Can Volume be More Informative than Prices? Evidence from Chinese Housing Markets

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Abstract

This paper examines pairwise intercity price-volume dynamics in China using novel daily transaction price and volume dataset from 32 Chinese cities. Despite geographical disparity and time variations, the volume-volume dynamic relationship plays a noticeably more significant role than price-price or price-volume relationships, suggesting that volume may be more informative than prices in China's pairwise intercity housing market spillovers. We further propose a new spillover/connectedness measure to summarize both price and volume information and better measure such spillovers. We find that the new measure can be significantly explained by economic fundamentals, which attests to the soundness of the basic finding.

Keywords: Housing markets; volume; daily data; connectedness; spillover index

JEL Classifications: G1, C3, R3

1. Introduction

Both the price and trading volume theoretically can play a key informational role in asset markets, and yet trading volume has received far less attention than prices in the literature (e.g., Lo and Wang, 2000; Halling et al., 2013; Roll et al., 2014; Yang et al., 2021; DeFusco et al., 2022). This may be partly due to the lack of clear evidence of the significant informational role of volume compared with prices, which is true based on evidence from the stock market, the asset market that receives the most attention in the literature (see Yang et al., 2021)[1]. A similar point also applies to housing, the most important asset to average households in the US or China. Earlier studies have addressed the housing price-volume dynamic relationship in the intracity context to shed light on the issue, yet produced opposite theoretical arguments and mixed empirical evidence. For example, Stein (1995) theoretically show that there should be the Granger causality from prices to trading volume in the US housing market, while Wheaton's (1990) theory suggests the opposite. Clayton et al. (2010) and Dröes and Francke (2018) also find mixed evidence to support both Stein (1995) and Wheaton (1990) in the US and European housing markets.

Recently, DeFusco et al. (2022) reexamine intracity price-volume dynamics, emphasizing that the same set of housing market information may be potentially first contained either in prices or volume or both on the housing market.[2] Based on 50 million home sales between 1995 and 2014 across 115 metropolitan statistical areas, they theoretically and empirically show that the

[1] Noteworthy, the accounting literature pays much attention to the informational role of trading volume of stocks around earnings announcements. See a review by Bamber et al. (2011).

[2] In the literature, the possible candidates for informativeness of volume or prices on the housing may include the information that can generate more accurate forecast on changes of the housing price (Bollerslev et al., 2016), on the price volatilities (Chinloy and Larson, 2017), on the spillover of housing prices (Han et al., 2018; Yang et al., 2018). The specific type of information we examine in this study is related to more accurate (in-sample) forecast on changes of housing prices or volume, most noticably in an intercity spillover context. We thank the referee for making the insightful suggestion.

volume may play a leading informational role over prices in recent US housing cycles. Their finding is also consistent with the earlier observation of Leamer (2007, 2015) that the US housing experiences a volume cycle rather than a price cycle. Yang et al. (2021) also show that housing trading volume dynamics across multiple cities in China may be informative and significantly explained by city-level economic fundamentals.

Extending the existing literature, this paper focuses on intercity rather than intracity price-volume dynamic relationships using a novel dataset of 32-city daily transaction data during 2009-2016.[3] The paper contributes to the literature in the following aspects. First, echoing the argument that the speculative dynamics of the volume is a less studied feature of asset bubbles (DeFusco et al., 2022), we first time document a significant informational role of volume beyond prices in pairwise intercity housing market information transmission in China. Specifically, the volume-volume dynamic relationship between Chinese cities is much more significant than the price-price or price-volume dynamic relationships. As further collaborative evidence, the documented pattern is shown to be fundamentals-based, refuting the possibility that it is simply due to biased sample data, government interventions, or any other unique features in China.[4] It thus provides the non-US evidence in a different (intercity) context to support the recent literature underscoring a significant informational role of transaction volume over prices in driving the US housing cycles

[3] This is defined by all possible price-volume, price-price, and volume-volume dynamic relationships between a pair of cities, which totals eight, as discussed below. Thus, in addition to its contribution to the literature on the price-volume dynamics, this study also substantially extends the related literature on housing market spillovers. Existing studies on housing market spillovers in China (e.g., Yang et al., 2018) or in other countries generally examine only intercity price-price dynamic relationships in a bivariate or multivariate context, with a noticeable exception of Yang et al. (2021), which, however, examines intercity volume-volume dynamic relationships alone.

[4] Unlike more developed housing markets, both prices and transaction volumes in Chinese housing markets have been to a varying degree explicitly subject to various government intervention policies in China to fight against a speculative mania on these markets. See, e.g., Du and Zhang (2015), Glaeser et al. (2017), and Yang et al. (2021).

(Leamer, 2007, 2015; DeFusco et al., 2022).[5] It is also consistent with the unique importance of housing transaction volume (Piazzesi and Schneider, 2009; Piazzesi et al., 2015). The finding is also important itself, as China's housing market has become twice as large as the US housing market (Xu et al., forthcoming).

Second, building on Billio et al. (2012), we propose a new spillover/connectedness measure to measure the pairwise intercity housing marker interactions/spillovers, summarizing information of all possible intercity price-volume dynamic relationships. Hence, (as discussed in more details in the methodology section), the paper further contributes to the literature on housing market spillovers/linkages in particular and asset market spillovers in general for the first time exploiting intercity housing market spillovers through both price and volume.[6] Arguably, the new connectedness measure would better describe housing market spillovers, in the sense that it additionally uses important information available from housing transaction volume. It would be particularly rewarding, in light of the possible leading informational role of housing transaction volume over prices, although the price-price dynamics have been the focus of almost all existing studies on asset market spillovers, including housing market spillovers (Yang et al., 2021). Further

[5] The possibility of a leading informational role of housing transaction volume over prices is also being informally recognized in a very few recent studies using international data. For example, although they do not present any empirical evidence, Badarinza and Ramadorai (2018, p. 546) implicitly admits the possibility in their statement that "We view this as encouraging evidence that our method is successful at identifying foreign demand effects *that impact volume, and ultimately prices* in the London residential real estate market."

[6] As our main interest is to shed more light on the informational role of volume versus prices in the pariwise intercity context, the effort nauturally leads to the measurement of pairwise housing market interactions, which nevertheless has the obvious limitations that it is only in the bivariate (rather than multivariate) context and further filtered by certain criteria (i.e., "geographical closeness"). Nevertheless, such a bivariate framework is still used in the recent literature on China's housing market network (e.g., Hurn et al.,2022). As discussed further below, such limitations may not undercut the inference of the main interest, although they do not offer a complete (multivariate) picture for housing market spillovers, despite its additional use of the information of volume. We leave a more comprehensive multivariate modelling of housing market interactions for future research, as it is beyond the scope of the current paper.

extending earlier studies using fundamentals of individual cities to explain lower frequency (monthly or quarterly) city-level housing price variables (e.g., Miller and Peng, 2006), price-volume relationships (e.g., Leung and Feng, 2005; Clayton et al., 2010) or housing market spillovers in China (e.g., Yang et al., 2018), we show that *the divergence of fundamentals between cities* (e.g., city-level GDP per capita and population growth), are significant determinants of intercity housing market spillovers. Equally important, they matter even when such (pairwise) intercity housing market interactions are measured initially using *daily* data. The finding also attests to the basic soundness of the basic findings of this study including the construction of the new connectedness measure, and thus is reassuring.

Finally, extending the recent literature (Bollerslev et al., 2016; Chinloy and Larson, 2017; Yang et al., 2021), the use of daily housing market data in China for both price and volume in this study should enable us to provide a finer and probably a more complete and accurate picture of intercity price-volume dynamics, partly by the allowance for the possible time variations in housing price-volume dynamics yet to be explored in the literature. Recently, Bollerslev et al. (2016) and Chinloy and Larson (2017) advocate for the advantages of using US housing prices measured at a daily frequency to mitigate the potential "aggregation biases" problem plaguing the traditional coarser monthly and quarterly data, which is shown to provide more accurate descriptions about the US housing market. Yang et al. (2021) also show similar advantages of using of daily housing volume data in China, compared with monthly data. While the graphical plot of the housing price changes and volume in Los Angeles shown in Leamer (2015, p. 48) clearly suggests the possibility of time variations, to our knowledge, no previous studies have explored the possibility of time-varying housing price-volume dynamics. This is mainly due to the unavailability of high-frequency daily housing market data with a long enough history, which can provide sufficient observations to conduct meaningful statistical analysis within various time windows. We fill the gap in the literature.

The rest of this paper is organized as follows. Section 2 briefly reviews the related literature. Section 3 describes the data and empirical methodology. Section 4 discusses the empirical results. Section 5 presents various robustness checks. Section 6 further investigates related fundamental determinants. Section 7 concludes the paper.

2. Related Literature

In this section, we provide a brief review of the related literature along several dimensions. First, this study is related to the literature on the price-volume dynamic relationship in the housing markets, which sheds light on the informational role of price and volume. While the large literature on examining price-volume dynamics in the stock market yield mixed evidence (see, e.g., Karpoff (1987) and Chen (2012)), the relative informational roles of price and volume in the housing market could be different from the stock market (Leung et al., 2006; Yang et al., 2021), because the housing market has lower informational efficiency than financial markets (Case and Shiller, 1989). Theoretically, several researchers argue that price changes may cause changes in trading volume, building on one of three factors: equity constraints (e.g., Stein, 1995), nominal loss aversion (e.g., Genesove and Mayer, 2001), or option value of homeowners. Nevertheless, Wheaton (1990) argues the opposite that the causality should run from trading volume to prices in the housing market. Mixed patterns of price-volume relationships in housing markets have been observed in the literature. While the Granger causality running from prices to volume is found by many earlier studies (e.g., Genesove and Mayer, 2001; Clayton et al., 2010; Dröes and Francke, 2018), the causality running from volume to prices is also documented by the others (e.g., Leung et al., 2002; Clayton et al.; 2010; Shi et al., 2010; Dröes and Francke; 2018; DeFusco et al., 2022).

A common feature of all these studies is their focus on the intracity price-volume relationship.

The study is also related to the recent literature on housing market spillovers in China. While China's housing market has attracted global attention because of its significant influence on the Chinese economy and the world economy (e.g., IMF, 2011; Glaeser et al., 2017), intercity housing market spillovers in China was examined only until recently (e.g., Gong et al., 2016; Yang et al., 2018). Nevertheless, as pointed out by Yang et al. (2021), all these studies follow the broader literature on house market spillovers in other countries (e.g., Al-Yahyaee et al., 2021), and typically use housing prices alone to measure housing market spillovers. Obviously, the potential information from volume is totally ignored in such studies, which contradicts with the earlier literature mentioned above documenting the causality running from trading volume to prices on the housing markets.

Finally, this study is motivated by the emerging literature on advocating for the use of daily housing market data to better examine information transmission (as captured by Granger causality tests). By constructing daily house price indices for 10 major metropolitan areas in the US, Bollerserlev et al. (2016, p. 1005-7) show that "…daily house price indices …produce forecasts longer-run monthly house price changes that are superior to various alternative forecast procedures based on lower-frequency data…thus directly underscoring the informational advantages of the new daily indices…". Chinloy and Larson (2017) demonstrate that the daily US house price index can be used to generate an accurate measure of house price volatility that can produce sensible risk-adjusted return measures in line with those estimated using micro-level data, while this is not the case for the widely used monthly US housing price index. Yang et al. (2021) further illustrate the aggregation bias problem in monthly housing trading volume in China, as much less significant information flow can be detected or clearly directed using monthly, compared with the results using daily data.

3. Data and Empirical Methodology

3.1 Data

The data used in this paper are daily logarithm differences of the city-level average housing transaction price (Yuan per square meters)[7] and trading volume (units sold) in China. The original data are reported by local governments (Bureau of Housing Management) and are collected from the CEIC database. According to the housing registration regulation of the Ministry of Construction, the People's Republic of China, a newly purchased house must be registered in the local housing management system within 30 days (including the weekends and public holidays, and not just working days) after transaction contracts are signed. Local governments report the daily housing transaction information (e.g., the daily transaction volume and average price) based on such registration. However, this city-level housing transaction information cannot be publicly available for all large or medium-sized cities in China, because different cities have different styles of issuing such information (including irregular release or no release of such information at many cities).[8] The CEIC database provides access to related information that dozens of cities have released.

Because the raw data are quite noisy and with many missing observations in some cities and in some years. Following Yang et al. (2021), we thus collect, clean, and process the data as follows.

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[7] In addition to the nonexisitnce of the official housing price indexes at the daily (or weekly) frequency, the city-level average housing transaction prices in China behaves better than official housing price indexes in accurately relecting the genuin housing price changes, at the comparably monthly frequency. By comparing the self-built housing price index from the mortage data with the Chinese official housing price index and the average transaction prices used in this study, Fang et al. (2016, p. 130) conclude that: "…the average price…exhibits highly synchronized comomoverments with our index……our index is capturing similar fluctuations as the straight calculation of average tansaction prices."

[8] Many cities might only report the transaction information in the past few months or never publicly report such information on their official websites.

We first collect all of the data that contain both daily housing transaction prices and units sold from 1 January 2009 to 30 June 2016, the longest dataset available across all the cities under consideration when this study was initiated. For a few cities with unusual time gaps of missing data, i.e., without any observations for one month or longer,[9] we only keep the longest time span with continuous observations for that city. To ensure a sufficient time span and include as many cities as we can, we exclude the cities with observations less than ten months from our sample, leaving us with 32 cities from 18 provinces (out of 31 provinces in mainland China). Excluding cities with observations less than twelve months as an alternative would only lead to somewhat fewer cities in the sample, but that would not affect our main finding below. Although only 32 cities are included in the sample and some important cities are not included due to the data unavailability (e.g., no daily transaction prices available for some important cities from the same data source), these cities cover all of the administrative levels, city tiers, and regional groups in China,[10] thereby being still able to provide a representative picture for the Chinese housing market. Further evidence below on the significance of economic fundamentals in explaining these intercity price and volume overall relationships also attests to the representativeness of the sample (despite its incompleteness). Figure 1 depicts the geographical distribution and regional groups of the sample cities.

[*Insert Figure 1 about here*]

We then process the data in three steps. First, we replace the missing observations of a city

[9] The longest public holidays in China, like the Spring Festival, are 7 days. But for some smaller cities, there might be up to ten days without housing registrations because of local government's extended holidays. Thus, if the observations are missing for one month or longer, it can hardly be attributed to public holidays, but instead reflects some irregularities of the concerned housing market.

[10] See Fang et al. (2016) for city tiers and Yang et al. (2018) for city administrative levels and city regional groups in China. These studies also provide more details about Chinese housing markets.

with its previous non-missing values. Second, we compute the rolling average of 30 days to control for potential time mismatch of the day the house was traded and the day it was registered in the local housing management system, as a newly purchased house is registered in the local housing management system within 30 days after transaction contracts are signed. The days open for registration vary in the same city during different time periods and vary for different cities during the same time period. Hence, the moving average is able to alleviate the problems caused by those two situations and make the observations generally comparable during different time periods for the same city or for different cities during the same time period. Such treatment of the data is similar in spirit to the practice of using rolling average to smooth out sharp daily movements and irregular trading (Yang and Zhou, 2013; Yang et al., 2021). Third, we discard the first 29 observations and then calculate the logarithm differences[11] for both prices and the volume of each city. Table 1 presents some details about the data. The data of economic fundamentals including the original data of city GDP, population, GDP per capita, unemployment, mortgage rate, and Shanghai Stock Market Composite Index are also collected from the CEIC database.

[*Insert Table 1 about here*]

3.2 Empirical Methodology

The intercity price-volume dynamics in the housing market, as a natural extension of the intracity housing price-volume dynamics popular in the existing literature, may imply a lead-lag relationship commonly modeled by Granger causality tests in this line of the literature (e.g., Stein, 1995; Wheaton, 1990; Clayton et al., 2010). However, VARs used in such Granger causality tests (e.g., Billio et al., 2012; Su, 2021) typically are symmetric and employ the same number of lags

[11] That is, 100×(log(current price or volume)-log(previous price or volume)). Thus, they are the logarithm differences of the price or the volume, although we still refer to these as price and volume below.

for each variable involved. Following Hsiao (1981), Keating (2000), and Zhang et al. (2021), we employ the Granger causality test based on the asymmetric VAR in this study (i.e., with possibly different optimal lags to be determined by the data, when dependent variables in each equation of the (bivariate) VAR system are different), rather than the commonly used symmetric VAR framework. With the asymmetric VAR model, each equation of the VAR system contains the same variables, and thus parameter estimates are both consistent and efficient, but the lags of the variables are allowed to be potentially different.

For the statistical viewpoint, the framework helps avoid possible misspecifiction in Granger causality tests due to overfitting, which is evidenced by the fact that the symmetric VAR estimates often tend to produce many insignificant coefficients (e.g., Hsiao, 1981; Keating, 2000; Zhang et al., 2021). Different optimal lags objectively determined by the data (and selected by the model selection criteria) in different cases would not reduce but rather improve the genuine comparability of Granger causality test results. This is because with asymmetric VAR, the causality tests in all cases would be consistently prevented from the potential overfitting problem leading to misleading statistical inference. From the economic viewpoint, the asymmetric VAR framework in this study allows for possible different speeds of information transmission between these two housing market variables involved (i.e., housing price and volume) for two reasons[12]. First, there could be different speeds of housing market information diffusion and absorption in different cities via the same price of volume variable, particularly when we consider the case of the information transmission from larger to smaller cities, versus from smaller to larger cities. Second, such potentially different speeds would be even more obvious when we consider the information transmission from one of

[12] There is an alternative meaning of asymmetry in the context of Granger causality tests in the literature (e.g., Wang and Ngene, 2018), where asymmetry is based on the differences between positive and negative changes in the variables involved.

the housing market information proxies (either prices or volume) to the other. In fact, various theoretical arguments suggesting different directions of causality on the price-volume dynamic relationship within the same housing market (e.g., Stein, 1995; Wheaton, 1990) also exactly imply different speeds in spreading and incorporating relevant housing market information for these two variables.

In line with the literature (e.g., Stein, 1995; Wheaton, 1990; Clayton et al., 2010), we focus on using Granger causality tests to explore information transmission between pairwise intercity housing market price-volume dynamic relationships. Let P denote price and V denote volume, to test the Granger causality running from prices to the volume and from the volume to prices; the following VAR system is commonly employed.

$$\begin{bmatrix} P_t \\ V_t \end{bmatrix} = \begin{bmatrix} A_{10} \\ A_{20} \end{bmatrix} + \begin{bmatrix} A_{11}(L) & A_{12}(L) \\ A_{21}(L) & A_{22}(L) \end{bmatrix} \begin{bmatrix} P_{t-1} \\ V_{t-1} \end{bmatrix} + \begin{bmatrix} e_{1t} \\ e_{2t} \end{bmatrix} \quad (1)$$

where A_{i0} (i=1,2) are the parameters representing intercept terms; $A_{ij}(L)$ (i=1,2; j=1,2) are the polynomials in the lag operator L; e_{it}(i=1,2) are the white-noise disturbances. The individual coefficients of $A_{ij}(L)$ are denoted by $\alpha_{ij}(1), \alpha_{ij}(2), \cdots$ Under the symmetric VAR framework, it sets that the polynomials $A_{ij}(L)$ are all of the same degree—a special case of the asymmetric VAR framework which allowing $A_{ij}(L)$ can be potentially different from each other. Letting $A_{ij}(L)$ potentially differ from each other, as emphasized in Hsiao (1981): "…provides a reasonable powerful test of exogeneity (or causality) …[and] economically meaningful… [pp. 87]" In practice, we examine each of four pairs/combinations of bivariate dynamic relationships between prices and the volume in two different cities separately, allowing $A_{ij}(L)$ potentially different from each other.

Specifically, using the Granger causality test running from the volume to prices within the same city as a more straightforward example, we first choose the lag of $A_{11}(L)$ (denoted by L_p) that minimizes the Akaike information criterion (AIC hereafter) of the autoregressions of

$$P_t = A_{11}(L)P_{t-1} + \mu_{1t} \qquad (2)$$

with the possible maximum lag set at seven (one week including the weekend), given the daily data[13]; then we choose the optimal/actual lag of $A_{12}(L)$ (denoted by L_v) that minimize the AIC of

$$P_t = A_{11}(L_p)P_{t-1} + A_{12}(L)V_{t-1} + \mu_{2t} \qquad (3)$$

with given L_p; finally, in line with Bessembinder et al. (1996), the following equation is estimated with the appropriate heteroscedasticity and autocorrelation-consistent (HAC) covariance matrix

$$P_t = A_{11}(L_p)P_{t-1} + A_{12}(L_v)V_{t-1} + e_{1t} \qquad (4)$$

(Newey and West, 1987). The application of HAC covariance can address any possible (higher-order) conditional heteroscedasticity (and possibly remaining autocorrelation) problems of the concerned variables. Thus, the Granger causality test from the volume to prices is equivalent to examining the null hypothesis of individual coefficients in $A_{12}(L_v)$ (Equation (5)). With the HAC covariance matrix estimation, the appropriate χ^2 statistic is used (instead of the F statistic) to test the above null hypothesis in equation (5). The method is applied to investigate *eight* intercity price-volume, price-price, and volume-volume dynamic relationships.[14]

$$\alpha_{12}(1) = \alpha_{12}(2) = \cdots = \alpha_{12}(L_v) = 0 \qquad (5)$$

As mentioned in the introduction, pairwise or bivariate intercity relationships do not provide a complete picture, unlike modelling multivariate intercity relationships. Nevertheless, it serves reasonably well as the most straightforward extension from the intracity price-volume dynamics in the literature to the intercity context, which is of main interest in this study. Given the fact the

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[13] There are price and volume data even over the weekends. The results are basically the sam when the longest lag is set at 14 (two weeks) or 30 (one month), because only just a few cities have a time lag approaching seven.

[14] More specifically, let P_1, V_1, P_2, and V_2 denote the housing transaction price and volume of city 1 and city 2, respectively; "$P_1 \rightarrow P_2$" denote Granger causality running from prices in city 1 to prices in city 2, and others are defined similarly. The eight possible intercity dynamic relationships thus are $P_1 \rightarrow P_2$, $P_1 \rightarrow V_2$, $V_1 \rightarrow P_2$, $V_1 \rightarrow V_2$, $P_2 \rightarrow P_1$, $P_2 \rightarrow V_1$, $V_2 \rightarrow P_1$, and $V_2 \rightarrow V_1$.

simple pairwise price-volume dynamic relationships already involve eight pairs to exhaust all possible cases, the extension to the multiple cities (beyond two) would result in a much larger number of possible price-dynamic relationships, to the extent that it is quickly intractable. This is particularly true in this case involving 32 cities. To address the tractability challenge more effectively, we further focus on pairwise intercity relationships between cities located in the same province or in the adjacent provinces (for both the full sample and each year). This is because although a national housing market may be composed of a series of interlinked local markets with several potential channels through which spatial interactions can occur, the housing market interactions can largely be attributed to "geographical closeness" or "economic similarity" (Ferreira and Gyourko, 2012; Zhu et al., 2013; Yang et al., 2018). Obviously, our intercity investigation does not explore all possibilities between any pairs of cities under consideration, but rather focuses on potentially the most interesting or straightforward cases which most likely lead to significant findings. We also leave it for further research to explore the issue more thoroughly.

Building on Billio et al. (2012), we further propose to build a housing market spillover index based on the above eight intercity dynamic relationships between each pair of cities under consideration. The intercity housing transaction connectedness (ICHTC) index is measured as the weighted average of the indicator of whether a specific Granger causal relationship is significant or not (see equation (6) below).

$$\mathrm{ICHTC}_{AB} = \sum_{i=1}^{8} \omega_i I_{i,AB} \qquad (6)$$

where weight ω_i is calculated as the ratio of the significant Granger causality detected for the *i*-th relationship from the whole sample, and $I_{i,AB} = 1$ (=0) if the Granger causality test for the *i*-th relationship between city A and B is (not) significant at the 5% significance level. Following Billio et al. (2012), we also consider measuring ICHTC as the simple ratio of the number of significant

Granger causality detected from the eight intercity housing transaction linkages for a specific city pair. The results are also quite similar (as discussed below).

Noteworthy, while Billio et al. (2012) and subsequent studies only apply their spillover/ connectedness index to asset prices or equivalently focus on only price-price Granger causality tests, we modify and extend the method of Billio et al. (2012) to allow for the information of volume, the other key indicator of the information about asset markets including the housing market. By doing so, we greatly expand the scope of investigation on dynamic relationships between any pair of asset markets. We further demonstrate for the first time that such extension of Billio et al. (2012) measure can produce statistically significant and economically meaning results, consistent with the recent argument that both volume and price can play key informational roles, particularly on the housing market. Nevertheless, also due to the dramatically increased number of possible dynamic relationships in our modified index construction method, we focus on the bivariate in this study rather than the multivariate context as in Billio et al. (2012). We leave the extension to the multivariate context and yet allow for both the price and the volume for future research.

Based on the spillover/connectedness index measure summarizing the price and volume, we further explore the economic determinants of pairwise intercity housing market connectedness using panel regressions (as discussed below). Noteworthy, as pointed out by Yang and Zhou (2013), such analysis essentially can serve as an important robustness check on the main result of the pairwise price-volume dynamic relationships. A potentially biased sample due to data unavailability and random errors possibly introduced in the (multi-step) estimation procedure, if substantial, should be biased toward no significant relationship between the pairwise price-volume dynamic relationships and the economic determinants.

4. Empirical Results

This section will examine intra-city price-volume correlation and intercity price-volume, price-price, and volume-volume dynamics for both the full sample and each year. As explained above, we focus on those intercity relationships between cities located in the same province or in the adjacent provinces (see Table 1 and Figure 1). This is consistent with "geographical closeness" and to a lesser extent "economic similarity", two main channels demonstrated in the earlier studies that largely would drive the intermarket spillovers. We will discuss the full sample results and then present the yearly results.

4.1 Full Sample Results

Table 2 reports the results of Granger causality tests running from price to volume and from volume to price within each city. We can find that the intracity price-volume dynamic relationship varies dramatically across cities: there is no significant Granger causality in either direction in 13 out of 32 cities. For the remaining cities, there is no causality from price to volume for another 5 cities, and no causality from volume to price for 7 more cities, while there exists bi-directional Granger causality for the rest of 19 cities. Therefore, the results show no consistent pattern of the intracity price-volume dynamic relationship that is applicable to all the sample cities. The finding may be consistent with earlier theoretical works and mixed empirical evidence on the price-volume relationship on the US housing market, as discussed above in the literature review. Furthermore, as housing assets play a dual role in the economy: as a consumption good in segmented local markets and also as an investment good in potentially inter-regionally integrated markets, the interaction between price and volume may not be fully revealed by only one uniform relationship. As pointed out by Campbell et al. (2011): "…the market for housing differs in several important ways from the textbook model of a liquid asset market with exogenous fundamentals…the price of which a house is sold can be influenced not only by general supply and demand conditions, but also by idiosyncratic factors…" Compared to the average result presented in earlier studies (e.g., Clayton et al., 2010; Dröes and Francke, 2018), we would like to emphasize these points, as they imply the geographical disparity. To a certain extent, Clayton et al. (2010) also indicate such geographical disparity, as their results of the intracity price-volume correlation differ between housing markets with and without supply elasticity.

[*Insert Table 2 about here*]

Table 3 reports the results of Granger causality tests for eight intercity price-price, price-volume, and volume-volume dynamic relationships between cities located within the same province (16 city pairs).[15] For each city pair, we examine the Granger causality running from either prices or the volume in city 1 to either prices or the volume in city 2, and vice versa. These Granger causality results of each city pair, according to Billio et al. (2012), may better reveal intercity housing market spillovers from the perspective of transaction connectedness (or interactions). In line with previous studies on housing price spillovers (at the monthly frequency) in China (e.g., Yang et al., 2018), we also find certain intercity Granger causality between daily housing prices ($P_1 \rightarrow P_2$ or $P_2 \rightarrow P_1$). Nevertheless, Table 3 shows an interesting new result: in contrast with relatively less frequently significant intercity Granger causality test results on (daily) price-price ($P_1 \rightarrow P_2$ and $P_2 \rightarrow P_1$) or price-volume ($P_1 \rightarrow V_2$, $V_2 \rightarrow P_1$, $V_1 \rightarrow P_2$, and $P_2 \rightarrow V_1$) dynamics, the (daily) volume-volume dynamics ($V_1 \rightarrow V_2$ and $V_2 \rightarrow V_1$) is much stronger. Such a finding further reveals a noticeably more significant informational role of volume than price in the housing market, which has been stressed by Leamer (2007, 2015), DeFusco et al. (2022), and Piazzesi and Schneider

[15] Whether two cities are located in the same province or in adjacent provinces can be seen either from Table 1 or from Figure 1. To ensure sufficient observations for the examination, at least three-month (one quarter) observations need to coexist for each pair of cities.

(2009, 2015). The finding also provides much supportive evidence for the few empirical studies exactly focusing on the crucial informational role of the volume-volume relationship on the housing market (Yang et al., 2021), the stock market (Halling et al., 2013), and derivative markets (Roll et al., 2014).

[*Insert Table 3 about here*]

Table 4 reports the results of Granger causality tests for eight intercity price and volume dynamic relationships between cities located in adjacent provinces (57 city pairs). Comparing with Table 3, we can find that the daily intercity housing market spillover pattern between cities located in adjacent provinces is very similar to that between cities located in the same province: the volume-volume dynamic relationship ($V_1 \rightarrow V_2$ and $V_2 \rightarrow V_1$) plays a much more significant role in intercity housing transaction connectedness than the price-price dynamic relationship ($P_1 \rightarrow P_2$ and $P_2 \rightarrow P_1$) or the price-volume dynamic relationship ($P_1 \rightarrow V_2$, $V_2 \rightarrow P_1$, $V_1 \rightarrow P_2$, and $P_2 \rightarrow V_1$). Specifically, 71 out of 73 city pairs in total (16 in Table 3 plus 57 in Table 4) have at least one significant Granger causality between volume and volume ($V_1 \rightarrow V_2$ or $V_2 \rightarrow V_1$) at the 5% significance level, while the comparable number of cases with significant Granger causality test results between prices in two cities (i.e., $P_1 \rightarrow P_2$ or $P_2 \rightarrow P_1$) (34 out of 73) or between prices and the volume (i.e., $P_1 \rightarrow V_2$, $V_2 \rightarrow P_1$, $V_1 \rightarrow P_2$, or $P_2 \rightarrow V_1$) (59 out of 73) is much smaller.

As mentioned above, these intercity results are also well in line with the emerging literature that emphasize the leading informational role of the volume rather than prices in the housing market (e.g., Yang et al., 2021; DeFusco et al., 2022). In addition, Piazzesi et al. (2015) demonstrate both theoretically and empirically that a typical home buyer in a housing market generally looks for a property in a search range that depends on the individual's geographical preference, budget, and family size. When she/he settles down, the property is not likely to be traded in the market again.[16] Thus, as a typical search market, there are no market equilibrium price and volume, but only transactions in search of the market price—it was a price discovery process (Leamer, 2015). The thin transaction volume makes the housing market have a volume cycle rather than a price cycle (Leamer, 2007, 2015; DeFusco et al., 2017), and thus enables a small number of momentum traders to drive housing prices up and down (Piazzesi and Schneider, 2009). DeFusco et al. (2022) present a dynamic model of price and volume in asset bubbles, which is among the first to both theoretically demonstrate and empirically confirm the lead-lag relationship between volume (taking the lead) and prices in the US housing cycles. Our results provide new evidence for such a leading informational role of the volume in China's housing market from the perspective of (daily) pairwise housing market interactions between cities.

In summary, based on the full-sample analysis, we find that despite the substantial geographical disparity in the price-volume relationship, the volume-volume dynamic relationship plays a much more significant role in intercity housing market spillovers, indicating a significant informational role of volume beyond prices on China's housing markets.

[*Insert Table 4 about here*]

4.2 Yearly Results

Table 5 reports the yearly results of Granger causality tests on intracity price-volume dynamics for each city.[17] Compared with the full sample results shown in Table 2, Table 5 reveals another interesting aspect of the price-volume dynamics: in addition to geographical disparity, the price-volume dynamic relationship is also time-varying. Among the cities with a significant price-volume dynamics in the full sample, Granger causality running either from price to volume or

[16] In the US, only about 6% of owner-occupied homes are traded per year (Piazzesi and Schneider, 2009).
[17] To ensure sufficient observations for the examination, again, at least three-month (a quarter) observations exists in a certain year for that city.

from volume to price can change dramatically over different years. Using Baotou as an example, the Granger causality running from price to volume is insignificant in 2009, 2012, and 2014 while statistically significant in 2010, 2011, and 2013. The finding is also in line with the time variation of the price-volume relationship in the Los Angeles housing market shown in Leamer (2015). Thus, our finding might provide another plausible explanation for mixed patterns observed in the previous literature (as discussed above) — the price-volume dynamics on the housing market may be time-varying rather than static. Due to differences along the time dimension (i.e., time-varying) and the cross-sectional dimension (i.e., geographical disparity), the conventionally used average results could be affected by the sample selection.

[*Insert Table 5 about here*]

Table 6 and Table 7 report the yearly results of Granger causality tests for eight intercity price-price, price-volume, and volume-volume dynamic relationships between cities located in the same province and in adjacent provinces, respectively. In addition to providing richer information on the potential evolution of the dynamic relationships, such allowance for pontentital time variations should be considered as a robustness check on the main finding based on the full sample. Again, these yearly results overall confirm the most significant role of the volume-volume relationship in pairwise intercity housing market interactions: among around 200 yearly test results for 73 city pairs (in which 16 from the same province in Table 3 and 57 from adjacent provinces Table 4), similar to the full sample results, the number or percentage of cases with significant Granger causality found in the volume-volume relationship ($V_1 \rightarrow V_2$ and $V_2 \rightarrow V_1$) is much higher than that in the price-price relationship ($P_1 \rightarrow P_2$ and $P_2 \rightarrow P_1$) or the price-volume relationship ($P_1 \rightarrow V_2$, $V_2 \rightarrow P_1$, $V_1 \rightarrow P_2$, and $P_2 \rightarrow V_1$). Nevertheless, Table 6 and Table 7 also reveal that the intercity price-volume dynamics is time-varying: all of the eight intercity relationships for a city pair can change sharply in different years (due to the limited space in Tables 6 and 7, we only report the p-values of each Granger causality test; the changes in the p-values are already sufficient to demonstrate sharp changes of these relationships under examination).

In sum, the yearly results of Granger causality tests for intercity price and volume dynamic relationships support the main findings above on the more significant role of volume compared with prices on China's housing markets, despite the allowance for the time variation.

[*Insert Table 6 about here*]

[*Insert Table 7 about here*]

5. Robustness Checks and Further Investigation

In this section, we further examine the robustness of our key finding. The first robustness check is to use the panel Granger causality test approach instead of the conventional Granger causality test applied to each city pair. The panel Granger causality test uses all the available observations in the spirit of a joint test across city pairs in our case, and thus may have higher test power (Bai, 2010). Table 8 reports the full sample and yearly results for the intracity price-volume relationship of the 32 cities. We can find significant Granger causality runs from price (volume) to volume (price) based on the full sample and most of the yearly results. When splitting the sample into residential and property samples, the results also remain almost the same. Consistent with the previous findings, Table 8 implies that although the price-volume relationship is time-varying, both price and volume may play a significant informational role in the intracity context.

Table 9 reports the panel Granger causality test results on intercity price and volume dynamic relationships. Again, the results confirm the main finding of this study that volume may play a more significant informational role than price in intercity housing market spillovers. Significant volume-volume (V1→V2 or V2→V1) relationships can be found for the full sample and yearly results. In contrast, the price-price (P1→P2 or P2→P1) relationships are not so significant in the majority of these cases. The results are similar when we further split the sample into two subsamples based on city pairs located within the same province versus those located in adjacent provinces, or the subsample of city pairs which are not all residential housing units.

To further check the robustness of the panel Granger causality test results, we also calculated the Romano-Wolf correction p-values (Romano and Wolf, 2005) for all the results shown in Tables 8 and 9. The results are also almost the same (see Table A-1 and A-2 in the appendix). Therefore, although the panel Granger causality test approach does not allow for the potential geographical disparity and different information transmission structures (e.g., different lags for different city pairs), the results confirm the main finding.

[*Insert Table 8 about here*]

[*Insert Table 9 about here*]

The second robustness check is to replace the volume with the floor space sold, allowing for the impact of potential different ratios of large versus small houses across different cities. As we focus on the key finding that volume may generally play an important informational role beyond price regardless of potential geographical disparity, for convenience, we also use the panel Granger causality test approach here. Table 10 reports the results for the intra-city price-volume relationship, while Table 11 reports the results of intercity spillovers. Both results are almost the same as those using the housing transaction units as the proxy for volume. Therefore, the main finding remains unchanged.

[*Insert Table 10 about here*]

[*Insert Table 11 about here*]

The third robustness check uses the monthly provincial-level data. As the daily housing transactions contain only 32 cities, one concern might be whether the results are representative. To answer this question, we reexamine all the eight possible price-price, price-volume, and volume-volume relationships using the monthly provincial-level housing market data which covers all the provincial jurisdictions (i.e., municipalities, provinces, or provincial-level autonomous regions) in China. We focus on the intermarket spillovers between Shanghai municipality and other provincial jurisdictions, because Shanghai has been a systematically important city with nationwide influence in the intercity housing price spillovers in China (Yang et al., 2018). Table 12 reports the results, showing a similar pattern to that found in our 32-city sample. The number of significant volume-volume (V1→V2 or V2→V1) relationships is much higher than that of the price-price or price-volume relationships. Therefore, the results from provincial data also reveal that volume plays an important informational role beyond price in intermarket housing spillovers.

[*Insert Table 12 about here*]

The fourth robustness check is about the applicability of the finding to housing submarkets within a specific city (or so-called administrative districts of a city in China). Local housing submarket spillovers have rarely been studied because of "…a lack of high-frequency, detailed information on transactions…" (Ferreira and Gyourko, 2012, p. 134). As pointed out in Yang et al. (2021), the daily housing transaction volume at the city level is quite thin and generally difficult to collect. Nevertheless, we were able to obtain daily housing transaction volume data for five major districts (or submarkets) in Shenzhen, one of the four first-tier cities in China. Thus, we reexamined all eight possible price-price, price-volume, and volume-volume housing submarket spillovers across different pairs of submarkets. Table 13 reports the results. Even though the evidence here based on only one city is of course preliminary in nature, the finding is quite similar to what we found above based on the intercity price-volume dynamics. The volume also plays an important informational role in housing submarket spillovers within a city.

[*Insert Table 13 about here*]

6. Further Analysis of Economic Determinants

We now move to examine whether the intracity price-volume relationship and intercity housing market spillovers may be explained by economic fundamentals. As discussed above, such analysis may be considered as an important robustness check (Yang and Zhou, 2013; Yang et al., 2021). Following Miller and Peng (2006), Clayton et al. (2010), and Webb et al. (2016), among others, we choose the following economic fundamental variables: GDP, GDP growth, population, population growth, GDP per capita, and the unemployment rate at the city level; the mortgage rate, the mortgage rate trend, and returns of the Shanghai Stock Exchange Composite Index at the national level.

First, we examine whether economic fundamentals may help explain the intracity price-volume dynamic relationship. We assign 1 (0) when there is a (no) significant Granger causality running from price to volume or from volume to price for a particular city-level market during a certain year (as documented in Table 5). A panel-probit model is estimated as follows :

$$\mathrm{P}(\text{Granger causality} = 1)_{it} = \alpha_0 + \beta \times F_{it} + city + year + \varepsilon_{it} \qquad (7)$$

where α_0 is the constant term; F_{it} is the vector of economic fundamental variables; $city$ is the city fixed effects; $year$ is the time-fixed effects; ε_{it} is the error term. Obviously, $\mathrm{P}(\text{Granger causality} = 1)_{it}$ has only two values (i.e., 1 or 0). We thus estimate equation (7) using panel-probit regression with robust stander errors. Table 14 reports the estimated results. Although our analysis is quite preliminary, the results reveal that city population, population growth, and the unemployment rate significantly affect whether there is Granger causality running from price to volume, while city population is the only variable significantly affecting whether there is Granger causality running from volume to price. Thus, the time variation and geographical disparity may be explained by economic fundamentals, at least to some extent.

[*Insert Table 14 about here*]

Second, based on an index of intercity housing transaction connectedness (ICHTC) at the yearly frequency, we examine whether divergence of economic fundamentals (also at the yearly frequency) affect intercity housing market spillovers (as measured by ICHTC). Following Billio et al. (2012) and using the results from Table 3 and Table 4, we calculate the ICHTC as the weighted average number of significant Granger causality tests of the eight intercity relationships.[18] Also, the divergences of economic fundamentals are calculated as the absolute value of the difference of city-specific economic fundamental variables. The panel econometric model is set up as follows:

$$\text{ICHTC}_{it} = \alpha_0 + \beta X_{it} + city + year + \varepsilon_{it} \quad (8)$$

where X_{it} is the vector of divergences of city-specific economic fundamentals. Similar to Miller and Peng (2006), feasible generalized least squares (GLS) regression with robust stander errors is applied. Note also that the analysis can serve as a further robustness check on the above main result of intercity relationships between cities located in the same province or in the adjacent provinces, as random errors introduced in the multi-step procedure or any other deficiencies possibly existing

[18] The weights are calculated from Table 3 and Table 4. The number of significant Granger causalities out of the 73 city pairs is18 for "$P_1 \rightarrow P_2$", 25 for "$P_1 \rightarrow V_2$", 25 for "$V_1 \rightarrow P_2$", 48 for "$V_1 \rightarrow V_2$", 22 for "$P_2 \rightarrow P_1$", 24 for "$P_2 \rightarrow V_1$", 22 for "$V_2 \rightarrow P_1$", and 58 for "$V_2 \rightarrow V_1$" (see Table 3 and Table 4). Take the first city pair "Anqing—Bengbu" in Table 5 in year 2009 as an example, its ICHTC at year 2009 is thus calculated as $\text{ICHTC}_{2009} = \frac{0\times18+0\times25+0\times25+0\times48+0\times22+1\times24+0\times22+1\times58}{18+25+25+48+22+24+22+58} \times 100$. We also calculate ICHTC without weight, i.e., $\text{ICHTC} = \frac{Total\ number\ of\ significant\ Granger\ caucalities\ found\ in\ the\ eight\ intercity\ correletions}{8} \times 100$, the estimation results are similar (available on request). Given the finding, it might be easier to use the ICHTC without weight in the future research.

in the research design, if substantial, should be biased toward finding no significant relationship between the index and economic fundamentals.

Table 15 reports the estimation results. Table 15 shows that the divergence of city GDP and population growth (in absolute values) are the two factors that significantly affect intercity housing transaction connectedness, although the housing market spillovers index in this study allows for the informational role of volume, which has been shown to be far more pronounced than prices during the sample period, and focuses on using the daily data on the housing market rather than the monthly data in previous studies. The result is generally consistent with earlier studies on Chinese housing markets (e.g., Han et al., 2018; Yang et al., 2018), where GDP or income growth and demographics are significant determinants of Chinese housing prices or net housing price spillovers. The result also confirms the robustness of the main finding above on intercity price-volume dynamic relationships in Tables 3 and 4, which confirms the more significant informational role of volume than price on China's housing markets during the sample period

[*Insert Table 15 about here*]

7. Conclusions

Using daily housing price and volume data from 32 Chinese cities from 2009 to 2016, this study examines housing market interactions between cities through both price and volume (i.e., pairwise intercity price-volume dynamic relationships) in Chinese housing markets. We find that the volume-volume dynamic relationship is more significant than other pairs of (i.e., price-price or price-volume) dynamic relationships in China's pairwise intercity housing market spillovers. This implies a more dominant informational role of volume than price in the context of intercity housing market spillovers. Based on a proposed pairwise housing market spillover/connectedness measure summarizing housing market information from both price and volume, further analysis shows that housing market fundamentals (such as city population and city-level GDP) are its significant determinants. Therefore, it attests to the soundness of the main finding of underscoring the more significant informational role of volume over prices in this study.

The finding is well in line with the emerging literature arguing for the leading informational role of volume over price on the US housing market (Leamer, 2007, 2015; DeFusco et al., 2022). It also lends much support to earlier studies focusing on examining the volume-volume dynamic relationship to shed light on information transmission on various asset markets (Halling et al., 2013; Roll et al., 2014; Yang et al., 2021). The non-US evidence in this study may also help ease the data-mining concern for the existing evidence for the lead-lag relationship between volume and price based on the US housing cycles alone, as shown in DeFusco et al. (2022).

Future research may be fruitful along several dimensions. It would be interesting to understand better the housing market dynamics and spillovers based on daily housing transaction price and volume data in China or other countries, as it may provide more timely information interesting to policymakers and other stakeholders (Bollerslev et al., 2016). Given the emerging evidence for a more significant informational role of volume than price in housing markets, future research should also go beyond housing price dynamics and also explore volume dynamics or the joint price and volume dynamics on the housing market (DeFusco et al., 2022).

References

Al-Yahyaee, Khamis Hamed, Walid Mensi, Hee-Un Ko, Massimiliano Caporin, Sang Hoon Kang 2021. "Is the Korean housing 'market following Gangnam style?" *Empirical Economics* 61, 2041-2072.

Badarinza, Cristian, and Tarun Ramadorai, 2018. "Home Away from Home? Foreign Demand and London House Prices. "*Journal of Financial Economics*, 130(3), 532-555.

Bai, Jushan, 2010. "Common breaks in means and variances for panel data." *Journal of Econometrics* 157, 78-92.

Bamber, Linda S., Orie Barron, and Douglas Stevens. 2011. Trading volume around earnings announcements and other financial reports: Theory, research design, empirical evidence, and directions for future research. *Contemporary Accounting Research*, 28(2): 431–471.

Bessembinder, Hendrik; Kalok Chan and Paul J. Seguin. 1996. "An Empirical Examination of Information, Differences of Opinion, and Trading Activity." *Journal of Financial Economics*, 40(1), 105-34.

Berkovec, James A. and John L. Goodman. 1996. "Turnover as a Measure of Demand for Existing Homes." *Real Estate Economics*, 24(4), 421-40.

Billio, Monica; Mila Getmansky; Andrew W. Lo and Loriana Pelizzon. 2012. "Econometric Measures of Connectedness and Systemic Risk in the Finance and Insurance Sectors." *Journal of Financial Economics*, 104(3), 535-59.

Bollerslev, Tim; Andrew J. Patton and Wenjing Wang. 2016. "Daily House Price Index: Construction Modelling and Longer-run Predictions." *Journal of Applied Econometrics*, 31, 1005-1025.

Campbell, John Y.; Stefano Giglio and Parag Pathak. 2011. "Forced Sales and House Prices." *The American Economic Review*, 101(5), 2108-31.

Case, Karl E. and Robert J. Shiller. 1989. "The Efficiency of the Market for Single-Family Homes." *American Economic Review*, 79(1), 125-38.

Chen, Shiu-Sheng. 2012. "Revisiting the Empirical Linkages between Stock Returns and Trading Volume." *Journal of Banking & Finance*, 36, 1781–1788.

Chinloy, Peter and William D Larson. 2017. "The Daily Microstructure of the Housing Market," Federal Housing Finance Agency, Working Paper No. 17-01.

Clayton, Jim; Norman Miller and Liang Peng. 2010. "Price-Volume Correlation in the Housing Market: Causality and Co-Movements." *Journal of Real Estate Finance and Economics*, 40(1), 14-40.

DeFusco, Anthony; Charles Nathanson and Eric Zwick. 2022. "Speculative Dynamics of Prices and Volume." *Journal of Financial Economics*， 146(1), 205-229.

Dröes, Martijn I. and Marc K. Francke. 2018. "What Causes the Positive Price-Turnover Correlation in European Housing Markets?" *Journal of Real Estate Finance and Economics*, 57, 618–646.

Du, Z., and L. Zhang (2015). "Home-Purchase Restriction, Property Tax and Housing Price in

China: A Counterfactual Analysis," *Journal of Econometrics*, 188, 558-568.

Fang, Hanming; Quanlin Gu; Wei Xiong and Li-An Zhou. 2016. "Demystifying the Chinese Housing Boom." *NBER Macroeconomics Annual*, 30(1), 105-66.

Ferreira, Fernando and Joseph Gyourko. 2012. "Heterogeneity in Neighborhood-Level Price Growth in the United States, 1993-2009." *American Economic Review*, 102(3), 134-40.

Genesove, David and Christopher Mayer. 2001. "Loss Aversion and Seller Behavior: Evidence from the Housing Market." *Quarterly Journal of Economics*, 116(4), 1233-60.

Gong, Yunlong; Jinxing Hu and Peter J. Boelhouwer. 2016. "Spatial Interrelations of Chinese Housing Markets: Spatial Causality, Convergence and Diffusion." *Regional Science and Urban Economics*, 59, 103-17.

Glaeser, Edward; Wei Huang; Yueran Ma and Andrei Shleifer. 2017. "A Real Estate Boom with Chinese Characteristics." *Journal of Economic Perspectives*, 31(1), 93-116.

Granger, Clive WJ. 1969. "Investigating Causal Relations by Econometric Models and Cross-Spectral Methods." *Econometrica*, 37, 424-38.

Han, Bing; Han, Lu, and Guozhong Zhu, 2018. "Housing price and fundamentals in a transition economy: The case of the Beijing market." *International Economic Review*, 59(3), 1653-1677.

Halling, M., P. Moulton, and M. Panayides. 2013. "Volume Dynamics and Multimarket Trading." *Journal of Financial and Quantitative Analysis*, 48, 489–518.

Hsiao, Cheng. 1981. "Autoregressive Modelling and Money-Income Causality Detection." *Journal of Monetary Economics*, 7(1), 85-106.

Hurn, Stan, Shuping Shi, and Ben Wang, 2022. "Housing networks and driving forces. " *Journal of Banking and Finance* 134, Article 106318.

Karpoff, Jonathan M. 1987. "The Relation between Price Changes and Trading Volume: A Survey." *Journal of Financial and Quantitative Analysis*, 22(1), 109-26.

Keating, John, W., 2000. "Macroeconomic modeling with asymmetric vector autoregressions", *Journal of Macroeconomics* 22 (1), 1-28.

IMF, 2011. Global Economic Prospects and Policy Challenges.

Leamer, Edward E. 2007. "Housing Is the Business Cycle." NBER Working Paper, No. 13428.

Leamer, Edward E. 2015. "Housing Really Is the Business Cycle: What Survives the Lessons of 2008–09?" *Journal of Money, Credit and Banking*, 47(S1), 43-50.

Leung, Charles K. Y. , Lau Garion, and Leong Youngman, 2002, Testing alternative theories of the property price-trading volume correlation, *Journal of Real Estate Research* 23, 253-264.

Leung, C.K.Y. and Feng, D. (2005). What Drives the Property Price-Trading Volume Correlation? Evidence from a Commercial Real Estate Market. *Journal of Real Estate Finance and Economics* 31, 241-255.

Leung, C.K.Y., Leong, Y.C.F. and Wong, S.K. (2006). Housing Price Dispersion: An Empirical Investigation. *Journal of Real Estate Finance and Economics* 32, 357-385.

Lo, Andrew W and Jiang Wang. 2000. "Trading Volume: Definitions, Data Analysis, and

Implications of Portfolio Theory." *Review of Financial Studies*, 13(2), 257-300.

Miller, Norman and Liang Peng. 2006. "Exploring Metropolitan Housing Price Volatility." *Journal of Real Estate Finance and Economics*, 33(1), 5-18.

Newey, Whitney K. and Kenneth D. West. 1987. "Hypothesis Testing with Efficient Method of Moments Estimation." *International Economic Review*, 777-87.

Piazzesi, Monika and Martin Schneider. 2009. "Momentum Traders in the Housing Market: Survey Evidence and a Search Model." *American Economic Review*, 99(2), 406-11.

Piazzesi, Monika; Martin Schneider and Johannes Stroebel. 2015. "Segmented Housing Search." NBER Working Paper, No. 20823.

Roll, R.; E. Schwartz and A. Subrahmanyam. 2014. "Trading Activity in the Equity Market and Its Contingent Claims: An Empirical Investigation." *Journal of Empirical Finance*, 28, 13-35.

Romano, Joseph P., and Michael Wolf, 2005, Stepwise multiple testing as formalized data snooping, *Econometrica* 73, 1237-1282.

Shi, S., Young, M. and Hargreaves, B. (2010). House Price-Volume Dynamics: Evidence from 12 Cities in New Zealand. *Journal of Real Estate Research* 32, 75-100.

Stein, Jeremy C. 1995. "Prices and Trading Volume in the Housing Market: A Model with Down-Payment Effects." *Quarterly Journal of Economics*, 110(2), 379-407.

Su, EnDer. 2021. Testing stock market contagion properties between large and small stock markets. *Review of Quantitative Finance & Accounting* 57, 147–202.

Wang, Jinghua, and Geoffrey Ngene, 2018. Symmetric and asymmetric nonlinear causalities between oil prices and the U.S. economic sectors. *Review of Quantitative Finance & Accounting* 51, 199–218.

Webb, Robert I, Jian Yang, and Jin Zhang, 2016, Price jump risk in the us housing market, *The Journal of Real Estate Finance and Economics* 53, 29-49.

Wheaton, William C. 1990. "Vacancy, Search, and Prices in a Housing Market Matching Model." *Journal of Political Economy*, 98(6), 1270-93.

Xu, Zhan, Qingbin Meng, and Song Wang, forthcoming. The effect of housing boom on firm leverage evidence from China. *Review of Quantitative Finance & Accounting*.

Yang, Jian; Meng Tong and Ziliang Yu. 2021. "Housing Market Spillovers through the Lens of Transaction Volume: A New Spillover Index Approach." *Journal of Empirical Finance*, 64, 351-78.

Yang, Jian; Ziliang Yu and Yongheng Deng. 2018. "Housing Price Spillovers in China: A High-Dimensional Generalized VAR Approach." *Regional Science and Urban Economics*, 68, 98-114.

Yang, Jian, and Yinggang Zhou. 2013. "Credit Risk Spillovers among Financial Institutions around the Global Credit Crisis: Firm-Level Evidence." *Management Science*, 59(10), 2343-59.

Zhang, Qingjing, Taufiq Choudhry, Jing-Ming Kuo and Xiaoquan Liu. 2021. Does liquidity drive stock market returns? The role of investor risk aversion. *Review of Quantitative Finance & Accounting* 57, 929-958.

Zhu, Bing; Roland Füss and Nico B. Rottke. 2013. "Spatial Linkages in Returns and Volatilities among U.S. Regional Housing Markets." *Real Estate Economics*, 41(1), 29-64.

Table 1: Data description

City	Province	Tier	Administrative Level	Region	Sample period	V	P	Observations
Anqing	Anhui	3	D	Central area	2009/01/31~2011/09/29	R	R	972
Baotou	Inner Mongolia	3	D	Western area	2009/01/31~2014/06/11	R	R	1958
Bengbu	Anhui	3	D	Central area	2009/09/05~2010/05/27	R	R	265
Changsha	Hunan	2	C	Central area	2009/04/01~2011/04/08	R	R	738
Chengde	Hebei	3	D	Eastern area	2011/09/07~2016/06/30	R	R	1759
Chongqing	Chongqing	2	A	Western area	2009/01/31~2011/05/18	R	R	838
Dandong	Liaoning	3	D	Northeastern area	2011/11/12~2015/03/04	R	R	1209
Dongguan	Guangdong	3	D	Eastern area	2011/03/03~2016/06/30	R	R	1947
Foshan	Guangdong	3	D	Eastern area	2014/02/04~2016/06/29	R	R	877
Fuzhou	Fujian	3	C	Eastern area	2009/01/31~2009/12/31	Pr	Pr	335
Haikou	Hainan	2	C	Eastern area	2010/06/18~2015/02/04	R	R	1693
Hangzhou	Zhejiang	2	B	Eastern area	2009/01/31~2011/05/01	Pr	Pr	821
Hefei	Anhui	2	C	Central area	2009/01/31~2009/12/16	Pr	Pr	320
Jiujiang	Jiangxi	3	D	Central area	2011/12/02~2016/06/30	R	R	1673
Kunming	Yunnan	2	C	Western area	2010/12/01~2011/08/17	Pr	Pr	260
Lanzhou	Gansu	2	C	Western area	2011/09/03~2014/03/20	Pr	Pr	930
Mudanjiang	Heilongjiang	3	D	Northeastern area	2009/12/11~2016/06/30	R	R	2394
Ningbo	Zhejiang	2	B	Eastern area	2015/04/08~2016/06/30	R	R	450
Sanya	Hainan	2	D	Eastern area	2013/07/31~2015/11/06	R	R	829
Shaoguan	Guangdong	3	D	Eastern area	2009/01/31~2016/06/30	R	R	2708
Shenzhen	Guangdong	1	B	Eastern area	2009/01/31~2016/06/30	R	R	2708
Suzhou	Jiangsu	2	D	Eastern area	2010/06/22~2011/07/18	R	R	392
Tangshan	Hebei	3	D	Eastern area	2011/04/01~2012/10/31	Pr	Pr	580
Tianjin	Tianjin	2	A	Eastern area	2009/02/03~2016/06/30	R	R	2705
Wuhan	Hubei	2	B	Central area	2009/01/31~2011/01/29	Pr	Pr	729
Wuxi	Jiangsu	2	D	Eastern area	2009/09/19~2013/09/24	R	R	1559
Xiamen	Fujian	2	B	Eastern area	2009/01/31~2010/10/29	Pr	Pr	637
Xiangyang	Hubei	3	D	Central area	2011/11/11~2016/06/30	R	R	1694
Yangzhou	Jiangsu	3	D	Eastern area	2009/01/31~2010/06/30	Pr	Pr	516
Yichang	Hubei	3	D	Central area	2013/09/20~2016/06/30	R	R	1015
Yinchuan	Ningxia	2	C	Western area	2009/02/03~2011/03/02	Pr	Pr	758
Yueyang	Hunan	3	D	Central area	2009/03/04~2011/08/23	R	R	903

Notes: Thirty-two city-level Chinese housing markets are included in the sample based on data availability. The city tier is classified according to Fang et al. (2016); the regional group is classified according to Yang et al. (2018). A, B, C, and D of the administrative level denote provincial-level municipalities, vice provincial-level cities, (prefectural level) provincial capital cities, and prefectural cities, respectively. V (P) denotes housing transaction volume (price) with R for residential and Pr for property which includes both residential and commercial real estate in China.

Table 2: Granger causality tests of intracity price-volume dynamics, full sample

	Granger Causality: P→V		Granger Causality: P←V	
City	χ^2	P-value	χ^2	P-value
Anqing	1.159	0.282	0.819	0.366
Baotou	4.591	0.032**	4.886	0.027**
Bengbu	0.466	0.495	1.202	0.273
Changsha	9.240	0.002***	0.462	0.497
Chengde	5.810	0.016**	0.259	0.611
Chongqing	0.104	0.747	0.172	0.678
Dandong	0.320	0.572	0.051	0.822
Dongguan	10.576	0.001***	14.002	0.051
Foshan	5.313	0.021**	4.184	0.041**
Fuzhou	2.654	0.103	15.098	0.020**
Haikou	0.625	0.429	6.735	0.009***
Hangzhou	0.060	0.807	0.114	0.735
Hefei	2.103	0.147	19.719	0.003***
Jiujiang	1.410	0.235	0.422	0.516
Kunming	17.637	0.007***	3.983	0.046**
Lanzhou	1.745	0.186	0.177	0.674
Mudanjiang	0.243	0.622	43.156	0.000***
Ningbo	5.435	0.020**	2.851	0.091
Sanya	0.069	0.793	0.692	0.406
Shaoguan	12.014	0.002***	7.161	0.028**
Shenzhen	15.891	0.000***	2.280	0.131
Suzhou	25.354	0.001***	7.521	0.006***
Tangshan	10.945	0.052	5.016	0.025**
Tianjin	7.294	0.007***	20.091	0.000***
Wuhan	9.392	0.002***	9.527	0.002***
Wuxi	0.631	0.427	0.102	0.750
Xiamen	0.029	0.865	13.843	0.001***
Xiangyang	0.516	0.473	1.327	0.249
Yangzhou	1.464	0.226	0.001	0.970
Yichang	0.384	0.535	2.496	0.114
Yinchuan	1.841	0.175	18.290	0.006***
Yueyang	0.195	0.659	0.003	0.954

Notes: P→V denotes Granger causality running from price to volume, and vice versa. *** and **denote that rejecting the hypothesis of no Granger causality at 1% and 5% significance level, respectively.

Table 3: Granger causality tests for intercity dynamics of price-price, price-volume, and volume-volume between cities located in the same province, full sample

	$P_1 \rightarrow P_2$		$P_1 \rightarrow V_2$		$V_1 \rightarrow P_2$		$V_1 \rightarrow V_2$		$P_2 \rightarrow P_1$		$P_2 \rightarrow V_1$		$V_2 \rightarrow P_1$		$V_2 \rightarrow V_1$	
Pairwise cities	χ^2	P-value	χ^2	P-value	χ^2	P-value	χ^2	P-value	χ^2	P-value	χ^2	P-value	χ^2	P-value	χ^2	P-value
Anqing—Bengbu	0.767	0.381	0.865	0.352	0.522	0.470	18.143	0.003***	9.676	0.008***	16.862	0.264	0.013	0.909	93.532	0.000***
Anqing—Hefei	4.724	0.193	32.838	0.003***	13.759	0.003***	18.983	0.166	0.074	0.785	45.980	0.000***	19.273	0.004***	70.598	0.000***
Bengbu—Hefei	3.001	0.083	2.711	0.100	0.359	0.549	247.968	0.000***	0.021	0.884	47.747	0.000***	0.737	0.391	64.836	0.000***
Fuzhou—Xiamen	0.816	0.366	31.603	0.003***	0.709	0.400	69.403	0.000***	12.773	0.047**	1.424	0.233	7.572	0.271	77.336	0.000***
Dongguan—Foshan	0.035	0.852	37.485	0.000***	0.315	0.575	9.759	0.008***	3.418	0.065	13.432	0.020**	6.159	0.013**	43.597	0.000***
Dongguan—Shaoguan	5.055	0.025**	0.800	0.371	0.046	0.830	53.796	0.000***	29.249	0.000***	0.332	0.565	5.584	0.061	7.473	0.006***
Dongguan—Shenzhen	1.840	0.175	45.850	0.000***	12.879	0.000***	81.940	0.000***	4.152	0.042**	9.391	0.009***	31.450	0.000***	36.068	0.000***
Foshan—Shaoguan	0.701	0.402	6.235	0.284	0.023	0.880	15.049	0.020**	0.205	0.651	0.263	0.608	3.567	0.059	0.560	0.454
Foshan—Shenzhen	2.591	0.107	38.835	0.000***	17.321	0.000***	103.061	0.000***	2.602	0.107	0.664	0.415	0.710	0.400	53.532	0.000***
Shaoguan—Shenzhen	1.356	0.244	0.270	0.603	3.706	0.054	2.408	0.121	0.006	0.938	3.380	0.066	0.012	0.914	21.000	0.000***
Haikou—Sanya	0.158	0.691	0.543	0.461	0.323	0.570	2.618	0.107	0.359	0.549	33.226	0.003***	1.203	0.273	79.060	0.000***
Chengde—Tangshan	7.219	0.027**	0.039	0.843	2.694	0.101	14.940	0.002***	61.317	0.000***	11.222	0.011**	1.223	0.269	0.502	0.479
Xiangyang—Yichang	0.872	0.350	0.111	0.739	0.584	0.445	1.243	0.265	3.245	0.072	7.362	0.061	0.333	0.564	18.342	0.000***
Changsha—Yueyang	3.475	0.324	3.061	0.080	5.914	0.015**	11.858	0.001***	0.102	0.750	0.140	0.708	0.066	0.798	0.246	0.620
Suzhou—Wuxi	2.020	0.155	36.767	0.000***	0.179	0.673	30.772	0.001***	7.278	0.007***	0.050	0.822	1.038	0.308	29.105	0.000***
Wuxi—Yangzhou	4.982	0.083	74.444	0.000***	0.432	0.511	18.483	0.000***	3.679	0.055	0.718	0.397	0.784	0.376	11.779	0.001***

Notes: $P_1 \rightarrow P_2$ ($V_1 \rightarrow V_2$) denotes the Granger causality test of house price (volume) from city 1 to city 2, resembling the others. *** and **denote that rejecting the hypothesis of no Granger causality at 1% and 5% significance level, respectively.

Table 4: Granger causality tests for intercity dynamics of price-price, price-volume, and volume-volume between cities located in adjacent provinces, full sample

	$P_1 \rightarrow P_2$	$P_1 \rightarrow V_2$	$V_1 \rightarrow P_2$	$V_1 \rightarrow V_2$	$P_2 \rightarrow P_1$	$P_2 \rightarrow V_1$	$V_2 \rightarrow P_1$	$V_2 \rightarrow V_1$
Panel A: Between the provinces of **Anhui** and **Hubei**								
Anqing-Wuhan	2.250	1.274	0.002	0.597	2.630	2.652	1.854	45.111***
	[0.134]	[0.259]	[0.966]	[0.440]	[0.105]	[0.103]	[0.173]	[0.000]
Bengbu-Wuhan	2.775	5.455	48.827***	8.193**	1.268	0.026	0.867	61.546***
	[0.428]	[0.244]	[0.000]	[0.042]	[0.260]	[0.871]	[0.352]	[0.000]
Hefei-Wuhan	4.348	0.832	3.651	73.240***	2.357	18.991	20.485***	174.271***
	[0.114]	[0.362]	[0.056]	[0.000]	[0.502]	[0.165]	[0.002]	[0.000]
Panel B: Between the provinces of **Anhui** and **Jiangsu**								
Anqing-Suzhou	2.834	0.074	1.225	1.010	5.353	28.550**	0.905	24.173**
	[0.092]	[0.785]	[0.268]	[0.315]	[0.069]	[0.012]	[0.342]	[0.019]
Anqing-Wuxi	0.541	0.072	0.501	0.470	3.978**	5.594	0.001	21.367**
	[0.462]	[0.788]	[0.479]	[0.493]	[0.046]	[0.133]	[0.976]	[0.011]
Anqing-Yangzhou	0.826	6.252**	1.591	8.997**	0.169	0.231	0.277	63.073***
	[0.363]	[0.012]	[0.207]	[0.011]	[0.681]	[0.631]	[0.599]	[0.000]
Bengbu-Wuxi	18.366***	0.406	44.235***	28.362***	20.206***	0.001	0.477	26.501***
	[0.003]	[0.524]	[0.000]	[0.000]	[0.000]	[0.972]	[0.490]	[0.000]
Bengbu-Yangzhou	11.428***	53.319***	8.915***	126.038***	0.236	0.243	0.008	134.213***
	[0.003]	[0.000]	[0.003]	[0.000]	[0.627]	[0.622]	[0.927]	[0.000]
Hefei-Wuxi	0.720	0.015	1.787	3.812	0.015	57.571***	33.320***	88.124***
	[0.396]	[0.902]	[0.182]	[0.051]	[0.902]	[0.000]	[0.000]	[0.000]
Hefei-Yangzhou	18.083***	32.421***	1.030	61.679***	4.266	29.751***	23.288***	67.078***
	[0.006]	[0.001]	[0.310]	[0.000]	[0.234]	[0.008]	[0.001]	[0.000]
Panel C: Between the provinces of **Anhui** and **Zhejiang**								
Anqing-Hangzhou	3.504	0.016	0.141	7.478***	3.832	0.756	0.583	0.051
	[0.061]	[0.900]	[0.708]	[0.006]	[0.050]	[0.385]	[0.445]	[0.822]
Bengbu-Hangzhou	5.206**	48.800***	5.018**	89.416***	7.631**	10.500***	1.081	19.447***
	[0.023]	[0.000]	[0.025]	[0.000]	[0.022]	[0.001]	[0.298]	[0.000]
Hefei-Hangzhou	11.170**	3.177	23.635***	107.853***	3.694	15.904	4.464	50.370***
	[0.025]	[0.075]	[0.001]	[0.000]	[0.296]	[0.319]	[0.216]	[0.000]
Panel D: Between the provinces of **Chongqing** and **Hubei**								
Chongqing-Wuhan	3.802	7.888***	6.559**	0.792	18.716***	5.117**	15.434**	70.770***
	[0.051]	[0.005]	[0.038]	[0.374]	[0.005]	[0.024]	[0.017]	[0.000]
Panel E: Between the provinces of **Chongqing** and **Hunan**								
Chongqing-Changsha	0.213	0.803	0.217	0.555	9.800**	6.343**	0.044	13.112***
	[0.644]	[0.370]	[0.641]	[0.456]	[0.044]	[0.012]	[0.834]	[0.004]
Chongqing-Yueyang	11.474***	0.004	0.575	0.216	36.601***	19.197***	4.165	67.251***
	[0.001]	[0.949]	[0.448]	[0.642]	[0.000]	[0.002]	[0.384]	[0.000]
Panel F: Between the provinces of **Fujian** and **Zhejiang**								
Fuzhou-Hangzhou	17.981***	0.461	11.561**	83.517***	23.272***	5.617**	1.012	56.753***
	[0.003]	[0.497]	[0.021]	[0.000]	[0.002]	[0.018]	[0.315]	[0.000]
Xiamen-Hangzhou	2.877	0.845	0.492	3.212	14.241***	1.776	12.049***	41.299***
	[0.090]	[0.358]	[0.483]	[0.073]	[0.001]	[0.183]	[0.007]	[0.000]
Panel G: Between the provinces of **Fujian** and **Guangdong**								
Fuzhou-Shaoguan	36.984***	0.206	31.917***	47.313***	10.334	0.094	7.116	141.030***
	[0.000]	[0.650]	[0.001]	[0.000]	[0.111]	[0.759]	[0.310]	[0.000]
Fuzhou-Shenzhen	1.948	0.321	2.104	1.366	33.958***	82.057***	9.413	42.768***
	[0.163]	[0.571]	[0.147]	[0.243]	[0.000]	[0.000]	[0.152]	[0.000]
Xiamen-Shaoguan	0.074	0.423	53.877***	2.104	2.693	8.352***	0.252	63.025***
	[0.785]	[0.515]	[0.000]	[0.147]	[0.101]	[0.004]	[0.616]	[0.000]
Xiamen-Shenzhen	1.934	0.011	2.290	3.940**	12.020***	40.706***	0.000	88.555***
	[0.164]	[0.915]	[0.130]	[0.047]	[0.002]	[0.000]	[0.995]	[0.000]
Panel H: Between the provinces of **Gansu** and **Inner Mongolia**								
Lanzhou-Baotou	1.678	2.060	7.294***	5.053**	3.738	0.058	0.762	3.077
	[0.195]	[0.151]	[0.007]	[0.025]	[0.053]	[0.810]	[0.383]	[0.079]
Panel I: Between the provinces of **Guangdong** and **Hainan**								
Dongguan-Haikou	1.680	12.093**	4.474	92.032***	5.991**	0.218	1.418	46.469***
	[0.432]	[0.017]	[0.107]	[0.000]	[0.014]	[0.640]	[0.234]	[0.000]
Dongguan-Sanya	11.061***	10.873***	2.885	3.247	1.369	0.215	0.418	0.002
	[0.001]	[0.001]	[0.089]	[0.072]	[0.242]	[0.643]	[0.518]	[0.962]
Foshan-Haikou	0.048	41.753***	6.020**	51.821***	2.993	0.002	1.061	0.179
	[0.827]	[0.000]	[0.014]	[0.000]	[0.084]	[0.968]	[0.303]	[0.672]

Foshan-Sanya	7.065***	6.111	0.264	1.753	0.038	0.746	0.913	20.270***
	[0.008]	[0.106]	[0.608]	[0.186]	[0.846]	[0.388]	[0.339]	[0.000]
Shaoguan-Haikou	1.315	0.430	9.417***	0.042	4.137	1.115	0.491	54.020***
	[0.251]	[0.512]	[0.002]	[0.838]	[0.126]	[0.291]	[0.484]	[0.000]
Shaoguan-Sanya	7.216***	0.633	7.028***	2.524	0.423	0.002	0.374	11.934***
	[0.007]	[0.426]	[0.008]	[0.112]	[0.516]	[0.968]	[0.541]	[0.003]
Shenzhen-Haikou	0.694	5.774**	0.146	4.343**	0.955	0.810	33.543***	72.833***
	[0.405]	[0.016]	[0.703]	[0.037]	[0.328]	[0.368]	[0.000]	[0.000]
Shenzhen-Sanya	0.721	22.561***	0.204	8.774***	17.992***	1.006	8.759**	35.203***
	[0.396]	[0.000]	[0.652]	[0.003]	[0.001]	[0.316]	[0.013]	[0.000]
Panel J: Between the provinces of **Guangdong** and **Hunan**								
Dongguan-Yueyang	33.666***	25.371**	0.614	35.154***	0.204	0.361	5.589**	0.002
	[0.000]	[0.031]	[0.433]	[0.000]	[0.652]	[0.548]	[0.018]	[0.963]
Shaoguan-Changsha	1.099	1.863	1.290	1.701	0.922	9.079	8.854***	27.514***
	[0.294]	[0.172]	[0.256]	[0.192]	[0.337]	[0.059]	[0.003]	[0.001]
Shaoguan-Yueyang	2.823	7.286***	0.001	73.202***	0.376	1.568	0.509	96.583***
	[0.093]	[0.007]	[0.973]	[0.000]	[0.540]	[0.210]	[0.475]	[0.000]
Shenzhen-Changsha	1.123	8.666***	0.876	7.163***	0.583	14.321***	0.027	8.471***
	[0.289]	[0.003]	[0.349]	[0.007]	[0.445]	[0.001]	[0.870]	[0.004]
Shenzhen-Yueyang	0.082	6.662***	1.323	0.616	5.270	1.026	55.637***	7.348**
	[0.775]	[0.010]	[0.250]	[0.433]	[0.072]	[0.311]	[0.000]	[0.025]
Panel K: Between the provinces of **Guangdong** and **Jiangxi**								
Dongguan-Jiujiang	1.863	3.436	11.601***	51.866***	0.037	9.897***	10.787***	112.748***
	[0.172]	[0.064]	[0.001]	[0.000]	[0.848]	[0.002]	[0.005]	[0.000]
Foshan-Jiujiang	9.807***	25.632***	0.009	98.688***	1.695	1.105	11.885***	75.514***
	[0.002]	[0.002]	[0.926]	[0.000]	[0.193]	[0.293]	[0.003]	[0.000]
Shaoguan-Jiujiang	0.042	4.875**	0.434	4.632**	0.778	6.310**	3.395	42.062***
	[0.838]	[0.027]	[0.510]	[0.031]	[0.378]	[0.012]	[0.065]	[0.000]
Shenzhen-Jiujiang	3.298	0.218	9.307***	68.699***	1.322	31.769***	6.747**	103.058***
	[0.069]	[0.640]	[0.002]	[0.000]	[0.516]	[0.000]	[0.034]	[0.000]
Panel L: Between the provinces of **Hebei** and **Inner Mongolia**								
Chengde-Baotou	1.042	0.040	0.914	4.278**	2.164	0.220	0.669	0.061
	[0.307]	[0.841]	[0.339]	[0.039]	[0.141]	[0.639]	[0.413]	[0.805]
Tangshan-Baotou	1.253	0.042	7.713	27.007**	0.205	25.838***	1.114	1.104
	[0.740]	[0.838]	[0.052]	[0.012]	[0.650]	[0.000(+)]	[0.291]	[0.293]
Panel M: Between the provinces of **Hebei** and **Liaoning**								
Chengde-Dandong	3.648	2.199	7.909***	5.407	1.879	1.987	0.680	16.565**
	[0.056]	[0.138]	[0.005]	[0.067]	[0.598]	[0.575]	[0.878]	[0.035]
Tangshan-Dandong	0.030	2.925	0.024	4.892**	0.739	17.341	0.334	15.875***
	[0.863]	[0.087]	[0.876]	[0.027]	[0.390]	[0.238]	[0.563]	[0.001]
Panel N: Between the provinces of **Hebei** and **Tianjin**								
Chengde-Tianjin	3.000	0.103	6.153**	0.844	3.028	2.440	0.285	2.143
	[0.083]	[0.748]	[0.013]	[0.358]	[0.082]	[0.118]	[0.594]	[0.143]
Tangshan-Tianjin	24.978***	21.188***	11.378	7.934**	0.656	1.883	1.189	3.669
	[0.000]	[0.000]	[0.077]	[0.047]	[0.418]	[0.170]	[0.276]	[0.160]
Panel O: Between the provinces of **Heilongjiang** and **Inner Mongolia**								
Mudanjiang-Baotou	1.589	1.141	0.005	28.834***	1.216	4.620**	2.553	58.306***
	[0.207]	[0.285]	[0.942]	[0.000]	[0.270]	[0.032]	[0.110]	[0.000]
Panel P: Between the provinces of **Hubei** and **Hunan**								
Wuhan-Changsha	1.049	0.010	0.550	5.230**	9.835***	0.520	2.941	5.011**
	[0.306]	[0.919]	[0.458]	[0.022]	[0.002]	[0.471]	[0.086]	[0.025]
Wuhan-Yueyang	5.865**	0.060	0.294	0.347	0.011	0.131	8.260***	4.195**
	[0.015]	[0.807]	[0.588]	[0.556]	[0.918]	[0.717]	[0.004]	[0.041]
Panel Q: Between the provinces of **Hubei** and **Jiangxi**								
Xiangyang-Jiujiang	0.621	2.507	9.599***	12.982***	7.321**	3.670	0.328	161.323***
	[0.431]	[0.113]	[0.008]	[0.000]	[0.025]	[0.055]	[0.567]	[0.000]
Yichang-Jiujiang	0.812	0.269	0.562	7.469**	3.846**	1.048	5.619**	2.281
	[0.367]	[0.604]	[0.453]	[0.024]	[0.050]	[0.306]	[0.018]	[0.131]
Panel R: Between the provinces of **Inner Mongolia** and **Liaoning**								
Baotou-Dandong	0.979	0.389	6.889**	0.020	0.049	32.813***	0.215	19.838***
	[0.322]	[0.533]	[0.032]	[0.888]	[0.826]	[0.003]	[0.643]	[0.006]
Panel S: Between the provinces of **Inner Mongolia** and **Ningxia**								
Baotou-Yinchuan	5.657**	1.518	0.444	0.226	0.001	0.845	50.069***	31.371***
	[0.017]	[0.218]	[0.505]	[0.634]	[0.976]	[0.358]	[0.000]	[0.000]
Panel T: Between the provinces of **Jiangsu** and **Zhejiang**								

Suzhou-Hangzhou	1.274	0.606	6.273**	10.350**	5.818	1.986	1.376	0.324
	[0.259]	[0.436]	[0.012]	[0.016]	[0.055]	[0.159]	[0.241]	[0.569]
Wuxi-Hangzhou	0.149	1.052	1.147	76.171***	3.682	0.859	3.967**	8.550***
	[0.700]	[0.305]	[0.284]	[0.000]	[0.055]	[0.354]	[0.047]	[0.003]
Yangzhou-Hangzhou	0.300	0.183	0.636	4.946**	24.852***	0.017	21.583***	57.434***
	[0.584]	[0.668]	[0.425]	[0.026]	[0.001]	[0.896]	[0.001]	[0.000]
Panel U: Between the provinces of **Jiangxi** and **Zhejiang**								
Jiujiang-Ningbo	2.330	14.271***	4.784**	12.064***	2.814	7.609	11.925***	0.410
	[0.127]	[0.000]	[0.029]	[0.001]	[0.093]	[0.179]	[0.001]	[0.522]

Notes: $P_1 \rightarrow P_2$ ($V_1 \rightarrow V_2$) denotes the Granger causality test of house price (volume) running from city 1 to city 2, resembling the others. *** and **denote that rejecting the hypothesis of no Granger causality at 1% and 5% significance level, respectively. p-values are in the brackets.

Table 5: Granger causality tests of intracity price-volume dynamics, P-values, each year

	Direction: Price→Volume								Direction: Volume→Price							
city	2009	2010	2011	2012	2013	2014	2015	2016	2009	2010	2011	2012	2013	2014	2015	2016
Anqing	0.303	0.129	0.485						0.830	0.626	0.439					
Baotou	0.227	0.016**	0.037**	0.417	0.038**	0.334			0.889	0.260	0.295	0.002***	0.702	0.051		
Bengbu	0.002***	0.589							0.281	0.069						
Changsha	0.032**	0.161	0.001***						0.629	0.584	0.975					
Chengde			0.007***	0.240	0.143	0.245	0.019**	0.019**			0.572	0.486	0.060	0.139	0.021**	0.151
Chongqing	0.156	0.581	0.115						0.087	0.248	0.964					
Dandong				0.108	0.967	0.418						0.779	0.913	0.835		
Dongguan			0.848	0.001***	0.734	0.002***	0.005***	0.142			0.087	0.002***	0.001***	0.052	0.020**	0.001***
Foshan						0.055	0.480	0.509						0.381	0.015**	0.468
Fuzhou	0.103								0.020**							
Haikou		0.924	0.563	0.171	0.172	0.804				0.039**	0.585	0.322	0.154	0.018**		
Hangzhou	0.440	0.986	0.187						0.002***	0.059	0.333					
Hefei	0.147								0.003***							
Jiujiang				0.419	0.001***	0.035**	0.857	0.322				0.254	0.606	0.002***	0.232	0.625
Kunming			0.001***								0.074					
Lanzhou			0.132	0.295	0.009***						0.567	0.760	0.355			
Mudanjiang		0.069	0.018**	0.072	0.034**	0.746	0.604	0.686		0.001***	0.214	0.019**	0.188	0.130	0.154	0.111
Ningbo							0.194	0.112							0.184	0.233
Sanya					0.157	0.373	0.219						0.309	0.676	0.090	
Shaoguan	0.224	0.115	0.003***	0.760	0.265	0.002***	0.907	0.196	0.001***	0.001***	0.023**	0.319	0.880	0.558	0.329	0.005***
Shenzhen	0.002***	0.003***	0.094	0.005***	0.007***	0.008***	0.638	0.651	0.032**	0.138	0.027**	0.014**	0.978	0.218	0.638	0.868
Suzhou		0.000***	0.038**							0.028**	0.355					
Tangshan			0.000***	0.018**							0.610	0.006***				
Tianjin	0.192	0.138	0.033**	0.235	0.001***	0.001***	0.000***	0.000***	0.070	0.341	0.001***	0.363	0.059	0.000***	0.000***	0.081
Wuhan	0.978	0.000***							0.007***	0.014**						
Wuxi	0.925	0.455	0.440	0.134	0.020**				0.420	0.003***	0.034**	0.000***	0.180			
Xiamen	0.197	0.490							0.007***	0.016**						
Xiangyang				0.925	0.058	0.948	0.333	0.649				0.271	0.433	0.054	0.357	0.125
Yangzhou	0.506	0.089							0.940	0.274						
Yichang					0.433	0.958	0.102	0.453					0.709	0.568	0.681	0.014**
Yinchuan	0.028**	0.520							0.010***	0.090						
Yueyang	0.015**	0.437	0.100						0.030**	0.250	0.358					

Notes: This table reports the p-value of Granger causality tests running from price to volume and from volume to price each year. *** and **denote that rejecting the hypothesis of no Granger causality at 1% and 5% significance level, respectively.

Table 6: Granger causality tests for intercity dynamics of price-price, price-volume, and volume-volume between cities located in the same province, P-values, each year

	Year	$P_1 \rightarrow P_2$	$P_1 \rightarrow V_2$	$V_1 \rightarrow P_2$	$V_1 \rightarrow V_2$	$P_2 \rightarrow P_1$	$P_2 \rightarrow V_1$	$V_2 \rightarrow P_1$	$V_2 \rightarrow V_1$
Anqing-Bengbu	2009	0.278	0.756	0.594	0.873	0.481	0.000***	0.491	0.000**
	2010	0.612	0.418	0.553	0.000***	0.004***	0.098	0.538	0.000***
Anqing-Hefei	2009	0.193	0.003***	0.003***	0.166	0.785	0.000***	0.003***	0.000**
Bengbu-Hefei	2009	0.083	0.100	0.549	0.000***	0.884	0.000***	0.391	0.000***
Fuzhou--Xiamen	2009	0.366	0.003***	0.400	0.000***	0.047	0.233	0.271	0.000***
Dongguan--Foshan	2014	0.580	0.081	0.903	0.012**	0.661	0.084	0.032**	0.000***
	2015	0.740	0.000***	0.099	0.131	0.094	0.181	0.519	0.002***
	2016	0.128	0.001***	0.350	0.045**	0.583	0.705	0.009***	0.003***
Dongguan--Shaoguan	2011	0.812	0.026**	0.059	0.000***	0.883	0.218	0.417	0.604
	2012	0.068	0.089	0.353	0.074	0.000***	0.157	0.021**	0.000***
	2013	0.088	0.900	0.040**	0.000***	0.146	0.275	0.033**	0.001***
	2014	0.033**	0.807	0.001***	0.000***	0.209	0.392	0.710	0.090
	2015	0.006***	0.088	0.395	0.001***	0.105	0.507	0.108	0.214
	2016	0.619	0.162	0.159	0.003***	0.413	0.242	0.003***	0.099
Dongguan--Shenzhen	2011	0.104	0.000***	0.026**	0.005***	0.052	0.000***	0.179	0.369
	2012	0.531	0.002***	0.292	0.009***	0.006***	0.258	0.002***	0.000***
	2013	0.418	0.060	0.050	0.000***	0.001***	0.051	0.000***	0.218
	2014	0.013**	0.770	0.031**	0.000***	0.003***	0.173	0.000***	0.000***
	2015	0.004***	0.000***	0.349	0.000***	0.346	0.703	0.130	0.001***
	2016	0.593	0.000***	0.257	0.000***	0.622	0.798	0.016**	0.035**
Foshan--Shaoguan	2014	0.401	0.124	0.892	0.062	0.998	0.442	0.001***	0.250
	2015	0.898	0.002***	0.144	0.000***	0.745	0.743	0.457	0.082
	2016	0.614	0.054	0.565	0.005***	0.657	0.889	0.279	0.060
Foshan—Shenzhen	2014	0.059	0.000***	0.015**	0.000***	0.068	0.301	0.850	0.002***
	2015	0.222	0.000***	0.012**	0.000***	0.739	0.588	0.030**	0.000***
	2016	0.015**	0.000***	0.062	0.000***	0.828	0.467	0.441	0.000***
Shaoguan—Shenzhen	2009	0.314	0.684	0.300	0.015**	0.150	0.341	0.135	0.020**
	2010	0.168	0.497	0.725	0.248	0.022**	0.056	0.284	0.010***
	2011	0.041**	0.171	0.021**	0.746	0.932	0.224	0.894	0.136
	2012	0.058	0.225	0.576	0.007***	0.292	0.072	0.118	0.726
	2013	0.117	0.600	0.412	0.021**	0.248	0.303	0.224	0.000***
	2014	0.071	0.189	0.152	0.724	0.182	0.854	0.018**	0.034**
	2015	0.717	0.527	0.045**	0.652	0.207	0.814	0.873	0.058
	2016	0.724	0.010***	0.235	0.670	0.773	0.095	0.119	0.040**
Haikou--Sanya	2013	0.609	0.919	0.416	0.803	0.402	0.000***	0.130	0.000***
	2014	0.962	0.541	0.792	0.055	0.723	0.000***	0.007***	0.000***
Chengde--Tangshan	2011	0.159	0.221	0.136	0.023**	0.000***	0.144	0.673	0.594
	2012	0.149	0.673	0.053	0.020**	0.000***	0.005***	0.017**	0.607
Xiangyang--Yichang	2013	0.247	0.407	0.995	0.270	0.044**	0.364	0.790	0.011**
	2014	0.196	0.889	0.874	0.062	0.092	0.015**	0.971	0.000***
	2015	0.194	0.244	0.591	0.707	0.067	0.269	0.170	0.135
	2016	0.459	0.185	0.033**	0.006***	0.249	0.480	0.106	0.193
Changsha--Yueyang	2009	0.003***	0.848	0.019**	0.207	0.005***	0.181	0.286	0.043**
	2010	0.484	0.181	0.023**	0.043**	0.242	0.523	0.615	0.393
	2011	0.010***	0.059	0.357	0.028**	0.158	0.536	0.196	0.128
Suzhou--Wuxi	2010	0.051	0.005***	0.103	0.103	0.440	0.494	0.310	0.000***
	2011	0.955	0.007***	0.455	0.001***	0.005***	0.409	0.921	0.001***
Wuxi--Yangzhou	2009	0.122	0.000***	0.022**	0.001***	0.001***	0.798	0.892	0.051
	2010	0.266	0.000***	0.582	0.144	0.058	0.171	0.335	0.008***

Notes: $P_1 \rightarrow P_2$ ($V_1 \rightarrow V_2$) denotes Granger causality test of house price (volume) from city 1 to city 2, resembling the others. *** and **denote that rejecting the hypothesis of no Granger causality at 1% and 5% significance level, respectively.

Table 7: Granger causality tests for intercity dynamics of price-price, price-volume, and volume-volume between cities located in adjacent provinces, P-values, each year

	Year	$P_1 \rightarrow P_2$	$P_1 \rightarrow V_2$	$V_1 \rightarrow P_2$	$V_1 \rightarrow V_2$	$P_2 \rightarrow P_1$	$P_2 \rightarrow V_1$	$V_2 \rightarrow P_1$	$V_2 \rightarrow V_1$
Anqing--Wuhan	2009	0.945	0.560	0.178	0.695	0.007***	0.656	0.317	0.000***
	2010	0.068	0.239	0.957	0.374	0.520	0.164	0.478	0.002***
Bengbu--Wuhan	2009	0.446	0.256	0.026**	0.003***	0.071	0.284	0.026**	0.000***
	2010	0.339	0.124	0.000***	0.093	0.390	0.984	0.731	0.000***
Hefei--Wuhan	2009	0.114	0.362	0.056	0.000***	0.502	0.165	0.002***	0.000***
Anqing--Suzhou	2010	0.226	0.293	0.169	0.721	0.000***	0.001***	0.439	0.155
	2011	0.109	0.826	0.528	0.301	0.919	0.006***	0.060	0.057
Anqing--Wuxi	2009	0.825	0.990	0.258	0.172	0.874	0.000***	0.646	0.000***
	2010	0.103	0.661	0.632	0.228	0.301	0.817	0.449	0.085
	2011	0.927	0.133	0.669	0.308	0.028**	0.310	0.437	0.000***
Anqing--Yangzhou	2009	0.155	0.028**	0.714	0.056	0.409	0.100	0.799	0.000***
	2010	0.773	0.392	0.017**	0.001***	0.992	0.020**	0.652	0.000***
Bengbu--Wuxi	2009	0.000***	0.072	0.063	0.000***	0.023**	0.381	0.366	0.437
	2010	0.005***	0.866	0.000***	0.000***	0.007***	0.812	0.602	0.000***
Bengbu--Yangzhou	2009	0.517	0.000***	0.155	0.000***	0.377	0.437	0.769	0.000***
	2010	0.002***	0.000***	0.013**	0.000***	0.936	0.364	0.950	0.000***
Hefei--Wuxi	2009	0.396	0.902	0.181	0.051	0.902	0.000***	0.000***	0.000***
Hefei-- Yangzhou	2009	0.006***	0.001***	0.310	0.000***	0.234	0.008***	0.001***	0.000***
Anqing--Hangzhou	2009	0.058	0.849	0.914	0.070	0.272	0.978	0.08	0.439
	2010	0.522	0.786	0.425	0.111	0.025**	0.023**	0.044**	0.880
	2011	0.111	0.372	0.639	0.072	0.151	0.119	0.631	0.530
Bengbu--Hangzhou	2009	0.251	0.001***	0.975	0.000***	0.328	0.169	0.770	0.000***
	2010	0.030**	0.000***	0.014**	0.000***	0.016**	0.000***	0.258	0.001***
Hefei--Hangzhou	2009	0.025**	0.075	0.001***	0.000***	0.296	0.319	0.216	0.000***
Chongqing--Wuhan	2009	0.282	0.000***	0.205	0.167	0.149	0.711	0.088	0.000***
	2010	0.242	0.652	0.094	0.684	0.003***	0.077	0.013**	0.000***
Chongqing--Changsha	2009	0.644	0.683	0.016**	0.574	0.653	0.849	0.064	0.107
	2010	0.857	0.890	0.094	0.024**	0.077	0.016**	0.323	0.007***
	2011	0.970	0.418	0.210	0.410	0.010***	0.171	0.596	0.037**
Chongqing--Yueyang	2009	0.807	0.590	0.863	0.471	0.001***	0.004***	0.008***	0.000***
	2010	0.000***	0.981	0.521	0.650	0.000***	0.226	0.086	0.000***
	2011	0.224	0.371	0.490	0.751	0.055	0.008***	0.950	0.000***
Fuzhou--Hangzhou	2009	0.003***	0.497	0.021**	0.000***	0.002***	0.018**	0.315	0.000***
Xiamen--Hangzhou	2009	0.941	0.872	0.544	0.141	0.002***	0.858	0.074	0.000***
	2010	0.071	0.250	0.342	0.163	0.025**	0.149	0.038**	0.002***
Fuzhou--Shaoguan	2009	0.000***	0.650	0.001***	0.000***	0.111	0.759	0.310	0.000***
Fuzhou--Shenzhen	2009	0.163	0.571	0.147	0.243	0.000***	0.000***	0.152	0.000***
Xiamen--Shaoguan	2009	0.004***	0.868	0.001***	0.162	0.480	0.038**	0.122	0.000***
	2010	0.046**	0.462	0.000***	0.047**	0.094	0.080	0.412	0.000***
Xiamen--Shenzhen	2009	0.944	0.408	0.172	0.161	0.655	0.000***	0.612	0.000***
	2010	0.169	0.646	0.325	0.127	0.001***	0.000***	0.779	0.000***
Lanzhou--Baotou	2011	0.907	0.024**	0.844	0.179	0.767	0.425	0.379	0.682
	2012	0.197	0.408	0.083	0.230	0.132	0.532	0.513	0.416
	2013	0.071	0.017**	0.011**	0.042**	0.058	0.321	0.087	0.018**
	2014	0.003***	0.291	0.116	0.049**	0.414	0.661	0.000***	0.500
Dongguan--Haikou	2011	0.038**	0.813	0.401	0.000***	0.253	0.975	0.008***	0.000***
	2012	0.140	0.095	0.452	0.000***	0.198	0.766	0.704	0.000***
	2013	0.322	0.437	0.641	0.000***	0.714	0.750	0.001***	0.000***
	2014	0.000***	0.000***	0.034**	0.000***	0.045**	0.164	0.328	0.004***
Dongguan--Sanya	2013	0.830	0.400	0.980	0.025**	0.198	0.861	0.016**	0.220
	2014	0.150	0.082	0.611	0.625	0.852	0.346	0.078	0.456
	2015	0.000***	0.000***	0.015**	0.146	0.032**	0.837	0.959	0.548

Foshan--Haikou	2014	0.611	0.002***	0.014**	0.000***	0.048**	0.808	0.276	0.620
Foshan--Sanya	2014	0.007***	0.810	0.543	0.130	0.347	0.230	0.308	0.004***
	2015	0.603	0.002***	0.052	0.864	0.148	0.780	0.952	0.003***
Shaoguan--Haikou	2010	0.303	0.802	0.549	0.153	0.244	0.068	0.155	0.102
	2011	0.834	0.633	0.031**	0.053**	0.344	0.206	0.961	0.004***
	2012	0.046**	0.178	0.048**	0.006***	0.295	0.370	0.086	0.003***
	2013	0.722	0.193	0.173	0.519	0.298	0.261	0.002***	0.000***
	2014	0.041**	0.876	0.646	0.014**	0.178	0.967	0.428	0.000***
Shaoguan--Sanya	2013	0.441	0.502	0.308	0.976	0.698	0.688	0.664	0.041**
	2014	0.004***	0.107	0.010***	0.077	0.741	0.491	0.514	0.018**
	2015	0.189	0.922	0.568	0.458	0.180	0.555	0.879	0.132
Shenzhen--Haikou	2010	0.417	0.075	0.619	0.144	0.701	0.517	0.000***	0.018**
	2011	0.802	0.118	0.462	0.294	0.418	0.861	0.269	0.002***
	2012	0.449	0.075	0.526	0.000***	0.734	0.254	0.106	0.000***
	2013	0.872	0.021**	0.147	0.000***	0.530	0.380	0.082	0.000***
	2014	0.005***	0.014**	0.845	0.087	0.264	0.444	0.000***	0.000***
Shenzhen--Sanya	2013	0.053	0.000***	0.525	0.885	0.300	0.330	0.028**	0.000***
	2014	0.037**	0.025**	0.419	0.018**	0.005***	0.023**	0.107	0.003***
	2015	0.675	0.078	0.010**	0.010**	0.064	0.082	0.303	0.000***
Dongguan--Yueyang	2011	0.000***	0.031**	0.433	0.000***	0.652	0.548	0.018**	0.963
Shaoguan--Changsha	2009	0.997	0.779	0.575	0.419	0.333	0.147	0.004***	0.025**
	2010	0.533	0.062	0.294	0.586	0.311	0.049**	0.040**	0.000***
	2011	0.157	0.399	0.430	0.015**	0.233	0.016**	0.704	0.000***
Shaoguan--Yueyang	2009	0.234	0.449	0.540	0.000***	0.097	0.731	0.070	0.000***
	2010	0.221	0.023**	0.990	0.001***	0.042**	0.007***	0.762	0.000***
	2011	0.872	0.156	0.823	0.000***	0.834	0.510	0.770	0.000***
Shenzhen--Changsha	2009	0.451	0.072	0.004***	0.982	0.039**	0.409	0.340	0.417
	2010	0.710	0.290	0.372	0.000***	0.324	0.000***	0.063	0.065
	2011	0.053	0.000***	0.083	0.660	0.364	0.716	0.066	0.028**
Shenzhen--Yueyang	2009	0.571	0.003***	0.007***	0.365	0.024**	0.039**	0.000***	0.002***
	2010	0.434	0.424	0.969	0.678	0.554	0.807	0.001***	0.176
	2011	0.414	0.585	0.622	0.074	0.315	0.052	0.000***	0.362
Dongguan--Jiujiang	2012	0.057	0.024**	0.002***	0.005***	0.222	0.441	0.048**	0.000***
	2013	0.547	0.291	0.000***	0.000***	0.003***	0.000***	0.000***	0.000***
	2014	0.379	0.072	0.183	0.001***	0.257	0.458	0.068	0.052
	2015	0.636	0.000***	0.237	0.008***	0.907	0.309	0.015**	0.000***
	2016	0.174	0.392	0.371	0.229	0.230	0.301	0.361	0.220
Foshan--Jiujiang	2014	0.010***	0.079	0.154	0.000***	0.475	0.765	0.074	0.001***
	2015	0.039**	0.000***	0.724	0.000***	0.852	0.316	0.158	0.000***
	2016	0.423	0.024**	0.108	0.000***	0.028**	0.446	0.057	0.000***
Shaoguan--Jiujiang	2012	0.903	0.009***	0.057	0.524	0.436	0.484	0.137	0.008***
	2013	0.547	0.538	0.157	0.800	0.806	0.382	0.397	0.002***
	2014	0.713	0.169	0.429	0.069	0.750	0.810	0.833	0.006***
	2015	0.966	0.547	0.960	0.785	0.000***	0.000***	0.620	0.000***
	2016	0.509	0.463	0.492	0.000***	0.303	0.047**	0.140	0.002***
Shenzhen--Jiujiang	2012	0.476	0.108	0.017**	0.000***	0.166	0.004***	0.641	0.000***
	2013	0.770	0.005***	0.002***	0.002***	0.514	0.000***	0.664	0.000***
	2014	0.732	0.858	0.093	0.000***	0.497	0.299	0.669	0.010**
	2015	0.014**	0.341	0.289	0.000***	0.120	0.002***	0.003***	0.000***
	2016	0.774	0.642	0.717	0.000***	0.087	0.010***	0.769	0.000***
Chengde--Baotou	2011	0.135	0.119	0.975	0.135	0.055	0.570	0.046**	0.032**
	2012	0.630	0.524	0.258	0.736	0.090*	0.260	0.970	0.552
	2013	0.010***	0.681	0.588	0.088	0.561	0.480	0.750	0.820
	2014	0.546	0.176	0.574	0.411	0.501	0.298	0.801	0.206
Tangshan--Baotou	2011	0.507	0.486	0.138	0.001***	0.918	0.000***	0.142	0.009***
	2012	0.414	0.498	0.005***	0.067	0.383	0.024**	0.589	0.961

Chengde--Dandong	2012	0.911	0.065	0.097	0.031**	0.001***	0.460	0.753	0.021**
	2013	0.149	0.345	0.040**	0.495	0.403	0.681	0.296	0.290
	2014	0.296	0.922	0.177	0.418	0.037**	0.654	0.056	0.163
Tangshan--Dandong	2012	0.934	0.067	0.868	0.021**	0.155	0.453	0.642	0.001***
Chengde--Tianjin	2011	0.084	0.655	0.000***	0.301	0.189	0.165	0.710	0.019**
	2012	0.001***	0.871	0.595	0.285	0.333	0.487	0.783	0.004***
	2013	0.481	0.595	0.279	0.657	0.101	0.001***	0.383	0.703
	2014	0.851	0.871	0.167	0.319	0.478	0.672	0.448	0.896
	2015	0.344	0.023**	0.162	0.018**	0.583	0.001***	0.199	0.091
	2016	0.795	0.656	0.767	0.510	0.048**	0.025**	0.769	0.537
Tangshan--Tianjin	2011	0.034**	0.001***	0.470	0.004***	0.089	0.672	0.879	0.000***
	2012	0.001***	0.107	0.425	0.001***	0.580	0.206	0.175	0.419
Mudanjiang--Baotou	2010	0.778	0.537	0.045**	0.000***	0.003***	0.019**	0.807	0.000***
	2011	0.724	0.945	0.134	0.006***	0.316	0.000***	0.148	0.004***
	2012	0.394	0.199	0.765	0.000***	0.211	0.606	0.220	0.002***
	2013	0.650	0.842	0.234	0.000***	0.535	0.137	0.559	0.000***
	2014	0.088	0.374	0.003***	0.075	0.794	0.431	0.216	0.000***
Wuhan--Changsha	2009	0.668	0.115	0.560	0.735	0.962	0.076	0.300	0.541
	2010	0.093	0.356	0.364	0.003***	0.002***	0.853	0.028**	0.041**
Wuhan--Yueyang	2009	0.756	0.144	0.707	0.083	0.164	0.748	0.866	0.516
	2010	0.002***	0.947	0.472	0.542	0.623	0.628	0.001***	0.014**
Xiangyang--Jiujiang	2012	0.209	0.063	0.005***	0.364	0.489	0.091	0.413	0.000***
	2013	0.004***	0.020**	0.007***	0.269	0.470	0.795	0.289	0.000***
	2014	0.623	0.199	0.173	0.000***	0.001***	0.034**	0.432	0.000***
	2015	0.927	0.219	0.013**	0.150	0.446	0.091	0.007***	0.000***
	2016	0.433	0.026**	0.375	0.225	0.440	0.099	0.018**	0.000***
Yichang--Jiujiang	2013	0.099	0.746	0.025**	0.550	0.511	0.072	0.577	0.408
	2014	0.152	0.207	0.355	0.119	0.008***	0.613	0.076	0.184
	2015	0.049**	0.703	0.078	0.187	0.202	0.124	0.304	0.557
	2016	0.320	0.540	0.827	0.105	0.883	0.133	0.379	0.962
Baotou--Dandong	2012	0.369	0.469	0.051	0.586	0.619	0.143	0.276	0.287
	2013	0.699	0.536	0.565	0.981	0.029**	0.000***	0.893	0.001***
	2014	0.928	0.832	0.550	0.072	0.330	0.007***	0.000***	0.043**
Baotou--Yinchuan	2009	0.485	0.743	0.831	0.444	0.003***	0.995	0.000***	0.006***
	2010	0.304	0.455	0.520	0.848	0.073	0.741	0.000***	0.000***
Suzhou--Hangzhou	2010	0.056	0.535	0.083	0.843	0.247	0.731	0.645	0.182
	2011	0.128	0.782	0.279	0.017**	0.020**	0.039**	0.977	0.500
Wuxi--Hangzhou	2009	0.001***	0.025**	0.615	0.000***	0.729	0.090	0.719	0.007***
	2010	0.183	0.700	0.027**	0.000***	0.261	0.107	0.020**	0.000***
	2011	0.363	0.461	0.661	0.000***	0.004***	0.071	0.238	0.277
Yangzhou--Hangzhou	2009	0.827	0.112	0.281	0.618	0.000***	0.138	0.079	0.000***
	2010	0.350	0.732	0.556	0.007***	0.004***	0.524	0.058	0.000***
Jiujiang--Ningbo	2015	0.394	0.000***	0.043**	0.086	0.112	0.379	0.108	0.295
	2016	0.102	0.312	0.117	0.001***	0.127	0.008***	0.003***	0.967

Notes: $P_1 \rightarrow P_2$ ($V_1 \rightarrow V_2$) denotes the Granger causality test of house price (volume) running from city 1 to city 2, resembling the others. *** and **denote that rejecting the hypothesis of no Granger causality at 1% and 5% significance level, respectively.

Table 8: Panel-Granger causality test for intracity price-volume dynamics, χ^2 statistics

Sample:	Number of cities	Price→Volume	Volume→Price
Whole (2009-2016)	32	30.642***	27.981***
2009	18	12.024***	13.343***
2010	19	0.092	0.079
2011	23	5.939**	7.330***
2012	14	4.068**	7.931***
2013	15	2.575	4.952**
2014	15	9.517***	5.842**
2015	14	9.001***	0.262
2016	11	2.086	1.454
Residential	19	26.995***	13.902***
Property	13	5.155**	13.809***

Notes: This table reports the results of panel Granger causality tests for intracity price-volume relationships. Price→Volume denotes Granger causality running from price to volume, and vice versa. ***, **, and * indicate rejecting the null hypothesis of no Granger causality relationship at 1%, 5%, and 10% significance level, respectively. "Residential" indicates the subsample of housing transactions of residential property, while "Property" implies the price or volume data are not residential.

Table 9: Panel Granger causality tests for intercity dynamics of price-price, price-volume, and volume-volume, χ^2 statistics

sample	pairs	$P_1 \rightarrow P_2$	$P_1 \rightarrow V_2$	$V_1 \rightarrow P_2$	$V_1 \rightarrow V_2$	$P_2 \rightarrow P_1$	$P_2 \rightarrow V_1$	$V_2 \rightarrow P_1$	$V_2 \rightarrow V_1$
Whole (2009-2016)	73	1.444	26.381***	16.153***	27.241***	11.694***	0.433	12.988***	114.187***
2009	38	0.002	0.059	0.881	3.295*	4.637**	1.532	0.709	0.057
2010	33	0.467	0.565	0.328	13.175***	0.195	5.447**	2.820*	16.431***
2011	39	0.004	0.911	3.228*	0.678	5.810**	0.182	4.605**	11.284***
2012	20	0.918	4.607**	0.132	18.417***	0.355	0.000	1.614	46.656***
2013	22	0.361	6.918***	0.006	0.063	0.312	7.810***	0.527	9.510***
2014	28	0.013	5.592**	15.076***	0.007	4.599**	0.477	16.555***	11.801***
2015	25	2.020	47.400***	26.648***	1.781	3.279*	7.393***	21.946***	19.137***
2016	15	0.865	0.427	3.508*	5.237**	1.407	0.003	3.260*	8.653***
Same province	16	1.540	12.639***	9.667***	2.892*	5.758**	0.001	2.890*	41.909***
Adjacent provinces	57	0.436	15.901***	8.037***	24.319***	6.363**	0.506	9.487***	76.470***
Residential	25	6.763***	18.433***	18.266***	4.784***	4.654**	3.276*	9.289**	73.707***
Property	48	0.076	7.978***	3.845**	27.684***	7.078***	0.091	4.264**	41.270***

Notes: $P_1 \rightarrow P_2$ ($V_1 \rightarrow V_2$) denotes the Granger causality test of house price (volume) running from city 1 to city 2, resembling the others. ***, **, and * indicate rejecting the null hypothesis of no Granger causality relationship at 1%, 5%, and 10% significance level, respectively. "Same province" indicates a subsample of the pair of cities located in the same province. "Residential" indicates the subsample of housing transactions of residential property, while "Property" implies that at least one city in the city pairs is not residential.

Table 10: Panel-Granger causality test for intracity price-volume dynamics, using areas of floor space sold as the proxy variable of volume, χ^2 statistics

Sample of	Number of cities	Price→Volume	Volume→Price
Whole (2009-2016)	32	38.168***	21.733***
2009	18	6.561***	8.075***
2010	19	0.018	0.331
2011	23	7.407***	6.197**
2012	14	4.893**	8.362***
2013	15	2.663	2.449
2014	15	18.279***	2.929*
2015	14	9.523***	1.176
2016	11	2.757*	1.270
Residential	19	36.767***	12.770***
Property	13	6.827***	9.007***

Notes: This table reports the results of panel Granger causality tests for intracity price-volume relationships. Price→Volume denotes Granger causality running from price to volume, and vice versa. ***, **, and * indicate rejecting the null hypothesis of no Granger causality relationship at 1%, 5%, and 10% significance level, respectively. "Residential" indicates the subsample of housing transactions of residential property, while "Property" implies the price or volume data are not all residential.

Table 11: Panel Granger causality tests for intercity dynamics of price-price, price-volume, and volume-volume, using areas of floor space sold as the proxy variable of volume, χ^2 statistics

sample	$P_1 \rightarrow V_2$	$V_1 \rightarrow P_2$	$V_1 \rightarrow V_2$	$P_2 \rightarrow V_1$	$V_2 \rightarrow P_1$	$V_2 \rightarrow V_1$
Whole	28.408***	12.566***	19.077***	0.887	8.155***	114.986***
2009	0.644	0.727	0.001	1.577	0.753	0.636
2010	0.004	1.068	2.408	8.248***	3.431*	15.427***
2011	0.848	5.283**	0.794	0.625	1.717	8.294***
2012	4.089**	0.139	27.789***	0.102	6.168**	41.423***
2013	7.625***	0.408	10.399***	5.252**	1.098	11.093***
2014	8.853***	14.738***	0.328	0.445	13.180***	20.846***
2015	39.969***	25.410***	1.378	6.305**	13.318***	16.573***
2016	0.572	3.955**	11.393***	0.048	6.699***	11.761***
Same province	11.337***	12.586***	16.013***	0.412	2.006	54.320***
Adjacent provinces	17.720***	3.829**	12.042***	0.432	6.065**	74.390***
Residential-Res	17.010***	18.397***	10.015***	7.177***	9.237***	124.131***
nonResidential	11.158***	1.862	12.409***	0.228	2.050	33.370***

Notes: $P_1 \rightarrow P_2$ ($V_1 \rightarrow V_2$) denotes the Granger causality test of house price (volume) running from city 1 to city 2, resembling the others. ***, **, and * indicate rejecting the null hypothesis of no Granger causality relationship at 1%, 5%, and 10% significance level, respectively. "Same province" indicates a subsample of the pair of cities located in the same province. "Residential-Res" indicates the subsample of housing transaction of residential housing units, while "nonResedential" implies at least one city in the city pairs is not residential.

Table 12: Granger causality tests for intercity dynamics of price-price, price-volume, and volume-volume between Shanghai and other provincial level jurisdictions, χ^2 statistics, February 2010—June 2022

	$P_1 \rightarrow P_2$	$P_1 \rightarrow V_2$	$V_1 \rightarrow P_2$	$V_1 \rightarrow V_2$	$P_2 \rightarrow P_1$	$P_2 \rightarrow V_1$	$V_2 \rightarrow P_1$	$V_2 \rightarrow V_1$
Shanghai --Beijing	12.40	4.49**	104.79***	13.92***	2.44	1.61	0.22	4.56**
Shanghai --Tianjin	0.11	28.49***	0.69	24.83***	2.49	3.37	0.01	14.39***
Shanghai --Chongqing	2.33	8.96***	0.02	0.73	17.46	2.49	0.01	92.87***
Shanghai --Heibei	0.47	4.17	0.22	20.90***	2.05	0.07	0.22	71.6***
Shanghai --Liaoning	0.26	0.24	0.74	18.82***	1.61	6.72**	0.97	1.75
Shanghai --Jiangsu	0.01	4.33**	15.81***	12.37***	0.12	2.12	0.48	0.06
Shanghai --Zhejiang	0.12	7.48***	12.20***	11.45***	0.41	0.27	0.04	0.22
Shanghai --Fujian	20.75*	3.62*	11.44	0.24	0.46	0.02	0.04	5.07**
Shanghai --Shandong	27.24***	3.56*	14.72	25.97***	2.90*	0.05	0.28	38.97***
Shanghai --Guangdong	11.60	3.31*	27.59***	12.17***	4.69**	2.46	0.05	0.22
Shanghai --Hainan	4.43**	0.00	0.01	1.26	0.05	10.01***	0.26	9.45***
Shanghai --Shanxi	1.40	5.53**	52.52***	0.20	0.48	0.00	0.00	17.55***
Shanghai --Jilin	8.48	5.60**	18.69*	8.57**	0.95	0.41	1.09	24.33***
Shanghai--Heilongjiang	15.17*	0.04	97.37***	6.86**	0.11	13.76***	0.13	11.04***
Shanghai --Anhui	35.44***	9.19***	54.36***	8.57**	0.08	0.59	0.06	6.29**
Shanghai --Jiangxi	0.37	8.17***	40.21***	21.14***	0.15	0.89	0.01	40.90***
Shanghai --Henan	12.64***	14.60***	10.13***	36.60***	1.82	0.28	0.03	62.61***
Shanghai --Hubei	0.85	6.26**	3.81*	0.55	4.65**	2.10	0.52	16.26***
Shanghai --Hunan	8.42	6.25**	21.19**	13.08***	1.28	0.70	0.00	29.05***
Shanghai --Inner Mongolia	13.57	0.81	20.78*	5.24*	40.70***	2.12	0.57	25.97***
Shanghai --Guangxi	0.02	10.26***	0.05	50.36***	4.43**	1.52	0.01	29.48***
Shanghai --Sichuan	19.39*	11.67***	15.59	31.69***	2.14	0.32	0.14	67.19***
Shanghai --Guizhou	16.72	8.88***	17.40	25.99**	2.73*	0.22	0.13	1.84
Shanghai --Yunnan	0.00	4.04**	2.96*	3.55*	7.60***	3.43*	0.01	0.00
Shanghai --Tibet	14.23	8.67	17.18	20.71**	4.20**	9.97***	18.34	18.99*
Shanghai --Shaanxi	8.75***	2.42	44.63***	8.84***	0.56	0.02	0.21	0.06
Shanghai --Gansu	7.32	11.22***	11.32	13.51***	1.12	0.04	0.33	0.49
Shanghai --Qinghai	14.20	9.51	41.98***	91.19***	0.31	0.05	0.23	0.15
Shanghai --Ningxia	0.51	5.97**	44.24***	28.83***	0.68	0.31	0.24	5.91*
Shanghai --Xinjiang	8.10	0.31	10.59	3.79*	0.52	0.01	0.00	0.16

Notes: All the data used for the tests are monthly data lasting from February 2010 to June 2022. $P_1 \rightarrow P_2$ ($V_1 \rightarrow V_2$) denotes the Granger causality test of house price (volume) running from Shanghai to other provincial-level jurisdictions, resembling the others. ***, **, and * indicate rejecting the null hypothesis of no Granger causality relationship at 1%, 5%, and 10% significance level, respectively.

Table 13: Granger causality test for dynamics of price-price, price-volume, and volume-volume between five submarkets/administrative districts in Shenzhen, 2009-2019

Region pair	**$P_1 \rightarrow P_2$**	**$P_1 \rightarrow V_2$**	**$V_1 \rightarrow P_2$**	**$V_1 \rightarrow V_2$**	**$P_2 \rightarrow P_1$**	**$P_2 \rightarrow V_1$**	**$V_2 \rightarrow P_1$**	**$V_2 \rightarrow V_1$**
Baoan--Futian	2.98*	0.29	0.46	3.87**	5.62**	2.36	0.56	0.56
Baoan--Longgang	1.80	0.00	6.13**	4.19**	18.92***	9.81***	1.56	24.62***
Baoan--Luohu	2.56	8.52***	1.53	2.43	1.53	30.05***	1.28	5.73
Baoan--Nanshan	0.10	0.71	0.01	17.37***	13.44***	11.59***	0.18	0.01
Futian--Longgang	1.33	1.02	0.51	3.91**	0.08	0.15	3.99	3.06*
Futian--Luohu	2.08	0.35	4.44**	0.38	0.07	0.20	0.01	0.25
Futian--Nanshan	11.50***	0.34	5.711**	0.40	0.63	0.15	1.17	8.30***
Longgang--Luohu	4.30**	0.11	6.73***	1.80	3.99**	0.01	6.61**	11.22***
Longgang--Nanshan	5.75**	0.26	6.40**	8.95***	1.58	0.10	5.61**	0.50
Luohu--Nanshan	0.54	38.5***	1.08	5.28**	0.10	0.02	1.36	2.12

Notes: All the data used for the tests are daily frequency. The valid observations of the five districts are 05/16/2009—04/24/2019 for the districts of Baoan, Longgang, and Nanshan, 05/16/2009—08/18/2016 for the Futian district, and 03/20/2014—04/24/2016 for the Luohu district. ***, **, and * indicate rejecting the null hypothesis of no Granger causality relationship at 1%, 5%, and 10% significance level, respectively.

Table 14: Determinants of intracity price-volume dynamics in China

	Dependent Variable: PV	Dependent Variable: VP
(log) City GDP	0.994	-0.330
	(0.12)	(-0.07)
City GDP Growth	-0.022	0.038
	(-0.30)	(0.51)
(log) City Population	-11.308**	-6.573*
	(-2.15)	(-1.95)
City Population Growth	1.091**	0.202
	(2.54)	(0.55)
(log) City GDP per capita	-3.710	-7.832
	(-0.46)	(-1.25)
Unemployment Rate	-0.623*	0.145
	(-1.78)	(0.54)
Mortgage Rate	5.962	3.961
	(1.33)	(0.85)
Mortgage Rate Trend	-1.505	-0.379
	(-1.44)	(-0.32)
Shanghai Composite Index	-0.293	-0.319
(log-growth)	(-0.93)	(-0.96)
Constant	101.281	120.162**
	(1.40)	(2.39)
City-fixed effect	Yes	Yes
Time-fixed effect	Yes	Yes
Observations	116	81

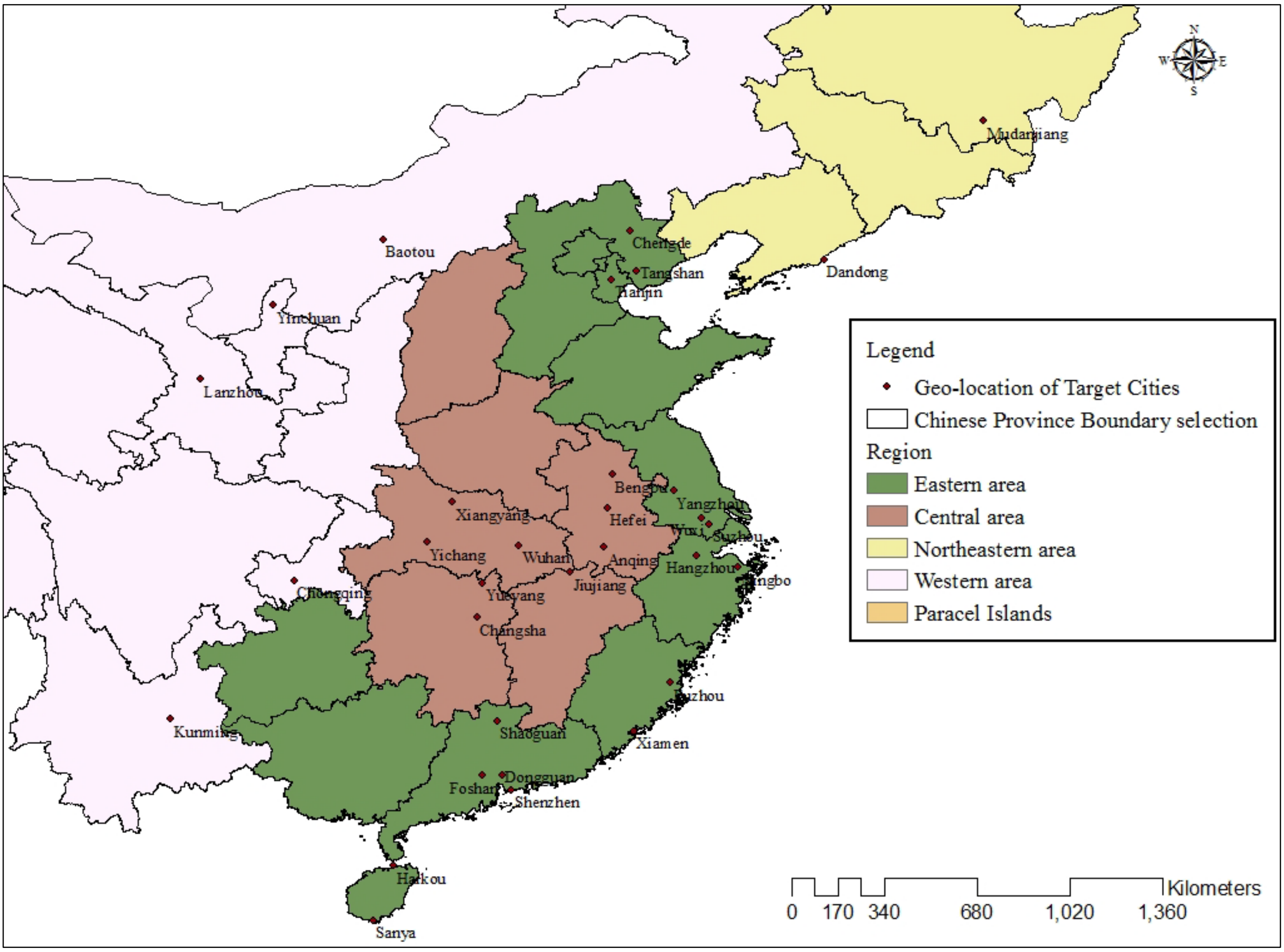
Notes: This table reports the estimated results of panel-probit regression with robust errors for the determinants of Granger causalities between the housing transaction price and volume. PV denotes Granger causality from price to volume at the 5% significance level (0 if the p-value is higher than 5%, 1 if elsewhere); VP denotes Granger causality from volume to price at the 5% significance level (0 if the the p-value is higher than 5%, 1 if elsewhere). *t* statistics in parentheses. ***, **, and * denote significant level of 1%, 5%, and 10%, respectively.

Table 15: The impact of economic fundamentals on intercity housing transaction connections (ICHTC) in China

	Dependent variable: ICHTC	
Divergence of City GDP	0.011**	0.011**
	(2.46)	(2.46)
Divergence of City GDP Growth	0.019	0.019
	(0.36)	(0.36)
Divergence of City Population	0.028	0.028
	(0.76)	(0.76)
Divergence of City Population Growth	0.001*	0.001*
	(1.75)	(1.75)
Divergence of City GDP per capita	0.009	0.009
	(0.22)	(0.22)
Divergence of Unemployment Rate	-0.014	-0.014
	(-0.94)	(-0.94)
Mortgage Rate		0.099
		(0.39)
Mortgage Rate Trend		-0.033
		(-0.25)
Shanghai Composite Index		-0.004
(log-growth)		(-0.32)
Constant	0.268	-0.278
	(1.44)	(-0.19)
City-fixed effect	Yes	Yes
Time-fixed effect	Yes	Yes
N	194	194
R^2	0.671	0.671

Notes: This table reports the estimated results of whether intercity housing transaction connectedness (ICHTC) is affected by the fundamental-factor divergences. The divergence of city GDP is calculated as the absolute value of city one's GDP minus city two's GDP, and other divergence variables are similarly measured based on the absolute values. *t* statistics in parentheses. ***, **, and * denote the significance level of 1%, 5%, and 10%, respectively.

Figure 1: Geographical distribution of Chinese cities in the sample



Appendix

Table A-1: Panel-Granger causality test for intracity price-volume dynamics, Romano-Wolf adjusted p-values

Sample of	Number of cities	Price→Volume	Volume→Price
Whole (2009-2016)	32	0.0010***	0.0010***
2009	18	0.0010***	0.0010***
2010	19	0.6903	0.5105
2011	23	0.0330**	0.0070***
2012	14	0.0340**	0.0040***
2013	15	0.1089	0.0260**
2014	15	0.0010***	0.0140**
2015	14	0.0020***	0.7003
2016	11	0.1678	0.1798
Residential	19	0.0010***	0.0010***
Property	13	0.0320**	0.0010***

Notes: ***, **, and * indicate rejecting the null hypothesis of no Granger causality relationship at 1%, 5%, and 10% significance level, respectively. "Residential" indicates the subsample of housing transaction of residential property, while "Property" implies the price or volume data are not all residential. The resample times of calculating the Romano-Wolf p-values are 1000.

Appendix

Table A-2: Panel Granger causality tests for intercity dynamics of price-price, price-volume, and volume-volume, Romano-Wolf adjusted p-values

sample	pairs	$P_1 \rightarrow P_2$	$P_1 \rightarrow V_2$	$V_1 \rightarrow P_2$	$V_1 \rightarrow V_2$	$P_2 \rightarrow P_1$	$P_2 \rightarrow V_1$	$V_2 \rightarrow P_1$	$V_2 \rightarrow V_1$
Whole	73	0.1429	0.0010***	0.0010***	0.0010***	0.0010***	0.1908	0.0020***	0.0010***
2009	38	0.9421	0.5225	0.1848	0.1778	0.0969*	0.0210**	0.4995	0.9021
2010	33	0.3147	0.1628	0.8751	0.0010***	0.6933	0.0889*	0.0360**	0.0010***
2011	39	0.9201	0.3546	0.0200**	0.1838	0.0120**	0.8222	0.0180**	0.0020***
2012	20	0.4086	0.0290**	0.5674	0.0010***	0.5894	0.9590	0.1978	0.0010***
2013	22	0.5534	0.0090***	0.9650	0.8302	0.5365	0.0050***	0.5065	0.0030***
2014	28	0.9451	0.0290**	0.0010***	0.8961	0.0430**	0.4665	0.0010***	0.0030***
2015	25	0.2188	0.0010***	0.0010***	0.0549*	0.0529*	0.0080***	0.0010***	0.0010***
2016	15	0.5744	0.3886	0.0989*	0.0230**	0.5325	0.9041	0.1309	0.0020***
Same province	16	0.2278	0.0030***	0.0070***	0.1089	0.0110**	0.7253	0.0889*	0.0010***
Adjacent provinces	57	0.3307	0.0010***	0.0040***	0.0010***	0.0080***	0.1848	0.0050***	0.0010***
Residential--Res	25	0.0190**	0.0010***	0.0010***	0.0290**	0.0390**	0.0350**	0.0040***	0.0010***
nonResidential	48	0.9181	0.0010***	0.1099	0.0010***	0.0010***	0.6743	0.0989*	0.0010***

Notes: $P_1 \rightarrow P_2$ ($V_1 \rightarrow V_2$) denotes Granger causality test of house price (volume) running from city 1 to city 2, resembling the others. ***, **, and * indicate rejecting the null hypothesis of no Granger causality relationship at 1%, 5%, and 10% significance level, respectively. "Same province" indicates subsample of the pair of cities located in the same province. "Residential" indicates the subsample of housing transaction of residential property, while "nonResedential" implies at least one city in the city pairs is not residential.