the transaction after 4 years since purchased is still not being observed at the time of writing. I find that the bunching estimates of the average cutoff waiting time is 13.32 week, slightly smaller than the estimate from the Special Stamp Duty but is associated with a smaller tax notch at 4%.

Using equation 11, one can apply the estimates obtained for  $E(\bar{t}-t(H, u)|H-u > \tau u)$  and the related size of tax notch to identify  $\frac{k_b+k_v}{E(p)}$  which is the proportional welfare cost of delaying a transaction by a week. From the 2 years tax notch of the Special Stamp Duty phase 1, the implied  $\frac{k_b+k_v}{E(p|H-u>\tau u)}$  is 0.29%, while from the last tax notch of the 3rd phase of Seller's Stamp Duty, the implied estimate for  $\frac{k_b+k_v}{E(p|H-u>\tau u)}$  equals 0.3%, suggesting delay in a single transaction would results in lost of trading surplus by 0.3% of the value of the transacted property.

## 8 Welfare analysis

Following the conceptual framework, the welfare gain from transaction in the economy per unit of property held less than 3 years when the tax rate is 0 is given by

$$W(0) = \int_t \int_{H-u>0} (H-u)dG(H, u)d\tilde{L}(t) \quad (12)$$

With tax rate  $\tau > 0$ , the welfare is given by

$$W(\tau) = \int_t \int_{A,T} (H-u)dG(H, u)d\tilde{L}(t) + \int_t \int_{W,B} (H-u)-(k_b+k_v)(\bar{t}-t)dG(H, u)d\tilde{L}(t) + \lambda R(\tau) \quad (13)$$

where  $A, T$  denote the value of  $H, u$  such that trading immediately is optimal,  $W, B$  denote the value of  $H, u$  where wait is the optimal decision, as shown in Figure A.12. Denoting the tax revenue by  $R(\tau)$  and the shadow value of tax revenue as  $\lambda$ , the change in welfare is given by

$$\begin{aligned}
W(\tau) - W(0) + \lambda R(\tau) = & \\
& - \int_t \int_{NT} H - u dG(H, u) d\tilde{L}(t) - \int_t \int_{W,B} (k_b + k_v)(\bar{t} - t) dG(H, u) d\tilde{L}(t) + (\lambda - 1)R(\tau)
\end{aligned} \tag{14}$$

To bound the welfare loss, I use the estimates of  $k_b + k_v$  from the previous section. The welfare cost associated with the second term, for which a property were forced to wait until 2 years, could be approximated by

$$\int_t \int_{W,B} (k_b + k_v)(\bar{t} - t) dG(H, u) d\tilde{L}(t) \approx (k_b + k_v) * \frac{E(\bar{t} - t(H, u) | H - u > \tau u)^2}{2} * P(H - u > \tau u) * l(\bar{t})$$

We could obtain an estimate of  $P(H - u > \tau u) * l(\bar{t})$  by the probability of a property trade per week after for  $t < \bar{t}$ , which is roughly 0.0005 under the 5% tax. Assuming the the tax rate was 5% everywhere with  $\bar{t}$  equals to 2 years, the welfare cost associated with the second term is  $\frac{17.36^2}{2} * 0.29\% * 0.0005 * E(p) = 0.02\% * E(p)$  of the average value of property in the market.

To quantify the welfare loss at the extensive margin, it would be important to understand how trading surplus is distributed among transactions that were crowded out. For example, at a tax rate of 5%, all the transaction that were crowded out must have surplus lower than 5% of the seller's reservation value. Whether the trading surplus concentrated mostly towards 0% versus 5% determine the size of the lost in trading surplus.

To understand better the distribution of trading surplus, I take advantage of the fact that under the same context both the Special Stamp Duty and the Seller's Stamp Duty generate exogenous variation in tax rate that results in different trading hazard at various tax level. The hazard rate of trade at a particular tax level depends on likelihood that trading surplus in proportional sense,  $z \equiv \frac{H-u}{u}$ , is greater than the transaction tax level. In particular, at different tax rate  $\tau$  and  $\tau'$  abstracting from the re-timing close to the notch, with  $h(\tau)$  being the hazard rate of trade at time  $t$  with tax rate  $\tau$ , we can calculate the density of the trading surplus

$$\lim_{\tau' \rightarrow \tau} \frac{h(\tau) - h(\tau')}{h(0) - h(\bar{\tau})} \frac{1}{(\tau - \tau')} == -j(\tau | 0 < z < \bar{\tau}) \tag{15}$$

for any  $\tau$  and  $\tau'$  that is close,  $\tau < \tau'$ , and  $\bar{\tau} > \{\tau, \tau'\}$ .<sup>22</sup>

That is, by comparing the rate in which the hazard rate decline with respect to tax rate, one could infer the density of the conditional distribution of the surplus. Moreover, with enough data point at each tax rate, one could estimate non-parametrically the density of the trading surplus.

For the Special stamp Duty, I get estimates from the earlier section on  $h(\tau)$  where  $\tau \in \{0, 5, 10, 15\}$

In practice, I use the hazard rate  $h(\tau)$  where  $\tau = \{0, 5\}$  to estimate the conditional density at  $\tau = 0$ , and use  $\tau = \{5, 10\}$  to estimate the conditional density at  $\tau = 5$  so and so forth.

The results for both trading surplus in Hong Kong and Singapore is presented in graph A.11, and the shape is very similar using the two procedures. It suggest that the trading surplus decline very rapidly at around 4-10%, and there is little mass above the threshold of 10%.

Using a linear approximation of the density between 0% and 5%, I find that the conditional expectation of the trading surplus is  $E(\frac{H-u}{u} | 0 < \frac{H-u}{u} < 0.05) = 2.23\%$ . Therefore the extensive margin lost would be  $-0.13 * 2.23\% = -0.29\%$  of the value of property.

In total, the lower bound of welfare loss would be the sum of the intensive and extensive margin, which amounts to 0.31% of the value of a representative property. This is the welfare loss per each new holding, and is increasing in the number of properties purchased in which the policy is in place. Given that very little tax revenue is generated from the tax schedule, this suggest non-trivial welfare loss to the property market as a whole.

## 9 Discussion

### 9.1 Comparison with capital gain tax

The extensive margin response or lock-in effect shown previously, in comparison to previous literature, is reasonably large. For example, [Shan \(2011\)](#) finds that 10,000 USD

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$$\begin{aligned} \lim_{\tau' \rightarrow \tau} \frac{h(\tau) - h(\tau')}{h(0) - h(\bar{\tau})} \frac{1}{(\tau - \tau')} &= \lim_{\tau' \rightarrow \tau} \frac{(P(z > \tau) - P(z > \tau'))l(t)}{(P(z > 0) - P(z > \bar{\tau}))(\tau - \tau')l(t)} \\ &= -j(\tau | 0 < z < \bar{\tau}) \end{aligned}$$

increase in capital gains tax liability reduces semiannual sales by 0.1 percentage points. Take the upper bound on the special stamp duty tax and assume the tax rate of 15% apply to all the transaction below 2 years, for a residential property at median price approximately 4,000,000 HKD, this only translates into 0.77 percentage point reduction in sales rate every half year, which in turns translate into 4.5 percentage point reduction in probability of sales in three years. This is only one-third of the extensive margin response from the RDD estimate.<sup>23</sup> It suggests that transaction tax have larger impact of on the extensive margin of transaction than capital gain tax in terms because the tax applies regardless of the magnitude of appreciation of the asset.

## 9.2 Simulation of short-holding trades and equilibrium price effect

To evaluate the effect on equilibrium price from reduction in effective supply of short-holdings properties, I proxy for the short-run supply by

$$SS_{dt} = \sum_{j=1}^{150} \hat{w}_{jt} N_{d,t-j}$$

where  $N_{d,t-j}$  is the number of transaction in district  $d$  in week  $t - j$ .<sup>24</sup> The effective supply is proxied by probability of the properties being sold in the market,  $w_{j,t-j}$ , multiplied by the number of properties purchased in period  $t - j$  in district  $d$ .

$w_{j,t-j}$  is time-varying. For the three period with different tax liability, from Jan 2009 to 19 November 2010, 20 November 2010 to 27 October 2012, 27 October 2012 to 31 December 2015, it equals to the estimated coefficient  $w_j$  in equation 3 estimated for properties purchased in the relevant period. The evolution of the variable  $SS_{dt}$  is plotted in Figure 10. During the period, predicted short-run re-sales drop continuously from December 2011 to December 2015. The continuous decline in predicted re-sales in 2012 coincides with rise in transaction price even within each districts, and the increase in transaction price come to a slow down in the last quarter of 2012 together with the increase in the predicted re-sales.

## 10 Conclusion

In this paper I show that tax notches at holding duration in Hong Kong and Singapore generate distinct incentives for buyer and seller in re-timing the transaction, on average

<sup>23</sup> $1 - (1 - 0.0077)^6 = 0.045$ , where  $(1 - 0.0077)^6$  is the probability of a property remain unsold in 3 years.

<sup>24</sup>Number of district is 3, the largest natural division for Hong Kong



for 3-4 weeks for each 1% of tax savings. Combined with the actual significant size of the tax, it reduced the probability of a property being traded by 13 percentage point even one year after the tax dropped to zero, which could be due to the search frictions in the property market. Buyer share up to 41-80% of the burden of the transaction tax, which may have high social cost in a policy that gives larger welfare weight to buyer than seller. This paper also provides evidence that the selection effect of the such a tax instrument is weak. Tax on holding duration were used as public policy tool to deter speculation in the 1970s in North America, but very little were known about the tool before the new wave of introduction of similar tax instrument in east Asia in 2010s. This paper suggest that the aggregate welfare loss could be large for an understudied tax instrument that survived through history.

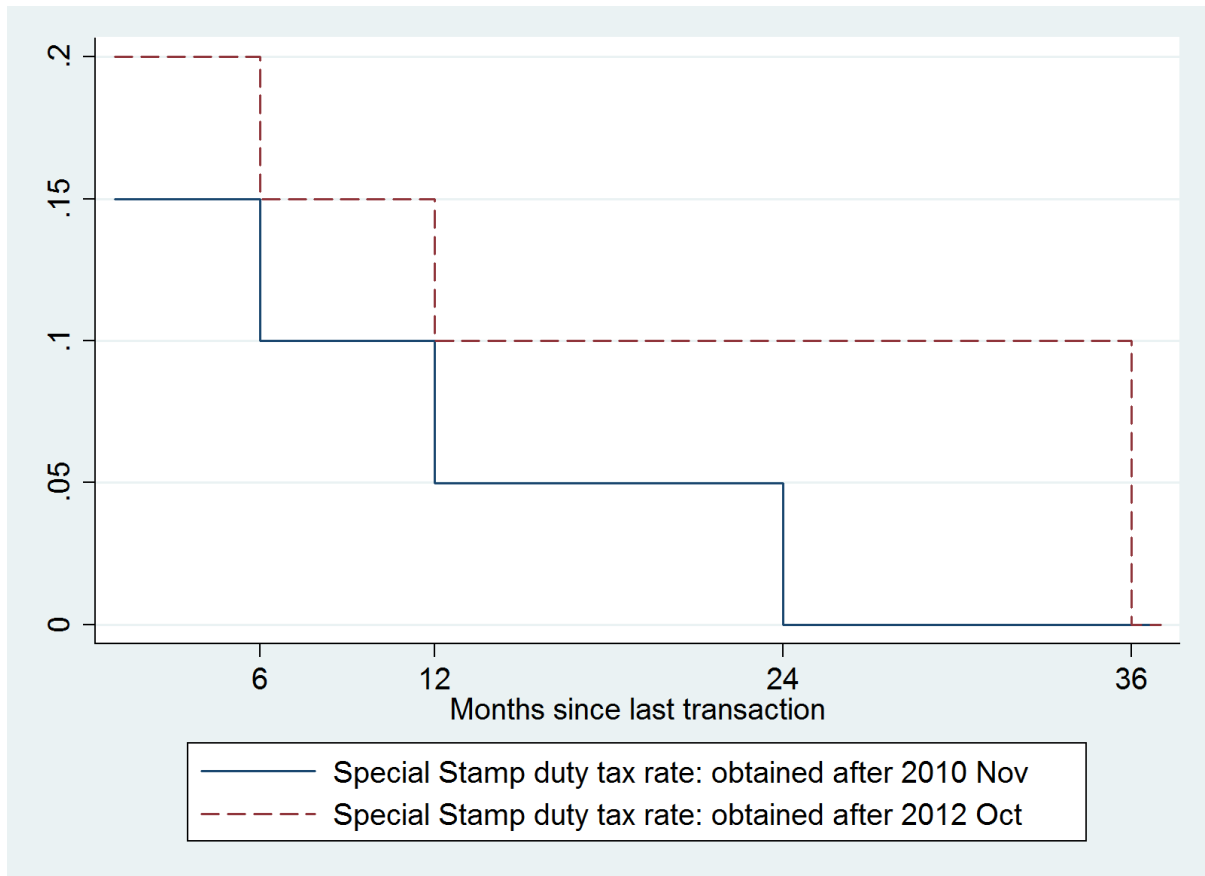
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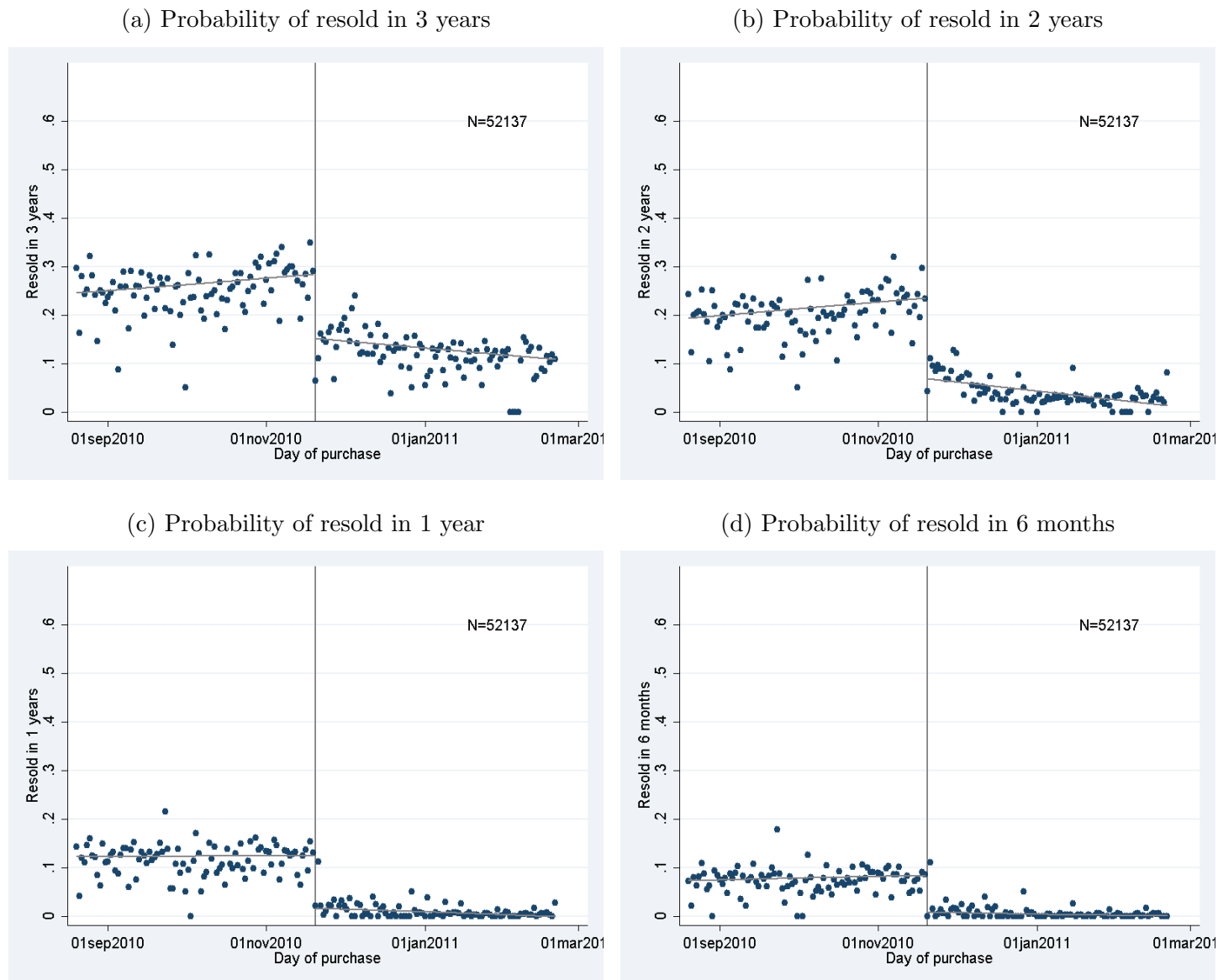
## 11 Figures

Figure 1: Tax on holding duration: Hong Kong



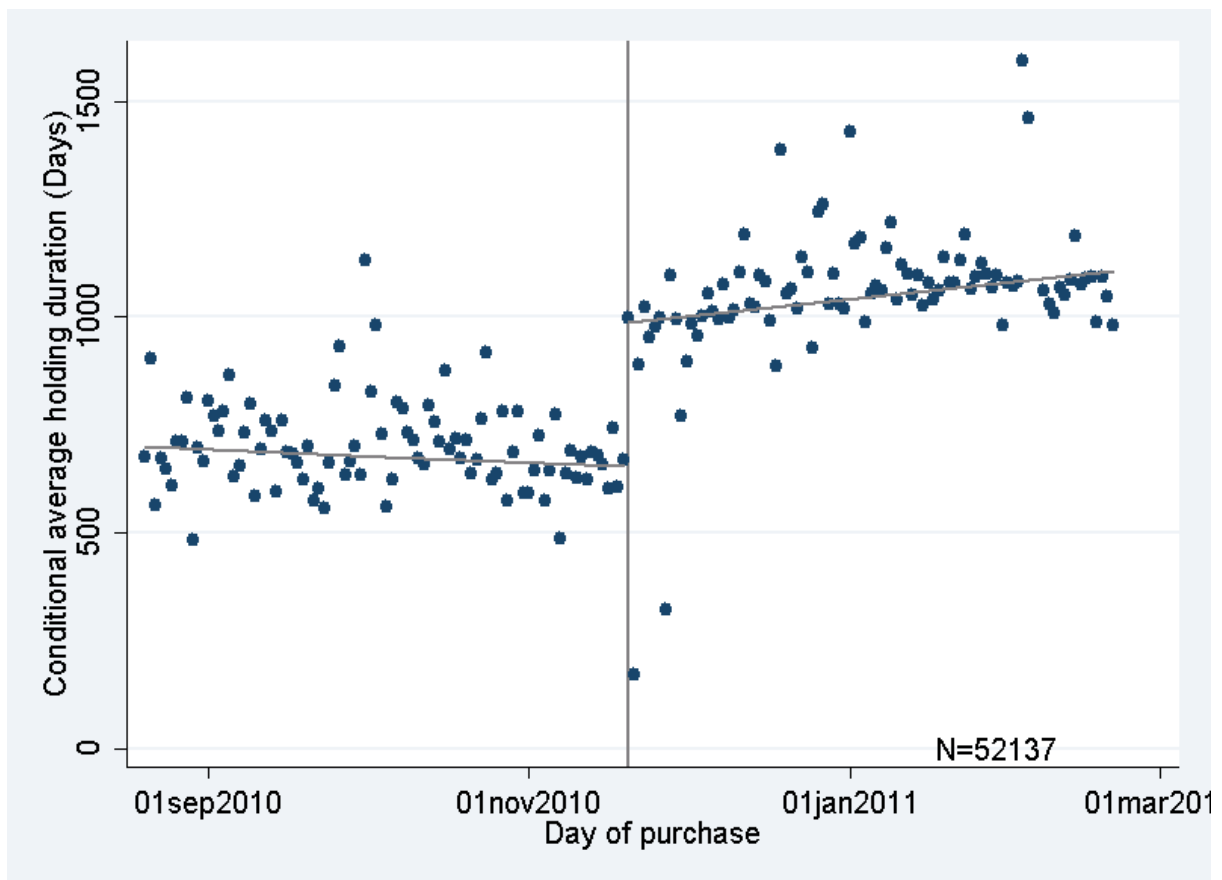
Notes: The graph plots the transaction tax rate as function of holding duration of properties since last purchased (the Special Stamp Duty), which applies to residential properties obtained after 20 November 2010 in Hong Kong (the solid line), and for those obtained after October 2012 (the dotted line). It is levied on top of the basic stamp duty rate that does not depend on the holding duration of a property.

Figure 2: RDD plot: all purchases



Note: The graphs plot the probability of a property being resold in 3,2,1 and 0.5 years since last purchased by the day in which they are obtained. The vertical line shows the day of 20 November 2010, in which the Special Stamp Duty first applies. The dotted lines are fitted linear trend in the probability of resold in the respective horizon, estimated separately for period before and after 20 November 2010.

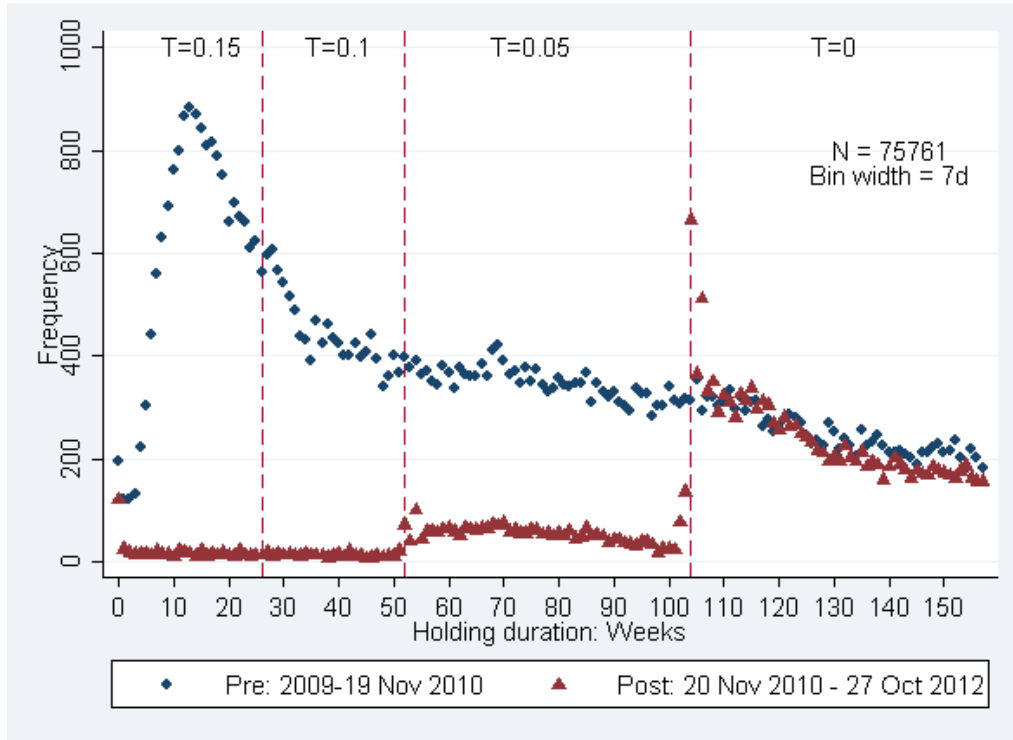
Figure 3: RD: Conditional average holding duration



Note: The graph plots the holding duration for residential properties in Hong Kong purchased in the window of 20 Aug 2010 to 20 Feb 2011, conditional on the properties being resold before Dec 2015. The dotted lines are fitted linear trend in the conditional holding duration in the respective horizon, estimated separately for period before and after 20 November 2010.

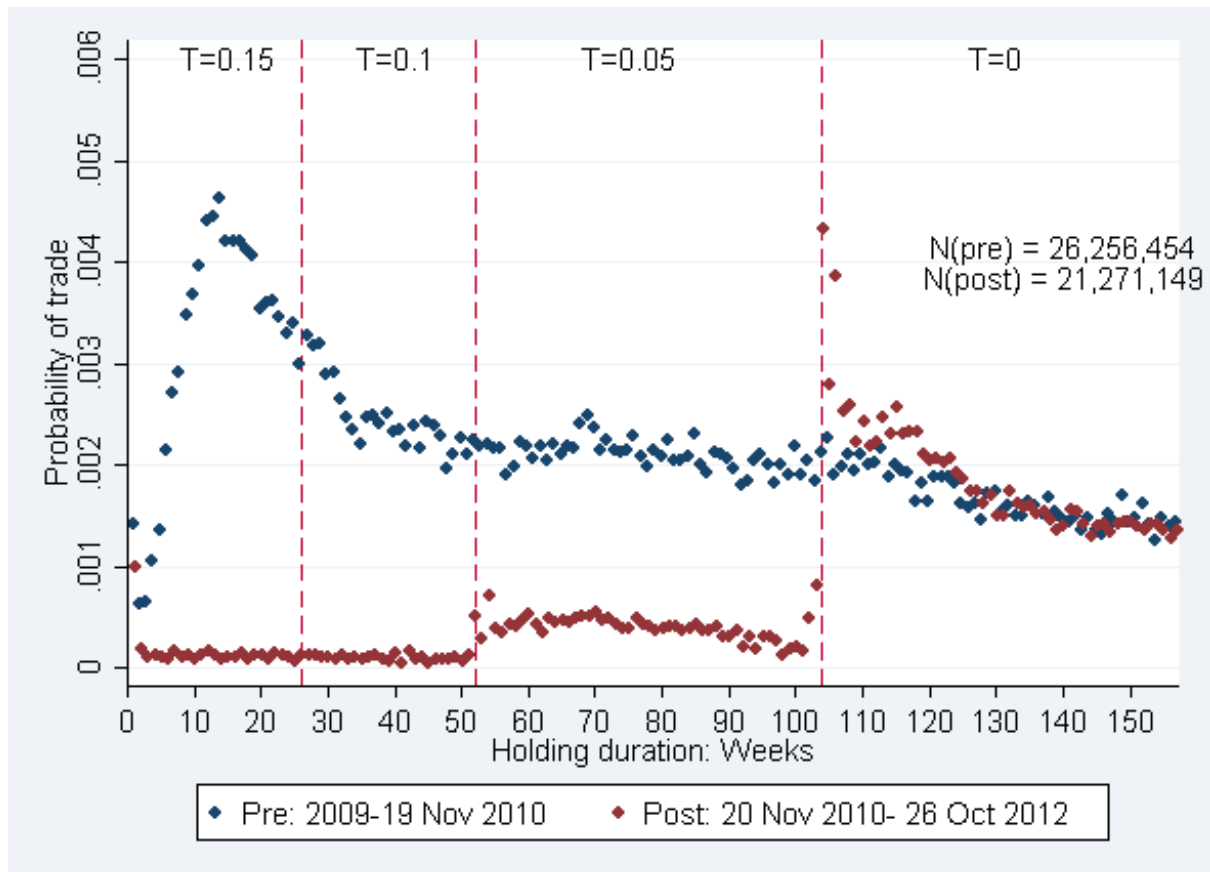
Figure 4: Duration of residential property holdings: 2009-2015

(a) Purchased before and under SSD phase 1



Notes: The graphs plot the distribution of holding duration for properties obtained in 2009 in Hong Kong, between 1 to 158 weeks. Each dot represent the frequency count of a bin width of 7 days period. The blue/circle dots plot the density of the holding duration for those obtained between January 2009 and 20 November 2010, where no tax rate is applied as function of holding duration. The red/triangle dots plot in addition the density of the holding duration for those obtained between 20 November 2010 to November 2012, where the 1st phase of special stamp duty applies. Sample includes all residential properties transactions as described in the data appendix.

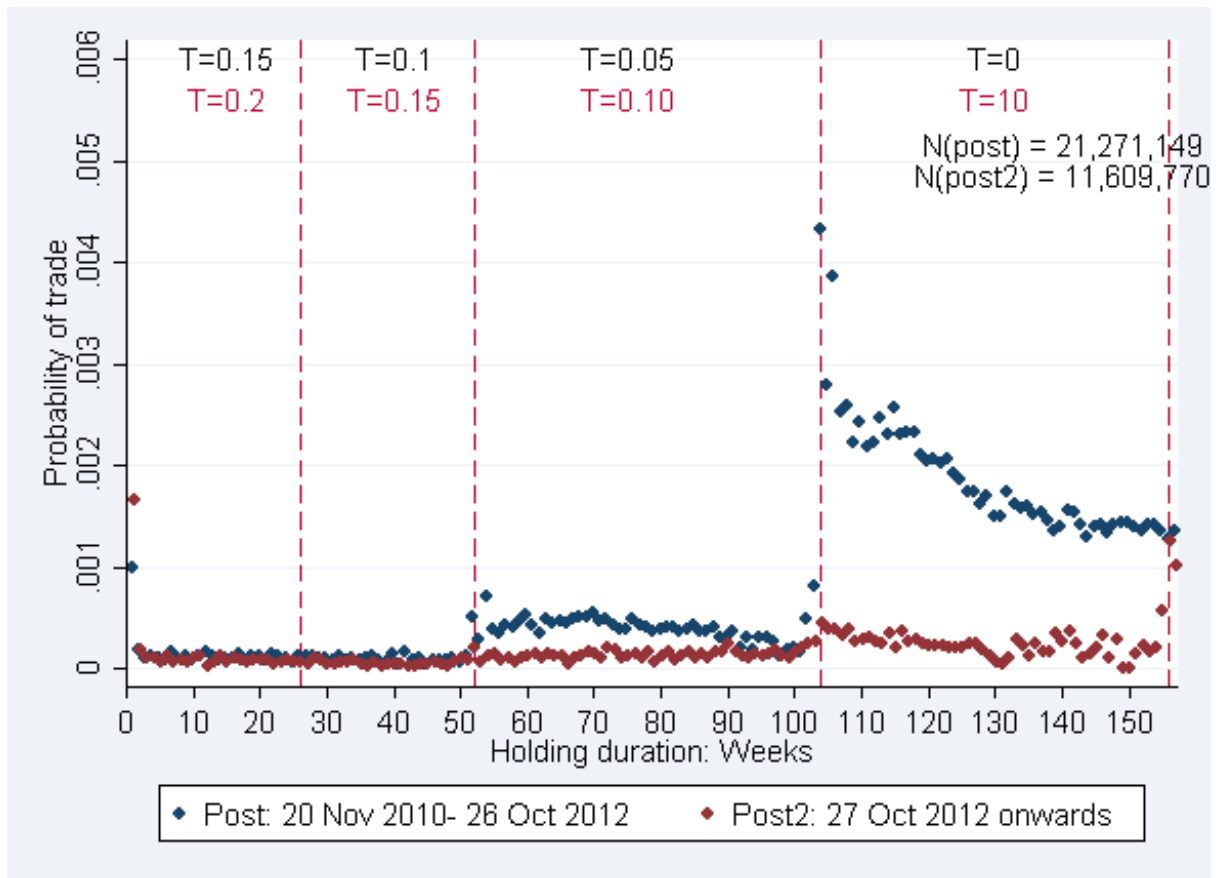
Figure 5: Hazard function of trade: holding duration by week



Notes: The graph plots the hazard function estimated using OLS of weekly dummies for the holding period, where the outcome variable is an indicator of a trade happening in week  $t$ , with a panel of trading record at each week since a property is obtained using the transaction history for properties. The blue dots plot the hazard rate at each week for properties purchased from January 2009 to 19 November 2010, and the red dots plot the hazard rate for properties purchased from 20 November 2010 to 26 October 2012. Trading date is adjusted to the date of the provisional contract first signed when applicable. The hazard functions are estimated separately for properties obtained in each period.



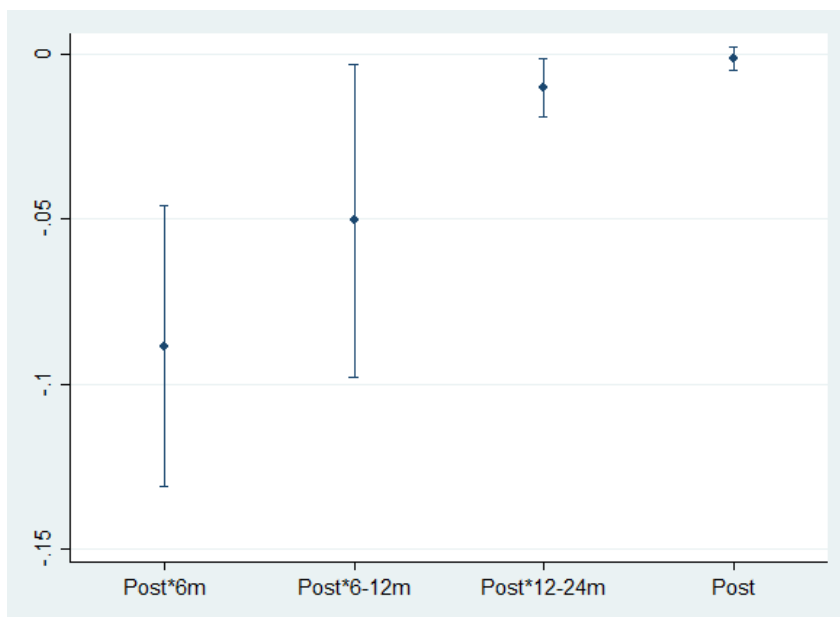
Figure 6: Hazard of trade: Special stamp duty phase 1 and phase 2, Hong Kong



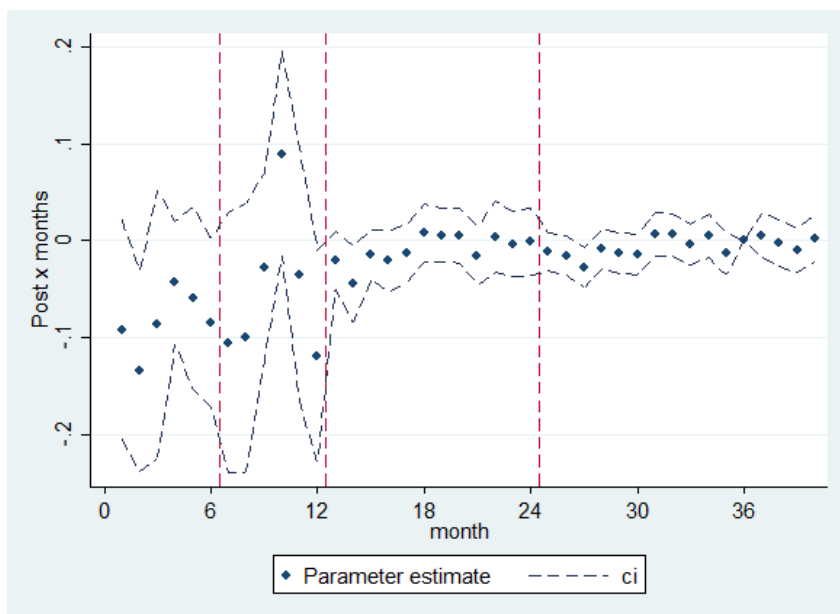
Notes: See note of Figure 5. The graph plots the hazard rate for properties purchased between 20 Nov 2010 to 27 Oct 2012 and from 28 Oct 2012 to 31 Dec 2015.

Figure 7: Pre-tax price regression: coefficient plots

(a) Broad category



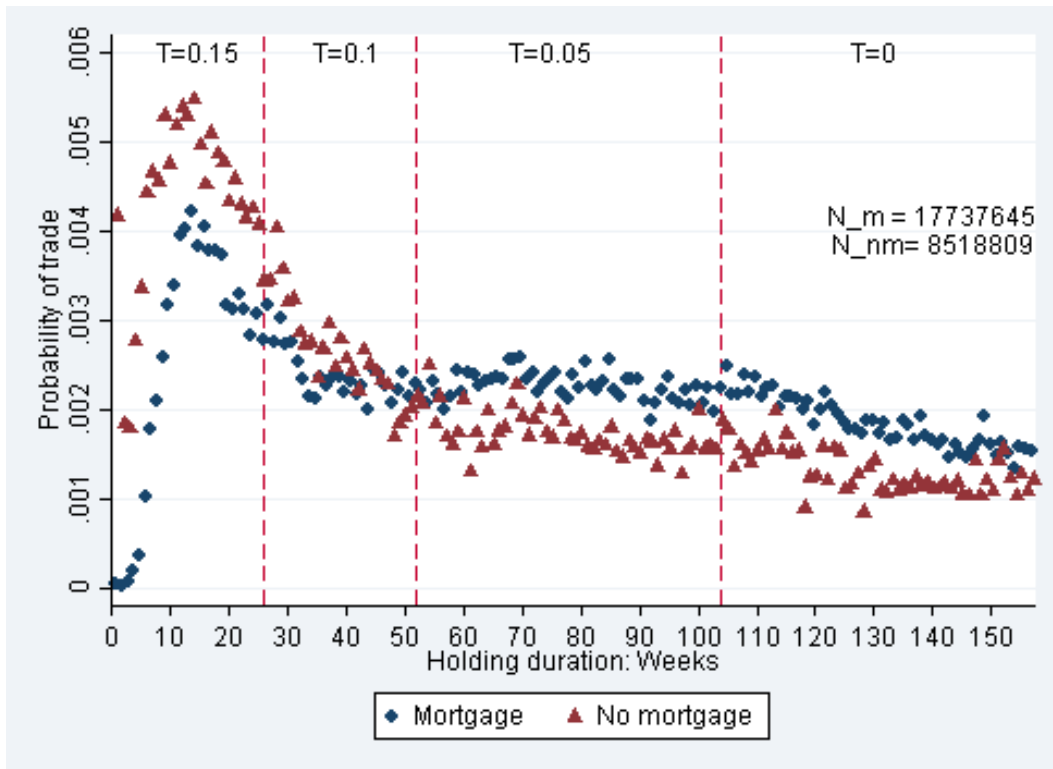
(b) Monthly non-parametric



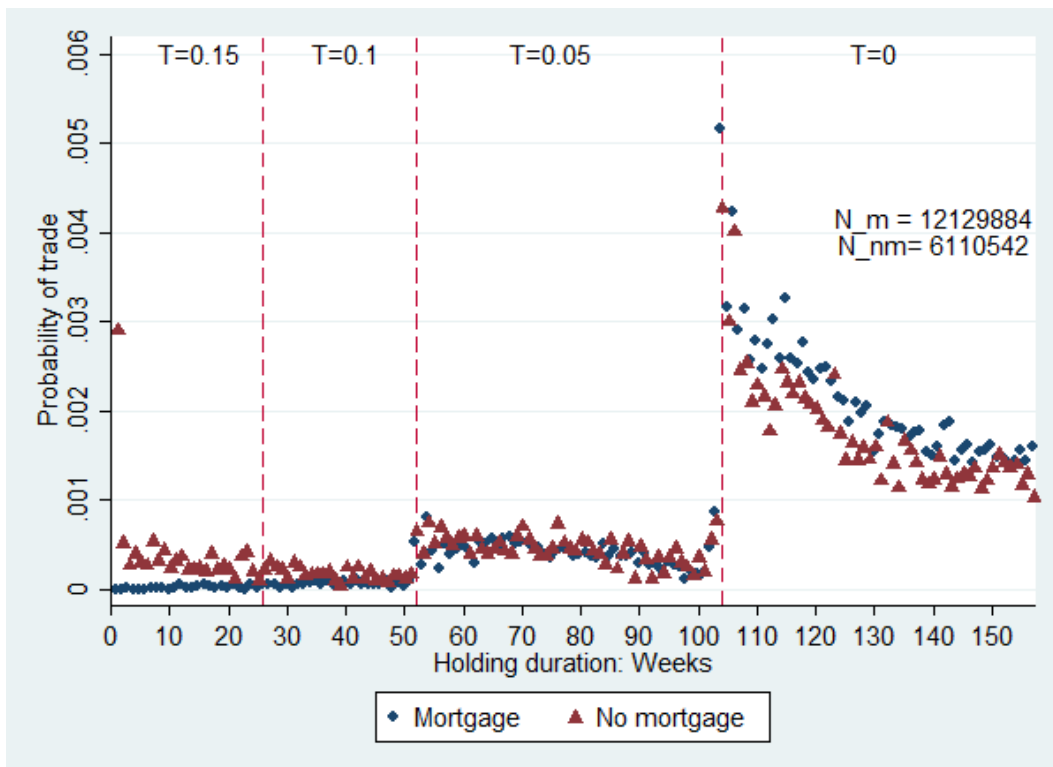
Notes: Panel (a) - The graph plots the  $post * H$  coefficients of the price regression in column 2 of Table 5; the coefficient of  $post * H_{i,j}$  indicate that the property is sold within the  $i$  and  $j$  month of holding the property; Outcome variable is log of pre-tax price; Controls includes holding duration FE in broad group, date of sales FE (Year-month), 2nd order polynomial of log of rateable values and its interaction with year-month dummies; Panel (b) - The graph plots the  $post * i^{th} months$  of holding duration coefficients of the price regression in column 2 of Table 5 in the flexible specification; the coefficient of  $post * i^{th} month$  indicate that the property is sold on the  $i^{th}$  month of holding the property; Outcome variable is log of pre-tax price; Controls includes holding duration FE in broad group, date of sales FE (Year-month), 2nd order polynomial of log of rateable values and its interaction with year-month dummies.

Figure 8: Hazard function of trade: by mortgage buyer and cash buyer

(a) Hazard of trade: pre

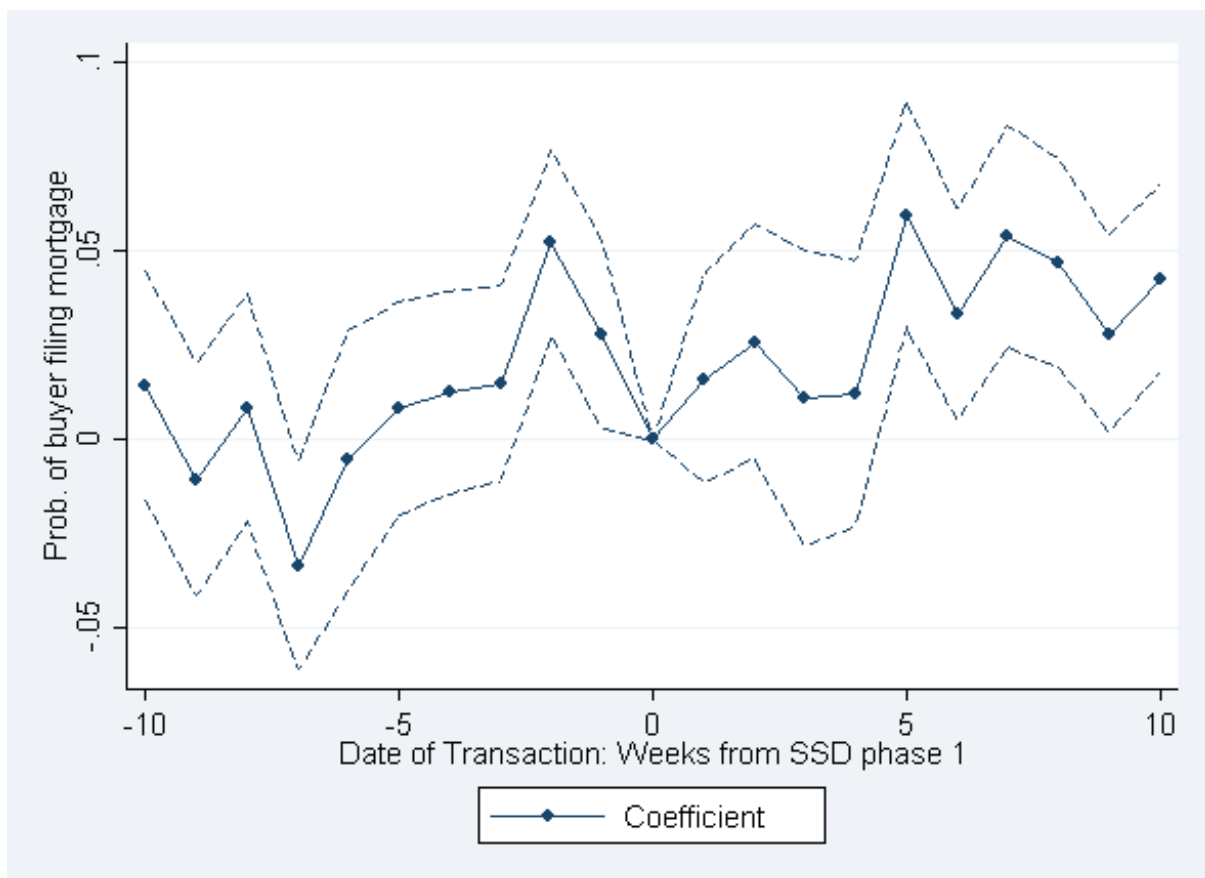


(b) Hazard of trade: post



Notes: See note of Figure 5. Panel (a) present the estimate for the hazard function for transaction spell that has an associated mortgage record and those that do not have an associated mortgage record. Panel (b) present the estimate for the hazard function for properties purchased under Special Stamp Duty phase 1, between 20 November 2010 to 26 October 2012.

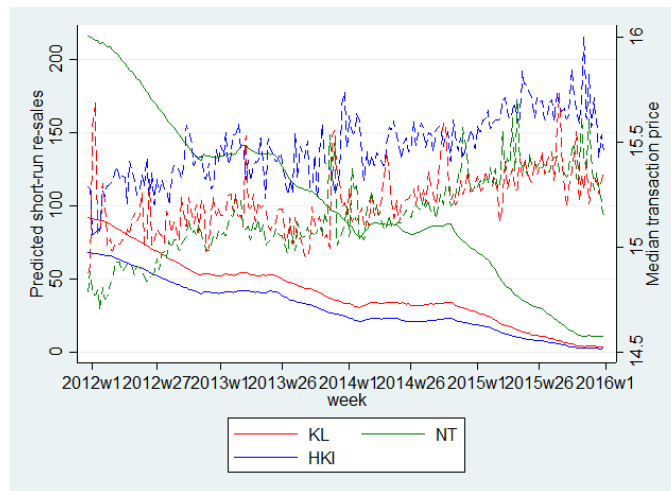
Figure 9: Effect of SSD on selection of type of buyers: event study



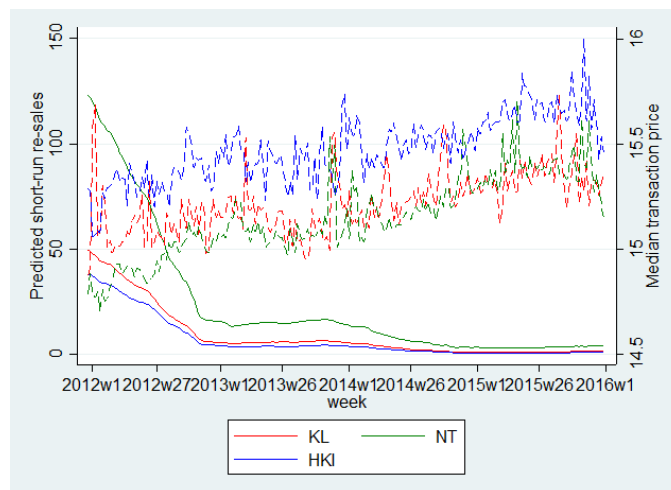
Notes: The graph presents estimates for equation 4. Sample include transaction in 20 Aug 2010 to Jan 20 March 2011 for properties purchased with price below HKD 6800000. Control includes districts fixed effects.

Figure 10: Predicted number of short-run resales

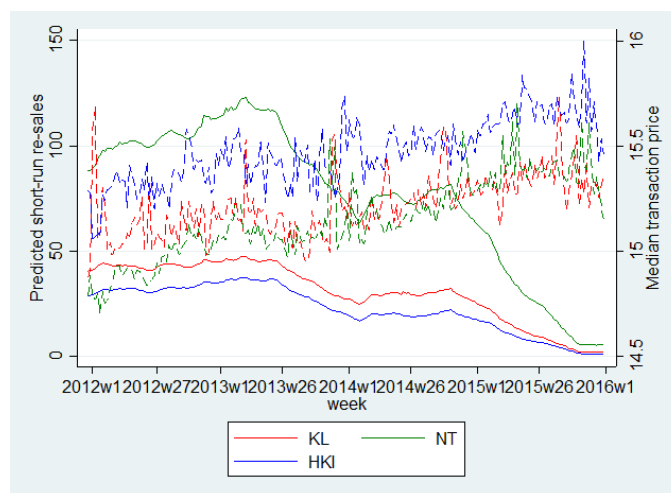
(a) All



(b) Midterm

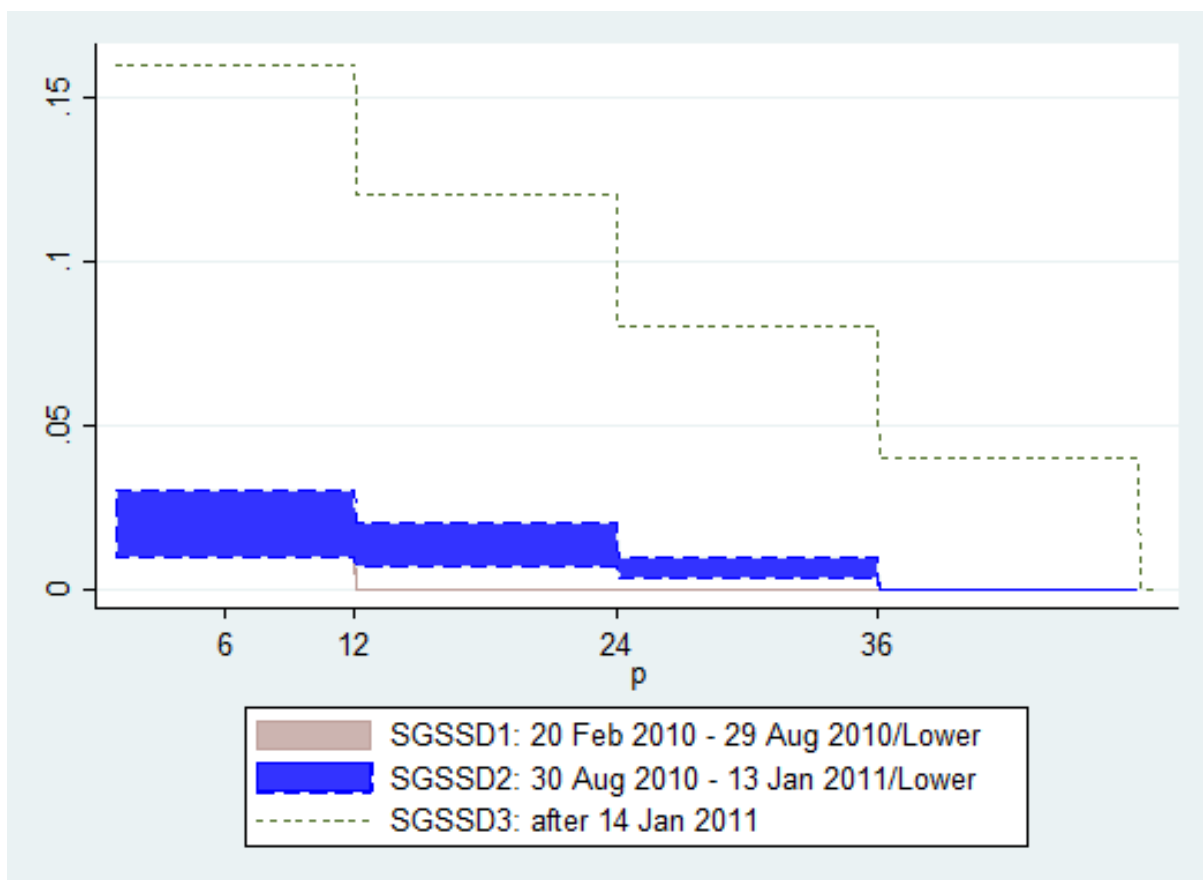


(c) Longterm



Notes: The graph plots the predicted number of sales from properties purchased in the past 3 years, using the number of transaction in  $j$ th week before time  $t$ , weighted by the estimates of hazard function  $w_j$ , according to the tax liability of  $t - j$ . It cover data from the December 2011 to Dec 2015. The dash-line plot the median (log) transaction price in the district in week  $t$ .

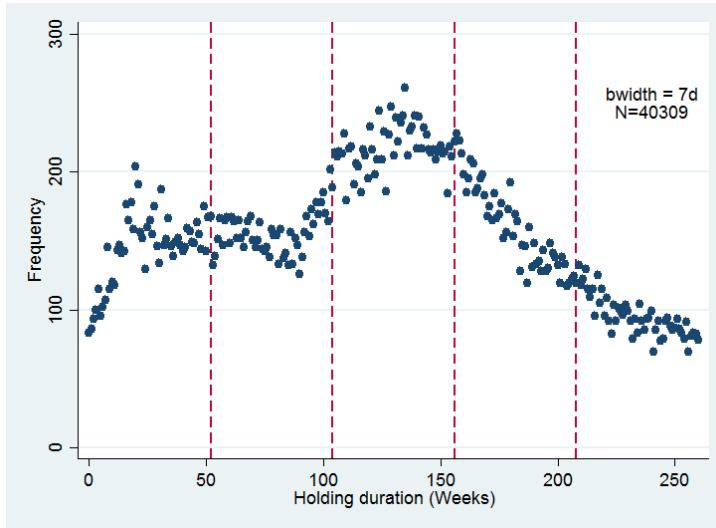
Figure 11: Tax on holding duration: Singapore



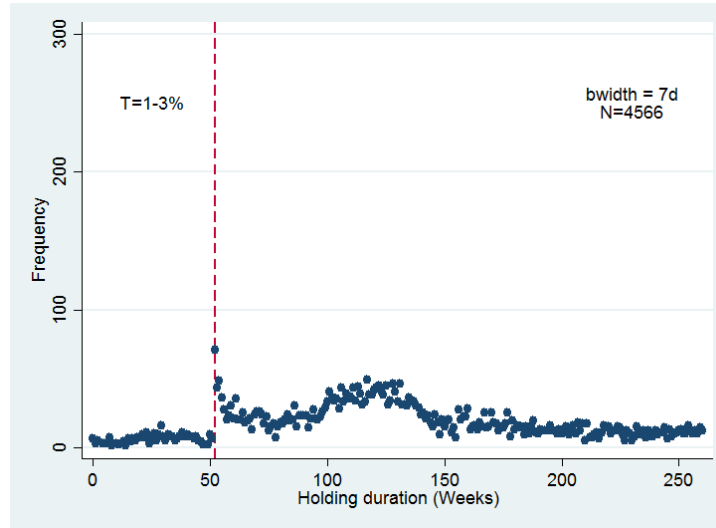
Notes: The graph plots the tax rate for residential properties under the Seller's Stamp Duty as function of holding period, for properties purchased in different period in Singapore from Phase 1 to Phase 3. In Phase 1 and 2 the Seller's Stamp Duty to be paid follows the rate at which the marginal rate is  $\{1, 2, 3\}\%$  in the three brackets of  $\{\leq 180000, 180000 - 360000, \geq 360000\}$  SGD in the 1st year; for Phase 2 it follows the same tax structure of rate  $\{\frac{2}{3}, \frac{4}{3}, 2\}\%$  in the 2nd year and  $\{\frac{1}{3}, \frac{2}{3}, 1\}\%$  in the 3rd year.

Figure 12: Holding duration: Singapore

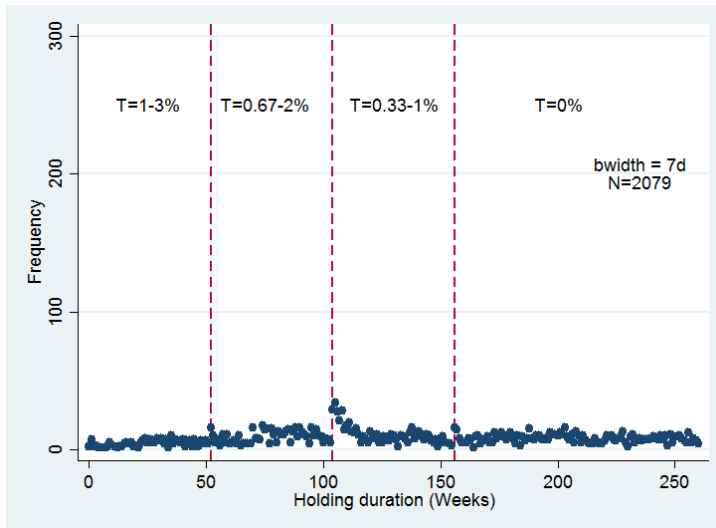
(a) Purchased from 2006 to 20 Feb 2010



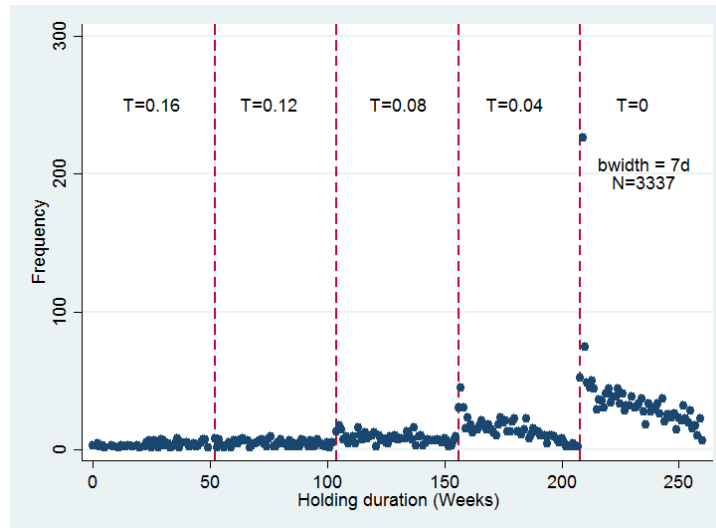
(b) Purchased between 20 Feb 2010, 29 Aug 2010



(c) Purchased between 29 Aug 2010, 13 Jan 2011



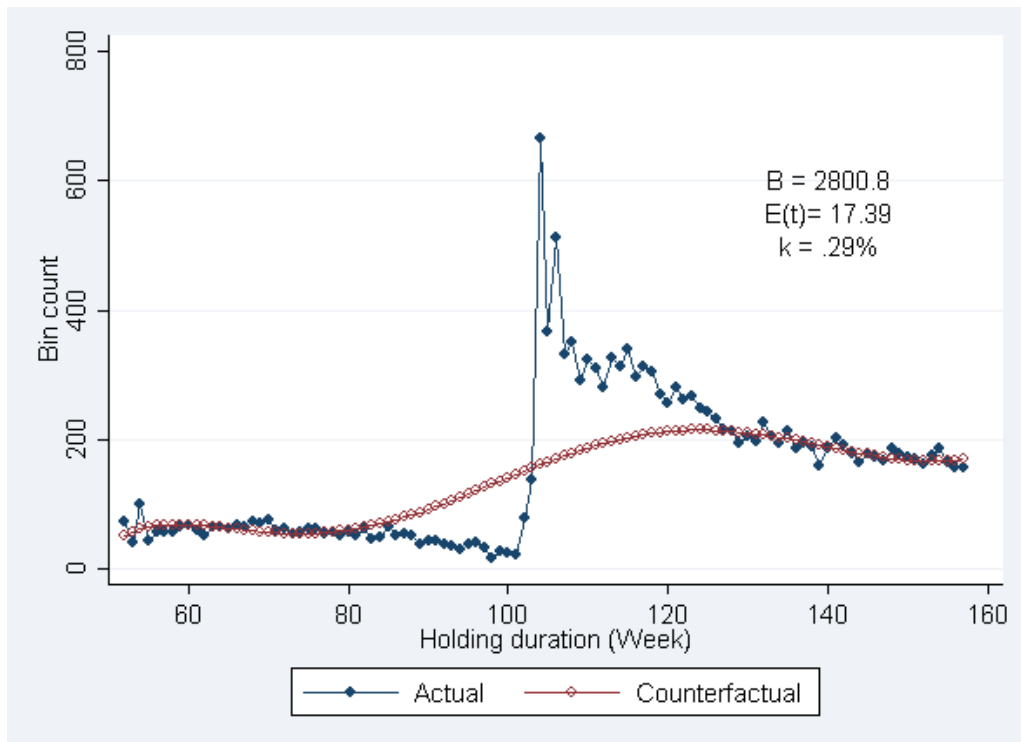
(d) Purchased on or after 14 Jan 2011-31 Sep 2016



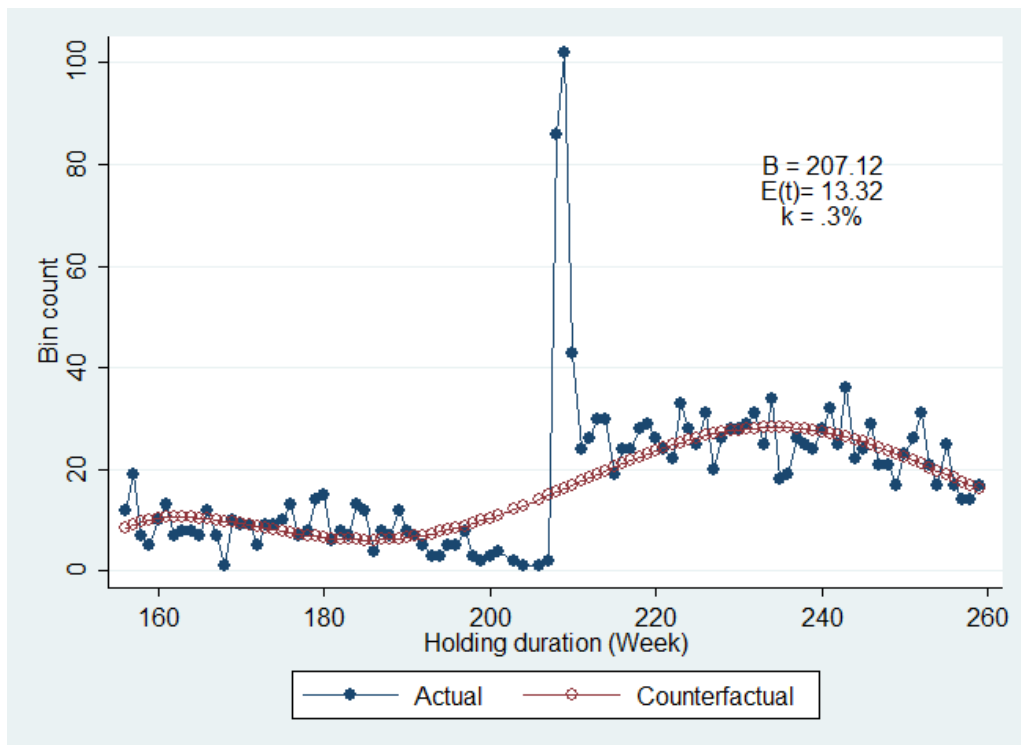
Notes: The graph shows the holding duration distribution of residential units in Singapore from same day to 5 years. Each point shows the frequency of holding at 7 days bin.

Figure 13: Estimation of average cutoff of waiting time

(a) Hong Kong SSD phase 1: 2 years notch



(b) Singapore SGSSD phsae 3: 4 years notch



Notes: Panel (a) - The graph plot the frequency of holding period at the bin of week same as Figure 5, for residential properties purchased between 20 Nov 2010 to 27 Oct 2012 in Hong Kong, and from 52th to 158th week. The data excluded are from 92th week to 124th week. The excess mass are defined as mass above the counterfactual density from 104 to 124th week. Panel (b) - The graph plot the frequency of holding period at the bin of week same for residential properties purchased between 14 Jan 2011 to 14 Jan 2012 in Singapore. Excess mass defined from 208th week to 213th week.



## 12 Tables

Table 1: RDD: HK SSD Phase 1

	Outcome: Probability of resold in			
	3 years	2 years	1 year	6 months
	(1)	(2)	(3)	(4)
RD estimate=1	-0.133*** (0.00934)	-0.168*** (0.00947)	-0.110*** (0.00477)	-0.0743*** (0.00358)
Observations	52137	52137	52137	52137
Baseline mean	0.290	0.225	0.135	0.0759

Notes: Sample includes residential properties purchased from 20 Aug 2010-20 Feb 2011 in Hong Kong. Cut off is defined for purchases before or after 20 November 2010, the specification allow differential linear trend function for properties purchased before and after 20 November 2010. Column (1) includes all transactions; Column (2) includes transactions that has no mortgage record associated; Column (3) includes transactions that has mortgage record associated. Standard errors are clustered at the level of day of purchase.

Table 2: RDD: HK SSD Phase 1, by type of purchases

	Outcome: Resold in 3 years		
	All	No mortgage	Mortgage
	(1)	(2)	(3)
RD estimate=1	-0.133*** (0.00934)	-0.166*** (0.0160)	-0.116*** (0.00968)
Observations	52137	16687	35450

Notes: Sample includes residential properties purchased from 20 Aug 2010-20 Feb 2011 in Hong Kong. Cut off is defined for purchases before or after 20 November 2010, the specification allow differential linear trend function for properties purchased before and after 20 November 2010. Column (1) includes all transactions; Column (2) includes transactions that has no mortgage record associated; Column (3) includes transactions that has mortgage record associated. Standard errors are clustered at the level of day of purchase.

Table 3: RDD: HK SSD Phase 1, conditional holding duration

	Outcome: Cond. holding duration		
	All	No mortgage	Mortgage
	(1)	(2)	(3)
RD estimate=1	334.1*** (18.98)	371.3*** (31.35)	314.2*** (21.77)
Observations	15650	4731	10919
Baseline mean	733.9	649.0	772.9

Notes: Outcome variable is the holding duration in days conditional on the property is resold before 31st Dec 2015. Sample includes residential properties purchased from 20 Aug 2010-20 Feb 2011 in Hong Kong. Cut off is defined for purchases before or after 20 November 2010, the specification allow differential linear trend function for properties purchased before and after 20 November 2010. Column (1) includes all transactions; Column (2) includes transactions that has no mortgage record associated; Column (3) includes transactions that has mortgage record associated. Standard errors are clustered at the level of day of purchase.

Table 4: RDD: Singapore SSD Phase 3

	Outcome: Resold in 5 years		
	All	HDB	Private
	(1)	(2)	(3)
RD estimate	-0.0577*** (0.0144)	-0.0866*** (0.0199)	-0.0382** (0.0181)
Observations	6271	2487	3784

Notes: Sample includes residential properties purchased from 15 Dec 2010-15 Feb 2011 in Singapore. Cut off is defined at purchased after 14 Jan 2011, the specification allow differential linear trend function for properties purchased before and after 14 Jan 2011. Column (1) includes all transactions; Column (2) includes transactions where the buyer address is from HDB housing; Column (3) includes transactions where the buyer address is from private address. Standard errors are clustered at the level of day of purchase.

Table 5: Estimation of tax incidence

	Ln of pre-tax price	
	(1)	(2)
post=1	-0.105*** (0.00469)	-0.00137 (0.00175)
post=1 × sold < 6m=1	0.273*** (0.0477)	-0.0885*** (0.0218)
post=1 × sold 6-12m=1	0.147*** (0.0426)	-0.0505** (0.0242)
post=1 × sold 1-2 years=1	-0.00948 (0.0127)	-0.0103** (0.00452)
Observations	97017	94503
Year-month of sales FE	Y	Y
ln Rateable value*month FE	N	Y
ln Rateable value <sup>2</sup> *month FE	N	Y

Notes: Sample include properties bought between Jan 2009 and 26 Oct 2012, and are sold before 31 December 2015. *post* is an indicator for property bought between 20 Nov 2010 to 26 Oct 2012. Column (2) includes 2nd order polynomial of log rateable values and its interaction with date of sales (Year-month) dummies. Standard errors are clustered at property level;

Table 6: Robustness of price regression: polynomial

	(1)	(2)	(3)	(4)	(5)
post=1	-0.105*** (0.00469)	-0.00182 (0.00181)	-0.00137 (0.00175)	-0.000824 (0.00175)	-0.00102 (0.00175)
post=1 × sold < 6m=1	0.273*** (0.0477)	-0.0507** (0.0225)	-0.0885*** (0.0218)	-0.0988*** (0.0220)	-0.0942*** (0.0220)
post=1 × sold 6-12m=1	0.147*** (0.0426)	-0.0306 (0.0247)	-0.0505** (0.0242)	-0.0549** (0.0243)	-0.0566** (0.0243)
post=1 × sold 1-2 years=1	-0.00948 (0.0127)	-0.00324 (0.00478)	-0.0103** (0.00452)	-0.0115** (0.00449)	-0.0115** (0.00447)
Observations	97017	94503	94503	94503	94503
Degree of polynomial	0	1	2	3	4

Notes: See notes of Table 5. Column (2)-(5) controls for time varying polynomial of log rateable value of properties with 1-4 degree respectively. Standard errors clustered at property level.

Table 7: SSD phase 1: selection in types of buyers

Outcome: Filing mortgage					
Sample: before/after 20 Nov 2010					
	Sep10-Jan11	Aug10-Feb11	Jul10-Mar11	Jul09-Mar11	Jul09-Mar11
	(1)	(2)	(3)	(4)	(5)
After SSD 1=1	0.0170*** (0.00535)	0.0266*** (0.00426)	0.0142*** (0.00361)	0.0292*** (0.00354)	0.0552** (0.0266)
Observations	30645	46335	64637	164551	164551
Baseline mean	0.687	0.696	0.699	0.688	0.688
District FE	x	x	x	x	x
District*month of the year FE				x	x
Property FE					x

Notes: Outcome variable is an indicator of whether the transaction has an associate mortgage record. Column (1) contains sample of properties purchased from 20 Sep 2010 to 20 Jan 2010; Column (2) contains sample of properties purchased from 20 Aug 2010 to 20 Feb 2010; Column (3) contains sample of properties purchased from 20 Jul 2010 to 20 20 March 2010; Column (4) contains sample of properties purchased from 20 Jul 2009 to 20 20 March 2011; Sample includes residential properties purchased in the relevant period in Hong Kong. Standard errors clustered at property level.

# A Appendix

Figure A.1: Timeline of the stamp duty tax policy change in Hong Kong since 2010

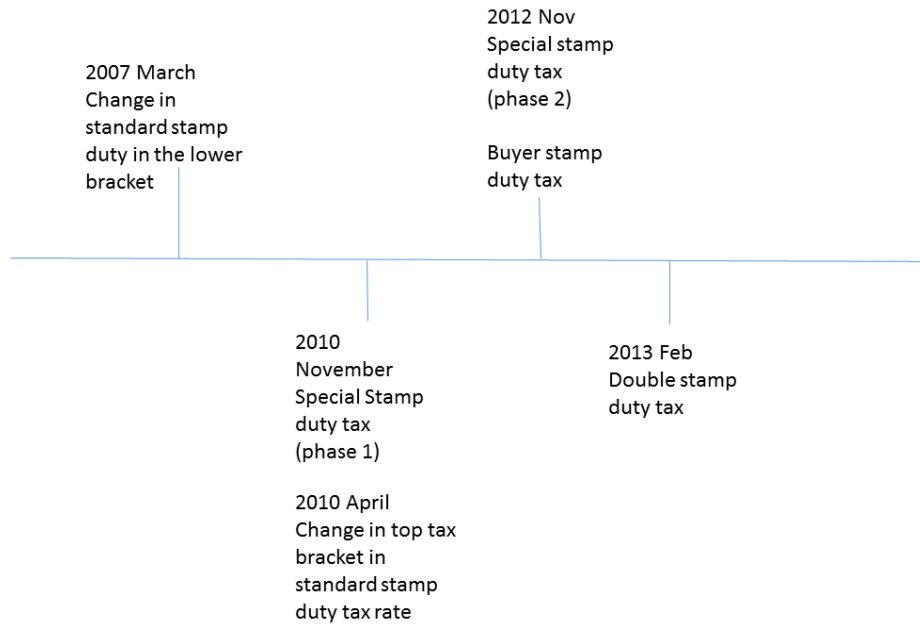


Figure A.2: Timeline of the Seller's Stamp Duty policy change in Singapore since 2010

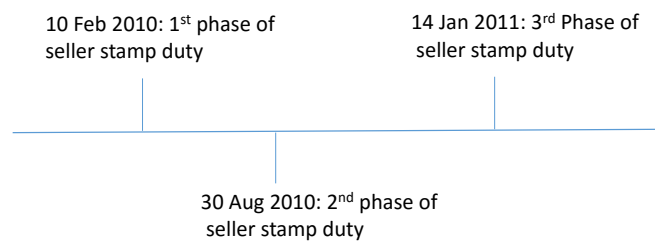
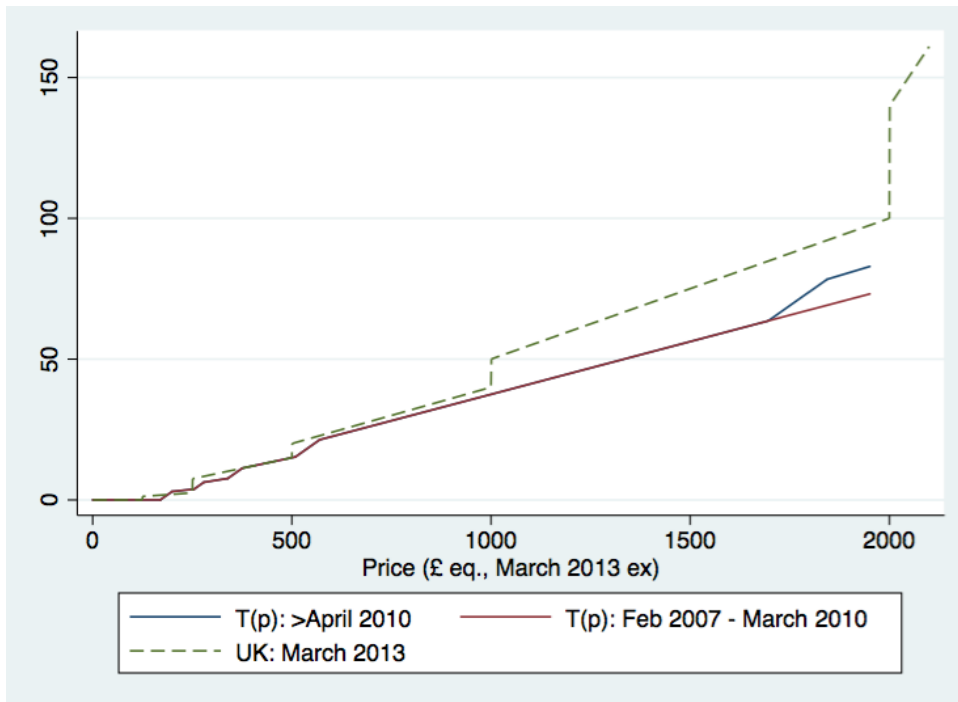
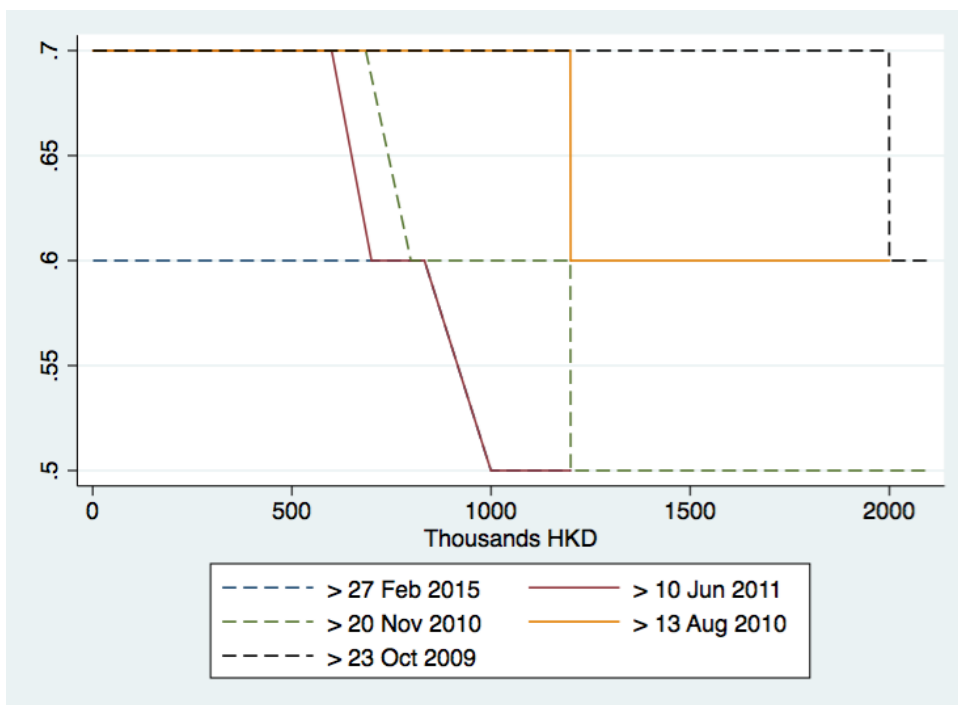


Figure A.3: Property stamp duty tax schedule of Hong Kong in various time point



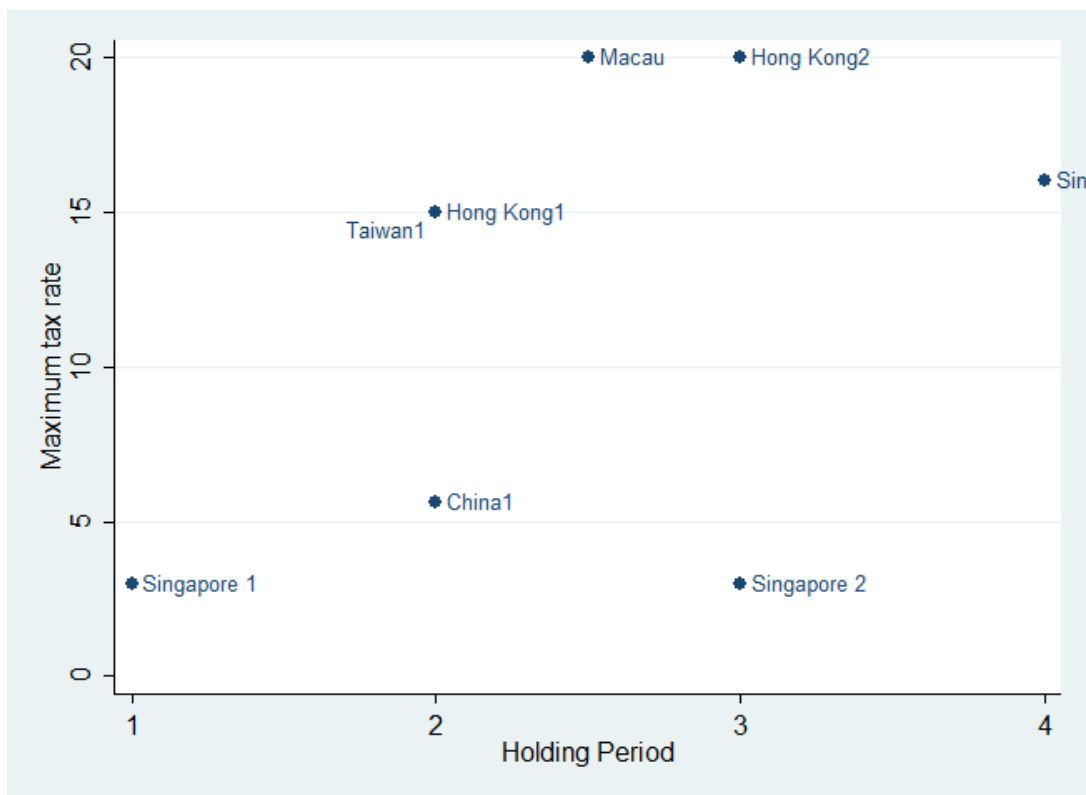
Note: Unit in thousands

Figure A.4: Changes in mortgage loan-to-value limit ratio



Note: For residential properties

Figure A.5: Use of transaction tax on holding period in Asia



Note: The graph plots the region/country that had implemented transaction tax on residential properties on holding period since 2010 in Asia, by the maximum transaction tax rate and when the last notch of the tax applies, of each phase of it being implemented.



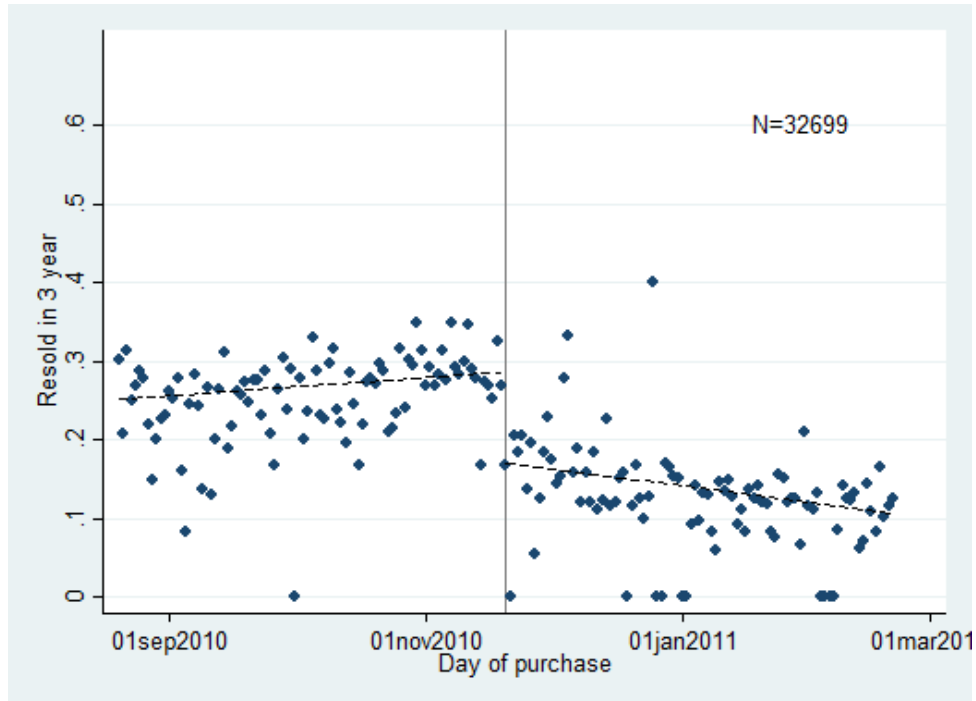
Table A.1: Probability of selling within 2 years since purchases

	Probability of selling in:		
	6 months	1 year	2 years
	(1)	(2)	(3)
Mortgage	-0.0418*** (0.00136)	-0.0461*** (0.00170)	-0.0206*** (0.00201)
Observations	201709	201709	201709
District FE	x	x	x
Week of purchases FE	x	x	x

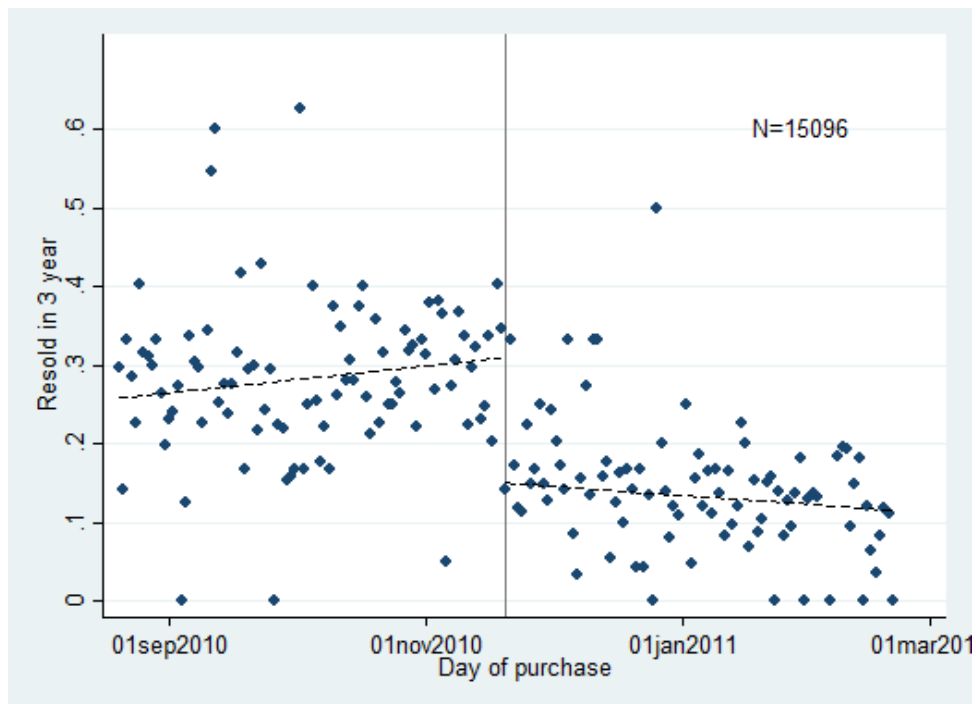
Notes: Sample includes residential properties purchased between January 2009 to 19 November 2010. Outcome variable is an indicator of the property being resold within  $j$ th month since purchase. *Mortgage* is an indicator for a transaction having an associated mortgage record.

Figure A.6: RDD plot: Probability of resold in 3 years - by mortgage record

(a) With mortgage

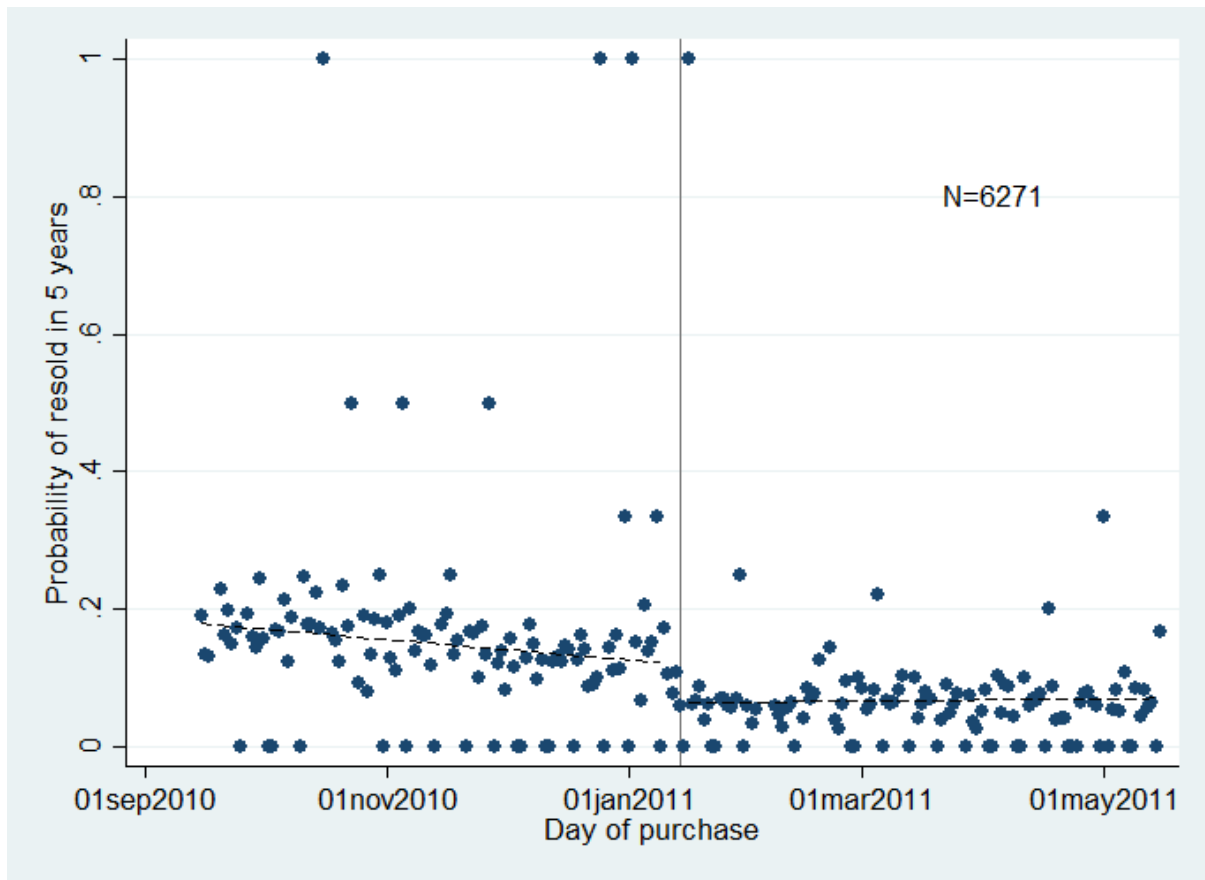


(b) Without mortgage



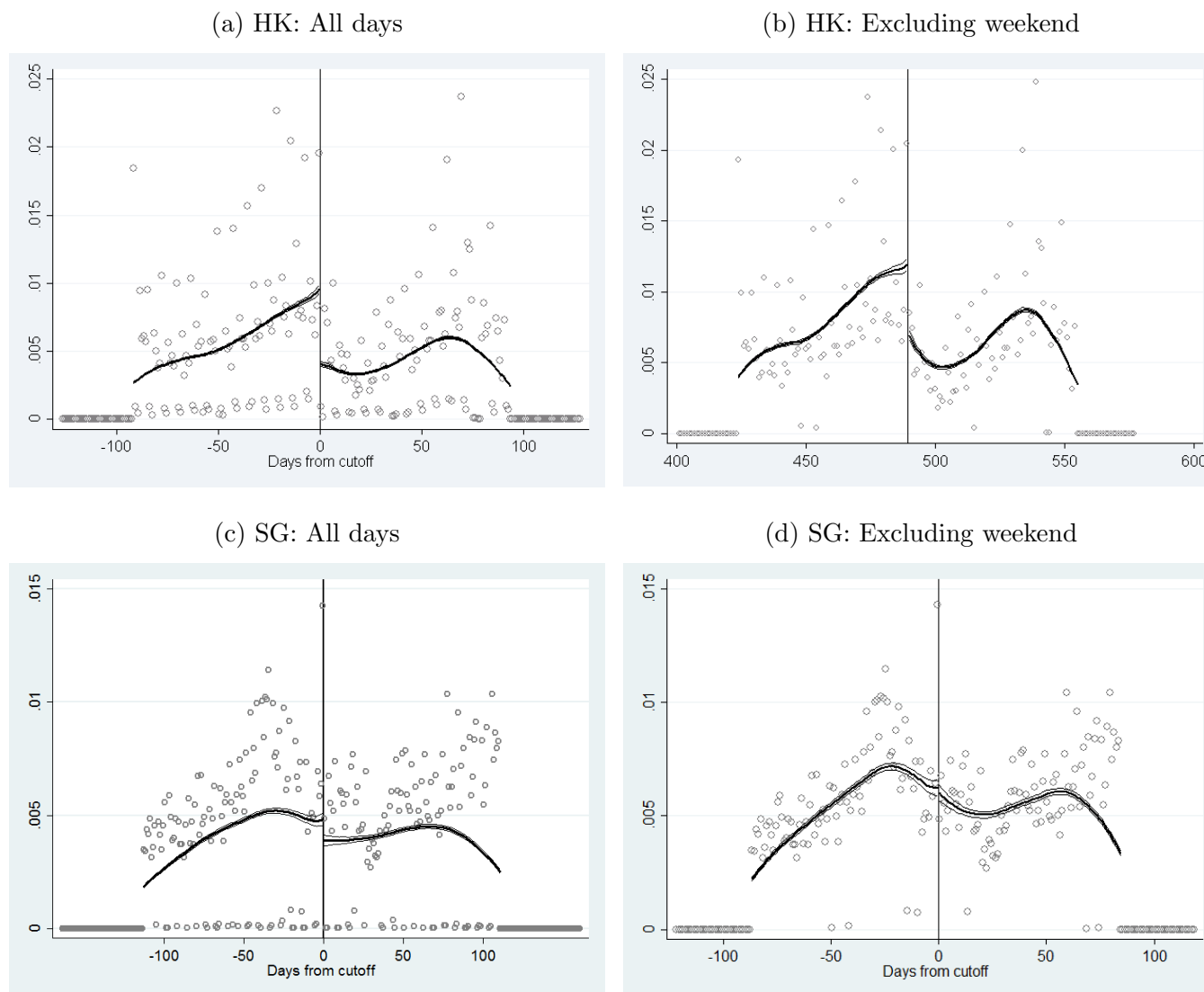
Note: See note of Figure 2. Panel (a) plot the holdings in which there is an associated mortgage record. Panel (b) plot the holdings in which there is no associated mortgage record.

Figure A.7: RDD: Singapore SSD Phase 3



Note: The graph plots the probability of a property being resold in 5 years since its purchased, by the day they are last obtained. The vertical line represent 14 Jan 2011. The dotted line are estimated linear trend in probability of resold in 5 years, separately for properties obtained before and after 14 Jan 2011.

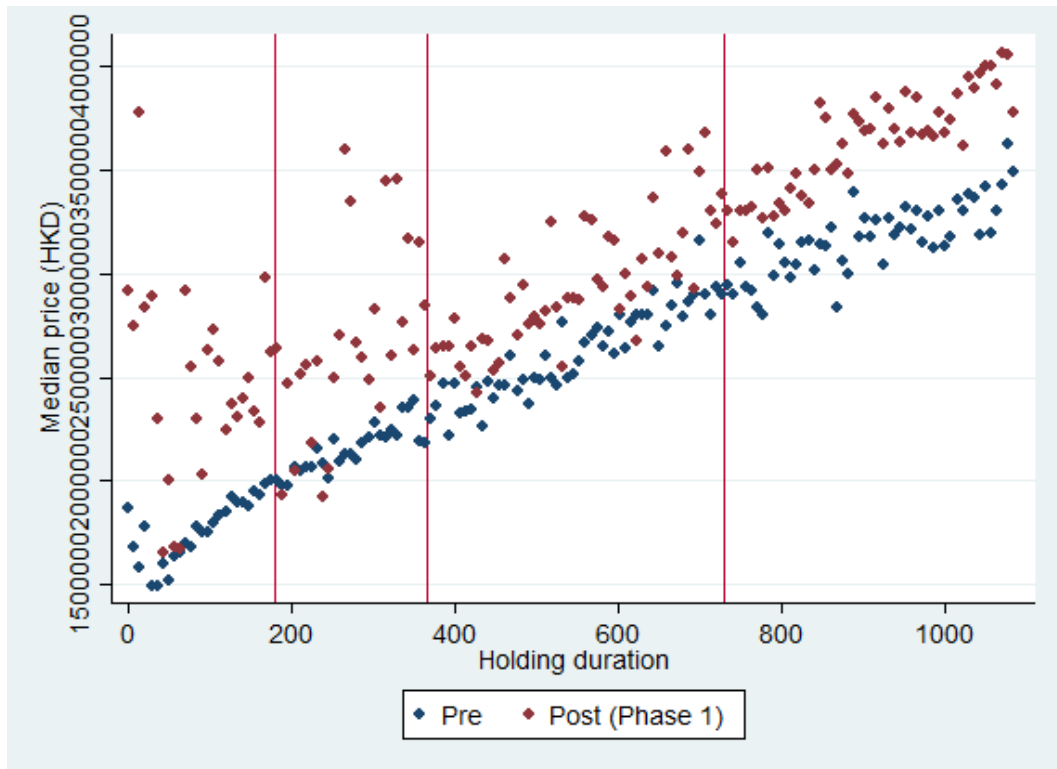
Figure A.8: Density of trading dates



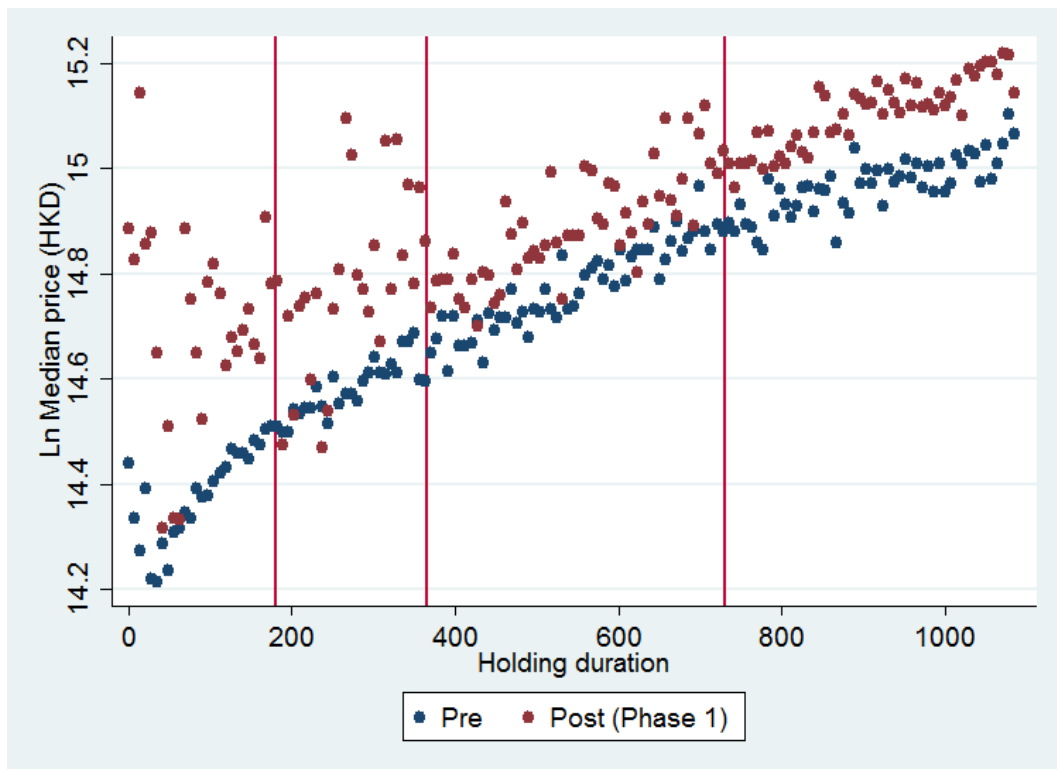
Panel (a) and (b) plot the density of transaction in Hong Kong by days from 20 Nov 2010, with all days and excluding weekends respectively; Panel (c) and (d) plot the density of transaction in Singapore by days from 20 Nov 2010, with all days and excluding weekends respectively.

Figure A.9: Median price conditional on holding duration

(a) Median price

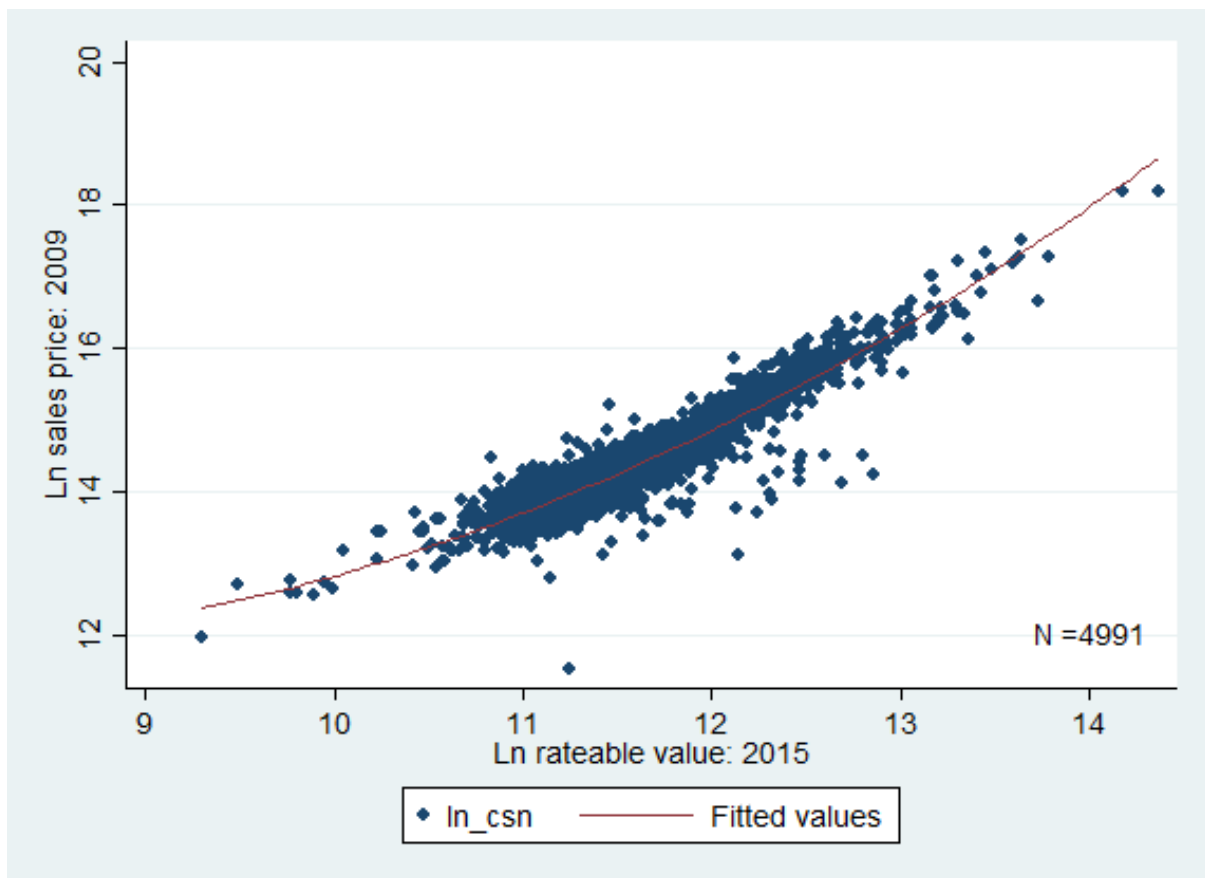


(b) Ln median price



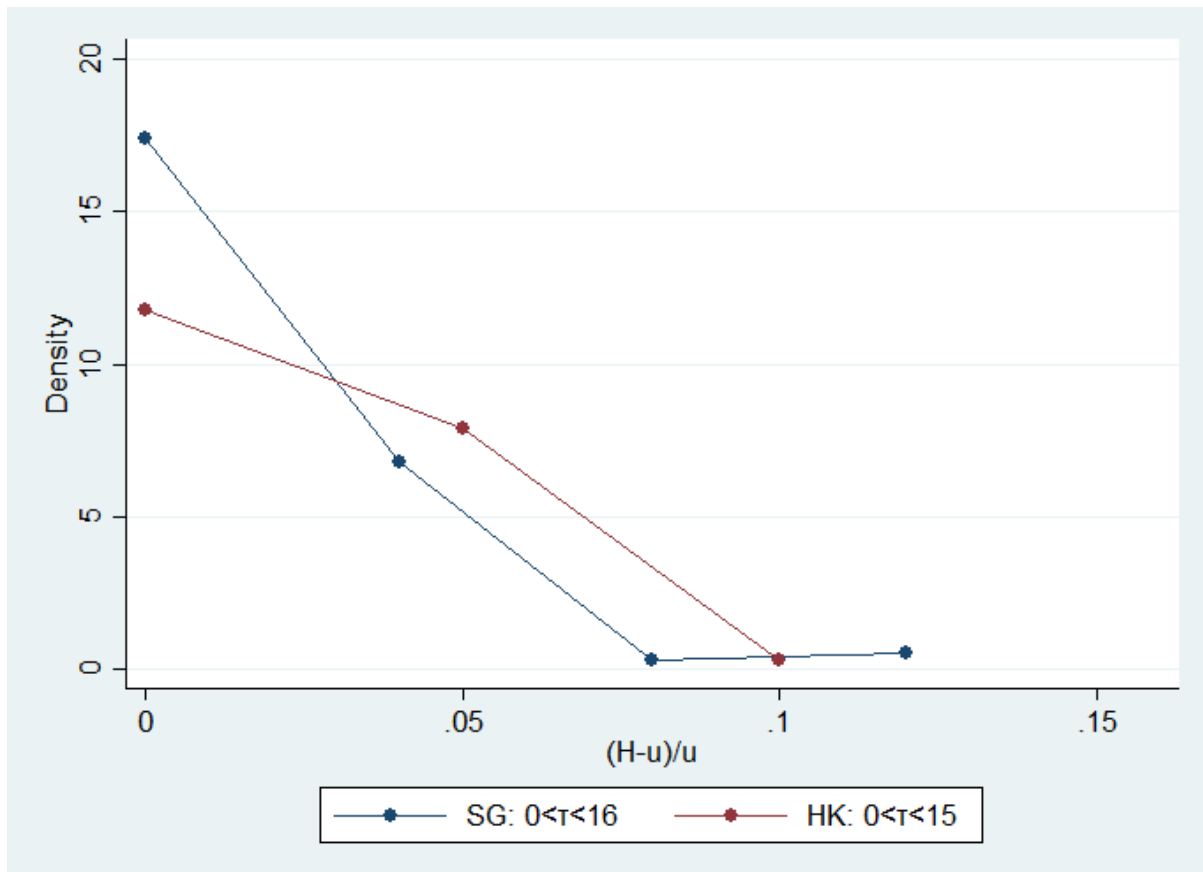
Notes: The graph plots the median price (current price) and median log price of residential properties traded at each holding period at week interval. The blue dots represent properties purchased between Jan 2009 to 19 Nov 2010. The red dots represent properties purchased between 20 Nov 2010 to 26 Oct 2012. The vertical lines represent holding period in which time notch is present in the Hong Kong Special Stamp Duty Phase 1, at 6 months, 1 year, 2 years intervals.

Figure A.10: Ratio of transacted price and government estimated rental rate



Notes: The graph plots the relationship between transacted price and the government estimate rateable values measured in 2015, for properties purchased and traded in 2009. It also shows fitted line using 2nd order polynomial.

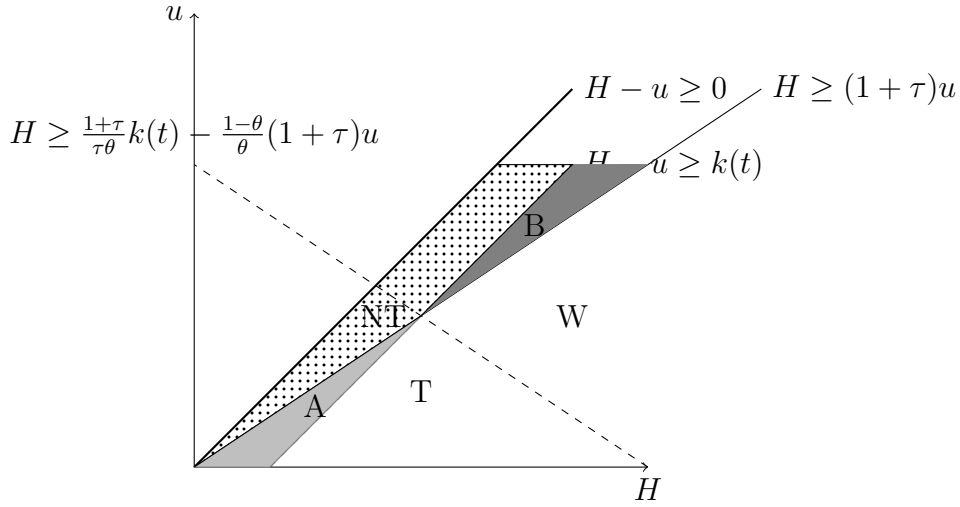
Figure A.11: Estimated distribution of trading surplus



Note: The graph plots the estimated density of the trading surplus distribution using equation 15, using the 1st phase of Special Stamp Duty and the 3rd phase of the Seller's Stamp Duty, computed from the hazard rate of trade in the flat region in each of distinct period with different tax rate within the same tax scheme. The red line plot the point estimates of the trading surplus at  $\{0, 0.05, 0.1\}$  using the trading hazard of properties purchased under the Special Stamp Duty phase 1 in Hong Kong. The blue line plot the point estimates of the trading surplus at  $\{0, 0.04, 0.08, 0.12\}$  using the trading hazard of properties purchased under the Seller's Stamp Duty phase 3 in Singapore.

## A.1 Explanatory note for conceptual framework

Figure A.12: Illustration of trade off between waiting and trade immediately



The area filled with dots is the strictly no trade area. The grey area represent the area in which trading would not happen in a universal transaction tax at rate  $\tau$ , but with the time notch design bunching expand the possibility of trade; the light grey area represent the case in which trading immediately dominates the bunching response. Area W and T are trade would have happen, while all the cases in W would choose to wait until the time notch instead of trading immediately.

When a transaction tax  $\tau$  is introduced, only matches with surplus higher than  $\tau$  percent of the reservation value of seller are traded. This typically reduced the number of transactions (i.e. area NT and B on the graph). However, with a specified time notch, a newly created area B exist that would yield positive surplus if the buyer and seller wait until  $t = \bar{t}$  to trade. The size of this area would depends on the utility cost of delaying transaction  $k_b + k_v$ .

The dotted line with negative slope indicate the trade off of bunching versus trade immediately even for those matches that would yield positive surplus if traded immediately. For matches that lies on the area W, both H and u are high, and thus the agreed price after bargaining would also be high, this implies that the proportional tax would be exceptionally costly for these transaction to happen. Therefore for matches in area W (and B) they would wait until time  $t$  to trade to evade the tax.

On the other hand, on the left of the downward sloping dotted line,  $H$  and  $u$  are smaller than those on the right, which implies a smaller price under Nash bargaining.



The tax to evade is too small relative to the total unit cost of waiting  $k_b + k_v$ , and thus for matches in area T (and A), trade would happen immediately.

When there is an exogenous increase in  $\tau$ , area A and T would decrease, but the cutoff  $H - u \geq k(t)$  remains unchanged, and thus area of B (and also W) would indeed increase. Increase the tax rate would increase the number of people who wait until  $\bar{t}$  to trade.

## A.2 Proofs for the conceptual framework

### *Proposition 1*

To see proposition 1, assume an arbitrary joint distribution of  $H$  and  $u - g(h, u)$ , and the density of match formation at time  $t - f(t)$ . Note that for every pair of  $H$  and  $u$ , we can map it into a price  $p$ . Then we can define the density of the conditional price distribution of  $p$ , the price distribution undistorted by the tax conditional on  $H - u > (k_b + k_v)(T - t) \cap H - u > 0$ , as  $P(p, k, t)$ . Then there is a critical price where the amount of buncher is given by the mass of price where for each time  $t$  being greater than  $p_d(\tau, t, k)$

$$p_d(\tau, t, k)\Delta\tau_t = (k_b + k_v)(\bar{t} - t) \quad (16)$$

Thus the amount of buncher is

$$B = \int_0^{\bar{t}} \int_{p_d(\tau, t, k)}^{\infty} P(p, k, t) \text{Prob}(H - u > (k_b + k_v)(T - t)) dp f(t) dt \quad (17)$$

$$\begin{aligned} \frac{dB}{d(k_v + k_b)} = & \int_0^{\bar{t}} -P(p_d(H, u, \tau, t, k)) \frac{dp_d}{d(k_v + k_b)} f(t) dt + \\ & \int_0^{\bar{t}} \int_{p_d(\tau, t, k)}^{\infty} P(p, k, t) \frac{d\text{Prob}(H - u > (k_b + k_v)(T - t))}{d(k_v + k_b)} dp f(t) dt \quad (18) \end{aligned}$$

where  $\int_0^{\bar{t}} -P(p_d(H, u, \tau, t, k)) \frac{dp_d}{d(k_v + k_b)} f(t) dt < 0$  as  $\frac{dp_d}{d(k_v + k_b)} > 0$ , and  $\frac{d\text{Prob}(H - u > (k_b + k_v)(T - t))}{d(k_v + k_b)} dp < 0$ . Thus if  $k_v + k_b$  is smaller, then the amount of bunchers is larger.

### *Propositions 2*

We prove the case where  $\tau_{\bar{t}} = 0$

Define  $(1 + \tau)u = L(\tau, u)$  and  $\frac{1+\tau}{\theta}k(t) - \frac{1-\theta}{\theta}(1 + \tau)u = U(\tau, t, u)$  and some arbitrary joint distribution of  $H$  and  $u$  -  $g(h, u)$

Probability of trade at time  $t =$

$$\begin{aligned} & \text{Prob}(L(\tau, U) < H < U(\tau, t, \theta, u)) \\ & \int_0^{\frac{k(t)}{\tau}} \int_{L(\tau, U)}^{U(\tau, t, \theta, u)} g(h, u) dh du \end{aligned} \tag{19}$$

Since the upper bound of the two integrals are decreasing in  $t$ , where the joint density is strictly positive and independent of  $t$ , we have  $\frac{d\text{Prob}(L(\tau, U) < H < U(\tau, t, \theta, u))}{dt} < 0$

Probability of forgone trade at time  $t =$

$$\int_{\frac{k(t)}{\tau}}^{\infty} \int_u^{k(t)+u} g(h, u) dh du + \int_0^{\frac{k(t)}{\tau}} \int_u^{(1+\tau)u} g(h, u) dh du \tag{20}$$

where  $\frac{d\text{Prob}(\text{forgone})}{dt} = \int_{\frac{k(t)}{\tau}}^{\infty} g(k(t) + u, u) k'(t) dh du < 0$

which is decreasing with  $t$

### A.3 Explanatory note on the bunching estimates

Define the distribution of timing of arrival of a match ( $q$ ) for a seller is  $L(t) = Prob(q \leq t)$ , then the density of the time of sales is

$$\begin{aligned} P(T \leq t) &= Prob(q \leq t) Prob(H - u > 0) \\ &= L(t) \int_{H-u>0} dG(H, u) \\ &= F(t) \end{aligned}$$

Define  $f(t)$  as the pdf of  $F(t)$

$$f(t) = l(t) \int_{H-u>0} dG(H, u)$$

and  $g(t)$  as

$$g(t) = l(t) \int_{H-u>\tau u} dG(H, u)$$

Then the expected waiting duration could be estimated using  $\hat{B}, \hat{f}(\bar{t})$  and  $\hat{g}(\bar{t})$

$$\begin{aligned}
B &= P(T = t) \in \{\underline{B}, \bar{B}\} \\
\bar{B} &= \int_0^{\bar{t}} \text{Prob}(q \geq t(H, u) \cap H - u > 0) dL(q) \\
&= \int_0^{\bar{t}} \int_{q \geq t(H, u) \cap H - u > 0} dG(H, u) dL(q) \\
&= \int_0^{\bar{t}} \int_{H - u > 0} I[q \geq t(H, u)] dG(H, u) dL(q) \\
&= \int_{H - u > 0} \int_0^{\bar{t}} I[q \geq t(H, u)] dL(q) dG(H, u) \\
&= \int_{H - u > 0} \int_{t(H, u)}^{\bar{t}} dL(q) dG(H, u) \\
&\approx \int_{H - u > 0} \int_{t(H, u)}^{\bar{t}} l(\bar{t}) dq dG(H, u) \\
&= \int_{H - u > 0} \int_{t(H, u)}^{\bar{t}} dq dG(H, u) l(\bar{t}) \\
&= \int_{H - u > 0} [\bar{t} - t(H, u)] dG(H, u) l(\bar{t}) \\
&= \int_{H - u > 0} [\bar{t} - t(H, u)] \frac{dG(H, u)}{\int_{H - u > 0} dG(H, u)} l(\bar{t}) \int_{H - u > 0} dG(H, u) \\
&= E(\bar{t} - t(H, u) | H - u > 0) l(\bar{t}) \int_{H - u > 0} dG(H, u) \\
&= E(\bar{t} - t(H, u) | H - u > 0) f(\bar{t})
\end{aligned}$$

and

$$\begin{aligned}
\underline{B} &= \int_0^{\bar{t}} \text{Prob}(q \geq t(H, u) \cap H - u > \tau u) dL(q) \\
&= E(\bar{t} - t(H, u) | H - u > \tau u) g(\bar{t})
\end{aligned}$$

This implies

$$E(\bar{t} - t(H, u) | H - u > 0) \geq \frac{\hat{B}}{f(\bar{t})}$$

and

$$E(\bar{t} - t(H, u) | H - u > \tau u) \leq \frac{\hat{B}}{g(\bar{t})}$$

And as  $p(\tau, H, u)\tau = \bar{t} - t(H, u)$

$$\begin{aligned} E(\bar{t} - t(H, u) | H - u > \tau u) &= E(p(\tau, H, u)\tau | H - u > \tau u) \\ &= \tau E(p(\tau, H, u) | H - u > \tau u) \\ &= \tau \frac{E(p(\tau, H, u) | H - u > \tau u)}{E(p | H - u > 0)} * E(p | H - u > 0) \\ &\geq \tau \frac{E(p(\tau, H, u) | H - u > \tau u)}{E(p | H - u > 0)} * E(p(\tau, H, u) | H - u > 0) \\ &= \frac{E(p(\tau, H, u) | H - u > \tau u)}{E(p | H - u > 0)} * E(\tau p(\tau, H, u) | H - u > 0) \\ &= \frac{E(p(\tau, H, u) | H - u > \tau u)}{E(p | H - u > 0)} * E(t - t(H, u) | H - u > 0) \\ &\geq \frac{E(p(\tau, H, u) | H - u > \tau u)}{E(p | H - u > 0)} * \frac{B}{f(\bar{t})} \end{aligned}$$

Thus

$$\frac{\hat{B}}{g(\bar{t})} \geq E(\bar{t} - t(H, u) | H - u > \tau u) \geq \frac{E(p(\tau, H, u) | H - u > \tau u)}{E(p | H - u > 0)} * \frac{B}{f(\bar{t})}$$

## A.4 Explanatory notes on welfare analysis

The welfare cost of having traders wait for the time notch is represented by the term

$$\int_0^{\bar{t}} \int_{W,B} (k_b + k_v)(\bar{t} - t) dG(H, u) d\tilde{L}(t) \quad (21)$$

This could be reduced to

$$\begin{aligned} \int_0^{\bar{t}} \int_{W,B} (k_b + k_v)(\bar{t} - t) dG(H, u) d\tilde{L}(t) &= \\ &\geq \int_0^{\bar{t}} \int_W (k_b + k_v)(\bar{t} - t) dG(H, u) d\tilde{L}(t) \\ &= \int_{H-u \geq \tau u} \int_{t(H,u)}^{\bar{t}} (k_b + k_v)(\bar{t} - t) dG(H, u) d\tilde{L}(t) \\ &= (k_b + k_v) \int_{H-u \geq \tau u} \int_{t(H,u)}^{\bar{t}} (\bar{t} - t) d\tilde{L}(t) dG(H, u) \\ &\approx (k_b + k_v) \int_{H-u \geq \tau u} \int_{t(H,u)}^{\bar{t}} (\bar{t} - t) l(\bar{t}) dG(H, u) \\ &= (k_b + k_v) l(\bar{t}) \int_{H-u \geq \tau u} \int_{t(H,u)}^{\bar{t}} (\bar{t} - t) dt dG(H, u) \\ &= (k_b + k_v) l(\bar{t}) \int_{H-u \geq \tau u} \frac{(\bar{t} - t)^2}{2} dG(H, u) \\ &= (k_b + k_v) l(\bar{t}) E\left(\frac{(\bar{t} - t)^2}{2} | H - u \geq \tau u\right) * \int_{H-u > \tau u} dG(H, u) \\ &\geq (k_b + k_v) l(\bar{t}) \frac{E((\bar{t} - t) | H - u \geq \tau u)^2}{2} * \int_{H-u > \tau u} dG(H, u) \\ &= (k_b + k_v) \frac{E((\bar{t} - t) | H - u \geq \tau u)^2}{2} * \int_{H-u > \tau u} dG(H, u) l(\bar{t}) \end{aligned}$$

which is the expression in the main text, and conceptually excluding those traders with surplus less than  $\tau u$  but who chose to trade at  $\bar{t}$ .

## B Data appendix

### Hong Kong

- **Source** The data used in this paper originated from the Memorial Day Book provided directly by The Land Registry of Hong Kong, and standardized by the author.
- **Transaction Record** The data used in this paper contains the "Agreement of Sales and Purchases" and its variations in the Memorial Day Book.
- **Sample construction** The data used in the current version of the paper does not include transactions that has multiple unit of real estate properties transacted in one single contract that constitute very small amount of all the contracts. The original data contains transactions of *all* real estate properties that are chargeable for stamp duty, that include properties for all uses including for example car parks and lands; the residential sample used in the current version of the paper is determined by the full address with official list of residential estates and other publicly available information, supplemented by information from the Rating and Valuation Department.
- **Date of purchase** The date of purchase is defined as the day in which the contract is signed, instead of the day it arrives in the Land Registry, under the column of "Date of Instrument" as opposed to "Date of Delivery". If there is a provisional agreement appears in the Memorial Day Book for the same property under the exact same price of formal agreement of sales and purchases and there is no other formal agreement of sales and purchased between the provisional agreement and the formal agreement in which it has the exact same price, it is considered as under the same transaction. The day of purchases is thus corrected for the day in which the provisional agreement is signed.
- **Mortgage record** For mortgages approved by financial institution, the Land Registry contains an entry and it appears in the Memorial Day Book. The description of mortgage entry in the Memorial Day Book allows identification between first time mortgage of the property, and for those transaction in which there is a mortgage entry record appearing in the 3 months that follows, before any other formal transaction record appears, it is defined as associated with a mortgage record.

## Singapore

- The transaction in which a property is transacted on the same day with exact same price is omitted from the data which is likely due to an entry mistakes in the original data from the Urban Redevelopment Board, a procedure also applied in [Giglio et al. \(2015\)](#)



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