Speculate a lot

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Abstract

While the residential and commercial property markets in Hong Kong are extensively discussed, little attention is paid to the carpark market. This work contributes to fill the research gap in three ways. First, it provides a simple empirical model to explain carpark ratios in residential buildings. Second, it hand-collects transaction-level data and constructs a price index for the carpark market in Hong Kong. Third, it shows that changes in stamp duties increase the volatility in the carpark market. This research may shed light to the current debate on the effectiveness of the stamp duty in stabilizing the real estate market.

JEL classification number: G18, R14, R30

Keywords: Carpark ratio, carpark price index, GARCH model, stamp duty, volatility

1. Introduction

Automobile is an indispensable component of the urban transportation in modern cities. Therefore, to facilitate smooth flows of people, goods and services, the amount, as well as the locations of carparks, are important choices for each city. Moreover, along with the economic growth, usage of cars is expanding rapidly. It results in a continuously growing demand for the carpark, which can be an issue as it would compete with other land uses. For instance, in the United States, it has around 105 million to 2 billion carparks, occupying 3,590 square miles of land.[1] On average, eight parking spots are built for a car. In *ReThinking a Lot* (2012), Ben-Joseph shows that parking lots cover more than one-third of the land area, and they should be restructured for extending their use for other purposes. In Australia, parking in Melbourne is an important concern of residents and slogans are set up in the carparks calling for actions against multi-storey development (Taylor, 2014). In short, city planners need to make a long-term forecast of parking demand and design the optimal carpark ratio among different parts of a city.

This paper studies the carpark market in Hong Kong, which is well-known to be a densely populated city with a high land price. In addition, Hong Kong has several distinctive features which would facilitate our understanding of issues related to the carpark. First, according to Van Audenhove et al. (2014), Hong Kong is ranked first in terms of urban mobility index [2] (Table 1). Its well-established transportation infrastructure allows almost 90% of residents to travel by public transport. On the contrary, none of the U.S. cities was listed in the top 30, in which private cars remain the most common mode of transport. In 2015, each Hong Kong household owned 0.3 private car on average, whereas the U.S. counterparts owned around 2 cars (Figure 1).

[1] Source: http://www.nytimes.com/2012/01/08/arts/design/taking-parking-lots-seriously-as-public-spaces.html

[2] The 19 criteria (with the corresponding points in parenthesis) for computing the urban mobility index include: Financial attractiveness of public transport (4); share of public transport in model split (6); share of zero-emission models in model split (6); roads density (4); cycle path network density (6); urban agglomeration density (2); smart card penetration (6); bike sharing performance (6); car sharing performance (6); public transport frequency (6); initiatives of public sector (6); transport related CO_2 emissions (4); NO_2 concentration (4); PM_{10} concentration (4); traffic related fatalities (6); increase of share public transport in model split (6); increase of share of zero emission modes (6); mean travel time to work (6); density of vehicles registered (6).

The sharp contrast in private car ownership ratio suggests that the demands of carpark are totally different in two areas, and this paper can therefore complement existing studies which focus on the case of the United States.

[Table 1 and Figure 1 are about here]

Second, Hong Kong is a mountainous terrain (Tse and Chan, 2003). As Figure 2a shows, more than three-fourths of land is zoned for grassland, woodland and shrubland, and the remaining portion was allocated for urban purposes. Together with the fact that the boundary of Hong Kong is fixed by Basic Law (Leung and Tang, 2015a), it has three important effects on the carpark market: (1) Unlike U.S., it is extravagant for Hong Kong to allocate large pieces of land for carparks, especially in urban areas[3]. For those idle sites, temporary outdoor carparks will be operated until the land is used for constructing premises. (2) To make efficient use of land resources, carparks are usually incorporated inside the high-rise residential buildings, office buildings and shopping arcades. Unless government approval is provided, the number of parking spaces inside the premises cannot be further extended later. (3) The growth of parking spaces is slower than the growth of automobiles, leading to a severe shortage of parking spaces. As Figure 2b shows, the ratio of carpark spaces to registered automobiles dropped from 1.32 in 2006 to 1.05 in 2016. It suggests that the current parking services cannot even satisfy employees who drive back and forth to work. Under an excess carpark demand and a frozen illegal parking penalty, the numbers of illegal parking between 2006 and 2015 doubled to 1,300,000 (Figure 2c).

[Figures 2a, 2b, and 2c are about here]

Third, private cars may be necessities among wealthy households living far from mass transit stations, and hence their carpark demands are relatively inelastic. This creates

[3] Currently, there are only 11 multi-storey carparks operated by the government, offering to 4,810 parking spaces for private cars.

lasting shortages of parking spaces and expensive parking fees in Hong Kong. When comparing to the parking fees in U.S. cities, Hong Kong parking service is the second most expensive (Figure 2d). Parking lots are soon turned into investment vehicles because of the continuous excess carpark demand, stable stream of rental income, low entry barrier, inexpensive management fee and low maintenance cost. More importantly, Hong Kong experiences continuing growth in terms of population and real GDP per capita (Figure 2e), which makes the land shortage problem even more serious. It is expected that these will be reflected by the surging carpark prices in the future.

[Figures 2d and 2e is about here]

Fourth, Hong Kong has a liquid and transparent real estate market protected by a well-established legal system (Leung and Tang, 2013). Regarding the parking spaces of the premises, it is well documented in the monthly digest of Buildings Department. The parking capacity will not be affected by how closely the cars are parked together. In addition, any real estate transactions require the signing of a sale and purchase agreement by both seller and buyer. Land Registry is responsible to keep updated information about the registered owner of the property. Therefore, our data is reliable and timely for exploring the research questions.

This paper attempts to make several contributions to the existing literature. First, it contributes to the empirical transportation economics. In the previous works, researchers mainly focused on the usage patterns of the on-street parking and multi-storey carpark (Ibeas er al, 2014; Amer and Chow, 2017; Pu et al., 2017). Residents in detached houses of the United States tend to park at homes, while renters tend to live in apartment buildings. In Hong Kong, most people, whether renters or owner-occupiers, live in high-rise buildings, and thus developers have to strike a balance between the number of carparks and housing units in their construction projects for profit maximization (Lai and Wang, 1999; Leung and Tang, 2015b). Carparks offer convenience to tenants and hence create added value to the residential properties, but

too much vacant parking spaces mean a waste of valuable floor areas.[4] Therefore, our analysis sheds lights on the role of carparks in real estate development and perhaps even city planning.[5] Second, this paper constructs a carpark index for Hong Kong.[6] It provides a valuable indicator for tenants, investors and government to make purchasing, investment and policy decisions respectively. Our paper will also apply time series techniques to uncover the inter-relationships between different asset markets. Last, but not least, it relates to the studies of the volatility of asset markets. Leung et al. (2015) found that property buyers in Hong Kong are likely to trade at the cutoff points of tax schedule for tax avoidance, meaning that investors will react differently for a shift of taxation regimes. Our paper will modify the GARCH model[7] to show that anti-speculative housing policies are catalysts for speculation in carpark market.

The rest of paper is organized as follows. In section 2, it runs a simple regression to explain carpark ratios in residential developments. In section 3, it constructs a weighted-average price index for measuring Hong Kong's carpark market and performs time series analysis. For section 4, it employs exponential GARCH-in-mean model to explain the effect of stringent stamp duty arrangements on the volatility of the carpark market. Concluding remarks will be made at the end.

2. Carpark ratio

As we have explained, the demand for carpark roots from the land scarcity. And since the demand for carpark tends to be *very local*, meaning that people typically park their cars within walking distance of their residence, it is necessary to first construct an index to indicate the local scarcity of carpark. Our measure, the carpark ratio (*CH_RATIO*),

[4] A growing body of literature have criticized the inefficiencies in forecasting parking spaces. Among others, see Manville (2013) and Guo and Ren (2013) for details.
[5] See Taylor (2014) for an example in Melbourne.
[6] Currently, Rating and Valuation Department provides price indexes for four kinds of premises, including residential buildings, offices, retail properties and industrial buildings.
[7] The literature is too large to be reviewed here. Among others, see Engle (1982) and Bollerslev (1986) for details.

is defined as the total number of carparks relative to the total number of housing units, is of interest to several stakeholders. For tenants, they would like to ascertain that sufficient parking spaces are available for their daily use; for developers, they have to assign an optimal number of carparks in their construction projects; for speculators, the carpark ratio relates to the tightness of the carpark market and sellers' bargaining power (Carrillo et al., 2015). Hence, this paper complements to the literature of economics of parking through investigating the carpark ratio among 285 residential estates[8] in Hong Kong:

$$CH\_RATIO = \gamma_0 + \gamma_1 PRIVATE + \gamma_2 MTR + \gamma_3 CBD + \gamma_4 CBD^2 + \gamma_5 KLN + \gamma_6 NT + \varepsilon \quad \ldots (1)$$

The highlights of equation (1) are as follows. First, it proposes that carpark ratio will be higher in private developments (*PRIVATE*), as wealthy families are more likely to own their private cars for commuting. Second, it hypothesizes that residents living close to mass transit station (*MTR*) will abandon using private cars and therefore carpark ratio is reduced. Third, it follows Tse and Chan (2003) to model a nonlinear relationship between carpark ratio and commuting time to the central business district (*CBD*). Last, it introduces two locational dummies (*KLN* and *NT*) to investigate whether carpark ratio differs significantly among different parts of Hong Kong. Our data comes from Rating and Valuation Department, Housing Authority, Link REIT and Google Map. The summary statistics are reported in Table 2.

[Table 2 is about here]

Our estimation results are reported in Table 3. Model 1 is a simpler version with the exclusion of locational dummies. Not surprisingly, γ_1 is positive and significant at 1% level. The carpark ratio of a private estate is 14.55% higher than that of a non-private estate, other things being equal. In addition, γ_2 is negative and significant at 5% level. If the residential estate is near the transit station, its carpark ratio is reduced by 4.36%.

[8] The list of residential estates is available upon request.

More importantly, our paper suggests a nonlinear relationship between commuting time and carpark ratio. On one hand, residential estates that are farther away from the central business district will be equipped with a higher carpark ratio. On the other hand, such a positive relationship will eventually die out, as residents living far away are usually having a lower median income (Figure 3) and prefers using public transport. The estimated coefficients γ_3 and γ_4 confirm this inverted U-shape relationship at 1% significance level.

In model 2, it includes a complete list of regressors. Our empirical results are robust that the estimated coefficients for γ_1, γ_2, γ_3 and γ_4 are significant and carry the expected signs. The two locational dummies are insignificant, meaning that no empirical evidence is found for a significant difference in carpark ratio among the residential estates located at different parts of Hong Kong. Overall, our results provide strong evidence that carpark ratio is explained by types of residential properties, proximity to mass transit and commuting time to the central business district.

[Table 3 and Figure 3 are about here]

3. Carpark price index

While carpark investment is popular in Hong Kong, it is surprising that an official carpark index is unavailable. Therefore, for measuring the performance of carpark market, our paper constructs a carpark index (CP) by the weighted average method:

$$CP_t = \frac{\sum NUMBER_i * \bar{P}_{i,t}}{\sum NUMBER_i} \quad \ldots (2)$$

where

$NUMBER_i$ is the carpark number in estate *i*;

$\bar{P}_{i,t}$ is the average transacted price of a parking space in estate *i* at time *t*.

As equation (2) shows, estates with higher carpark numbers have a greater impact on the carpark index than those with lower carpark numbers. Moreover, the average transacted carpark price for an estate in a given quarter is computed based on transaction-level data[9] from EPRC dataset. After construction of the carpark index, it is deflated by consumer price index (A) to obtain real carpark index (RCP)[10]:

$$RCP_t = \frac{CP_t}{CPI(A)_t} \quad \ldots (3)$$

For the sake of comparison, the real price indexes of the carpark and other asset markets, rebased as 100 in 1999, are plotted in Figure 4. In 1997, the arrival of Asian Financial Crisis resulted in a significant drop in the real asset prices. Some of the investors were suffered from negative equity and declared bankruptcy (Leung and Tang, 2011). Between 1999 and 2002, Hong Kong experienced a recession and the real asset prices showed a similar downward trend. In 2003, Hong Kong got recovered from SARS epidemic. Individual Visit Scheme was introduced in the same year, which allowed visitors from the Mainland to visit Hong Kong on an individual basis. With the expansion of the tourism industry, the retail sales and business environment kept improving, which resulted in fast-paced growth in real retail and office prices (Chong and Yiu, forthcoming). Since 2009, strong market sentiment existed in the housing market and bubbles were found in real housing prices (Yiu et al., 2013). Given the strong economic growth, carparks have been another popular kind of investment vehicle and the real carpark index was catching up with the upward trend from 2012.

[Figure 4 is about here]

[9] Altogether, 22,281 transactions were used in the construction of carpark index.
[10] See Leung et al. (2006) for details.

To further explore the inter-relationships between asset markets and the macroeconomy, the paper follows Chang et al. (2013) to introduce real GDP, TED spread[11] and TERM spread[12] in the system (Table 4) and applies time series analysis. In the first step, it performs the Augmented Dickey-Fuller test to check the stationarity of the series. It is evident from Table 5 that the level series contains a unit root (i.e. non-stationary) while the first-differenced series does not contain a unit root (i.e. stationary). In the second step, it runs the granger causality test[13] on the first-differenced data. Several interesting patterns are found in Table 6:

First, unidirectional causality runs from RHP to RCP at 1% significance level. As the public transportation network is well-established in Hong Kong, residents can choose to commute by public transport instead of private cars. Therefore, carparks are not a must-have item for families. Under "housing comes first, car follows" scenario, it is reasonable that previous change in real carpark prices cannot explain the current change in real housing prices.

Second, RSP granger causes ROP at 1% significance level, RCP and RHP at 5% significance level and RRP at 10% significance level. This confirms "wealth effect hypothesis" (Case, Quigley and Shiller, 2005) that a rising wealth, created from the surging value of stock portfolios, drives up property investments and results in rising real property price indexes. It also coincides with the view that the performance of the stock market is a leading indicator for predicting macroeconomy.

Third, bi-directional causality runs between output and property prices (except carpark). On one hand, an economic boom strengthens investor confidence and triggers the demand for housing, office and retail spaces. On the other hand, it supports "credit price effect" (Kapopoulos and Siokis, 2005) that changes in property prices have significant

[11] TED spread measures the perceived credit risk in the macroeconomy. It increases with the risk of default on interbank loans.
[12] A positive TERM spread means the economy is doing well and long-term borrowing is rewarded more than short-term borrowing. When it is near zero, it suggests uncertainty of the economy.
[13] See Granger (1969).

implications on the borrowing capacity of households and firms, thus affecting the consumption and investment plans in the economy.

Last, TED spread granger causes RCP at 10% significance level, but it does not granger cause RHP. The intuition is simple. As Hong Kong has a well public transportation system, the mode of commuting is more flexible, meaning that the carpark demand is more elastic than the housing demand. So, when the TED spread widens, deterioration of the credit environment induces households to cut the expenses on the private car first and results in a decline in real carpark prices.

[Tables 4, 5 and 6 are about here]

4. Volatility of residential carpark market

In the previous section, we have constructed a carpark price index. This section would, therefore, study the volatility of carpark market based on that index. Inspired by Wong et al. (2006), who found that the volatility of real estate market is significantly driven by government anti-speculation policies, our paper revisits similar research question and hypothesizes that the adoption of extraordinary taxes on the housing market would pose higher volatility on carpark market.

Considering a housing bubble from 2009Q4[14], the government introduced a series of countercyclical housing policies, including special stamp duty (SSD) and double stamp duty (DSD), to cool down the housing market. However, SSD and DSD brought different effects to carpark market. SSD, introduced in 2010Q4, imposes an extra stamp duty for those who resell the residential property within a short period of time (less than 3 years) but encourages investors looking for non-residential investments (e.g. carpark) at the same time. DSD is effective from 2013Q1 and charges a higher rate for those who transacted a second ("non self-occupied") property. For example, an existing

[14] See Tang (2017) for details.

homeowner has to pay DSD if he purchases a parking space. Hence, DSD targets to reduce speculation activities and stabilize the real estate market.

To determine the effects of housing cooling measures on the volatility of the carpark market, one standard approach is to use generalized autoregressive conditional heteroskedasticity (GARCH) model (Bollerslev, 1986). The model suggests that the conditional variance is explained by a weighted function of long-term average value, information about volatility during previous period and the fitted variance from the model during the previous period (Brooks, 2008). However, it encounters several problems such as breaching non-negativity conditions, skipping the leverage effect and ignoring the feedback effect between conditional variance and conditional mean. Therefore, our paper adopts the exponential GARCH-in-mean model (Nelson, 1991; Engle et al., 1987), with some modifications:

$$r_t = \beta_0 + \beta_1 r_{t-1} + \beta_2 r_{t-2} + \beta_3 r_{t-3} + \beta_4 r_{t-4} + \beta_5 ln(\sigma_t^2) + \varepsilon_t \quad \ldots (4)$$

$$\varepsilon_t \sim N(0, \sigma_t^2) \quad \ldots (5)$$

$$ln(\sigma_t^2) = \alpha_0 + \alpha_1 ln(\sigma_{t-1}^2) + \alpha_2 \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \alpha_3 \frac{|u_{t-1}|}{\sqrt{\sigma_{t-1}^2}} + \alpha_4 D_{1,t} + \alpha_5 D_{2,t} \quad \ldots (6)$$

where

D_1 = 1 for the period from 2010Q4 – 2012Q4 (only special stamp duty is introduced);

D_2 = 1 for the period from 2013Q1 – 2015Q4 (special stamp duty and double stamp duty are introduced)

Equation (4) represents the conditional mean equation where the carpark market return (r_t) is explained by its four previous lags ($r_{t-1}, r_{t-2}, r_{t-3}, r_{t-4}$) and natural logarithm of contemporaneous conditional variance ($ln(\sigma_t^2)$). If β_5 is positive and statistically significant, it suggests that a rise in conditional variance will result in an increase in mean return. In other words, such a setting allows us to capture an idea that the investors should be compensated for bearing additional risks. For equation (5), it assumes the

residual in conditional mean equation (ε_t) to be conditionally normally distributed with mean zero and variance σ_t^2.

The conditional variance equation is expressed as equation (6). Several objectives are achieved through its specifications. First, by incorporating the natural logarithm on conditional variance, it avoids imposing non-negativity conditions on alphas. Second, it allows us to account for the leverage effect. Specifically, if the relationship between volatility and returns is negative, α_2 will be negative and significant. Third, two dummy variables are included in the conditional variance equation to capture the effect of stringent stamp duty rules. If DSD promotes more carpark investments and SSD discourages carpark speculation, we will expect α_4 is positive and $\alpha_4 > \alpha_5$.

After estimating the EGARCH-in-mean model by the method of maximum likelihood, the results are reported in Table 7. Regarding the conditional mean equation, the coefficient of β_5 is positive and 10% significant, thus confirming the finance theory that investors will be rewarded for higher risks. For the conditional variance equation, α_1 is significant at 5% level and has a value of 0.45, suggesting volatility in carpark market is persistent to a certain extent. α_2 is insignificant, thus leverage effect cannot be found. More importantly, the coefficient of SSD dummy (α_4) is positive and significant at 5% level, and $\alpha_4 > \alpha_5$ is found. On one hand, these confirm the proposition that SSD switches funds from investing residential properties to non-residential assets and rises the carpark market volatility since 2010Q4. On the other hand, DSD dampens the speculation to all kinds of real estates effectively. Overall, there is no statistical evidence that implementing SSD and DSD together can reduce the volatility from 2013Q1 onwards (α_5 is insignificant).

[Table 7 is about here]

In summary, our results support the argument that the government tackles housing issues in bits and pieces. When the housing bubble emerged in 2009Q4, the government introduced SSD to cool down the housing market but failed to alert that speculative funds, under a free capital market, will be reallocated to other real estate markets and hence imposing greater volatilities to them. To minimize the negative consequences of the "government intervention", the government should take a long-term and comprehensive view of the real estate market and carefully consider the effects of a policy before it is launched.

5. Conclusion

Like many well-populated Asian cities, Hong Kong government has concentrated their efforts on building an efficient public transportation network. The car ownership ratio used to be low as well. Thus, shortages in carpark supply seem not to be an important public concern. With continuous economic and population growth, however, the carpark shortage becomes an increasingly important issue. For instance, Griffiths (2018) reports that "Next time you're griping about having to feed coins into a parking meter, spare a thought for drivers in Hong Kong, where a single parking space has just sold for $760,000." Wu (2017) also writes that "Henderson Land Development… won a hotly contested auction on Tuesday, agreeing to pay a record HK$23.3 billion for a commercial property site in the heart of Hong Kong's central business district currently being used as a public car park…. European and U.S. financial firms, trying to cut costs, reduced their presence in the greater Central area by 146,000 square foot and 28,000 square foot respectively in the three-year period to March 2016, according to a November report by property consultancy CBRE." Obviously, carparks are now not solely providing parking services but acting as an investment vehicle.

For a variety of reasons, Hong Kong's carpark market is totally different from the U.S. counterpart. This paper, therefore, takes an initial step to study the carpark ratio in residential buildings, construct a carpark price index and investigate its volatility. Several key insights are found. First, carpark ratio is significantly explained by types

of residential properties, proximity to mass transit and commuting time to the central business district. Second, “wealth effect” and “credit price effect” are observed in the carpark market. Third, the countercyclical housing policies have a significant effect on the volatility of the carpark market.

Our results have important implications for policymakers. While SSD aims to stabilize the housing market by imposing an extra cost on speculation activities, funds, under a free capital environment, can be easily switched to other asset markets. This results in an increase in the volatility of carpark market. More importantly, because of a lack of long term and comprehensive real estate policies, it was later found that these extraordinary arrangements are shortsighted and could only cure the problem temporarily. The overall asset market exuberated again and created greater bubbles, thus the economy is exposing to greater risk (Tang, 2017). The government should carefully consider the effects of a policy before it is launched.

For future research, it is suggested to investigate the rental carpark market. In particular, we have already obtained three important elements of DiPasquale-Wheaton (1992) model, including the carpark price (constructed in this paper), new construction and total stock (obtained from Monthly Digest of Buildings Department). The only missing element is the rental price. For completeness, future work may consider constructing the hourly and monthly rental carpark indexes for residential buildings.

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Table 1 Urban Mobility Index

Ranking	City	Index value	Ranking	City	Index value
1	Hong Kong	58.2	43	Manila	43.6
2	Stockholm	57.4	44	Lima	43.5
3	Amsterdam	57.2	45	Saint Petersburg	43.4
4	Copenhagen	56.4	46	Sydney	43.1
5	Vienna	56	47	Tianjin	42.6
6	Singapore	55.6	48	Buenos Aires	42.4
7	Paris	55.4	49	Mexico City	42.2
8	Zurich	54.7	50	Melbourne	41.9
9	London	53.2	51	Lisbon	41.3
10	Helsinki	53.2	52	Boston	40.9
11	Munich	53	53	Rome	40.9
12	Stuttgart	51.9	54	Chennai	40.7
13	Berlin	51.7	55	Hyderabad	40.7
14	Wuhan	51.1	56	Dubai	40.6
15	Madrid	50.3	57	Philadelphia	40.3
16	Hanover	50.1	58	Caracas	40.1
17	Brussels	49.7	59	Athens	40
18	Seoul	49.3	60	Ho Chi Minh City	39.8
19	Tokyo	49.2	61	Karachi	39.5
20	Barcelona	49.1	62	Kinshasa	39.4
21	Shanghai	49.1	63	Dhaka	39.2
22	Frankfurt	48.8	64	Chicago	39.1
23	Prague	47.8	65	Bangalore	38.9
24	Warsaw	47.8	66	Osaka	38.5
25	Nantes	47.7	67	Los Angeles	38.1
26	Shenzhen	47.7	68	Portland	37.8
27	Istanbul	47.2	69	Jakarta	37.4
28	Beijing	47.2	70	Cairo	37.4
29	Guangzhou	47.2	71	Miami	37.3
30	Santiago de Chile	47.1	72	Lagos	37.1
31	Kolkata	47	73	Addis Ababa	36.5
32	Bogota	46.3	74	Bangkok	35
33	Ankara	46.1	75	Johannesburg	35
34	Sao Paulo	45.7	76	Houston	34.7
35	New York	45.6	77	Kuala Lumpur	34.6
36	Montreal	45.4	78	Dallas	33.8
37	Moscow	44.4	79	Delhi	33.5
38	Toronto	44.4	80	Lahore	33.1
39	Curitiba	44	81	Tehran	33
40	Rio de Janeiro	44	82	Atlanta	32.5
41	Mumbai	43.9	83	Hanoi	30.9
42	Washington, D.C.	43.7	84	Baghdad	28.6

Source: "The Future of Urban Mobility 2.0" (January 2014), by Arthur D. Little, retrieved from: http://www.adlittle.com/future-of-urban-mobility.html

Table 2 Summary statistics

Variable	Definition	Mean	Standard deviation
CH_RATIO	Ratio of carpark number to housing units	0.211	0.172
PRIVATE	= 1 if it is private housing; 0 otherwise	0.211	0.409
MTR	= 1 if it is within 500 meters walking distance from Mass Transit, 0 otherwise.	0.320	0.467
CBD	Travelling minutes to Central Business District (by private car)	20.292	6.793
KLN	= 1 if it locates in Kowloon, 0 otherwise	0.271	0.445
NT	= 1 if it locates in New Territories, 0 otherwise	0.577	0.495

Table 3 Regression results

Dependent variable: CH_RATIO		
	Model 1	Model 2
PRIVATE	0.1455 ***	0.1354 ***
MTR	-0.0436 **	-0.0475 **
CBD	0.0293 ***	0.0262 ***
CBD^2	-0.0007 ***	-0.0006 ***
KLN		-0.0230
NT		0.0355
Constant	-0.0978	-0.0554
N	285	285
Adjusted R^2	0.129	0.138

Note: *** and ** denote 1% and 5% statistical significance respectively.

Table 4 List of variables in time series analysis

Sampling period: 1996Q1 – 2015Q4

Variable	Definition	Source
RCP	Real carpark price index	Author's calculation
RHP	Real housing price index	Rating and Valuation Department
RRP	Real retail price index	Rating and Valuation Department
ROP	Real office price index	Rating and Valuation Department
RSP	Real Hang Seng Index	Hong Kong Exchanges and Clearing Limited
RGDP	Real gross domestic product	Census and Statistics Department
TERM	10 year – 3 month Treasury yield spread	U.S. Federal Reserve
TED	3 month LIBOR – 3 month Treasury yield spread	U.S. Federal Reserve

Table 5 Unit root test

	Level	1st difference
RCP	0.8506	-4.9982 ***
RHP	0.2348	-5.0533 ***
RRP	0.2188	-3.9236 ***
ROP	0.0246	-3.6775 ***
RSP	-0.2844	-7.9800 ***
RGDP	1.4275	-3.2039 ***
TERM	-1.2294	-7.2947 ***
TED	-1.5304	-8.3971 ***

Note: The optimum lag is determined by AIC criteria at a maximum lag of 4 quarters.

*** denotes 1% statistical significance.

Table 6 Granger causality

		RCP	RHP	ROP	RRP	RSP	RGDP	TERM	TED
RCP	Granger causes						*		
RHP		***					**		
ROP		***					**		
RRP		***					***		
RSP		**	**	***	*				
RGDP			***	***	***				
TERM									
TED		*		*					

Notes: All variables are first-differenced. The lag is chosen to be one. ***, ** and * denote 1%, 5% and 10% statistical significance respectively.

Table 7 Results of EGARCH (1,1)-in-mean model

Panel A - Conditional mean equation:

$$r_t = \beta_0 + \beta_1 r_{t-1} + \beta_2 r_{t-2} + \beta_3 r_{t-3} + \beta_4 r_{t-4} + \beta_5 ln(\sigma_t^2) + \varepsilon_t$$

β_0	0.1966 **
β_1	0.6865 ***
β_2	0.2356 ***
β_3	-0.0257
β_4	-0.4000 ***
β_5	0.0334 *

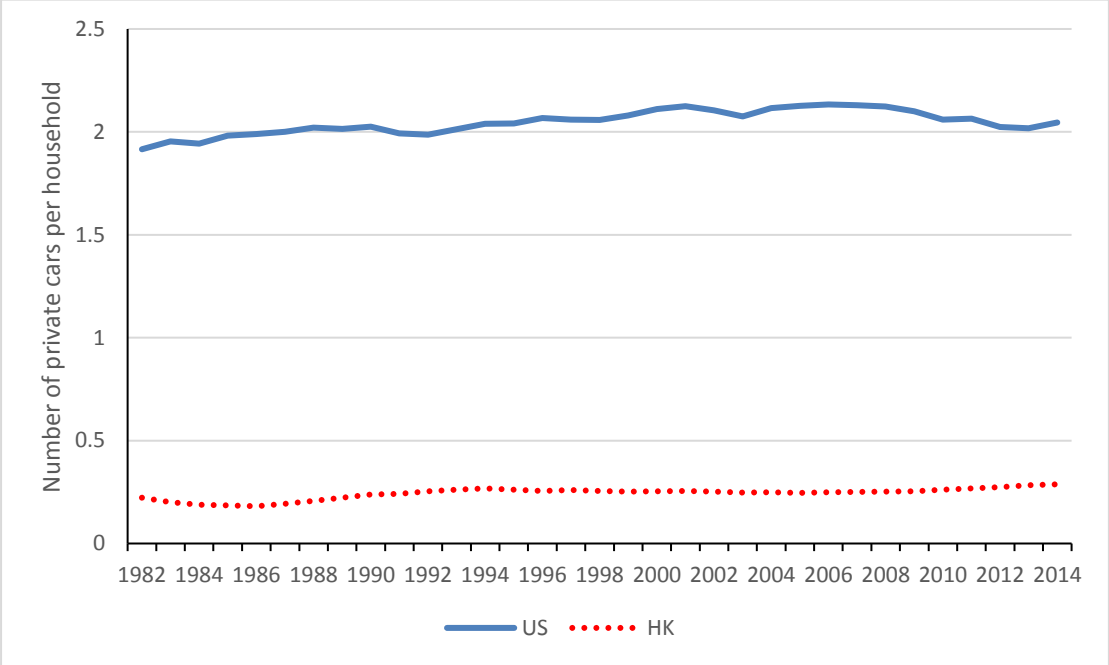
Panel B - Conditional variance equation:

$$ln(\sigma_t^2) = \alpha_0 + \alpha_1 ln(\sigma_{t-1}^2) + \alpha_2 \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \alpha_3 \frac{|u_{t-1}|}{\sqrt{\sigma_{t-1}^2}} + \alpha_4 D_{1,t} + \alpha_5 D_{2,t}$$

α_0	-3.9238 ***
α_1	0.4475 **
α_2	0.0122
α_3	1.0579 ***
α_4	0.7241 **
α_5	0.3733

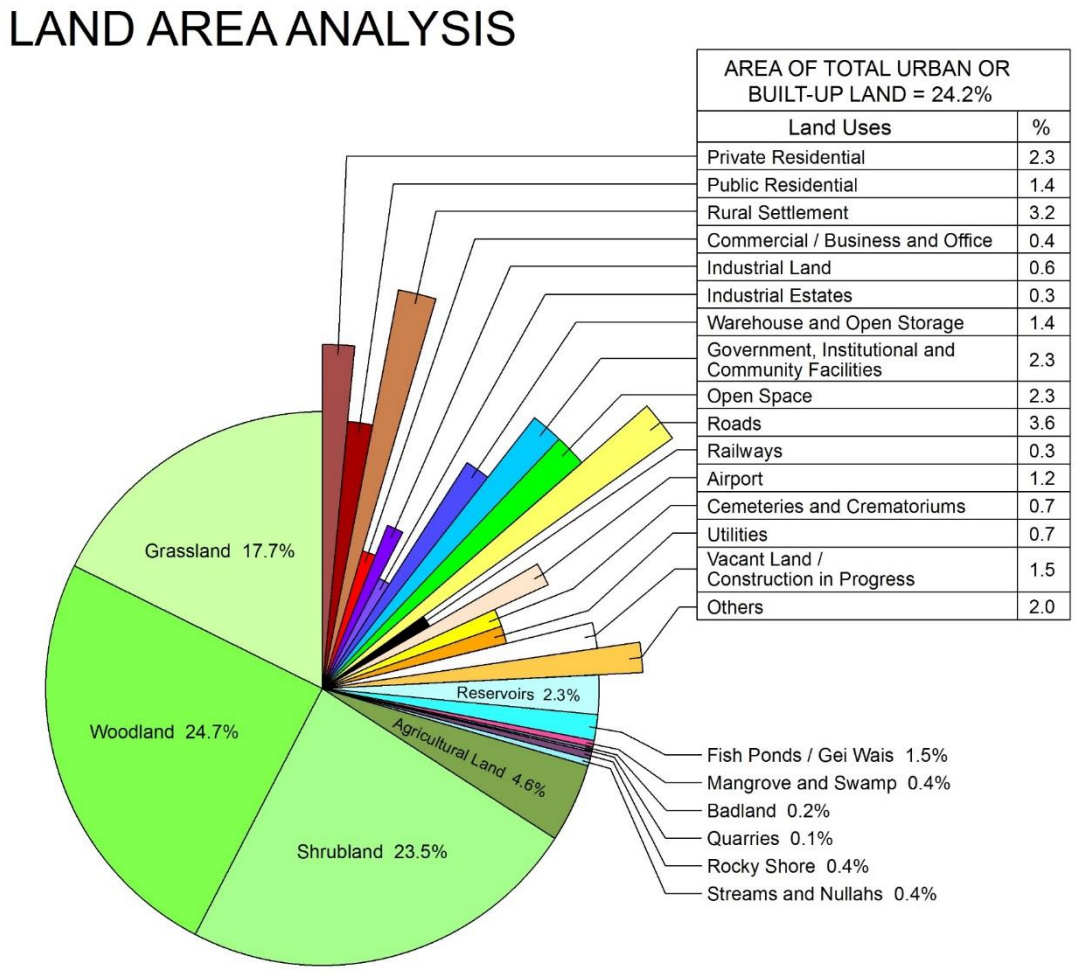
Note: *** and ** denote 1% and 5% statistical significance respectively. The standard errors are computed using the robust method of Bollerslev-Wooldridge (1992).

Figure 1 Number of private cars per household



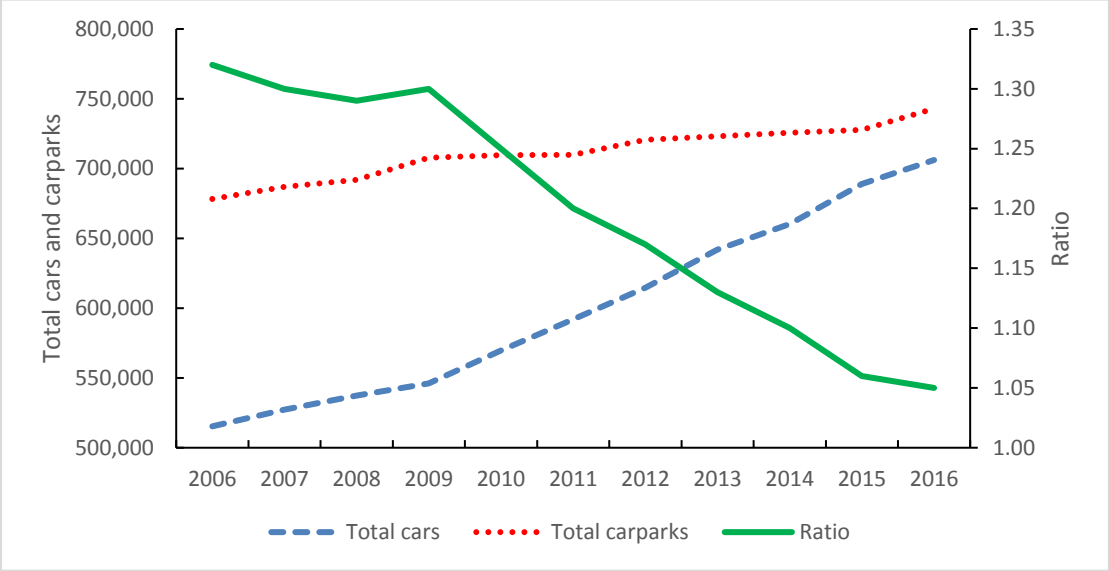
Sources: Hong Kong Census and Statistics Department; U.S. Department of Transportation; U.S. Census Bureau

Figure 2a Land area analysis (Hong Kong)



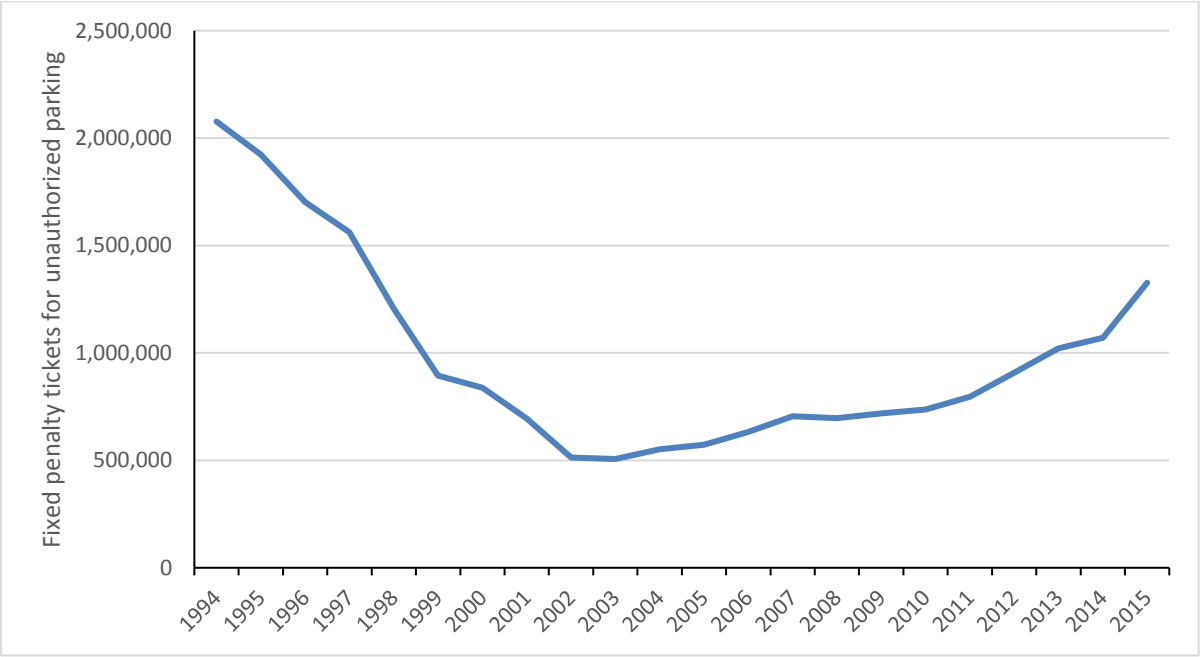
Source: Hong Kong Planning Department

Figure 2b Total number of cars and carparks (Hong Kong)



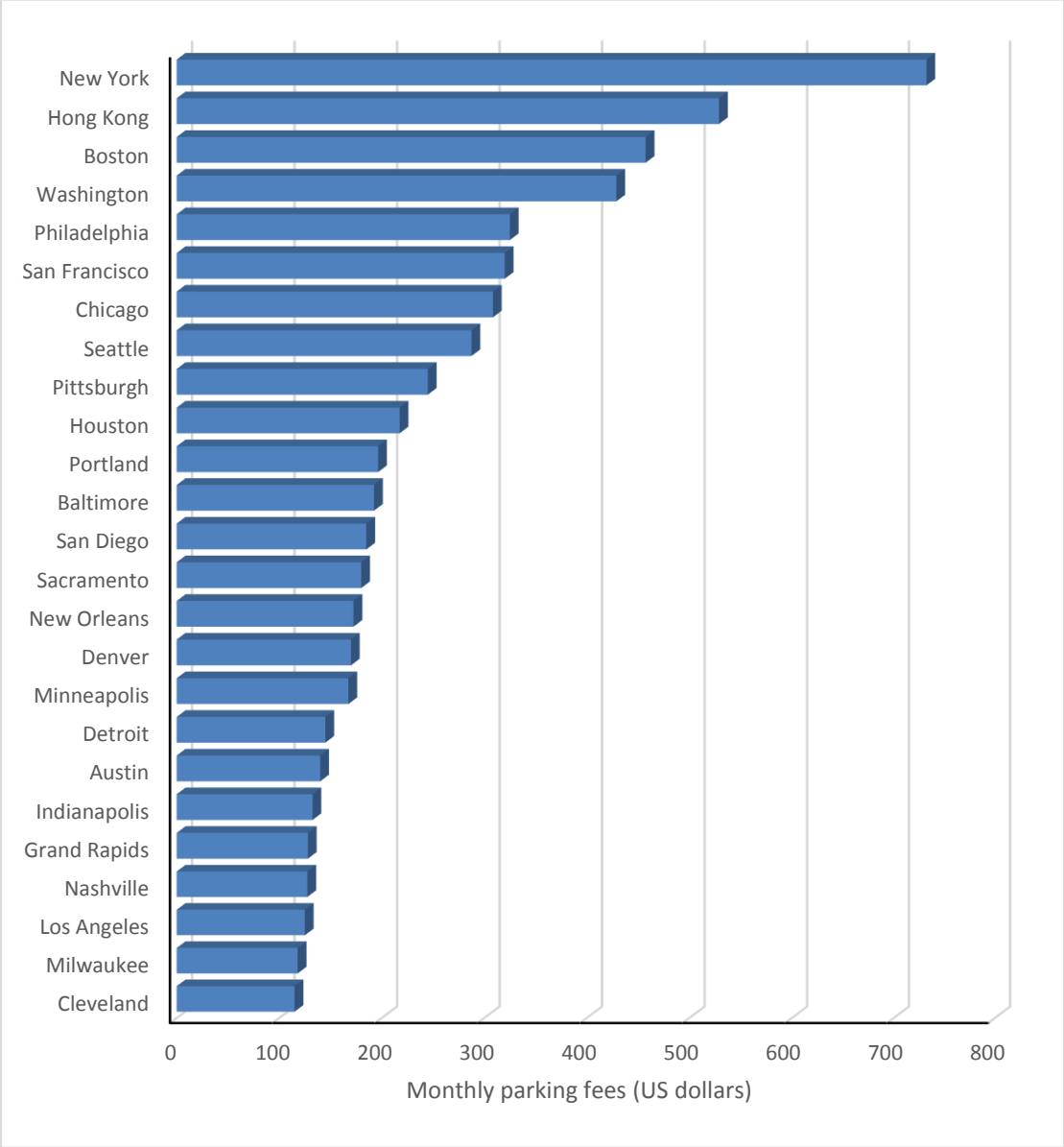
Source: Legislative Council Panel on Transport

Figure 2c Fixed penalty tickets for unauthorized parking (Hong Kong)



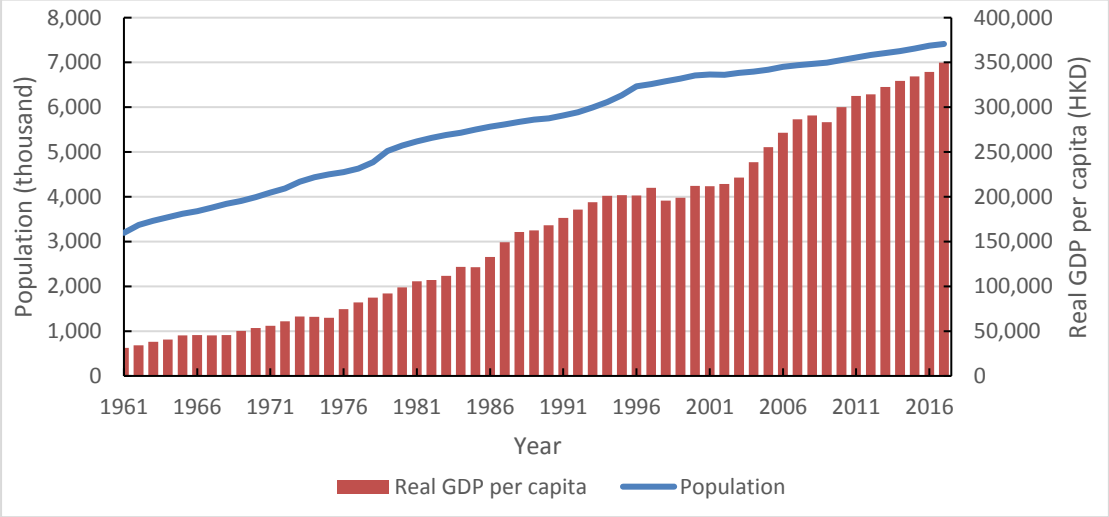
Source: Hong Kong Police Force

Figure 2d Monthly parking fees



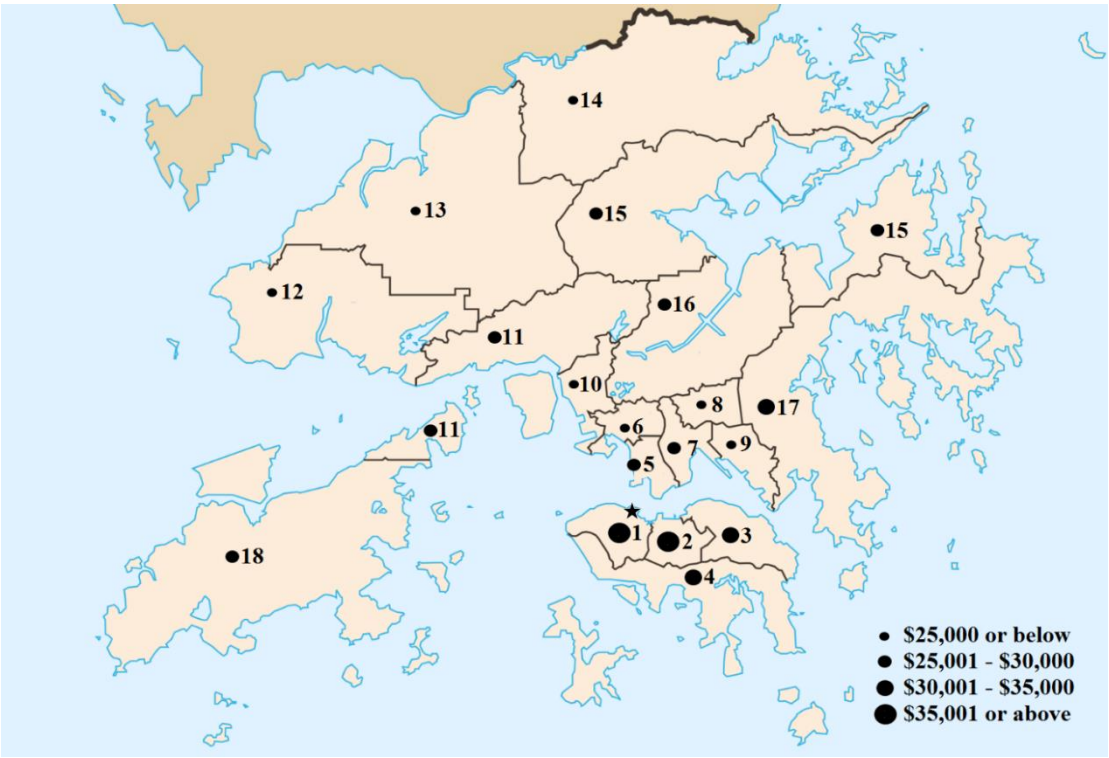
Sources: Hong Kong Transport Department; "The price of parking" (18 October 2016), by J. Cortright, retrieved from: http://cityobservatory.org/the-price-of-parking

Figure 2e Population and real GDP per capita (Hong Kong)



Source: Hong Kong Census and Statistics Department

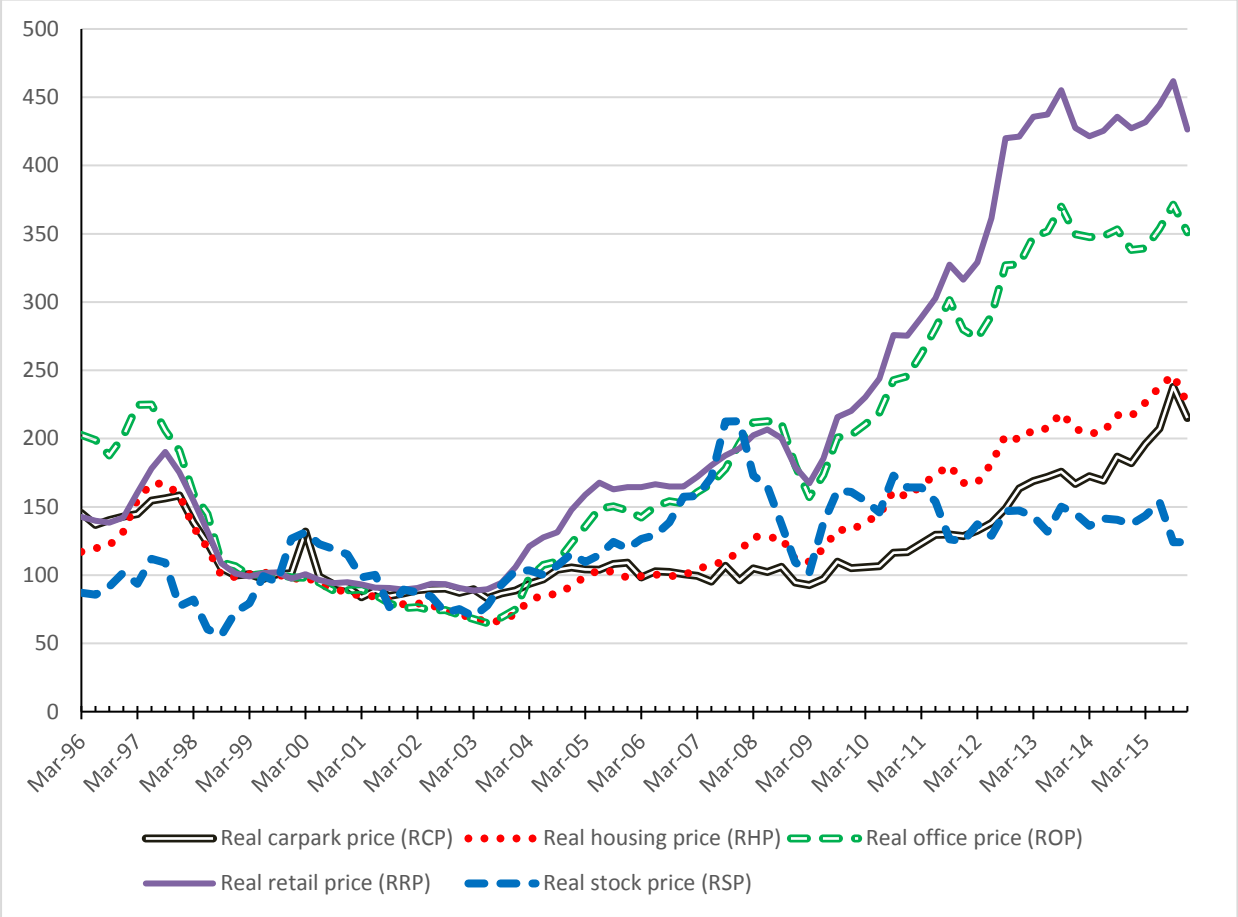
Figure 3 Median monthly income in Hong Kong 18 districts (year 2016)



Notes: 1 – Central & Western; 2 – Wan Chai; 3 – Eastern; 4 – Southern; 5 – Yau Tsim Mong; 6 – Sham Shui Po; 7 – Kowloon City; 8 – Wong Tai Sin; 9 – Kwun Tong; 10 – Kwai Tsing; 11 – Tsuen Wan; 12 – Tuen Mun; 13 – Yuen Long; 14 – North; 15 – Tai Po; 16 – Sha Tin; 17 – Sai Kung; 18 – Islands; ★ – Central Business District (CBD)

Source: Hong Kong Census and Statistics Department

Figure 4 Real asset price index (1999 = 100)



Sources: Hong Kong Rating and Valuation Department; author's calculation

Appendix 1 List of private estates in the calculation of carpark price index

Estate name	Housing units	Carpark number	Weight
Aberdeen Center	2804	471	0.17
Allway Garden	3421	1003	0.29
Avon Park	1304	234	0.18
Belair Gardens	1944	1484	0.76
Belvedere Garden	6016	2010	0.33
Chi Fu Fa Yuen	4333	926	0.21
City Garden	2406	586	0.24
City One Shatin	10643	2781	0.26
Fortress Metro Tower	757	114	0.15
Garden Rivera	1583	356	0.22
Golden Lion Garden	2768	936	0.34
Greenland Garden	960	201	0.21
Hanford Garden	1502	237	0.16
Heng Fa Chuen	6504	849	0.13
Hilton Plaza	928	232	0.25
Hong Kong Garden	2830	2835	1.00
Jubilee Garden	2260	508	0.22
Kingswood Villas	15880	2294	0.14
Kornhill	6648	1168	0.18
Laguna City	8072	1500	0.19
Lei King Wan	2300	393	0.17
Marina Garden	1000	632	0.63
Mei Foo Sun Chuen	13149	3736	0.28
Miami Beach Towers	1272	778	0.61
Nan Fung Sun Chuen	2832	800	0.28
Parc Oasis	1730	1247	0.72
Pierhead Garden	1432	168	0.12
Pokfulam Garden	1120	368	0.33
Provident Center	1450	420	0.29
Riviera Garden	5692	1198	0.21
Sceneway Garden	4112	611	0.15
Sea Crest Villa	2239	1664	0.74
Serenity Park	2475	355	0.14
Shatin Center	1480	753	0.51
South Horizons	9812	1963	0.20
Sunshine City	4760	1459	0.31
Tai Hing Gardens	3647	231	0.06
Tak Bo Garden	2016	400	0.20
Tsing Yi Garden	1520	353	0.23
Tsuen King Garden	3024	333	0.11
Whampoa Garden	10486	2900	0.28
Wonderland Villas	1502	2300	1.53

Source: Monthly Digest, Buildings Department

Appendix 2 Robustness check

In this appendix, it attempts to construct another carpark price index by using the carpark ratio as the weight:

$$CP_t = \frac{\sum CH\_RATIO_i * \bar{P}_{i,t}}{\sum CH\_RATIO_i}$$

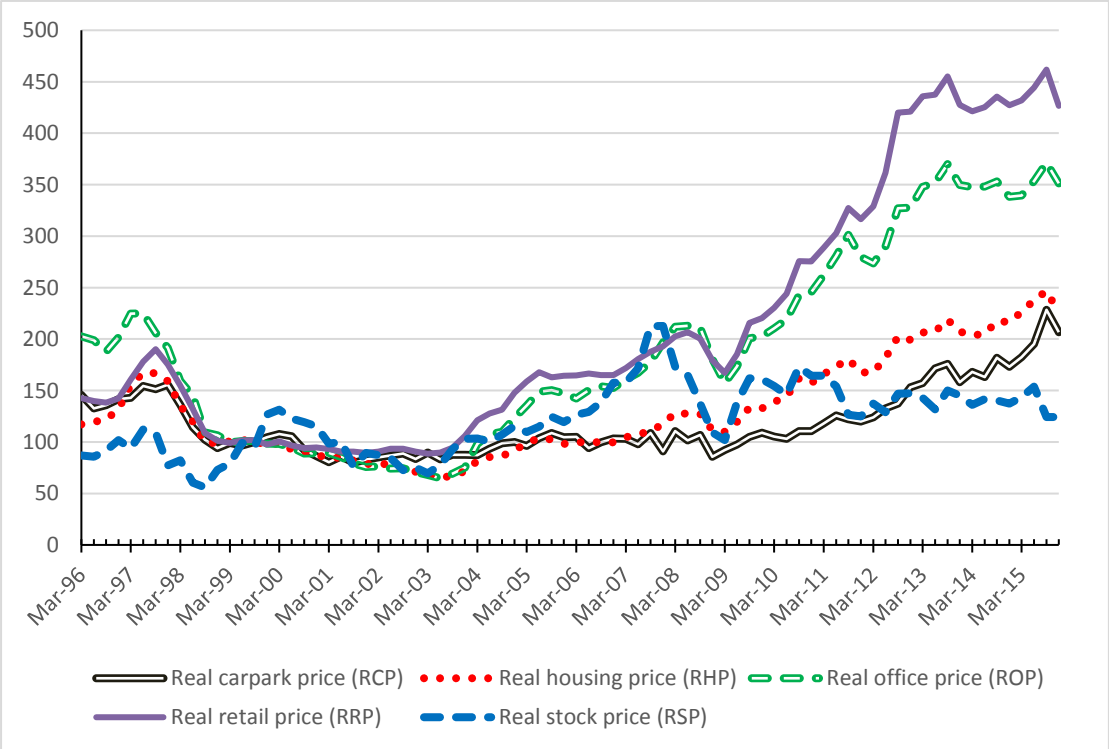
where

CH_RATIO_i is the carpark ratio in estate *i*;

$\bar{P}_{i,t}$ is the average transacted price of a parking space in estate *i* at time *t*.

The time plot of real carpark index is similar to the one constructed in the main text. It experienced a sharp decline during Asian Financial Crisis in 1997, and remained stable during 1999-2009. After that, it exhibited an upward trend. It has been confirmed that an asset bubble existed from 2014Q3 to 2015Q4. (*Details are available upon request.*)

Figure A.1 Real asset price index (1999 = 100)



The unit root test suggested that the newly constructed carpark index is non-stationary in levels, but it achieves stationary after taking first-differencing. In addition, similar results were found in table A.2, where real asset prices granger cause real carpark prices at 1% significance level. Finally, table A.3 suggests that investors can receive extra return for bearing additional risk, and SSD indeed imposes extra volatility to carpark market.

Table A.1 Unit root test

	Level	1st difference
RCP	0.7931	-4.9704 ***
RHP	0.2348	-5.0533 ***
RRP	0.2188	-3.9236 ***
ROP	0.0246	-3.6775 ***
RSP	-0.2844	-7.9800 ***
RGDP	1.4275	-3.2039 ***
TERM	-1.2294	-7.2947 ***
TED	-1.5304	-8.3971 ***

Note: The optimum lag is determined by AIC criteria at a maximum lag of 4 quarters. *** denotes 1% statistical significance.

Table A.2 Granger causality

		RCP	RHP	ROP	RRP	RSP	RGDP	TERM	TED
RCP	Granger causes						*		
RHP		***					**		
ROP		***					**		
RRP		***					***		
RSP		***	**	***	*				
RGDP			***	***	***				
TERM									
TED		*		*					

Notes: All variables are first-differenced. The lag is chosen to be one. ***, ** and * denote 1%, 5% and 10% statistical significance respectively.

Table A.3 Results of EGARCH (1,1)-in-mean model

Panel A - Conditional mean equation:

$$r_t = \beta_0 + \beta_1 r_{t-1} + \beta_2 ln(\sigma_t^2) + \varepsilon_t$$

β_0	0.8088 ***
β_1	0.7763 ***
β_2	0.1659 ***

Panel B - Conditional variance equation:

$$ln(\sigma_t^2) = \alpha_0 + \alpha_1 ln(\sigma_{t-1}^2) + \alpha_2 \frac{u_{t-1}}{\sqrt{\sigma_{t-1}^2}} + \alpha_3 \frac{|u_{t-1}|}{\sqrt{\sigma_{t-1}^2}} + \alpha_4 D_{1,t} + \alpha_5 D_{2,t}$$

α_0	-2.3981 ***
α_1	0.4826 ***
α_2	-0.1837 **
α_3	-0.1589
α_4	0.0995 **
α_5	0.0641 **

Note: *** and ** denote 1% and 5% statistical significance respectively. The standard errors are computed using the robust method of Bollerslev-Wooldridge (1992).