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Foreign liquidity to real estate market: Ripple effect and housing price dynamics

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Abstract

Globalisation enables foreign liquidity to access local property markets. This paper depicts a strong connection between foreigners' property acquisitions and regional housing price movements in Singapore. Testing structure breaks also illustrates a ripple effect of prices from the central city to suburbs. A structural vector autoregression incorporates these two observations. Impulse-response function and forecast-error variance decomposition show that central region's foreign-liquidity shocks can greatly impact housing price growth in not only the central region but also the non-central region where foreign buyers are inactive. The ripple effect of prices plays an important role. Non-central region's foreign-liquidity shocks, in contrast, have small effects on both regions. Impacts of foreign-liquidity shocks can reach the public-housing market, where foreigners' participation is prohibited. The findings are useful to policy makers who consider regulations of foreign home buyers as an instrument to stabilise housing markets.

Keywords

housing price ripple effect, international real estate, Singapore, structural break, structural vector autoregression

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Introduction

Globalisation has induced various forms of financial liberalisation, and foreign liquidity has played increasingly important roles in shaping regional and local real estate markets. An emerging global trend of foreign liquidity in local property markets has surfaced (Bardhan and Kroll, 2007). In 2007, about 10% by volume of real estate sales in the Americas were to foreigners. In the Asia Pacific region, liquidity from foreigners constituted approximately 35% real estate transactions. Foreign liquidity can be a cure for a bearish property market.[1] However, it may worsen housing affordability when the market is tight. In Singapore, the government has long used foreign liquidity to stabilise the nation's real estate market by easing rules and regulations on foreign investment when the market is dull and tightening them when the market overheats. Understanding the effects of foreigners' activities on the real estate market is important, as this may offer insights to policy makers.

The housing market is segmented, particularly geographically. While a positive relationship between foreigners' acquisitions and national property-price movement is apparent, the effect of their acquisition activity on regional property prices is less obvious. Are there differential impacts on regional submarkets? Are submarkets affected through the same mechanism?

This paper aims to focus on the above questions with Singapore as an interesting case study. Foreigners' purchases have weighed a handsome share of property transactions in Singapore. About 11% of private-housing sales were to foreigners (excluding permanent residents) between 2004 and 2011. However, the foreign liquidity to Singapore is geographically uneven. Foreign buyers have acquired more private-housing properties in prime areas than in emerging suburbs. During 2004–2011, sales to foreigners on average totalled 14% of all sales in the Central region, but were only 5% in the Northeast and North regions. Possibly because of low concentration of foreign purchases in suburban areas, although the growth of central region's residential properties sold to foreigners significantly impacts housing price growth in that region, the growth of foreigners' acquisitions in the non-central region has small impacts on these regions' property prices. This research shows that the growth of suburban housing prices is still significantly affected by foreign buyers through the 'ripple effect'. Influx of foreign liquidity to the central region's housing submarket can trigger an upsurge of property prices in that region, and the effect of the upsurge can ripple out to the non-central region.

The literature on housing price dynamics describes the *ripple effect* as a housing price shock in one location affecting housing prices in other areas. Studies have provided cross-regional evidence (Chen et al., 2011; Chien, 2010; Holly et al., 2011; Oikarinen, 2004), and others have examined the ripple effect across submarkets within a city (Oikarinen, 2004). However, a complete definition of the ripple effect should comprise two parts. First, there is a pronounced *shock* entering a market (submarket) that is significant in the regional (city) economy. Second, a *price-diffusion* mechanism exists, allowing price movements, which are a result of the shock, of the significant market to affect prices of other markets (submarkets). While the second part of the definition, the price diffusion, has gained much attention in the literature, the first part, the content of the shock, has been neglected. This paper, which studies both parts, can help in understanding the impact of a large policy shift that can swing a particular market segment.

Research on international real estate acquisition dates back to the 1980s, but it has mainly focused on why investors choose

to own foreign real estate, and primarily on benefits of diversifying property assets internationally in the mean-variance framework. Among the literature, one strand of research analyses investment decisions on real estate-only portfolios (Case et al., 2000; Eichholtz et al., 1995) and another concerns mixed-asset portfolios combining both real estate and financial assets (Cheng et al., 1999; Hoesli et al., 2004; Newell and Webb, 1996). The review by Sirmans and Worzala (2003) highlights the diversification benefits of inclusion of international real estate, and efficient portfolios with international real estate outperforming those without, hence indicating that international diversification appears to be important.

Taking a new angle, this paper researches international real estate acquisition from the recipient country's perspective. It appears that only a few existing papers take this line. Gerlowski et al. (1994) find that US states with higher income level or population growth attract more foreign direct investment (FDI) in real estate, but high property prices can diminish the attractiveness. Aizenman and Jinjarak (2009) investigate linkages between international capital inflows and real estate valuation for OECD and non-OECD countries, highlighting growing globalisation of national real estate markets, and notable association between current account deficit and property price appreciation. Jiang et al. (1998) note that FDI to China and its engagement in the real estate sector can help the sector to sustain growth under tightening monetary policy. Guo and Huang (2010) suggest speculative capital inflow to China as a main factor enlarging the appreciation and volatility of property prices. This paper differs from previous research to generate new insights on spatial interaction between foreigners' real estate acquisitions and property-price dynamics, and offers intriguing policy implications.

The next section reviews policy shifts on regulations of foreigners' property ownership in Singapore. This helps readers to sense a strong connection between foreigners' buying activities and the nation's property-price cycles. Then, following an introduction to the data sources, we discuss the construction of housing price indices. In the following section, structural break-point analysis is conducted to show an interesting spatial pattern of ripple effect. Motivated by these two notable features – the connection between foreigners' acquisitions and property prices, and the ripple effect – a structural vector autoregressive model is constructed to analyse foreign liquidity's impact on regional property-price movements.

Background: Foreign home buyers in Singapore's property market

Regulations on foreign buyers' home purchases date back to 1973. To ensure affordable and sufficient housing for Singaporeans, the Residential Property Act imposed restrictions on foreign ownership of private residential property. Foreigners could only acquire apartments in buildings higher than six stories or in approved condominium developments.

The housing market was dull after the Dot-Com bubble burst in late 2000 and the outbreak of Severe Acute Respiratory Syndrome (SARS) in 2003. A strong recovery from the market downturn was necessary to Singapore's economy. As housing asset is the largest component of household wealth, a prolonged decline can cause financial hardship especially to the elderly whose retirement savings are largely in terms of housing assets (Ronald, 2010). As such, the government introduced several measures to boost the market. First, foreigners were allowed to buy land parcels and complete homes at Sentosa Cove since August 2004. The favourable policy caused a surge of

foreign liquidity into the private residential market. The percentage of foreign buyers rose from 6% to 10% within two quarters and the presale segment increased from 6% to 17%. In mid-2005, the government removed the restriction on foreigners owning apartments below six stories, raised the loan-to-value limit and reduced the cash downpayment. An upward trend in housing price appreciation was observed until end 2007. Between 2005 and 2007, foreign buyers accounted for 10% and 15% sales in the entire private residential market and the presale segment, respectively. In contrast, between 2000 and 2004 total sales made to foreigners were only 6%. The rise in foreign buyers was in tandem with the recovery of Singapore's housing market, as evidenced by the rebound in housing prices in 2004 led by an influx of foreign liquidity into the high-end private-housing market which then aided the general recovery of the market (Deng et al., 2012).

Even after the Global Financial Crisis, foreign investment still played an important role in supporting or raising Singapore's private-housing prices. For instance, in the recent recovery from the last downturn, significant appreciation of housing prices and upsurge of foreigners' buying activity were observed.

The foreign liquidity into Singapore's property market is sensitive to government policy shifts. Although changes in regulations had been successful in attracting foreigners to buy properties in Singapore, as continual hikes in housing prices could cause issues in housing affordability, the government introduced the Additional Buyer's Stamp Duty (ABSD) in December 2011, targeting foreigners and non-individuals. With ABSD costing 10% of property value, foreigners became inactive and prices in the central region dropped. In 2012 Q1, home prices had fallen for the first time in almost three years.

Estimation and results

Data

The primary data source is Singapore Urban Redevelopment Authority's (URA) data base, the Real Estate Information System (REALIS), which provides micro transaction data of private residential properties (non-public housing). The research records 255,452 transactions from 1996 Q2 to 2011 Q4. Sales information such as contract date, transaction price and property characteristics such as floor level, floor area, tenure and location are used to construct quarterly hedonic housing price indices for private housing.

URA delineates Singapore into 55 planning areas. Among them, 38 areas had transactions during the sample period. Areas with sales are grouped into 25 'consolidated planning areas' through merging those places which had less than 2000 transactions with adjacent places having a higher volume of transactions. These 25 consolidated planning areas are the geographic units of a later analysis.

The research also obtains quarterly time series of location-specific quantities of housing stock, land sales and private residential property sales to foreigners from URA and HDB (public housing) resale price index, GDP, CPI and mortgage interest rate of 15 years housing loan from the relevant authorities.

Hedonic housing price index

The research estimates location-specific housing price indices for private residential properties, because URA and the Institute of Real Estate Studies at National University of Singapore, which regularly publish housing price indices, do not report the indices by detailed location. We prefer the hedonic price index to the repeat-sales index among the quality-adjusted indices, because lack of

repeat-sales observations is an issue when the sample is divided into locations. For planning area price indices, the model for each area j is:

$$ln(P_{i,j,t}) = \alpha_j + \beta_j X_{i,j,t} + \rho_{j,t} + \varepsilon_{i,j,t} \quad (1)$$

where the time fixed effect $\rho_{j,t}$ is area j's price index in time t relative to the base period (2001 Q4), $P_{i,j,t}$ is the housing price, and $X_{i,j,t}$ consists of housing characteristics. The parameter α_j captures the value of amenity in area j, and β_j reflects the implicit prices of the housing characteristics. We similarly estimate the following model for each region r:

$$ln(P_{i,r,j,t}) = \alpha_r + \beta_r X_{i,r,j,t} + \rho_{r,t} + \xi_{r,j} + \varepsilon_{i,r,j,t} \quad (2)$$

where $\rho_{r,t}$ is the regional price index in time t, and the location fixed effect $\xi_{r,j}$ of area j in region r and α_r capture the prices of amenities. This model is also used to estimate the national price index. REALIS data are applied to the estimation of all these indices.

Figure 1(a) presents all planning areas' hedonic price indices and Figure 1(b) shows the national index. The area indices exhibit a similar trend to the national index. Singapore's private-housing market had experienced several booms and busts during the 16-year study period. The first peak of prices occurred in 1996 Q2, followed by a period of contraction after the Asian Financial Crisis. The second peak was in 2000 Q1, and subsequently prices decreased after the bust of the Dot-Com bubble and the outbreak of SARS. The most recent peak in 2007 Q4 occurred before the US subprime mortgage and global financial crises. The market plunged sharply, but a pronounced rebound happened in 2009. Since then, the market has experienced an upward trend of housing price movement. Considering the housing price trend and foreigners' buying activity described above, the property-price movement in Singapore could be connected to foreigners' property acquisitions. In fact, the correlation between foreigners' share of property purchases and the national price index was 0.7 during the study period.

Geographic diffusion of structural break points

Another notable feature of the Singapore market is price diffusion across space, besides the strong correlation of private-housing prices with foreign liquidity in the market. This is illustrated with a presentation of the structural break point of each consolidated planning area's housing price index for private residential properties.

Break-point analysis is a growing literature, not only in finance but also in real estate (Chen, 2010; Ferreira and Gyourko, 2011, 2012). Banerjee and Urga (2005) provide an overview of the literature on the econometric analysis of structural break. The 2000–2008 period is used as a case study, and the structural break point of each area-specific housing price index during this time is estimated. The estimation requires a time series of a substantial length. Thus, the 9-year period, which is Singapore's most recent and complete real estate cycle where the price peaked in 2007, is chosen. With 36 quarters of data, this period is most suitable for a break-point analysis compared with other shorter cycles in our study period. Moreover, the 9-year period comprised a time during which a surge in foreigners' acquisitions of private-housing properties occurred.

The estimation of structural break points follows Ferreira and Gyourko (2011, 2012). The growth rates of prices are generated by dividing the estimated value of the price index in period t by the value in period $t-4$ to control seasonality in housing transactions. As the resulting series of growth rates may consist of multiple jumps, the quarter in

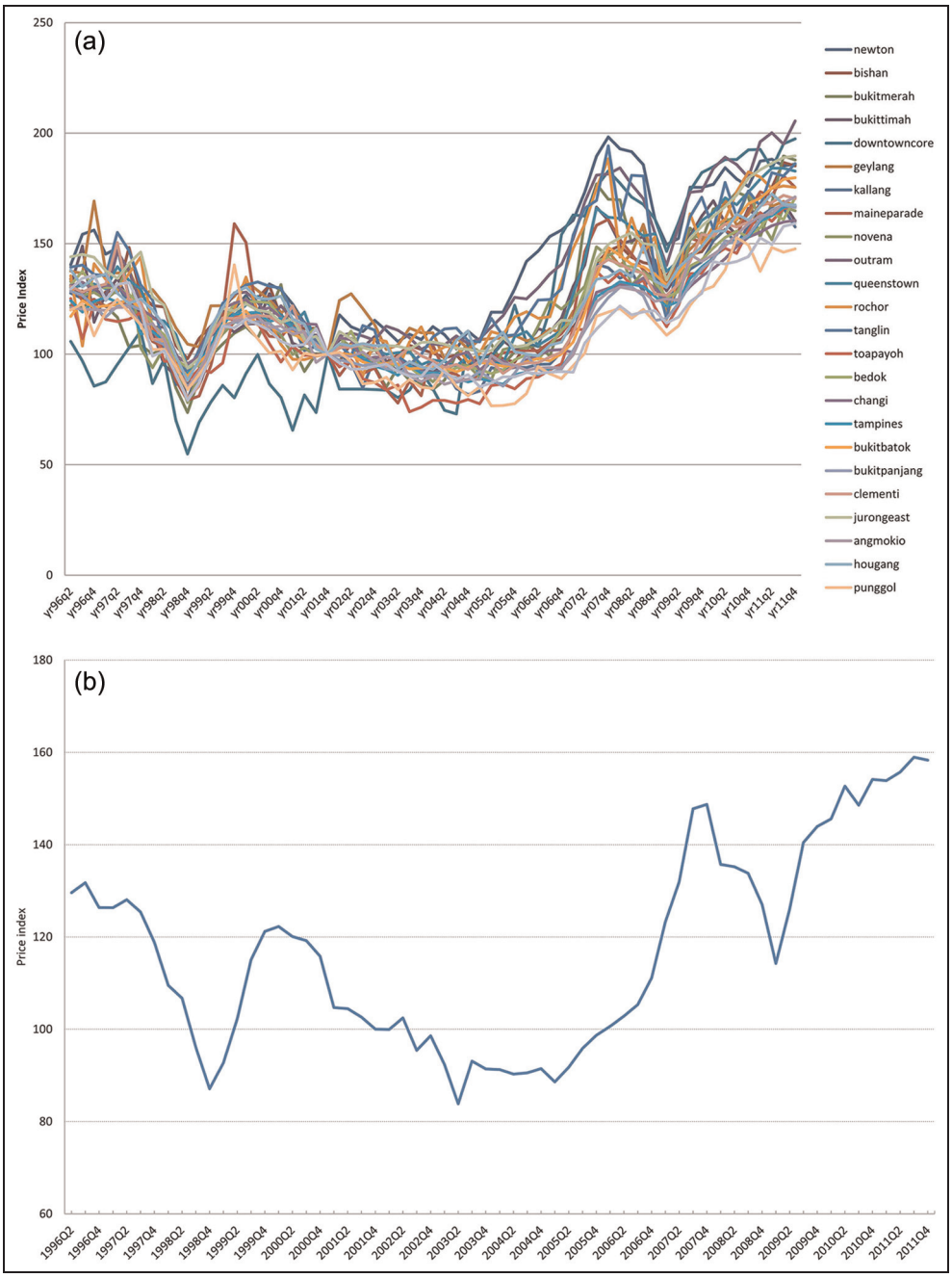

Figure 1. Hedonic price indices for private residential properties. (a) Planning areas' price indices. (b) National price index.

which the global structural break occurred needs to be determined. For each planning area j, we estimate:

$$PG_{j,t} = \alpha_j + \beta_j 1\left[q_{j,t} \geq q^*_{j,t}\right] + \upsilon_{j,t} for\, T_{j,1} < q_{j,t} < T_{j,N} \quad (3)$$

where $PG_{j,t}$ is the housing price growth over the past four quarters, $q_{j,t}$ indicates the corresponding quarter of the observation, $T_{j,1}$ indicates the first quarter of the time series in the regression, $T_{j,N}$ indicates the last quarter of the time series in the regression, and it is the quarter that returns the highest growth of area j between 2000 and 2008. $q^*_{j,t}$, which is an element of $\{T_{j,1},\ldots T_{j,N}\}$, is the quarter that is considered as the potential structural break point, and it is arbitrarily picked and fixed in each regression. $1[q_{j,t} \geq q^*_{j,t}]$ is an indicator function that maps $\{T_{j,1},\ldots T_{j,N}\}$ to $\{0,1\}$, and its value is 1 if $q_{j,t} \geq q^*_{j,t}$ and 0 otherwise. Thus, β_j is the effect of the potential structural break point on the price growth. For each planning area j, we run a total number of N_j regressions, from which the first (last) regression considers the first (last) quarter in $\{T_{j,1},\ldots T_{j,N}\}$ as the potential break point. The $\hat{q}^*_{j,t}$ in the regression that returns the maximum R^2 is the estimated structural break point. Generally, R^2 of the regression that returns the maximum R^2 and identifies the structural break point of its respective planning area ranges from 0.30 to 0.73 with an average of 0.57. Table 1 shows the estimation results including the estimated structural break points of the planning areas.

The map in Figure 2 presents the structural break point of every consolidated planning area, and visualises an interesting spatial diffusion pattern. The figure broadly categorises the areas into two groups: early boomers and late boomers. Early boomers were those with a structural break occurring in 2004 or 2005, and late boomers were those with a structural break occurring in 2006 or 2007. The figure shows that earlier boomers were clustered in the central region, and late boomers were mostly in the non-central region. Unless the price change of a region is mostly affected by factors specific to the region, Figure 2 suggests that the shock causing structural breaks of private-housing prices in the central region rippled out and caused structural breaks in the non-central region. It is interesting to know the underlying shock and understand the shock's ability to explain regional price movements.

The influx of foreign liquidity into the private-housing market could be the underlying shock. As mentioned in the section 'Background', a surge of foreigners' acquisitions of private residential properties started in late 2004 following the relaxation of restrictions on foreign ownership, and this led to the rebound of private-housing prices. As foreigners mainly purchased properties in central areas, the influx of foreign liquidity would only cause structural breaks of housing prices there. Nevertheless, when housing prices in central areas surged, the positive movement could affect Singapore's entire private-housing market, where the strong housing price growth in central areas could ripple out and cause structural breaks and housing price booms in non-central areas. This explanation coherently interprets the observed spatial diffusion pattern of the structural break points of area housing prices illustrated in Figure 2.

Structural vector autoregression (SVAR) analysis

We analyse foreign liquidity's impact on regional private-housing prices using a SVAR model with data from 1996 Q2 to 2011 Q4. Detailed review of the method and relevant techniques can be found in Kilian (2011), Lutkepohl (2005), StataCorp (2009) and Stock and Watson (2001). Foreigners' private-property acquisitions in the central region have large effects on both central and

Table 1. Estimated structure-break point by consolidated planning area.

Consolidated planning area	Region	Estimated break point	R^2	Break-point coef. β_j	Consolidated planning area	Region	Estimated break point	R^2	Break-point coef. β_j
Ang Mo Kio	Non-central	Q2, 2007	0.51	0.28*** (0.06)	Kallang	Central	Q3, 2005	0.56	0.18*** (0.03)
Bedok	Non-central	Q1, 2006	0.61	0.20*** (0.03)	Mandai	Non-central	Q2, 2007	0.65	0.24*** (0.03)
Bishan	Non-central	Q2, 2007	0.52	0.29*** (0.06)	Marine Parade	Central	Q1, 2004	0.56	0.24*** (0.04)
Bukit Batok	Non-central	Q2, 2007	0.73	0.32*** (0.04)	Newton	Central	Q2, 2005	0.61	0.26*** (0.05)
Bukit Merah	Central	Q2, 2007	0.46	0.54*** (0.12)	Novena	Central	Q3, 2005	0.53	0.19*** (0.04)
Bukit Panjang	Non-central	Q2, 2007	0.64	0.27*** (0.04)	Outram	Central	Q2, 2005	0.69	0.20*** (0.03)
Bukit Timah	Central	Q1, 2005	0.53	0.18*** (0.04)	Punggol	Non-central	Q2, 2006	0.67	0.27*** (0.04)
Changi	Non-central	Q2, 2007	0.58	0.24*** (0.04)	Queenstown	Central	Q4, 2005	0.57	0.20*** (0.04)
Clementi	Non-central	Q2, 2007	0.69	0.37*** (0.05)	Rochor	Central	Q4, 2005	0.42	0.21*** (0.05)
Downtown Core	Central	Q4, 2004	0.33	0.22*** (0.07)	Tampines	Non-central	Q2, 2007	0.66	0.32*** (0.05)
Geylang	Central	Q1, 2007	0.30	0.19*** (0.06)	Tanglin	Central	Q1, 2004	0.50	0.23*** (0.05)
Hougang	Non-central	Q2, 2004	0.44	0.14*** (0.03)	Toa Payoh	Central	Q3, 2004	0.69	0.19*** (0.03)
Jurong East	Non-central	Q4, 2006	0.69	0.22*** (0.03)					

Notes: The structural break point is estimated for each consolidated planning area using the area-specific housing price index. The potential structural break point in the regression that returns the maximum R^2 is the estimated structural break point, and the R^2 and break-point coefficient reported in the table are estimates returned from this regression. *** indicates the corresponding coefficient estimate is statistically significant at the 1% level, and standard error is in parentheses.

Figure 2. Diffusion of the structural breaks.

non-central regions' price dynamics, but their purchases in the non-central region have small effects on the two regions' prices.

Methodology. A typical VAR model with p lags can be written as:

$$\boldsymbol{y_t} = \boldsymbol{c} + \boldsymbol{A}_1\boldsymbol{y_{t-1}} + \ldots + \boldsymbol{A_p}\boldsymbol{y_{t-p}} + \varepsilon_t \quad (4)$$

where y_t are K vectors of endogenous variables, A_1 through A_p are $K \times K$ square matrices of parameters, ε_t is a K vector of white noise with $\varepsilon_t \sim N(0, \sum)$ and $E(\varepsilon_t\varepsilon_s') = 0$ for $t \neq s$, and c is a constant. As the cross-equation error variance-covariance matrix is not diagonal, causal interpretation is impossible.

A remedial method is SVAR, and this paper adopts the short-run model imposing identifying assumptions on the contemporaneous correlations between the endogenous variables. The model is:

$$A\left(I_K - A_1L - A_2L^2 - \ldots - A_pL^p\right)y_t = A\varepsilon_t = Be_t \quad (5)$$

where A and B are $K \times K$ non-singular matrices, and inside the parentheses is the underlying VAR as L is the lag operator. Importantly, e_t is a K vector of orthogonalised disturbances with $e_t \sim N(0, I_K)$ and $E(e_te_s') = 0$ for $t \neq s$. Let P denote $A^{-1}B$ and note that $\sum = PP'$. The P matrix, which is identified by the identifying assumptions made to A and B, defines a transformation of $\sum$ to orthogonalise the disturbances. With orthogonalised disturbances, causal interpretations are obtainable.

Impulse-Response Function (IRF) is useful for inference. Because SVAR involves complex dynamics, researchers typically leave regression results unreported and use IRFs to predict the impact of an endogenous variable on another (Stock and Watson, 2001). The IRFs take into consideration

direct channels between the two variables and indirect linkages among all endogenous variables. Specifically, when the underlying VAR in equation (5) is stable, the SVAR model has a moving average representation:

$$y_t = \mu + \sum_{i=0}^{\infty} \Phi_i P e_{t-i} \tag{6}$$

where

$$\Phi_i = \begin{cases} I \ if \ i = 0 \\ \sum_{j=1}^{i} \Phi_{i-j} A_j \ if \ i = 1, 2, \ldots \end{cases} \tag{7}$$

and

$$A_j = 0 \, if \, j > p \tag{8}$$

Here, $\Phi_i P$, a $K \times K$ matrix, contains the period-i short-run structural IRFs; the (k_1,k_2) element of the matrix gives the effect of a shock to the k_2-th endogenous variable on the k_1-th endogenous variable after i periods, ceteris paribus.

Forecast-Error Variance Decomposition (FEVD) allows inference over the ability of shocks to explain future movement of the data (Kilian, 2011), meaning it can be used to estimate the proportion of forecast-error variance in a time series that can be explained by shocks to the time series itself or to another time series (Enders, 2004). Recent applications include Giordani (2004), Kim and Roubini (2000) and Shan (2002). Specifically, the matrix of short-run structural FEVD h-period ahead is:

$$\begin{aligned} W_h &= F_h^{-1} M_h \\ F_h &= \left(\sum_{i=0}^{h-1} \Theta_i \Theta_i' \right) \odot I \\ M_h &= \sum_{i=0}^{h-1} \Theta_i \odot \Theta_i \end{aligned} \tag{9}$$

where $\Theta_i = \Phi_i P$ and $\odot$ denote the Hadamard (element-wise) product. Here, the (k_1,k_2) element of W_h is the fraction of h-period-ahead forecast-error variance of the k_1-th endogenous variable that is attributable to a shock to the k_2-th endogenous variable.

A stable underlying VAR, which has a moving average representation, is a necessary condition to derive IRF and FEVD. We test our time series' stationarity using Augmented Dickey Fuller (ADF) and Dickey Fuller Generalized Least Squares (DF-GLS) tests, as ADF is popular, and DF-GLS is advantageous for small samples (Stock and Watson, 2007). Lag-length selection is important in the testing. Serial correlation in the errors can induce bias if lag-length is too short, but the power can suffer if the length is too long. Following Ng and Perron (1995), ADF starts from a large number of lags. The number is reduced one by one until the t-statistics of the last lag difference are greater than 1.6. For DF-GLS, an ARMA(1,1) model is applied in accordance with Ng and Perron (2001), who caution against low test power when the root of the autoregressive polynomial is close to but less than 1 and against severe size distortion when the moving average polynomial of the first-differenced series has a negative root close to -1. If either problem presents, the Modified Information Criteria (MIC) replaces the typical Bayesian Information Criterion (BIC) in lag-length selection.

Reasons to use SVAR and model specification. We choose SVAR for two reasons. The first is the need to model multiple endogenous variables jointly. Foreign liquidity may be endogenous. Although a positive shock to foreign liquidity may increase housing demand and breed price growth, the stronger growth might subsequently attract more foreign buyers. Also, regional housing prices can be interdependent. A type of VAR is helpful in this regard of endogeneity. Second, interest in causal relationship motivates us to apply SVAR. We use the short-run model, which

performs well on small samples (Christiano et al., 2006; Ravenna, 2007), and also make small-sample corrections including the small-sample degrees-of-freedom adjustment and small-sample test statistics.

The SVAR comprises seven endogenous variables spanning 63 quarters from 1996 Q2 to 2011 Q4. The first six variables are private-housing prices, foreign liquidity and private-housing supply of the central and non-central regions, where this geographic division is motivated by the spatial diffusion pattern exhibited in Figure 2. The key question is how foreign-liquidity shocks affect regional private-housing prices, but one might also conjecture influence from the housing supply. The housing prices are the estimated regional price indices for private residential properties. The foreign liquidity and housing supply are regional-specific quantities of private residential property sales to foreigners and private-housing stock, respectively. The last endogenous variable is HDB (public housing) resale price index. Private residential and HDB resale markets' prices are co-integrated (Ong and Sing, 2002; Phang and Wong, 1997; Sing et al., 2006). As the majority of Singaporeans live in HDB flats, it is interesting to examine whether the impact of foreign-liquidity shocks can ripple out to the HDB resale market where foreigners' participation is prohibited.[3]

The SVAR also comprises exogenous variables including GDP, interest rate and regional-specific variables of land-sale intensity, which is the deviation of the region's quarterly land sales from its average during the sample period. Over the years, the government uses land sales to influence development of the private-housing market (Phang and Wong, 1997). The SVAR variables are deflated by CPI when appropriate, and they are in logarithmic form except the interest rate and land-sale intensity.

All variables in our SVAR are first-differenced variables, because IRF and FEVD require a stable underlying VAR. Using ADF and DF-GLS unit root tests, we find the levels of the above-mentioned variables are all non-stationary, but the first-differenced time series of these variables are all stationary. Table 2 provides the definitions, summary statistics and results of the unit root tests for these first-differenced variables.

The contemporaneous correlations of the SVAR are governed by matrices A and B in equation (5). The latter is assumed diagonal as in the literature. The structure of matrix A assumes that growth of foreigners' purchases and housing stock in a region have an immediate impact on that region's private-housing price growth, as they reflect changes in housing demand and supply, respectively. Furthermore, central region's private-housing price and foreign-liquidity growths may spill over into the non-central region, given central region's dominant importance, which may drive market sentiment. Additionally, private-property prices may affect HDB resale prices – an assumption consistent with the findings of Ong and Sing (2002).

The underlying VAR is assumed with two lags, as longer lag-length increases values of information criteria, including AIC. Constraints are imposed after learning from unreported unconstrained regression. The effects of a variable's lagged variables on another variable are assumed zero, if both lags have highly insignificant coefficients in the unconstrained regression. The imposed constraints reflect the following assumptions. The regional growth of private-housing stock is affected by previous growth of quantities and prices of the regional private-housing market. The regional private-housing price growth is determined by its own previous growth and the past regional growth in quantities of private-housing stock and foreigners' private-housing purchases, which reflect past situations of supply and demand. Additionally, private-housing price growth in the central region can

Table 2. Variable definitions, summary statistics, and unit root tests.

Variable	Definition	Endogenous/ exogenous	Summary statistics		ADF		ARMA (1,1)		DF-GLS		
			Mean	Std. dev.	Lags	Test stat.	AR	MA	Criterion	Lags	Test stat.
Δs_t^c	Δ central region's total number of private-housing units	Endogenous	0.009	0.006	0	− 4.06**	0.69**	− 0.20	BIC	1	− 3.52*
Δs_t^{nc}	Δ non-central region's total number of private-housing units	Endogenous	0.011	0.009	1	− 3.04**	0.97**	− 0.79**	MIC	6	− 1.88
Δf_t^c	Δ central region's total number of private-housing sales to foreigners	Endogenous	0.007	0.459	1	− 6.38**	− 0.95**	0.98**	BIC	1	− 5.01**
Δf_t^{nc}	Δ non-central region's total number of private-housing sales to foreigners	Endogenous	0.025	0.445	4	− 4.31**	− 0.89**	0.77**	BIC	1	− 5.01**
Δp_t^c	Δ central region's real private-housing price	Endogenous	−0.001	0.068	4	− 4.46**	− 0.20	0.37	BIC	1	− 4.96**
Δp_t^{nc}	Δ non-central region's real private-housing price	Endogenous	−0.001	0.046	5	− 4.07**	− 0.03	0.61**	BIC	1	− 3.99**
Δp_t^{hdb}	Δ real HDB resale price	Endogenous	0.002	0.028	5	− 3.61**	0.67**	0.13	BIC	1	− 3.39**
Δg_t	Δ real GDP	Exogenous	0.011	0.037	4	− 4.50**	− 0.14	0.28	BIC	4	− 4.59**
Δr_t	Δ real interest rate of 15-year mortgage	Exogenous	−0.049	0.798	6	− 5.29**	0.60**	− 1.00**	MIC	3	− 3.64**
Δl_t^c	Δ central region's land-sale intensity	Exogenous	0.043	1.535	7	− 4.24**	− 0.72**	0.15	BIC	1	− 5.22**
Δl_t^{nc}	Δ non-central region's land-sale intensity	Exogenous	−0.042	1.845	3	− 7.20**	0.21	− 0.83**	MIC	7	− 2.66*

Notes: ** and * indicate 5% and 10% levels of significance, respectively. Δ denotes the first difference of the variable. All variables are in logarithmic form except the interest rate and land-sale intensity. The land-sale intensity is the deviation of the region's quarterly land sales from its average during the sample period.

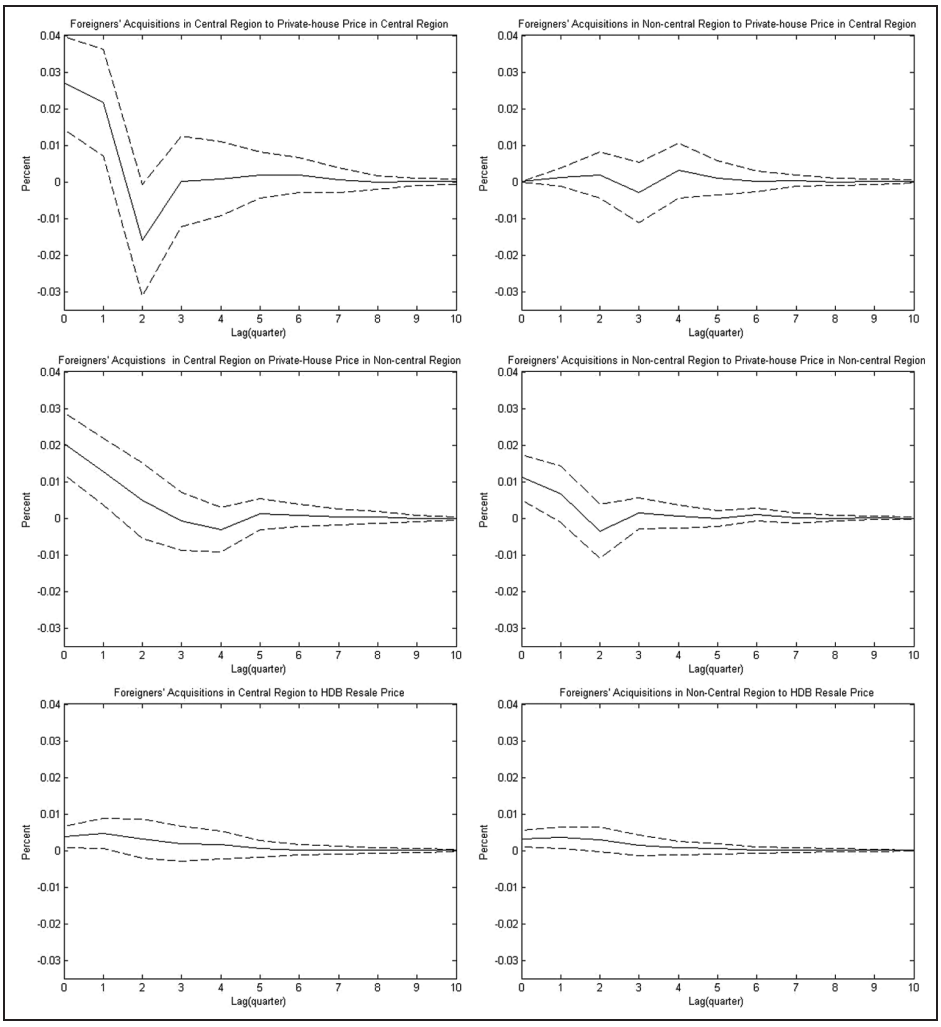

Figure 3. Impulse-response functions.

Note: This figure presents the impulse-response functions (IRF) of property prices to shocks to foreigners' acquisitions of private housing. From top to bottom, the first two charts in the left column concern the effects of a shock, which adds 1% growth of central region's private-housing sales to foreigners, on the growth rates of private-housing prices in the central and non-central regions, respectively, and the last chart concerns the effect of that shock on the growth rate of HDB resale prices. Likewise, the three charts in the right column present the effects of an equivalent shock to foreigners' purchases in the non-central region. The 95% confidence intervals are also plotted.

subsequently affect the growth in the non-central region, and this ripple effect is motivated by the diffusion pattern in Figure 3. Furthermore, regional growth of foreigners' purchases is assumed dependent upon all pieces of historical information in the private market. Lastly, the private residential and HDB resale markets are interconnected through prices. The imposed constraints allow the system to follow theory, although the unreported regression without these constraints produces similar basic results.

Results. Because VAR involves complex dynamics, regression results are typically unreported, and IRF and FEVD, which are more informative, are used instead (Stock and Watson, 2001). Nevertheless, this paper reports estimates of matrices A and B and the underlying VAR in Table 3, because the estimates really highlight the importance of private-housing prices and foreign liquidity and the critical role of price ripple effect in the system dynamics of the SVAR. The likelihood ratio test of identifying restrictions cannot reject the validity of any over-identifying restrictions (null hypothesis) at 10% significance level, and the equation-level model tests suggest that none of the equations has zero number of significant coefficients at 5% significant level, indicating proper model specification.

Matrix *A* indicates a significant positive contemporaneous effect of central region's growth of foreign liquidity on foreigners' buying activities outside that region.[2] Moreover, central region's foreign-liquidity growth significantly stimulates that region's growth of private-housing prices. This is also true for the non-central region, albeit a smaller magnitude. Interestingly, higher growth of central region's private-housing prices significantly and contemporaneously enhances growth of its non-central region counterpart, and higher growth of non-central region's prices significantly breeds growth of HDB resale prices. This is intuitive and consistent with the fact that high-end, upper-middle-class, and middle-class property markets are located in the central region, non-central region and HDB resale segment, respectively. The connectivity of prices is stronger between markets offering closer substitutes. The estimates of the underlying VAR suggest significant links between central region's foreign-liquidity growth and its subsequent growth of private-housing prices, but such linkage is insignificant in the non-central region. Additionally, there is a significant ripple effect of private-housing price growth from the central to the non-central region.

Scrutiny on IRF is necessary to grasp how SVAR endogenous variables respond to shocks. The short-run structural IRFs in Figure 3 plot the impulse of property prices to shocks to foreigners' acquisitions of private housing period by period. A shock adding 1% growth of central region's sales to foreigners can cause an immediate 0.027% higher growth of central region's private-housing prices. Significant impact sustains for another quarter. Thereafter, the impact virtually remains in the 95% confidence interval of zero effect. Although indirectly affected by the shock, non-central region's private-housing prices still grow significantly by 0.020% through the ripple effect of prices. The impact diminishes gradually. Through the ripple effect, the impact of this shock to foreigners' purchases of private housing in the central region can also reach the public-housing market where foreigners' participation is prohibited. The shock causes a small, yet significant, 0.004% growth of HDB resale prices.

Contrastingly, an unexpected 1% growth of non-central region's private-housing sales to foreigners has much smaller effects on private-property prices. The shock has an insignificant effect on the central region's prices, and only immediately raises the non-central region's price growth by 0.011%, which fades away quickly, possibly owing to the small volume of foreigners' private-housing acquisitions in the non-central region. Notably, this shock can stimulate a HDB resale price growth comparable with the effect from the central region's foreign-liquidity shock, probably because of tighter connectivity between non-central region's private market and HDB resale market.

Shocks to foreigners' purchases in the central region have a substantial impact on private-housing prices, as a back-of-the-envelope calculation can show. Examining

Table 3. Estimation outcomes of SVAR.

	Dependent variables													
	Δs_t^c		Δs_t^{nc}		Δf_t^c		Δf_t^{nc}		Δp_t^c		Δp_t^{nc}		Δp_t^{hdb}	
	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.
Transpose of matrix A														
Δs_t^c	1								0.44	(1. 10)				
Δs_t^{nc}			1								0.17	(0.46)		
Δf_t^c					1		− 0.56**	(0.10)	− 0.07**	(0.02)				
Δf_t^{nc}			1				1				− 0.04**	(0.01)		
Δp_t^c									1		− 0.44**	(0.07)	0.08	(0.05)
Δp_t^{nc}											1		− 0.29**	(0.07)
Δp_t^{hdb}													1	
Transpose of matrix B														
Δs_t^c	0.01**	(0. 00)												
Δs_t^{nc}			0.01**	(0.00)										
Δf_t^c					0.37**	(0.03)								
Δf_t^{nc}							0.27**	(0.02)						
Δp_t^c									0.05**	(0.00)				
Δp_t^{nc}											0.03**	(0.00)		
Δp_t^{hdb}													0.02**	(0.00)
Underlying VAR														
Endogenous variables														
Δs_{t-1}^c	0.61**	(0.14)			−13.94*	(7.78)	− 9.15	(7.37)	− 3.27**	(1.03)				
Δs_{t-2}^c	0.00	(0.14)			20.52**	(7.89)	6.38	(7.48)	2.71**	(1.03)				
Δs_{t-1}^{nc}			0.30**	(0.13)	2.40	(6.02)	0.12	(5.65)			− 0.58	(0.53)		
Δs_{t-2}^{nc}			0.23*	(0.13)	− 8.71	(5.57)	−11.17**	(5.22)			0.96*	(0.50)		
Δf_{t-1}^c					− 0.34**	(0.17)	0.01	(0.16)	0.06**	(0.02)				
Δf_{t-2}^c					− 0.31*	(0.17)	− 0.03	(0.16)	− 0.03*	(0.02)				
Δf_{t-1}^{nc}					0.27*	(0.16)	− 0.15	(0.15)			0.02	(0.01)		
Δf_{t-2}^{nc}					0.12	(0.16)	0.04	(0.15)			− 0.01	(0.01)		
Δp_{t-1}^c	− 0.01	(0.02)	0.01	(0.03)	1.87	(1.30)	0.70	(1.22)	− 0.08	(0.15)	0.24*	(0.13)	− 0.01	(0.06)
Δp_{t-2}^c	− 0.01	(0.02)	0.02	(0.02)	0.32	(1.09)	− 0.26	(1.03)	0.07	(0.13)	0.15	(0.11)	− 0.04	(0.05)
Δp_{t-1}^{nc}	− 0.00	(0.02)	− 0.01	(0.03)	− 6.18**	(1.57)	− 3.83**	(1.50)			0.06	(0.16)	0.12	(0.09)

(continued)

Table 3. (Continued)

	Dependent variables													
	Δs_t^c		Δs_t^{nc}		Δf_t^c		Δf_t^{nc}		Δp_t^c		Δp_t^{nc}		Δp_t^{hdb}	
	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.	coef.	s.e.
Δp_{t-2}^{nc}	0.03	(0.02)	− 0.07*	(0.03)	− 2.22	(1.74)	− 0.45	(1.66)			− 0.17	(0.16)	0.01	(0.09)
Δp_{t-1}^{hdb}									0.40	(0.37)	0.36	(0.28)	0.69**	(0.15)
Δp_{t-2}^{hdb}									0.08	(0.37)	− 0.01	(0.28)	− 0.10	(0.13)
Exogenous variables														
Δg_t	0.00	(0.02)	0.01	(0.03)	6.71**	(1.62)	6.35**	(1.51)	0.95**	(0.22)	0.22	(0.18)	0.04	(0.08)
Δr_t	0.00	(0.00)	− 0.00	(0.00)	− 0.15**	(0.07)	− 0.18**	(0.06)	− 0.00	(0.01)	− 0.01	(0.01)	0.00	(0.00)
Δl_t^c	− 0.00	(0.00)	− 0.00	(0.00)	0.15**	(0.05)	0.06	(0.04)	0.01	(0.01)	− 0.00	(0.01)	0.00	(0.00)
Δl_t^{nc}	0.00	(0.00)	0.00	(0.00)	0.00	(0.03)	− 0.02	(0.03)	− 0.01	(0.00)	− 0.00	(0.00)	− 0.00	(0.00)
Δg_{t-1}	− 0.01	(0.03)	− 0.02	(0.04)	− 1.80	(1.89)	− 3.61*	(1.76)	− 0.14	(0.25)	− 0.28	(0.21)	− 0.07	(0.09)
Δr_{t-1}	− 0.00	(0.00)	− 0.00	(0.00)	0.09	(0.08)	0.04	(0.07)	0.01	(0.01)	− 0.00	(0.01)	− 0.01**	(0.00)
Δl_{t-1}^c	0.00	(0.00)	0.00	(0.00)	0.09	(0.05)	0.03	(0.04)	0.00	(0.01)	− 0.00	(0.01)	0.00	(0.00)
Δl_{t-1}^{nc}	− 0.00	(0.00)	− 0.00	(0.00)	0.02*	(0.03)	− 0.01	(0.03)	− 0.00	(0.00)	− 0.00	(0.00)	− 0.00	(0.00)
Constant	0.00**	(0.00)	0.00**	(0.00)	− 0.01	(0.10)	0.15	(0.09)	− 0.01	(0.01)	− 0.01	(0.01)	0.00	(0.00)
Equation-level model test														
R^2	0.49		0.43		0.53		0.57		0.56		0.39		0.63	
chi^2	39.21		31.97		63.22		63.24		73.51		31.44		76.96	
p-value	0.00		0.00		0.00		0.00		0.00		0.03		0.00	
LR test of identifying restrictions														
			$chi^2(13) = 19.03$				Prob $> chi^2 = 0.12$							

Notes: Matrices A and B are the contemporaneous and residual matrices in the SVAR, respectively. The estimates of the underlying VAR are also reported. ** and * indicate 5% and 10% levels of significance, respectively. The significant levels of coefficients are determined by small-sample t-test. Standard errors are in parentheses.

the post-estimation ε_t in equation (4), the errors observed were substantial when the events described in the section 'Background' occurred. The unexpected growth of central region's private-housing sales to foreigners were 72%, 181% and −75% in association with the removal of foreigners' buying restrictions in mid-2005, influx of foreign liquidity in mid-2009 and the imposition of extra stamp duty on foreigners in 2011 Q4. Based on IRF estimates, events that cause 70% to 180% unexpected growth of central region's private-housing sales to foreigners will imply immediate 1.9% to 4.9% and 1.4% to 3.7% extra private-housing price increased in the central and non-central regions, respectively, and vice versa.

Table 4 reports short-run structural FEVDs of property-price growths resulting from shocks to the sales to foreigners period by period. Central region's foreign-liquidity shock is a major source of forecast-error variances of private-housing price growths in both regions. Over the 10-quarter-ahead horizon, the shock, the innovation, to central region's sales to foreigners ultimately contributes 34% of the central region's price-growth fluctuation resulting from all sources of innovations. It also eventually explains 25% of the fluctuation in the non-central region. On the contrary, the liquidity shock to the non-central region only accounts for about 1% and 8% of forecast-error variance of price growths in the central and non-central regions, respectively, and the small effect may be because foreigners' purchases are only a small fraction of private-housing sales in the non-central region and thus a high growth of foreign liquidity there only increases demand slightly. Lastly, although foreign liquidity shocks to the central and non-central regions could explain some small fractions of variations of HDB resale price growth, they are not significant sources.

A few alternative SVAR model specifications were attempted. They also carried the basic results. With a ripple effect from the non-central to central region, IRF indicates approximately 0.025% higher private-housing price growth lasting two quarters in the central region and 0.020% higher growth gradually fading away in one year in the non-central region after a 1% growth shock to central region's sales to foreigners. In contrast, an equivalent shock to the non-central region only causes at most 0.011% higher price growth in that region and minimal change in the central region. Additionally assuming away the contemporaneous effect of central region's price growth on non-central region's prices, the two regions have a symmetric price-diffusion mechanism, and the ripple effect occurs in a lead-lag fashion. Foreign-liquidity shock to the non-central region can stimulate up to 0.018% price growth there, while other impulse responses remain similar, but this case does not pass the identifying restriction test.

Conclusion

With globalisation, foreign liquidity has played an increasingly important role in shaping regional and local markets, including real estate. Global investors are attracted to international real estate markets, which may be more segmented than highly integrated stock markets, as lower correlation with other asset classes offer diversification benefits. From the perspective of recipient countries, governments often like to maintain stable and moderate growth of housing prices since housing is often the largest component of household wealth, and it also offers shelter. Foreign liquidity can lend support to the market, but it may worsen housing affordability when the market is tight. In Singapore, the government often eases rules and regulations on foreigners' purchases

Table 4. Forecast-error variance decompositions.

Response series	Number of quarters	Structural shocks					
		Foreigners' acquisitions in central region			Foreigners' acquisitions in non-central region		
			95% interval			95% interval	
Private-housing price in central region	1	25.4%	6.4%	44.4%	0.0%	0.0%	0.0%
	2	32.3%	13.1%	51.4%	0.0%	−0.1%	0.2%
	3	35.7%	17.5%	53.9%	0.1%	−0.5%	0.8%
	4	34.8%	17.3%	52.3%	0.3%	−1.2%	1.8%
	5	34.4%	17.2%	51.7%	0.6%	−1.5%	2.7%
	6	34.4%	17.1%	51.6%	0.6%	−1.4%	2.6%
	7	34.4%	17.1%	51.7%	0.6%	−1.4%	2.6%
	8	34.4%	17.1%	51.7%	0.6%	−1.4%	2.6%
	9	34.4%	17.1%	51.7%	0.6%	−1.4%	2.6%
	10	34.4%	17.1%	51.7%	0.6%	−1.4%	2.6%
Private-housing price in non-central region	1	24.0%	9.6%	38.4%	7.2%	−0.4%	14.8%
	2	26.4%	11.0%	41.7%	7.6%	−0.4%	15.6%
	3	25.6%	10.5%	40.8%	7.7%	0.1%	15.2%
	4	25.4%	10.4%	40.4%	7.7%	0.2%	15.1%
	5	25.6%	10.5%	40.6%	7.6%	0.2%	15.0%
	6	25.5%	10.6%	40.5%	7.6%	0.2%	15.0%
	7	25.5%	10.5%	40.5%	7.6%	0.2%	15.0%
	8	25.5%	10.5%	40.5%	7.6%	0.2%	15.0%
	9	25.5%	10.5%	40.5%	7.6%	0.2%	15.0%
	10	25.5%	10.5%	40.5%	7.6%	0.2%	15.0%
HDB resale price	1	3.8%	−1.7%	9.3%	2.8%	−0.9%	6.6%
	2	5.7%	−2.1%	13.5%	3.7%	−1.1%	8.4%
	3	6.3%	−3.6%	16.2%	4.4%	−1.4%	10.2%
	4	6.4%	−4.2%	17.1%	4.4%	−1.6%	10.4%
	5	6.6%	−4.3%	17.6%	4.4%	−1.6%	10.4%
	6	6.6%	−4.3%	17.6%	4.4%	−1.6%	10.4%
	7	6.6%	−4.3%	17.6%	4.4%	−1.6%	10.4%
	8	6.6%	−4.3%	17.6%	4.4%	−1.6%	10.4%
	9	6.6%	−4.3%	17.6%	4.4%	−1.6%	10.4%
	10	6.6%	−4.3%	17.6%	4.4%	−1.6%	10.4%

Notes: This table presents the forecast-error variance of central and non-central regions' private-housing prices and HDB resale prices attributable to shocks to central and non-central regions' private-housing sales to foreigners. The 95% confidence intervals are also reported.

when the market is dull and may tighten them when the market overheats.

This paper finds that such policy shocks to foreigners' property acquisitions do have large impacts on housing price movement. The research depicts a strong relationship between foreign-liquidity to real estate and housing price change, and indicates the ripple effect of regional housing prices. The structural vector autoregressive model, which incorporates these observations, shows that shocks to foreigners' buying activities in the central region greatly affect housing price growth and account for 34% fluctuations of the growth there. The shocks also explain 25% fluctuations of housing price growth in the non-central regions through the ripple effect of regional home prices, even though foreigners' purchases in the central region do not directly affect prices in the other region. Possibly because of low concentration of foreign home buyers in the non-central region, shocks to foreigners' acquisitions in that region have minimal impact on housing price movements in both regions. Additionally, the impacts of shocks to central and non-central regions' private-housing sales to foreigners both can reach the public-housing market, where foreigners' participation is prohibited, and stimulate a small, yet significant, extra growth of public-housing prices through the ripple effect. These findings warrant policy consideration. For instance, the effects of adjusting influx of foreign liquidity can be general, even though foreign home buyers are mainly interested in a particular segment of the housing market.

This study will also be useful to researchers on the ripple effect, as the effect critically transmits impact of foreign-liquidity shock across housing submarkets. Plausible economic explanations to the ripple effect (see Meen, 1999) such as residential mobility and spatial arbitrage could apply to Singapore. For example, the influx of foreign liquidity into housing markets in 2006 and 2007 resulted in numerous en-bloc sales in the central region. Many residents moved to lower priced suburbs and consequently increased prices there (Zhen and Shaik, 2007). When central-region housing prices rise, arbitrage intension should raise prices in contiguous areas. Future research could examine these economic explanations. Also, since extant ripple effect literature focuses on price diffusion instead of the shock causing the ripple effect, future research could study content of the shock to widen possible applications and directions of the ripple effect literature.

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Notes

1. For instance, the Spanish Government launched a reform of immigration regulations in November 2012 to offer permanent residency to foreign home buyers in order to promote the stagnant housing sector.
2. The off-diagonal elements of matrix A capture the negative of the contemporaneous effects. Thus, the estimated effect on housing price growth in the central region is positive.
3. Prices of new HDB flats are tightly controlled by the government, but the resale segment is a free market.

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