The spillover effects of public attention and real estate market: A case study in the city of Shanghai

Type of the Article： Original Research Article

Abstract

The real estate industry is closely linked to the national economy, and fluctuations in house prices have long been a major focus of public attention. This study explores the relationship between public attention and the real estate market, using public attention as a focal point. It systematically explains how public attention affects investment decisions in real estate. Taking Shanghai as a case, this study empirically examines the dynamic time-varying relationship between public attention and house prices, sales, investment and floor space completed by building a Time-Varying Parameter Vector Autoregression (TVP-VAR) model with data from 2011 to 2024. The research shows that the spillover index of house prices on public attention is positive and house prices acting as the sender of the shock, with rising house prices boost public attention. Conversely, the spillover index of public attention on house prices is negative, with public attention acting as the receiver of the shock. Based on the empirical results, it is recommended to incorporate public attention into the real estate market monitoring system, observe the real estate industry using multiple indicators, and enhance the regulation of online media to ensure policy transparency.

Keywords Public attention · Real estate · TVP-VAR model · Web search data · House price

JEL Classification C90 · D84 · E71 · R31

1 Introduction

With the advancement of urbanization in China, the real estate sector has followed a market-oriented development path since the 1980s. After decades of development, real estate has become increasingly significant in the national economy of China. In 2022, real estate accounted for 6.1% of the national GDP, the construction industry 6.9%, and the broader real

estate sector nearly 13%.[1] Clearly, real estate has become one of the key pillars of the national economy.

With the development of the real estate industry, the price of commercial housing has repeatedly reached new highs. In 2007, the average price of commercial housing in China was about 0.39 million yuan per square meter, while in 2022 it exceeded 10,000 yuan per square meter, reaching 1.07 million yuan per square meter.[2] Prices have risen even faster in first- and second-tier cities, with commercial house priced in the tens of thousands, hundreds of thousands, or even two to three hundred thousand yuan per square meter. Shanghai is one such representative city, its 2011-2024 house prices as shown in Figure 1.

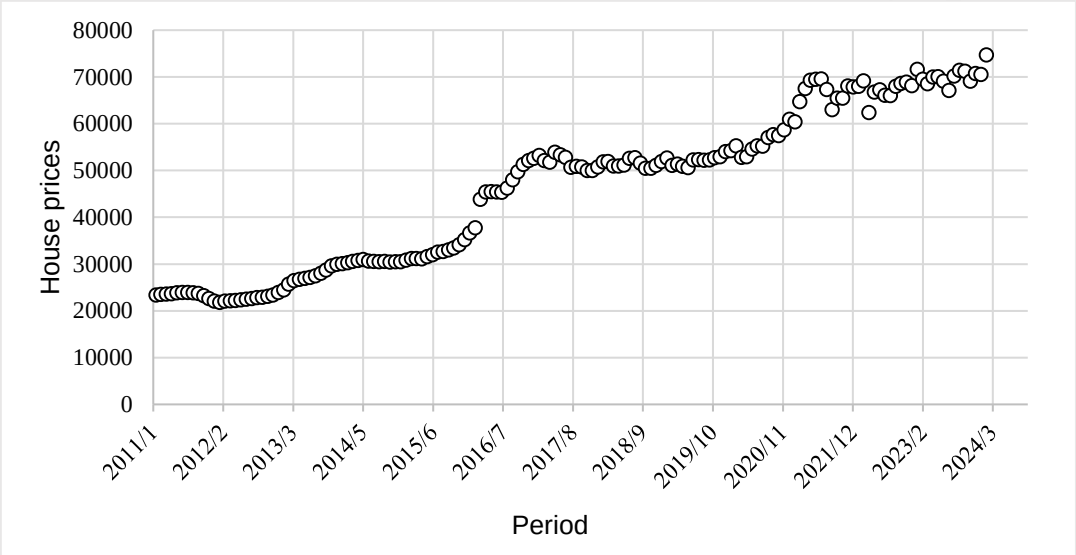


Fig. 1 Time series plot of Shanghai commodity house prices, January 2011-February 2024

Changes in house prices have a significant impact on the development of the real estate industry and serve as a barometer for the real estate market (Dai et al. 2022). In the past forty years, while house prices have generally increased, there have been several periods of sharp fluctuations. Since the 21st century, the house prices have roughly experienced three upswings and downswings in China. In 2009, the government launched the "4 trillion bailout plan" (Dai et al. 2022), house prices stopped falling and entered the first rising stage (2010-2011). The rapidly soaring house prices also made the central bank limit purchase and loan policies again kicked off, affected by the differentiated credit policy, regulation of down payment interest rates and intensively raise the quasi-interest rate and other policies, the national house prices fell (2011-2013). In 2012, the central bank to implement the loose monetary policy, the two quasi-interest rate cuts, so that the sales and real estate investment rebounded (2013-2014), but this was followed by an adjustment period under policy controls (2014-2015). By 2016, real estate policies continued to be relaxed, with many related policies introduced intensively, and house prices in many cities increased steeply (2016-2020). Since 2021, influenced by the COVID-19 pandemic and the national "housing is for living in, not speculation" principle[3], house prices in China have entered another adjustment phase (2021 to present). The future trends in house

[1] Data from the 2023 National Statistical Yearbook of China.
[2] Data compiled from the website of the National Bureau of Statistics of China.
[3] In mid-December 2016, the China's Central Economic Work Conference proposed to adhere to the positioning of "housing is for living in, not speculation", requiring a return to the residential properties of housing.

prices continue to be a major focus and hot topic of social concern.

Real estate is a special commodity that involves almost all households, and people are inevitably affected by social behaviors such as the group effect during transactions. The amount of information on search engines like Baidu and Google increases year by year, and consumers often consult these sources for relevant policies before buying property. Public attention to the real estate market is reflected in online searches, which represent potential demand and concern. These online search behaviors can become a significant source of information and a basis for decision-making in real estate.

Based on this, in the context of uncertain future trends in house prices, this study uses public attention as an observation point, leveraging large-scale data from Baidu Index search volumes. By applying theories from behavioral economics and constructing statistical models, this study aims to reveal the house price information embedded in media content and user search behaviors. This has reference value for both public real estate investment decisions and government macroeconomic adjustments in the real estate sector. The research is significant both theoretically and practically.

The rest of the paper is organized as follows. Section 2 consists of literature review. Section 3 screening indicators and constructing index of public attention. Section 4 involves the construction and empirical analysis of the TVP-VAR model. Section 5 concludes the paper.

2 Literature review

2.1 Research on the influencing factors and forecasting of house price

The level of house price is directly related to the level of living standard of the residents, and the problem of house prices is a social and economic problem that concerns the immediate interests of the residents. The influencing factors and forecasting methods of house prices have always been the hot issues explored by scholars, and a large number of research results have been produced. Currently, it mainly focuses on two perspectives, one is based on traditional macroeconomics, and the other is based on behavioral economics.

Case and Shiller (1990) used time-series cross-sectional regression analysis to show that house prices are correlated with macroeconomic variables such as employment, population, and income. Poterba (1991) found that fluctuations in the macroeconomy have explanatory power for house price changes and strong predictive capability by studying house prices in 39 U.S. cities. Englund and Loannides (1996) discovered that GDP growth promotes house price increases, while interest rates have an inverse relationship with house price changes using data from 15 OECD member countries. Lian (2010), and Ding (2014) used forecasting models such as ARIMA model, polynomial regression model, and neural network to predict house prices. Clayton (2009) indicated that while macroeconomic factors are key drivers of house prices, investor sentiment also affects final pricing. Malia et al. (2024) applies the Hedonic Pricing Model (HPM) method to identify the critical factors that affect the value of houses， and it was found that the attributes such as location and nearby amenities have a significant impact on the price of houses. Baker et al. (2016) pointed it to that in the context of real estate, house prices can be a source of shock, influencing public attention, while public sentiment can impact real estate market dynamics through changes in demand and expectations.

Common quantitative forecasting methods for house prices include time-series cross-sectional analysis (Malpezzi, 1999), VAR models (Anglin, 2006), autoregressive models,

multiple regression analysis, grey system theory, and various comparative and combined prediction methods.

With the deepening of research, it has been found that the fluctuation of house prices cannot be completely determined by the economic fundamentals. Black, Brown, Diaz, et al. (2009) pointed that the psychological and behavioral aspects of various market participants should also be considered. In addition, human behavior is not isolated but rather interrelated, leading to a comprehensive impact on house prices. Thus, research on house prices needs to explore multidimensional perspectives.

2.2 Research on the relationship between public attention based on web searches and house prices

With the widespread use of the internet, people's life and work are closely connected with the Internet. People are accustomed to obtaining the required information through search engines, and the network footprint left by this search information behavior reflects people's needs in a real and timely manner, mapping people's attention to certain types of issues, which is reflected in the increased attention to certain keywords on the network, and corresponds to the changes in certain economic phenomena in real life. Therefore, in recent years, researchers have attempted to explore house price issues from the perspective of public attention.

Da, Engelberg, and Gao (2011) pioneered this approach by using Google search data as a proxy variable for investor attention and found a strong correlation between search volume and asset prices. Wu and Brynjolfsson (2009) studied the relationship between the search volume of the keyword "real estate" on Google and house prices. Their research found a high correlation between web search data and housing sales, as well as house prices, and the correlation is granger causality. Brown and Williams (2017) conducted empirical research showing that increased media attention is often associated with short-term fluctuations in house prices. Positive news coverage usually leads to a temporary surge in demand and subsequent house price increases, especially in city centers and desirable neighborhoods. Chen et al. (2020) indicates that fluctuations in media attention correlate with short-term house price changes. Peaks in media coverage often coincide with peaks in housing demand, particularly in urban areas and during periods of economic optimism. However, Jones et al. (2019) showed that the sustainability and long-term implications of these price movements remain a subject of ongoing research. Zhang, Wang, and Li (2019) analyzed the impact of web search trends related to real estate in China on house prices, discovering that an increase in the search volume of real estate-related terms often predicts significant house price changes. In using Baidu index keyword search data as a proxy variable for public attention and conducting socioeconomic-related research, Sun (2014) creatively proposed an index synthesis method using principal component analysis to synthesize the consumer price index based on the idea of dimensionality reduction of the data, which resulted in an index of public attention with a higher degree of stability and fit.

Overall, the research on the influencing factors and forecasting of house prices and the application of web search data in the field of house prices research have become more mature with the development of time, yielding abundant results. However, there remain areas for improvement, for example, studies examining the relationship between web search data and house prices often fail to adequately consider regional disparities in development levels.

Additionally, the selection of web search keywords in existing research tends to be overly subjective, relying on direct selection methods. This study takes Shanghai as the case, utilizing web scraping technology to collect corresponding index data from Baidu and quantifying public attention and the time span of the data is 2011-2024. Finally, a TVP-VAR model is constructed to explore the relationship between public attention and house prices, and providing policy recommendations for the development of the real estate market (Dai et al. 2022).

3 Indicators screening and index construction of public attention

3.1 Variables and data source

This study aims to explore the relationship between public attention and the real estate market, focusing on how public attention impacts the real estate sector. Therefore, in this study, public attention is treated as the independent variable, while house prices, sales, investment, and floor space completed in the real estate market are selected as dependent variables. The total indicator of public attention is decomposed into three indicators: public attention to macro policy, public attention to economic environment, and public attention to real estate. The variables are described in Table 1.

Table 1 Variables' descriptions

Variable Name	Variable Abbreviation
Public attention to the real estate market	Public attention/Total Public attention
House prices	Prices
Commodity house sales	Sales
Real estate investment	Investment
Floor space of commercialized buildings	Floor space completed
Public attention to macro policy	Macro policy
Public attention to economic environment	Eco environment
Public attention to real estate policy	Real estate policy

This paper focuses on the Shanghai area, obtaining relevant data to study the impact of public attention on regional house prices. Specifically, using house prices as the core keyword, 113 related keywords were identified from Baidu Index demand maps, categorized into real estate, macro policy, and economic environment (see Table 2). Then use big data Python crawler technology to crawl the relevant data to get the user's mobile and PC search volume on a daily basis, and then integrate it to form the user's monthly search volume. House prices information for Shanghai from January 2011 to February 2024 was also searched online, and the same scraping technology was used to obtain monthly average house prices data.

In addition, in order to explore the spillover effects of public attention and the real estate market better, this study will introduce relevant variables: sales, investment, and floor space completed of commercial housing, with monthly data sourced from the National Bureau of Statistics.

In conjunction with Shanghai house prices, four variables are divided into two groups for the experiment. One group includes house prices and sales. The former represents the average monthly price per square meter of residential property in Shanghai, while the latter reflects changes in public housing demand. The other group comprises investment and floor space

completed. The former partly reflects changes in the supply of the real estate market, while the latter indicates the degree of investment completion under various social and economic risks, representing the portion of total investment that can actually enter the real estate market and potentially yield future returns. This grouping allows for a more comprehensive understanding and analysis of dynamic changes in the real estate market and its relationship with public attention.

Table 2 List of Baidu Index demand map keywords related to house prices

categories	related keywords
Real estate	1. Provident fund；2. Provident fund loan；3. Provident fund loan limit；4. Provident fund withdrawal；5. Shanghai provident fund management center；6. Housing provident fund；7. Social security；8. Social security bureau；9. Down payment for buying a house；10. How much is the down payment for buying a house；11. How much is the minimum down payment for buying a house；12. How much is the down payment for buying a house；13. Buying a house；14. Shanghai real estate；15. Shanghai real estate information；16. Shanghai real estate information network；17. Shanghai real estate website；18. Shanghai property website；19. Real estate agents；20. Shanghai house price；21. Shanghai house price trend；22. Shanghai house price trend chart；23. Rising house price；24. Falling house price；25. House price website；26. New housing project；27. Housing project；28. Opening quotation；29. Housing project website；30. Housing project advertising；31. Housing project map；32. SouFun；33. Housing resources；34. Ganji rental website；35. Lianjia website；36. Fangke website；37. Housing resources information；38. House type；39. Shanghai renovation companies；40. Shanghai renovation company rankings；41. Floor plan；42. Floor plan design；43. Floor plan introduction；44. Tenancy；45. 58.com rental with the city；46. Rental website；47. Rental contract；48. 58.com rental；49. Shanghai Second-Hand houses；50. Shanghai Second-Hand house prices；51. Shanghai Second-Hand house transaction process；52. House sale contract；53. House sale agreement；54. Notes of buying a house；55. Process of house buying；56. Building materials website；57. China building materials website；58. Building materials online；59. Building materials agents
Macro policy	1. Real estate policy；2. Latest real estate policy；3. Real estate regulation；4. Real estate regulation policy；5. New real estate regulation policy；6. Policy for purchasing house；7. Policy for security housing；8. Security housing of Shanghai；9. Affordable housing；10. Security housing；11. Resettlement housing；12. Application conditions for public rental housing；13. Public rental housing；14. Low-Rent apartments；15. Differences between public rental housing and Low-Rent housing；16. Public rental housing information network；17. Public rental housing policy；18. Public rental housing application process；19. Does resettlement housing have a property certificate；20. Affordable housing policy；21. Can affordable housing be bought and sold；22. Social housing；23. Price limit order；24. National real estate policy；25. Recognize the house, not the loan
Economic environment	1.GDP; 2. Exchange rate; 3. Loan rate; 4. Loan rate calculator; 5. Loan calculator; 6. Interest; 7. Bank loan rate; 8. Benchmark loan rate; 9. Mortgage rate; 10. Mortgage rate calculator; 11. Mortgage interest; 12. Mortgage loan rate; 13. Deposit interest rate

calculator; 14. How to calculate the deposit interest rate; 15. Deposit interest rate adjustment; 16. Deposit interest rate calculation; 17. Deposit interest; 18. Mortgage calculator; 19. Repay mortgage in advance; 20. Mortgage; 21. Inflation; 22. Deflation; 23. Inflation rate; 24. Era of negative interest rates; 25. Monetary tightening; 26. Tightening; 27. Mortgage loan; 28. Bank deposit rate; 29. Bank deposit interest

3.2 Keyword screening and correlation analysis

Based on the determination principles of Pearson correlation analysis, assess the actual correlation between house price-related Baidu Index demand map keywords and house prices, the keywords were initially screened, and a total of 61 keywords were screened out, with 52 remaining.

Table 3 shows the keywords after initial screening and their correlation coefficients with house prices. Among them, house prices have a strong correlation with 13 keywords. Keywords such as public rental housing, resettlement housing, and application conditions for public rental housing may be closely related to government real estate policy adjustments. As mentioned in the introduction, the measures introduced by government departments in February 2016 significantly boosted the public's enthusiasm for homeownership. Policies supporting the construction of public rental and resettlement housing adjust the supply and demand relationship in the real estate market, thereby affecting house prices (Dai et al. 2022). Additionally, keywords like loan rate and mortgage rate calculators are related to financial policies. The central bank's adjustments to interest rates directly impact the cost of loans, loan amounts, and repayment amounts for homebuyers, thus affecting the availability of homebuying funds and debt conditions. If post-adjustment rates are favorable to buyers, it may increase housing demand, thereby potentially raising house prices. At the same time, economic stability and regional development levels are also closely related to exchange rate and inflation, and these factors directly affect people's ability and willingness to purchase homes, which in turn affects the trend of house prices.

Table 3 Analysis data of the correlation between the keywords after initial screened and house prices

keywords	r	p	keywords	r	p
SouFun	-0.85	0.000	Notes of buying a house	-0.41	0.000
Shanghai property website	-0.78	0.000	Public rental housing	0.78	0.000
Shanghai Second-Hand house prices	0.75	0.000	Public rental housing information network	-0.74	0.000
How much is the down payment for buying a house	0.75	0.000	Resettlement housing	0.72	0.000
Floor plan	0.74	0.000	Application conditions for public rental housing	0.71	0.000
Building materials website	-0.73	0.000	Real estate policy	0.64	0.000
Housing project advertising	-0.70	0.000	Real estate regulation policy	-0.62	0.000
Building materials agents	-0.68	0.000	Security housing	0.61	0.000
How much is the down payment for buying a house	-0.66	0.000	Social housing	0.56	0.000
Building materials online	-0.65	0.000	Price limit order	0.45	0.000
Social security bureau	0.65	0.000	Low-Rent apartments	0.41	0.000
Rental website	-0.62	0.000	Mortgage rate calculator	0.80	0.000
House type	0.62	0.000	Exchange rate	0.78	0.000
Housing project map	-0.61	0.000	Mortgage interest	0.78	0.000
Opening quotation	0.60	0.000	Inflation	0.78	0.000

Housing project	0.58	0.000	Inflation rate	0.77	0.000
Shanghai house price trend chart	0.53	0.000	Mortgage rate calculator	0.74	0.000
China building materials website	-0.47	0.000	Mortgage calculator	0.74	0.000
Floor plan design	0.47	0.000	GDP	0.72	0.000
Shanghai house price	0.46	0.000	Mortgage rate	0.71	0.000
House price website	-0.46	0.000	Mortgage	0.68	0.000
Shanghai real estate information network	-0.45	0.000	Deflation	0.65	0.000
Shanghai provident fund management center	0.45	0.000	Loan calculator	0.65	0.000
Real estate agents	0.44	0.000	Bank deposit interest	0.64	0.000
58.com rental	0.43	0.000	Deposit interest rate calculator	0.62	0.000
Housing resources	0.41	0.000	Benchmark loan rate	0.43	0.000

On the other hand, the four keywords of SouFun, Shanghai Property Website, Building Materials Website, and Public Rental Housing Information Network show a strong negative linear correlation with Shanghai monthly house prices. This phenomenon may result from a phase shift in information acquisition channels. As house prices begin to rise, buyers often prefer to obtain real estate information through non-online methods, such as consulting sales offices or real estate agents directly, for more direct, transparent, and accurate market information. Consequently, buyers who are already familiar with the market might reduce their reliance on online search platforms like SouFun and Shanghai Property Website.

The number of keyword searches usually reflects the level of public concern and anticipated demand for the real estate market. During certain periods, a surge in search volume for specific keywords may indicate that related real estate or financial policy adjustments have garnered significant public attention. With the dissemination of positive market news, such as favorable market conditions or policy changes, more people may actively participate in homebuying activities. This not only boosts the investment enthusiasm of existing buyers but also attracts new potential buyers, increasing overall market demand and driving up house prices.

3.3 Construction of the Public Attention Index

Based on principal component analysis and data dimensionality reduction methods, this study constructed the Public Attention Index.

3.3.1 Introduction to Principal Component Analysis (PCA)

Principal Component Analysis (PCA) transformed multiple correlated indicators into one or a few composite indicators, thereby reducing the dimensionality of the data and simplifying the complexity of data computation.

The basic idea of PCA is to de-mean the related data set $X = (X1, X2, X3, \ldots\ldots, Xn)$ and derive the covariance matrix XX^T, where the covariance formula is:

$$Cov(X_i, X_j) = \frac{1}{n-1}\sum_{i=1}^{n}(Xi - \bar{X}_\iota)(X_j - \bar{X}_j) \quad (1)$$

Performed eigenvalue decomposition of the covariance matrix to find the eigenvalue λ and the corresponding eigenvector *w*:

$$XX^T w_i = \lambda w_i \quad (2)$$

Taked the eigenvector corresponding to the eigenvalue of the largest target dimension and formed the projection matrix W:

$$W = (w_1, w_2, \ldots\ldots, w_k) \tag{3}$$

3.3.2 Calculation and analysis by PCA

Take keywords related to macro policy as an example, this paper used the 10 data screened by the previous correlation analysis. Let the standardized data be x_i, with the correspondence is shown in Table 4.

Table 4 Correspondence between variable names and the standardized keyword data names

x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}
Public rental housing	Public rental housing information network	Resettlement housing	Application conditions for public rental housing	Real estate policy	Real estate regulation policy	Security housing	Social housing	Price limit order	Low-Rent apartments

Transform the standardized keyword search data variables into 10 principal components. The eigenvalue analysis of the correlation matrix obtained through PCA using Minitab is shown in Table 5.

Table 5 Eigenvalue analysis of principal components

Component	Eigenvalue	Ratio	Cumulative
1	5.4737	0.547	0.547
2	1.5768	0.158	0.705
3	0.8969	0.090	0.795
4	0.6897	0.069	0.864
5	0.5189	0.052	0.916
6	0.3347	0.033	0.949
7	0.2578	0.026	0.975
8	0.1100	0.011	0.986
9	0.0765	0.008	0.994
10	0.0650	0.006	1

Conduct a comprehensive evaluation of the 10 principal components and select the component where the cumulative eigenvalue is closest to 85% as the cutoff point. The first 4 components can capture most of the data, while the remaining components contribute very little to the variance and can be ignored.

Use the first 4 components for weighted summation and calculate the final evaluation value.

$$\text{Component 1:}\ PC_1 = 0397x_1 - 0.204x_2 + 0.385x_3 + 0.303x_4 + 0.348x_5 - 0.245x_6 + 0.356x_7 + 0.314x_8 + 0.342x_9 + 0.194x_{10} \tag{4}$$

$$\text{Component 2:}\ PC_2 = -0.006x_1 - 0.541x_2 - 0.247x_3 + 0.258x_4 + 0.254x_5 + 0.056x_6 - 0.17x_7 - 0.457x_8 - 0.169x_9 + 0.496x_{10} \tag{5}$$

Component 3： $PC_3 = -0.124x_1 + 0.314x_2 - 0.194x_3 + 0.415x_4 - 0.15x_5 +$

$$0.618x_6 + 0.348x_7 - 0.031x_8 + 0.31x_9 + 0.232x_{10} \quad (6)$$

Component 4： $PC_4 = 0.271x_1 - 0.361x_2 + 0.025x_3 - 0.044x_4 + 0.284x_5 +$

$$0.634x_6 - 0.167x_7 + 0.114x_8 + 0.012x_9 - 0.52x_{10} \quad (7)$$

Finally, standardized total search volume：

$$\mathrm{TPC} = 5.4737\mathrm{PC}_1 + 1.5768\mathrm{PC}_2 + 0.8969\mathrm{PC}_3 + 0.5189\mathrm{PC}_4 \quad (8)$$

Repeat the above calculation process to obtain the principal component evaluation data for economic environment-related keywords, real estate-related keywords, and total keyword search volume data. Plot all principal component analysis results in chronological order, and the results are shown in Figure 2.

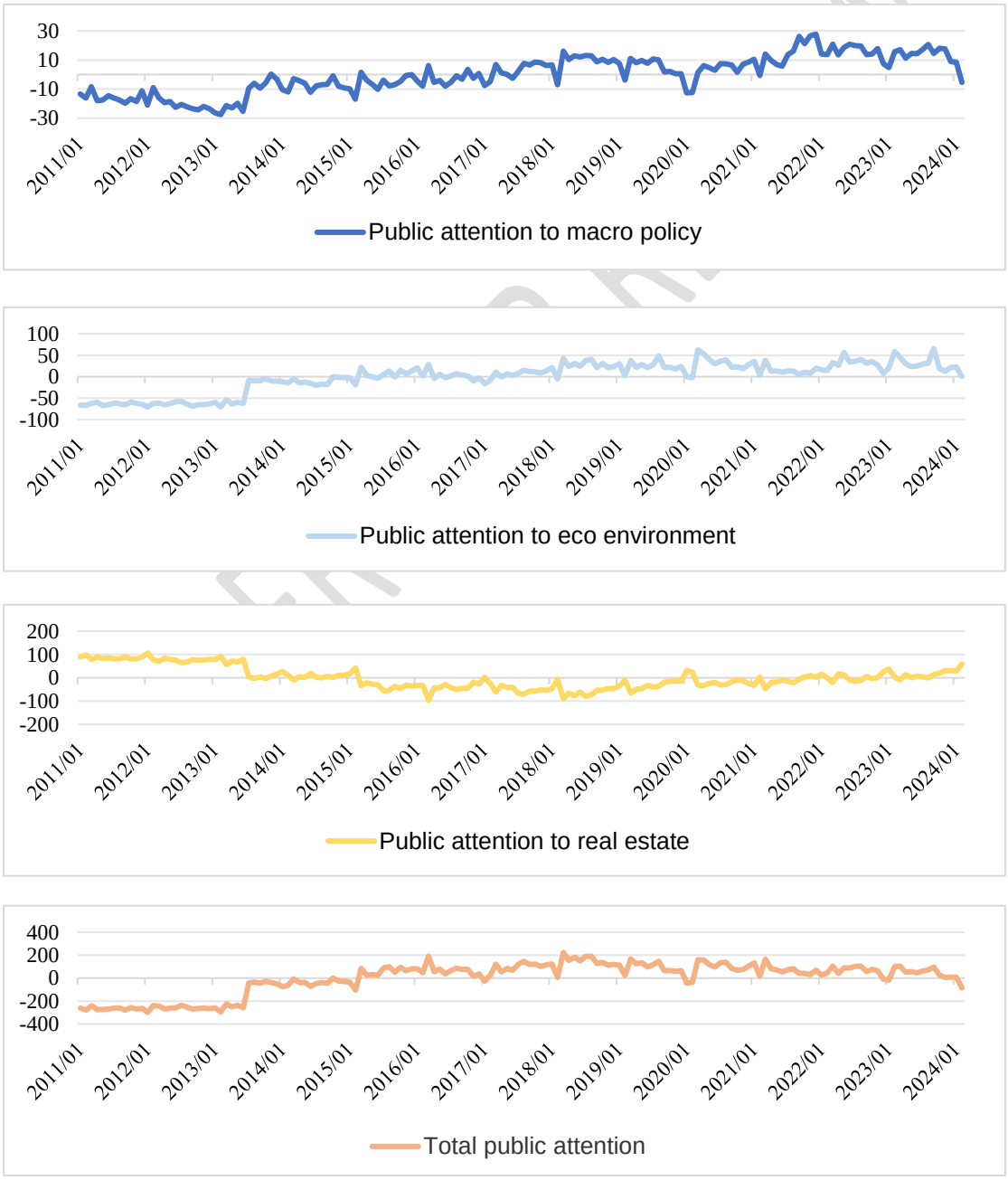


Fig. 2 Time series plots of the PCA for each type of data

Figure 2 shows that from 2011 to mid-2013, the real estate search index was higher compared to the entire period, while the total search index was relatively low, showing large negative values. During this period, China experienced its first adjustment in house prices, leading to increased public attention to real estate policies. In June 2013, the total search index rebounded to average levels, while the real estate search index decreased to average levels. In the same year, house prices in Shanghai saw a significant increase, entering a second phase of sustained growth, which might have heightened residents' perception of real estate changes and boosted the search index. From the second half of 2013 to the end of 2014, all search indices stabilized around the average. During this time, house prices rose steadily without the sharp increase seen in mid-2013, which aligns with the stable search indices. After the end of 2014, the real estate search index remained below average until the end of 2021, while the total search index increased, showing phase fluctuations with peaks in early 2016, 2018, and early 2020. The macro policy and economic environment search indices were relatively stable, close to average levels. Regarding house prices, there was a sharp increase in mid-2016, remaining high until 2018, with a slight rise from the second half of 2017 to mid-2020, followed by another significant increase in 2020, and then entering a third adjustment period with increased price fluctuations. As a whole, changes in house prices align with fluctuations in the search index.

Overall, the real estate search index and the total search index showed significant fluctuations throughout the entire period, while the fluctuations in the macro policy and economic environment search indices were relatively small. The changes in key time periods and time points are more consistent with the changes in Shanghai house prices, the country's major real estate policies and their periods. Prior to 2016, changes in house prices tended to precede changes in the search index, and preliminary analysis indicates a relationship between public attention and real estate prices. Thus, before 2016, fluctuations in house prices predominantly drove changes in the search index, and residents perceived market risks mainly through changes in house prices with a certain lag. After 2016, the dominant role of house prices in influencing search index weakened, and the two began to influence each other.

4 Model construction of TVP-VAR and empirical analysis

4.1 Introduction to the TVP-VAR model

So far, widely used dynamic measurement models for assessing systemic spillover effects include the rolling window VAR model and the Time-Varying Parameter Vector Autoregression (TVP-VAR) model. The advantage of the latter is that it avoids issues associated with the rolling window VAR model, such as arbitrary selection of the rolling window size, sensitivity to outliers, and loss of effective observations during the modeling process. Therefore, this study employs the TVP-VAR model to investigate the spillover effects between public attention and regional house prices. The TVP-VAR model used is as follows:

$$y_t = \varphi_{0t} + \varphi_{1t} y_{t-1} + \varphi_{2t} y_{t-2} + \cdots + \varphi_{pt} y_{t-p} + \varepsilon_t \quad (9)$$

where p is the lag order and ε_t is a white noise vector with a mean of zero.

Following the approach of Antonakakis N (2020), the level of house prices spillover $C^{H}_{i \to j,t}$ at moment *t* from variable *i* to variable *j* under forecast period *H* can be defined as:

$$C_{i\to j,t}^{H} = \frac{\phi_{i\to j,t}^{H}}{\sum_{i=1}^{M} \phi_{i\to j,t}^{H}} \tag{10}$$

Based on $C_{i\to j,t}^{H}$, the net spillover index $NC_{i\to j,t}^{H}$ of variable *i* to variable *j* at time *t* can be further measured:

$$NC_{i\to j,t}^{H} = \left(C_{i\to j,t}^{H} - C_{j\to i,t}^{H}\right) \times 100 \tag{11}$$

Based on the spillover index $C_{i\to j,t}^{H}$, we can further measure the spillover index $C_{it,to}^{H}$ of variable *i* to all other variables in the system at time *t*, the spillover index $C_{it,from}^{H}$ that variable *i* receives from all other variables in the system, and the net spillover index $C_{it,net}^{H}$ that variable *i* receives to all other variables in the system (Sayed and Charteris 2022).

$$C_{it,to}^{H} = \sum_{j=1,j\neq i}^{M} C_{i\to j,t}^{H} \times 100 \tag{12}$$

$$C_{it,from}^{H} = \sum_{j=1,j\neq i}^{M} C_{j\to i,t}^{H} \times 100 \tag{13}$$

$$C_{it,net}^{H} = C_{it,to}^{H} - C_{it,from}^{H} \tag{14}$$

4.2 Modeling ideas and process

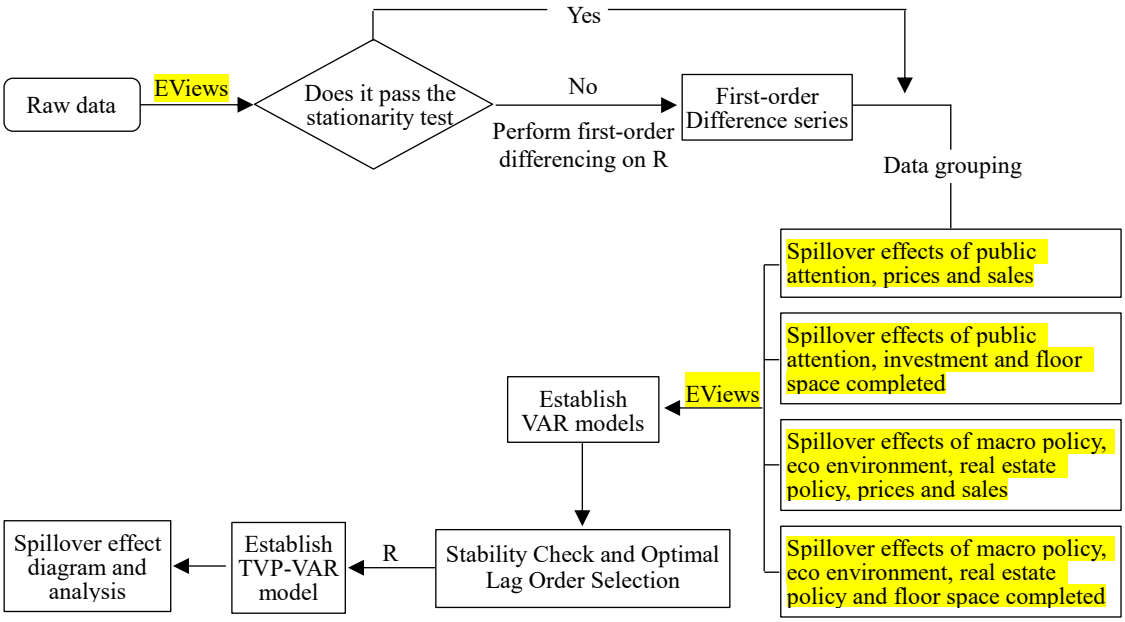


Fig. 3 Flowchart of TVP-VAR modeling

4.3 Visualization and analysis of spillover effect results

4.3.1 Spillover effects of public attention, prices and Sales

Based on the comprehensive consideration of LR, FRE, AIC, SC, and HQ criteria, the lag order p of the TVP-VAR model is set to 5, with the default forecast period being 10.

a) Total spillover effects

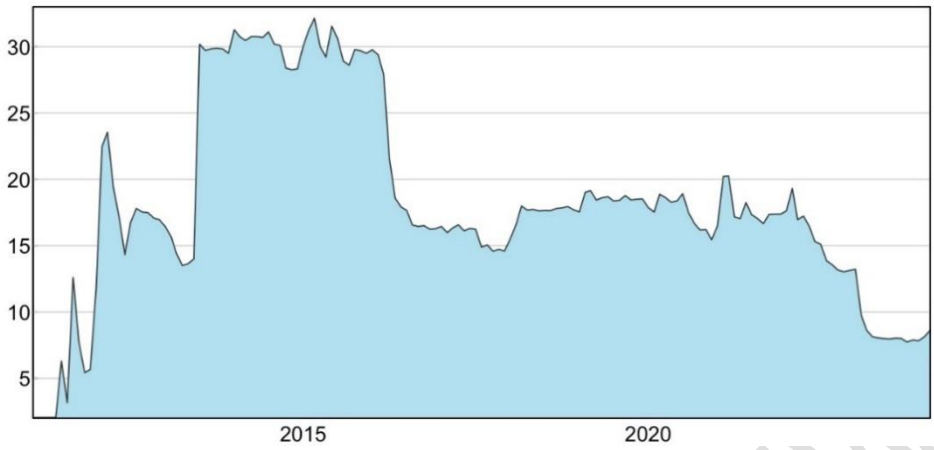


Fig. 4 Total spillover effects of public attention, prices and sales

Figure 4 shows that the total spillover index of public attention, house prices, and sales fluctuated significantly throughout the entire period. It began to rise steadily from mid-2011 to early 2013, then sharply declined in early 2016. Afterward, it showed fluctuations around the previous peak level, with a notable weakening of the total spillover effect starting in 2022, which has remained stable since 2023. The total spillover effect is divided into four segments at 2013, 2016, and 2022, so the following analysis will delve into the directional spillover effects, net spillover effects and net pairwise spillover effects for these four periods (Gao 2021).

b) Directional spillover effects

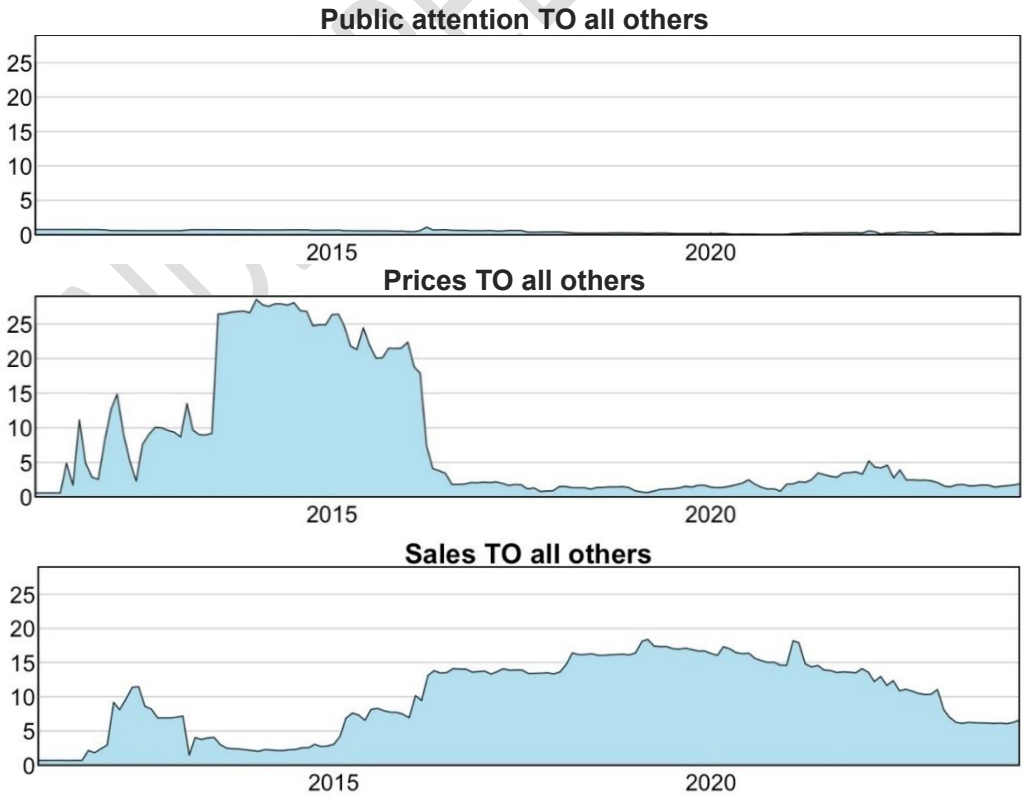


Fig. 5 Spillover effects of public attention, prices and sales

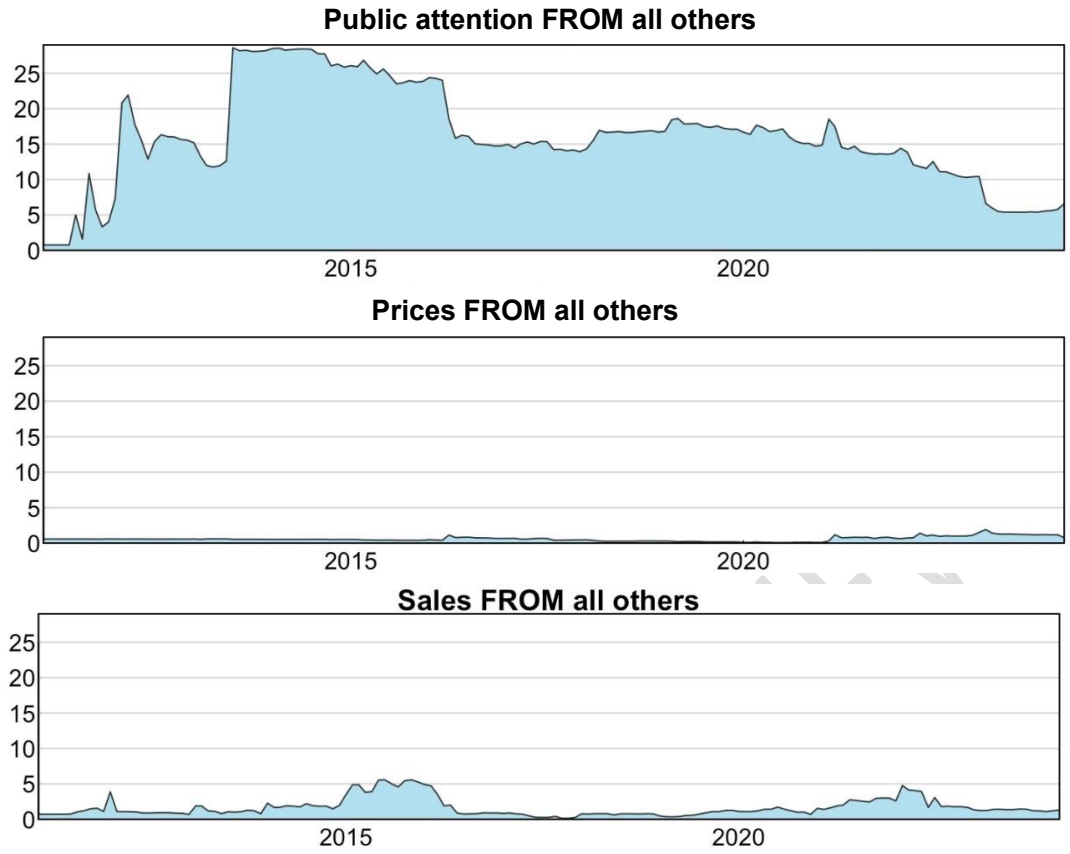


Fig. 6 Spill-in effects of public attention, prices and sales

Figure 5 indicates that the spillover effect of public attention on house prices and sales is relatively weak and shows no significant fluctuation. Conversely, the spillover effect of house prices on public attention and sales is notably higher. The changes in the first two time periods are similar to the total spillover effect graph, which also corresponds to the four trillion investment stimulus plan in 2009, and the 2010 real estate boom. In the latter two periods, the impact weakened and stabilized, benefiting from the clear housing policy encouragement in 2016.

The first part of Figure 6 shows that public attention is influenced by the spill-in effects from house prices and sales, with significant fluctuations. It presents four time periods similar to the total spillover effect graph. In the second part, the spill-in impact on house prices from other system factors is minimal and stable. Additionally, the spillover effects of the first two factors on sales are relatively minor, with market demand from 2015 onwards increasing public attention.

c) Net spillover effects

According to the net spillover effects figure, the influence of public attention, house prices, and sales on the system can be judged. In Fig. 7, the net spillover index of public attention is negative for the whole period, so it behaves as a receiver of shocks in the system, while house prices and the sales act as transmitters. In addition, the trends, fluctuations, and peaks in the net spillover effects of public attention, house prices, and sales are generally consistent with the spillover effects of each factor on the others, although some periods show reductions due to positive spill-in shocks from the other two factors.

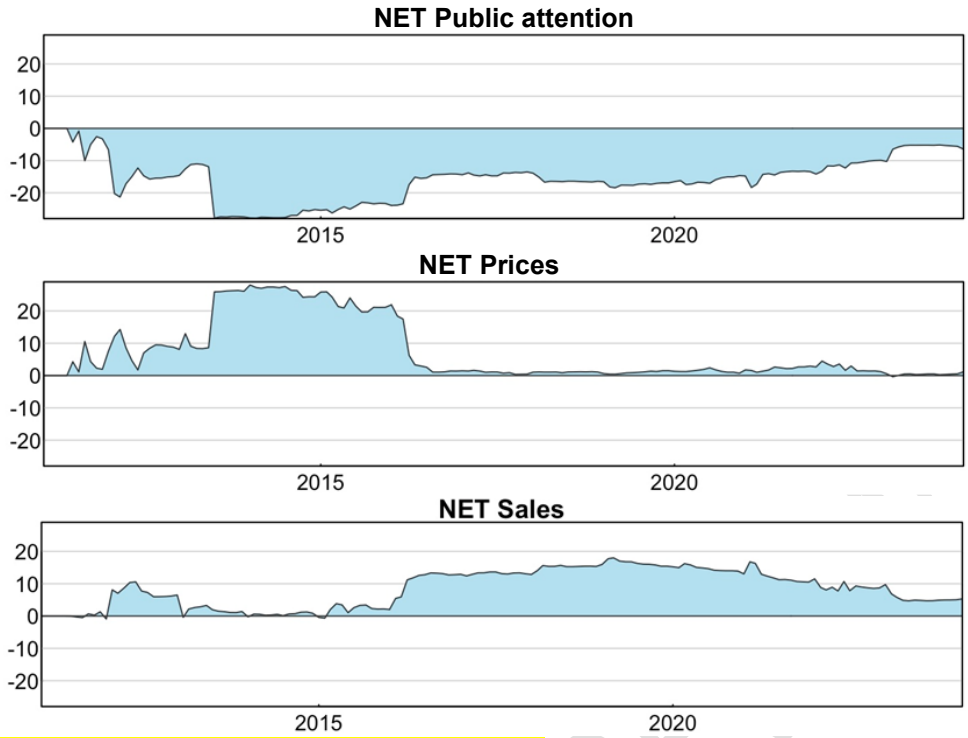
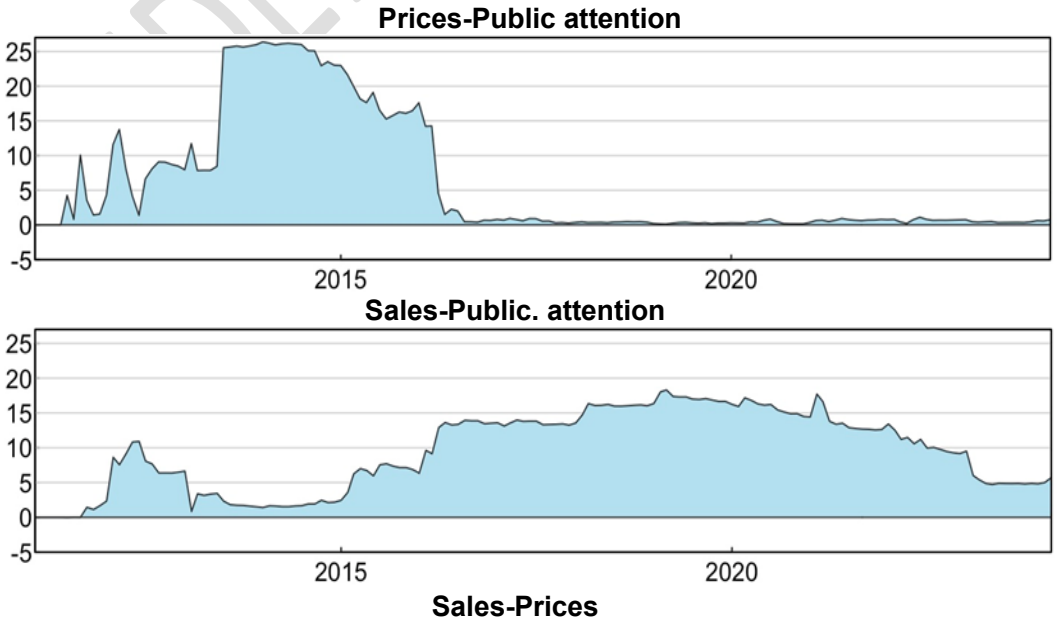


Fig. 7 Net spillover effects of public attention, prices and sales

d) Net pairwise spillover effects

According to the image of net pairwise spillover effects, the dominant relationships among public attention, house prices, and sales are clearly shown. In Figure 8, house prices have been dominant, while public attention is in the dominated state, and the role of sales is also evident. Combined with Figure 5, it is observed that the impact of house prices on other system factors mainly manifests through public attention, and this also supports the previous analysis of the public media attention behavior out of control. Additionally, house prices influence sales, while sales have a dominant effect on public attention, aligning with the analysis of increased housing demand in 2015.



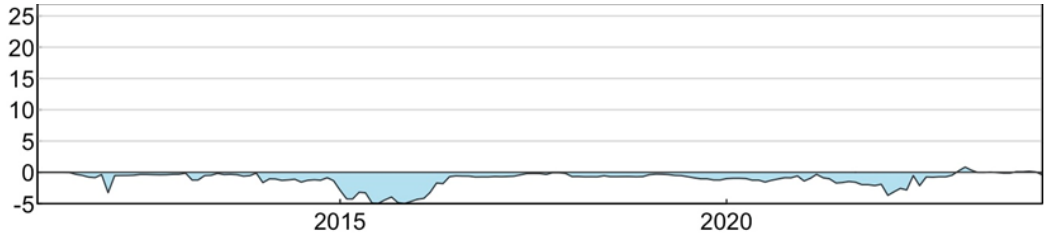


Fig. 8 Net pairwise spillover effects of public attention, prices and sales

4.3.2 Spillover effects of public attention, investment and floor space completed

Note that the TVP-VAR model is set with a lag order of 5 and a default forecast period of 10.

a) Total spillover effects

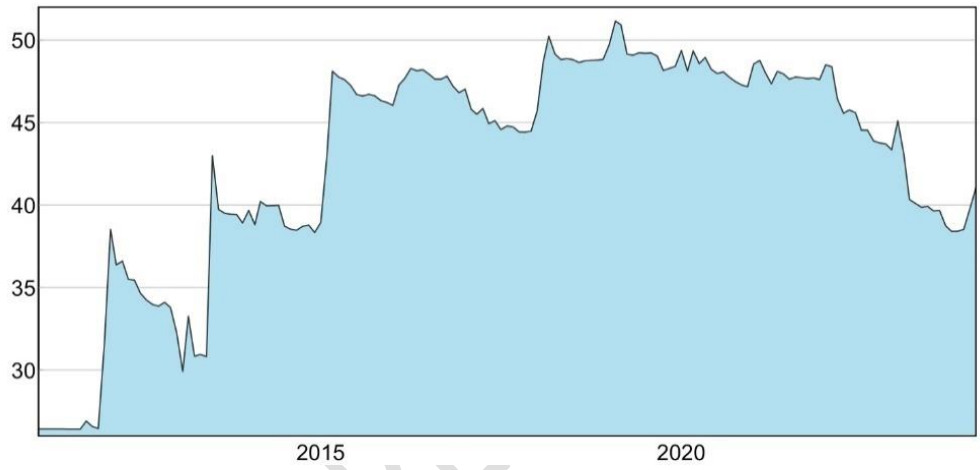
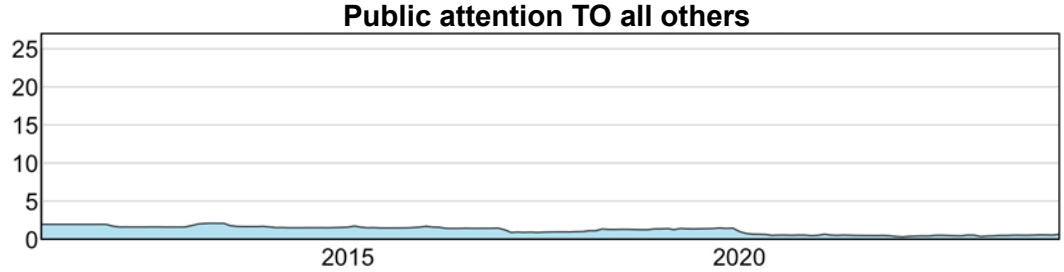


Fig. 9 Total spillover effects of public attention, investment and floor space completed

Figure 9 shows that the total spillover index of public attention, investment, and floor space completed fluctuates significantly, with a noticeable trend of periodic surges and subsequent declines since 2012. Specifically, there were large fluctuations in early 2012, mid-2013, early 2015, early 2018, and early 2023, with an overall trend of rising and then correcting downward.

b) Directional spillover effects

Public attention has a relatively weak and continuously decreasing impact on other factors within the system. In contrast, its reception of impacts from other factors has been relatively strong and continuously increasing. The total spillover effects of investment and floor space completed on other system factors is significant and show an upward trend, while the level of impact received by both remains stable at a moderate level.



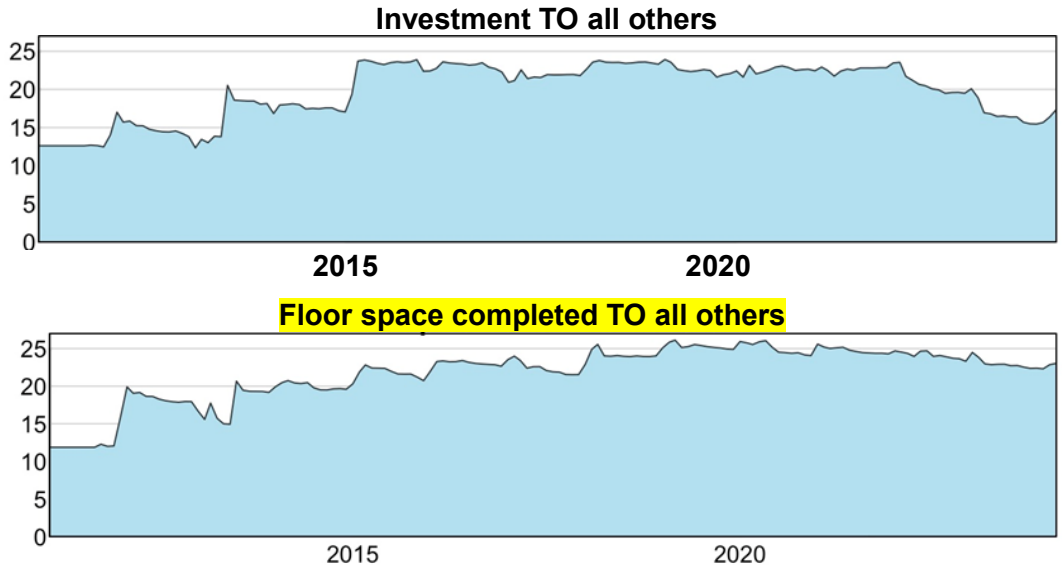
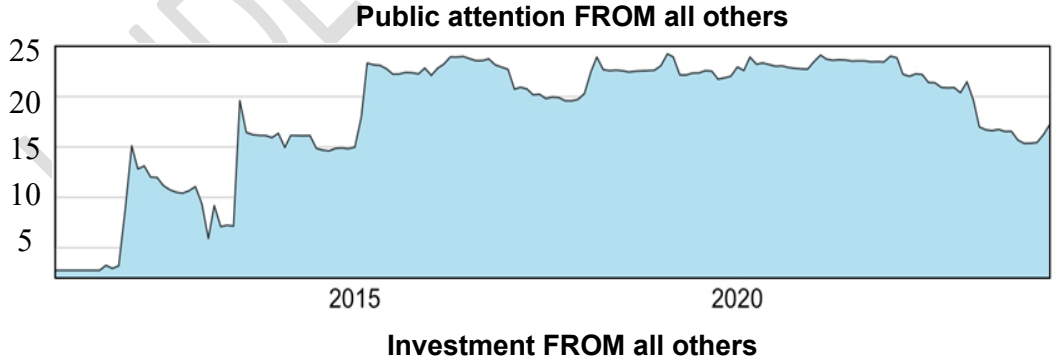


Fig. 10 Spillover effects of public attention, investment and floor space completed

In Figures 10 and 11, the early period shows a generally upward trend with fluctuations. This is evident as the real estate industry's bull market before 2017 expanded the influence of investment and construction activities on public attention. In the later period, the trend mostly shows stable fluctuations and then declines, likely due to the formal introduction of "housing is for living in, not speculation" in the national two sessions in March 2018, coupled with the impact of the COVID-19 pandemic on China's economy and financial markets, leading to a cooling of credit flows into the real estate sector (Bei and Wang 2023). Particularly, the COVID-19 pandemic had a disastrous impact on China's real estate investment and construction activities. According to the National Bureau of Statistics of China, Shanghai's real estate investment declined by 8.2% year-on-year in the first quarter of 2020, and the area of new residential construction declined by 44.3% year-on-year, as evidenced by the impact on the completion of construction. The complex and changing market environment and policy changes in the later period also contributed to the heightened and volatile public attention.



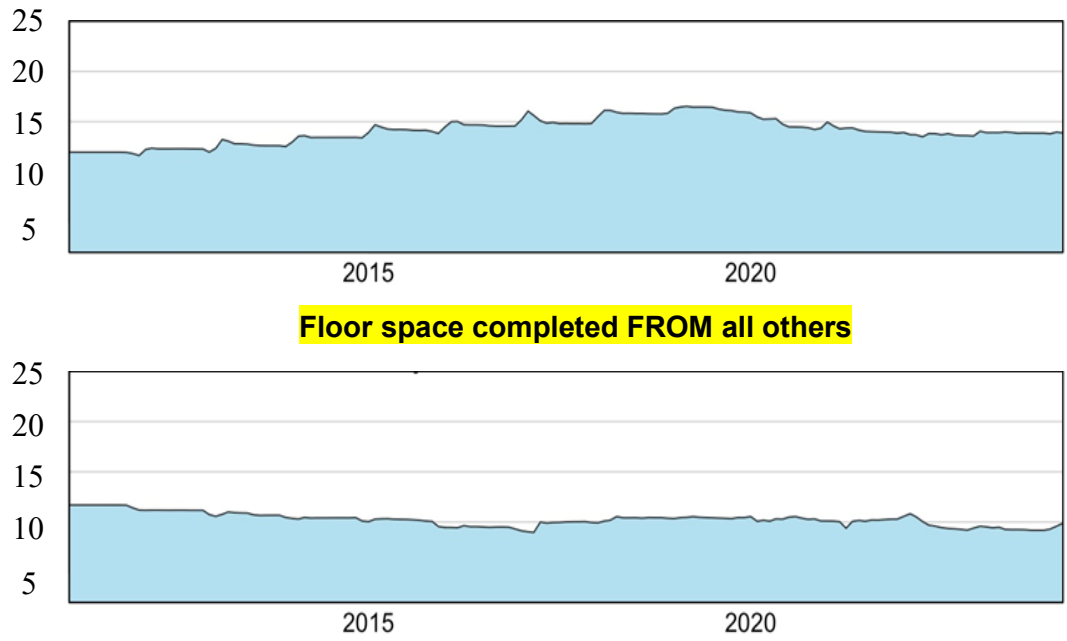


Fig. 11 Spill-in effects of public attention, investment and floor space completed

c) Net spillover effects

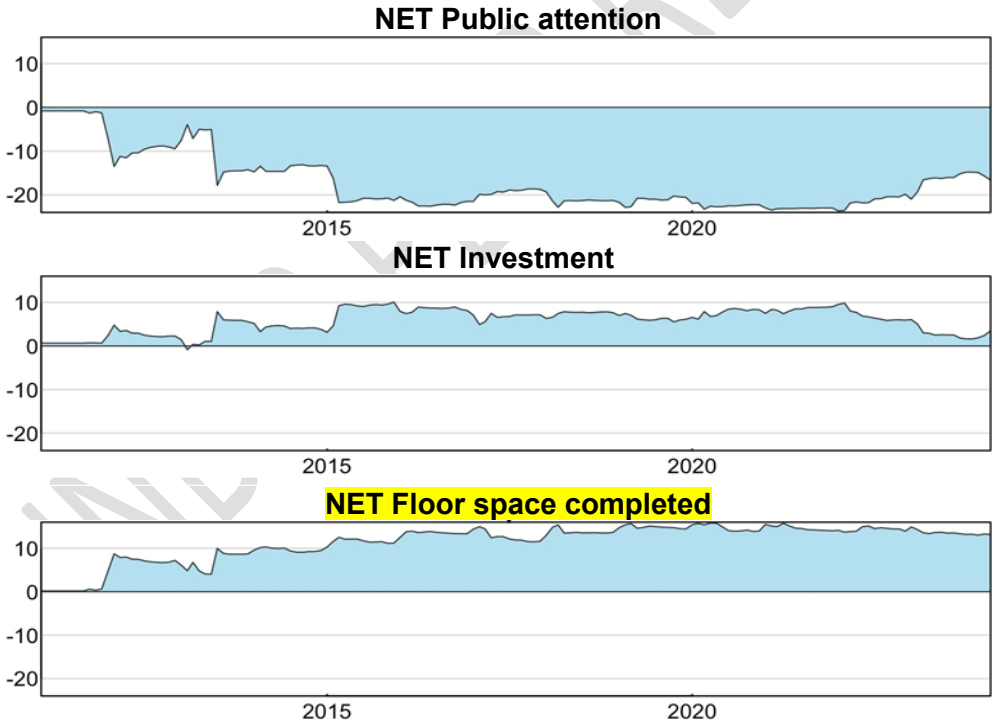


Fig. 12 Net spillover effects of public attention, investment and floor space completed

Figure 12 shows that housing investment and construction activities are primarily sources of shocks in the system, while public attention acts as a receiver of shocks.

d) Net pairwise spillover effects

According to Figure 13, investment and floor space completed dominate the spillover effects with public attention, while among the pairs formed by the first two, the influence of floor space completed is more pronounced. This is because the real estate industry has always

been a crucial pillar of China's economy (Li 2021). The influx of significant social and economic resources inevitably attracts public attention, and the completion of construction activities is not only the basis for investors' confidence in returns and future investment activities but also a channel for the public's perception of the stability within the real estate market.

Based on the empirical analysis of the first two sections, it is found that the spillover effect of public attention is not significant in the systems involving it. This is likely because the principal component analysis method combines evaluation results, where the input of too many indicators may cause the impact effects of some indicators to be overlooked or offset during the measurement process. In order to better explore its spillover effects on house prices, sales, investment, and floor space completed, this paper decomposes the total public attention indicator into three indicators, namely, macro policy perception, real estate policy perception, and economic environment perception, then groups them again and conducts a further empirical analysis in sections three and four to investigate clearer shock effects and more specific sources of impact.

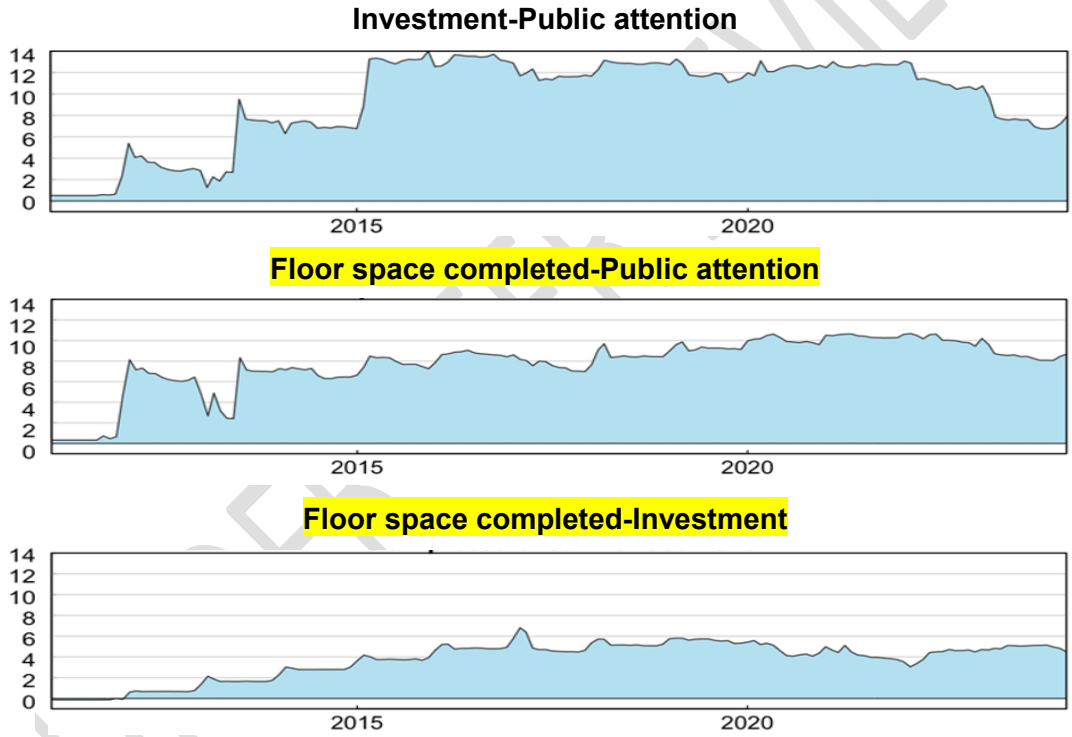


Fig. 13 Net pairwise spillover effects of public attention, investment and floor space completed

4.3.3 Spillover effects of macro policy, eco environment, real estate policy, prices and sales

In this section, the lag order *p* of the TVP-VAR model is set to 7, with the default forecast period being 10.

a) Total spillover effects

Fig. 14 Total spillover effects of macro policy, eco environment, real estate policy, prices and sales

From Figure 14, it can be seen that the total spillover indices of public attention on macro policy, economic environment, and real estate with house prices and sales have three periods of rapid change and two periods of oscillating plateau in the whole time period. It surged dramatically starting from mid-2011, entered a high-level oscillation plateau in 2012, and remained high until 2016. During this period, there was a downward trend in 2013 and 2015, with a peak in 2014. A significant decline occurred in 2016, continuing until 2018. In 2018, a slight increase was observed, entering a low-level oscillation plateau, and started a fluctuating downward trend from 2023, continuing to decline. Therefore, the following section will focus on the directional spillover effects, net spillover effects and net pairwise spillover effects of these three time points and one time period.

b) Directional spillover effects

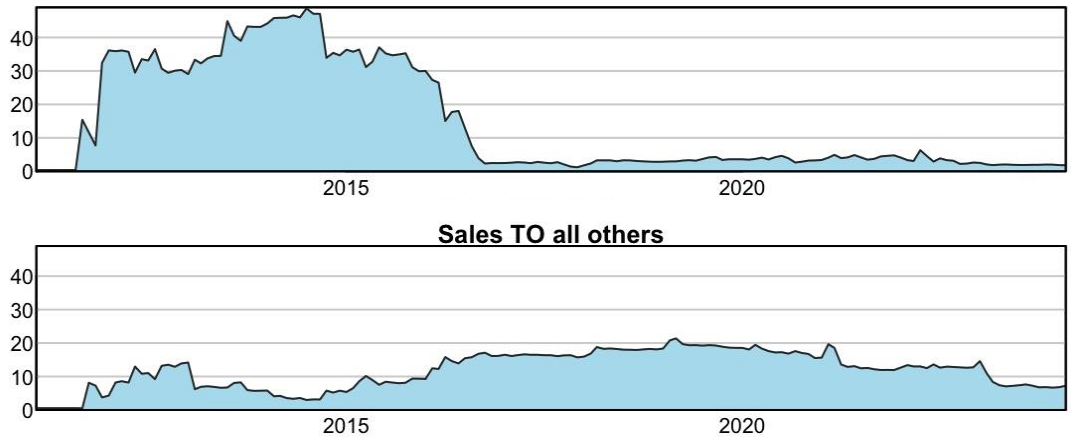
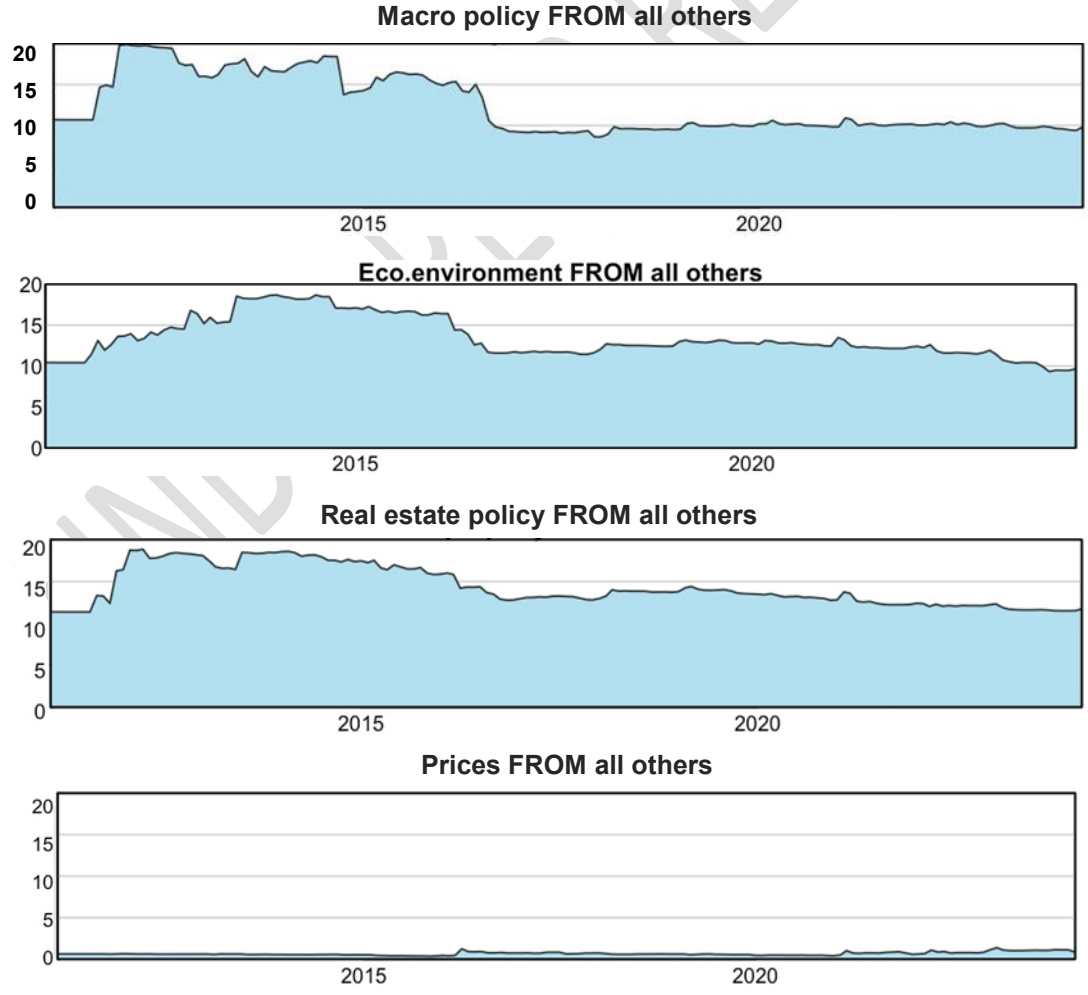


Fig. 15 Spillover effects of macro policy, eco environment, real estate policy, prices and sales

In Figure 15, the spillover effects of public attention on real estate policy, economic environment, and macro policy are not significant and follow similar trends. In contrast, the spillover effects of house prices on the three public attention factors, as well as residential sales, are clearly noticeable. The spillover effects of house prices are similar to the changes observed in the total spillover effects during the earlier period, and the spillover effects of sales align with the total spillover effects in the later period.



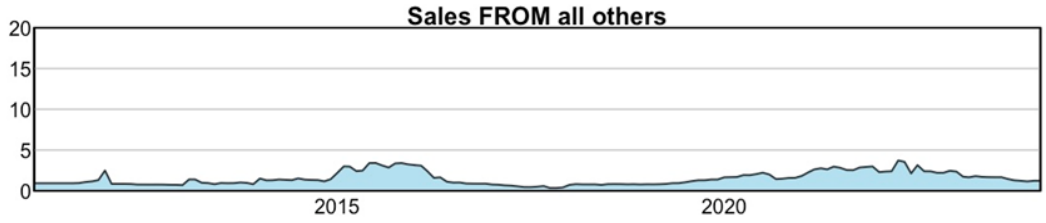
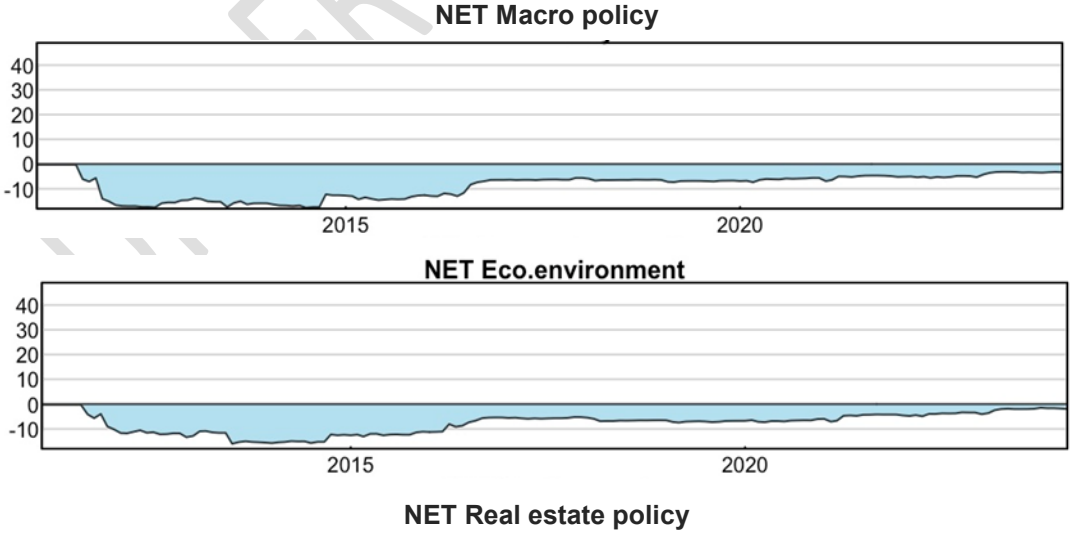


Fig. 16 Spill-in effects of prices and sales on macro policy, eco environment and real estate policy

In Figure 16, the three public attention related variables experience significant spillover effects from other factors, particularly during the periods from 2013 to 2015 and from 2017 to 2023. House prices and sales are subject to small spill-in from public attention factors, with sales subject to spill-in that partially increase in 2016 and 2020.

In practical terms, in 2012, the central bank's announcement of reduced reserve requirements and interest rates led to a surge in house prices (Chen 2021). This increase in house prices became a major factor in public attention. In 2014, the peak of the house price influence was likely due to the policy of "Recognize the house, not the loan", which further increased house prices and public attention. By 2016, with the easing of home-buying policies and the introduction of the concept "housing is for living in, not speculation"[4], the impact of rising house prices on homebuyers diminished. In 2018, the concentration of the real estate industry and the cooling of the sector shifted public attention from house prices to sales. In 2020, the influence of sales on public attention decreased due to the crisis of some real estate companies.

c) Net spillover effects



[4] The "Recognize the house, not the loan" policy was introduced in the notice titled "Notice on Optimizing the Criteria for Determining the Number of Housing Units in Personal Housing Loans", which was jointly issued by the Ministry of Housing and Urban-Rural Development, the People's Bank of China, and the National Financial Regulatory Administration on August 25, 2023.
"Recognize the house, not the loan" means that regardless of whether there has been a loan, as long as there is no property under the name of the current, can be based on the first mortgage loan to enjoy the down payment ratio and interest rate concessions.

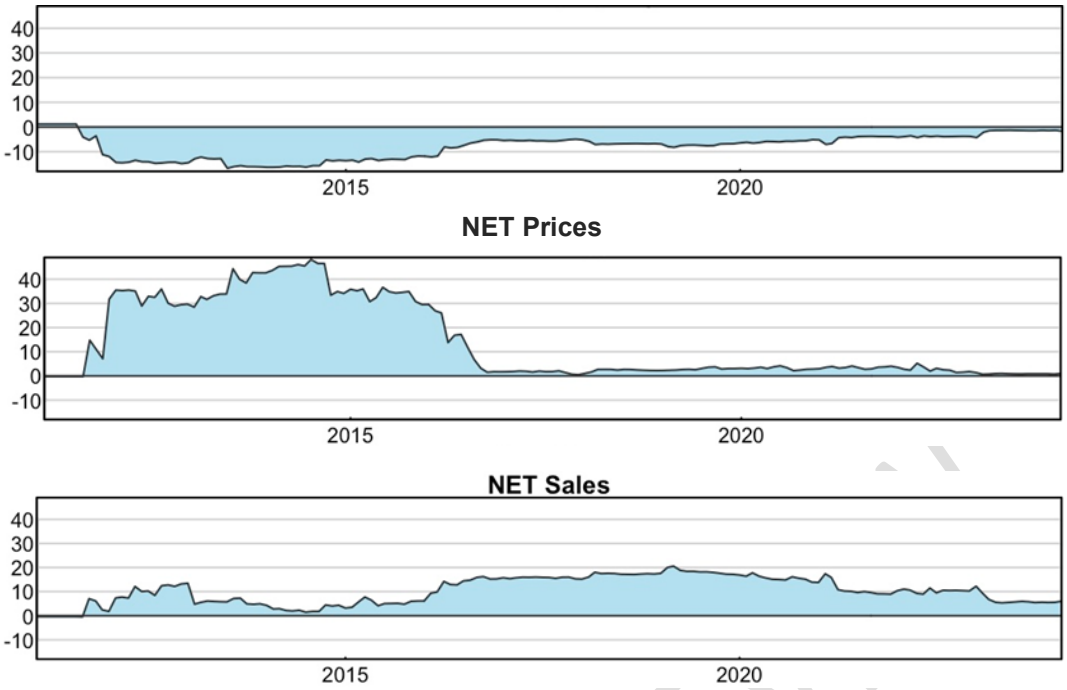
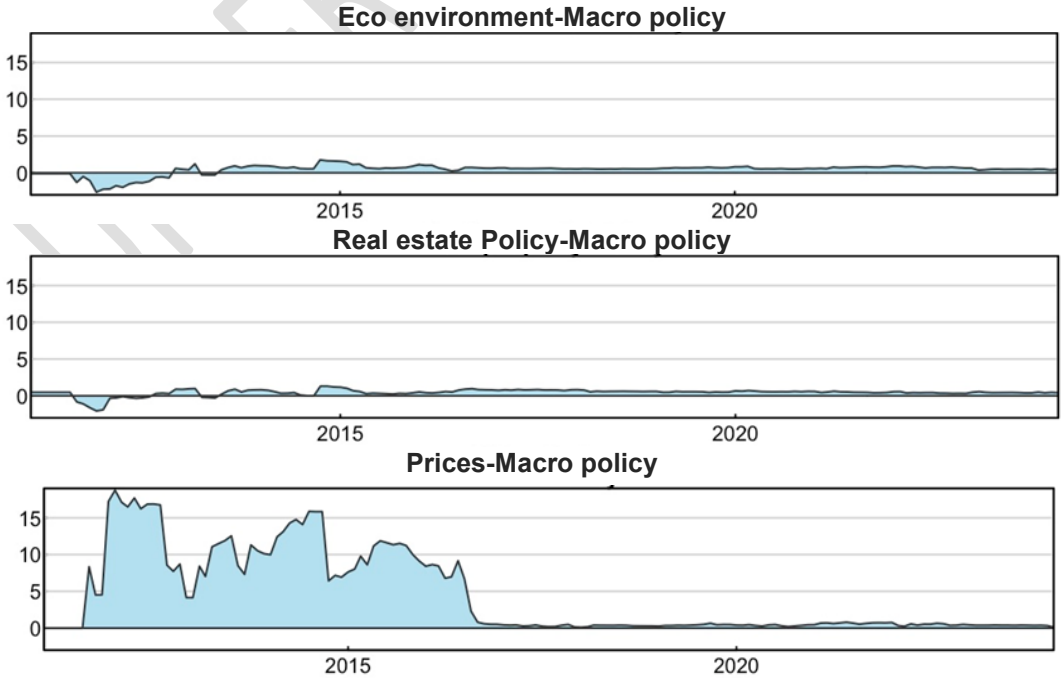


Fig. 17 Net spillover effects of macro policy, eco environment, real estate policy, prices and sales

According to Figure 17, it can be seen that the three variables of public attention, namely, macro policy, economic environment, and real estate are recipients of shocks, influenced by changes in house prices and sales, and all three are affected by similar shocks. Meanwhile, house prices and sales are the emitters of shocks, particularly influencing public attention from 2012 to 2015 and from 2017 to 2023. This is consistent with the spillover effects observed in Figure 15. This indicating that house prices and sales jointly influence public attention towards macro policy, economic environment, and real estate policies.

d) Net pairwise spillover effects



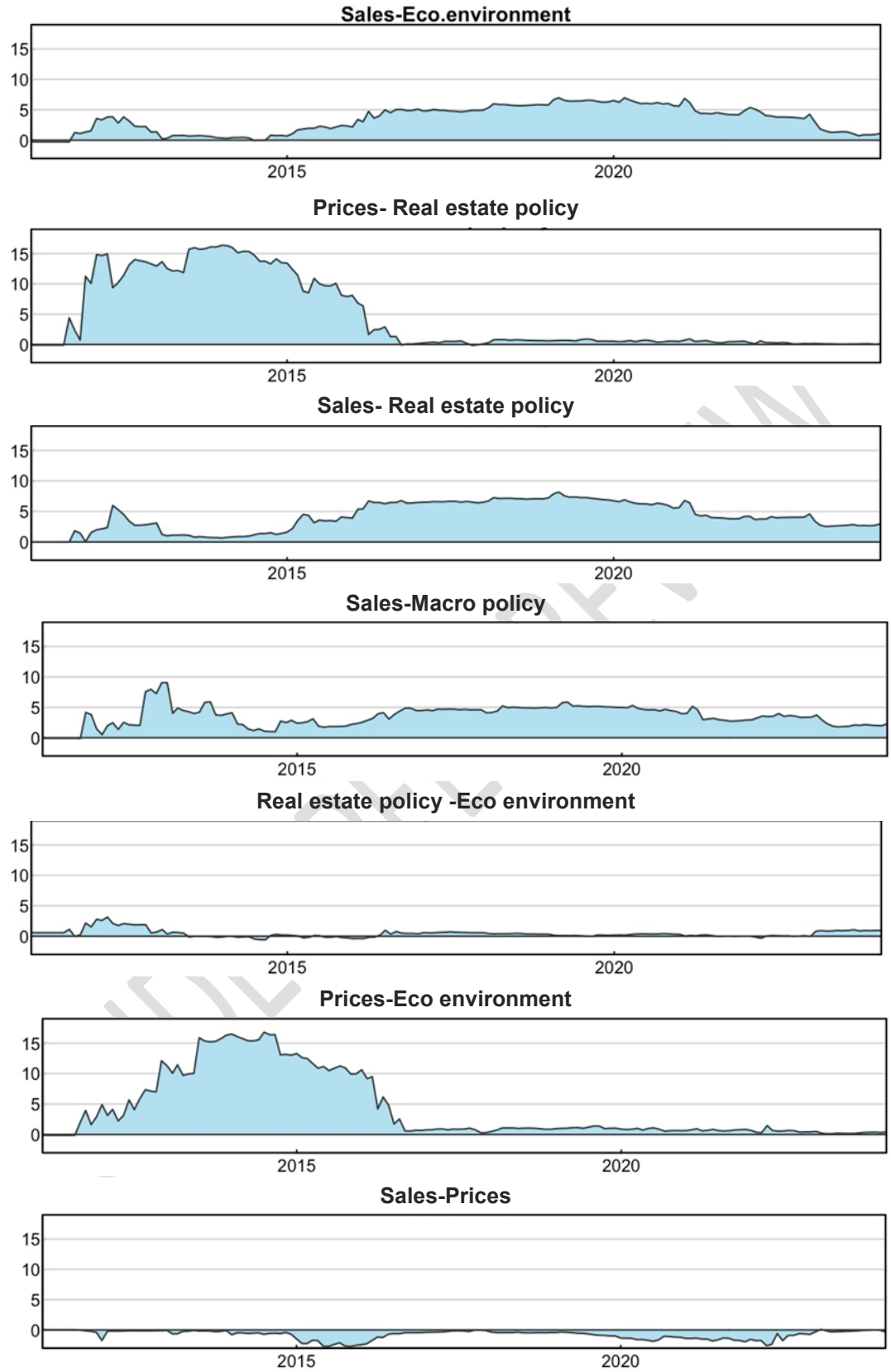


Fig. 18 Net pairwise spillover effects of macro policy, eco environment, real estate policy, prices and sales

Figure 18 shows that house prices dominate the three variables of public attention to macro policy, economic environment and real estate, and the dominant role is concentrated in 2012 to

2015, with similar effects on all three. Similarly, housing sales also dominate these three variables of public attention, with a more modest influence between 2018 and 2023 compared to house prices. This aligns with the total and net spillover effects. Notably, the spillover effect of house prices on sales was higher in 2015 and 2022, reflecting significant house price fluctuations and relatively lower sales volumes during these periods.

4.3.4 Spillover effects of macro policy, economic environment, real estate policy and floor space completed

In this section, the lag order p of the TVP-VAR model is set to order 4, with the default forecast period being 10.

a) Total spillover effects

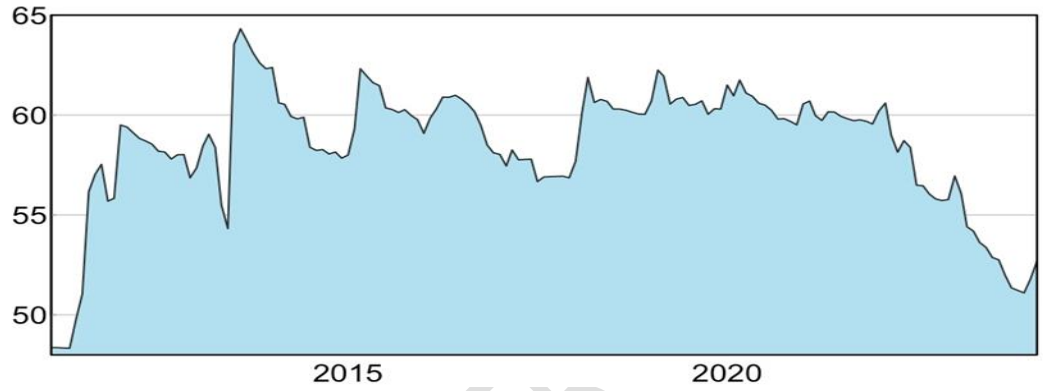
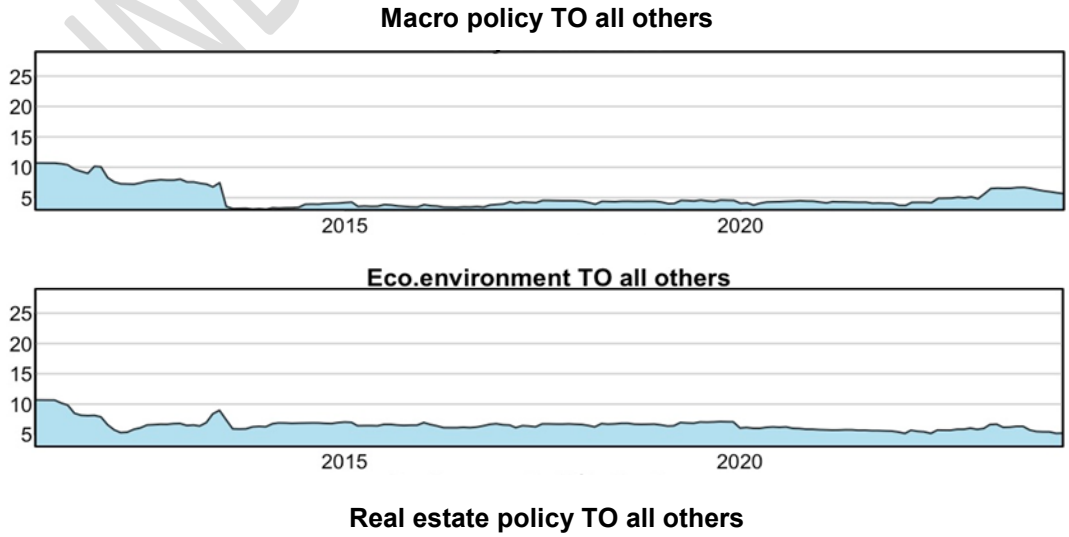


Fig. 19 Total spillover effects of macro policy, eco environment, real estate policy, investment and floor space completed

Figure 19 shows that the total spillover index of each variable exhibited overall high fluctuations during the selected time period, except for the initial and final periods. Initially, the index experienced a significant increase, then remained at a relatively high level. It decreased consecutively in 2013, 2015, and 2017, followed by a surge and stabilization. Finally, from 2022 onwards, the index began to show a gradual decline, eventually reaching a trough.

b) Directional spillover effects



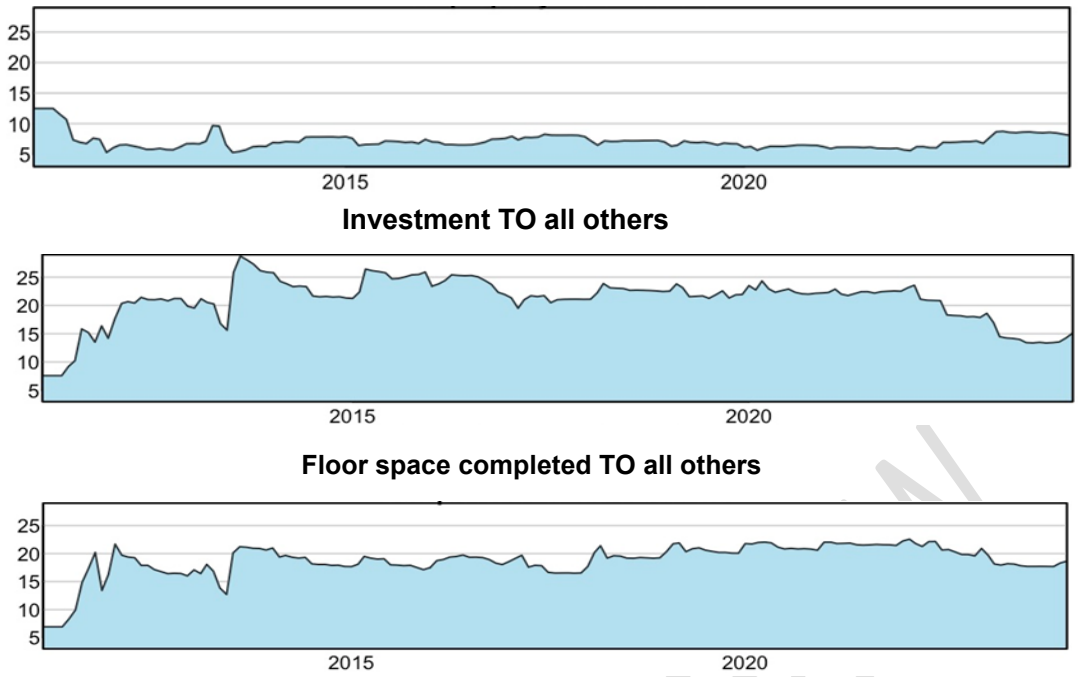
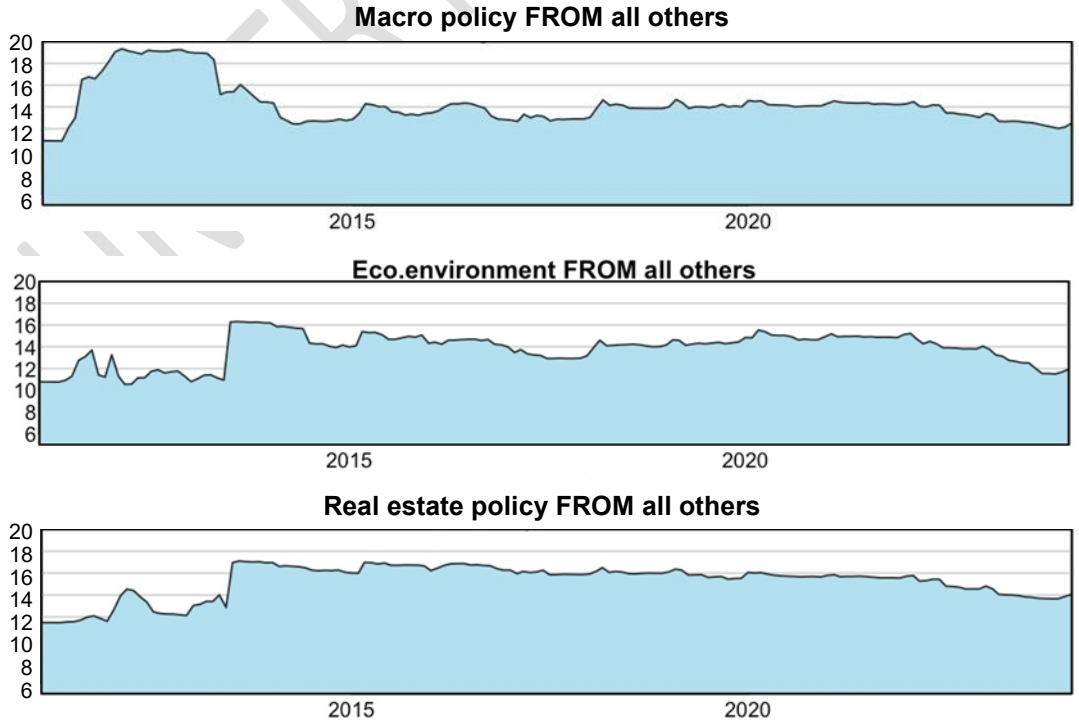


Fig. 20 Spillover effects of macro policy, eco environment, real estate policy, investment and floor space completed

Figure 20 shows that the positive shock effects of macro policy, economic environment and real estate policy, which are the three variables of public attention, on the investment and floor space completed are small and relatively stable over the time period. In contrast, the positive shock effects of investment and floor space completed on the three public attention variables were more pronounced, especially for investment, whose spillover effect trend closely matched the overall spillover effect trend. This highlights the significant influence of investment and floor space completed in this system.



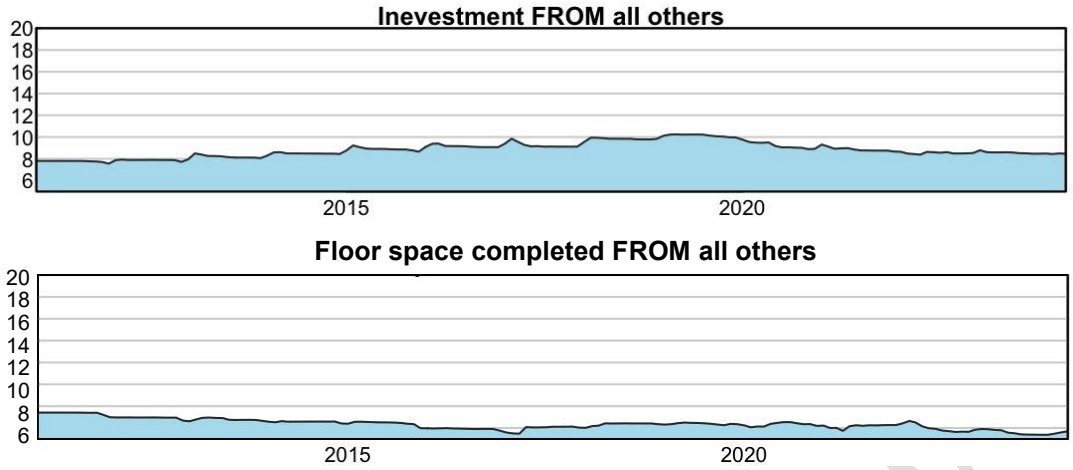
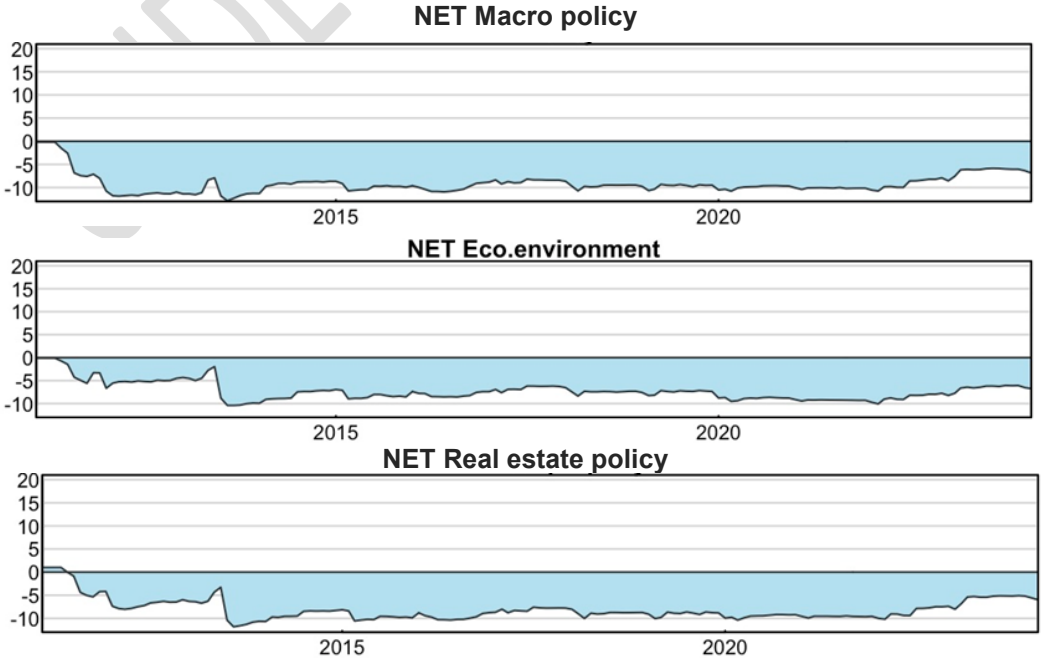


Fig. 21 Spill-in effects of macro policy, eco environment, real estate policy, investment and floor space completed

Figure 21 presents the public attention to macro policy, economic environment and real estate policy is greatly affected by the spill-in of investment and floor space completed, while the latter two are relatively less affected by the spill-in effect of other variables and are relatively smooth. This observation complements and explains the spillover effects of the five variables.

Specifically, in late 2013, government measures such as differentiated credit policies, adjustments to down payment rates, and frequent reserve requirement increases led to a significant drop in house prices, which directly affected the investment activities of real estate developers and the area of completion. Subsequently, the government adopted loose monetary policies, reduced reserve requirements, and lowered interest rates, which quickly stimulated sales activities and a recovery in real estate investment. Public media often closely monitors government policy changes and incorporates them into housing decisions, potentially leading to an increase in public attention. Around 2022, due to social events such as COVID-19 pandemic and the "housing is for living in, not speculation" policy, economic growth slowed, the credit environment tightened, and real estate market heat decreased, leading to a decline in public attention.

c) Net spillover effects



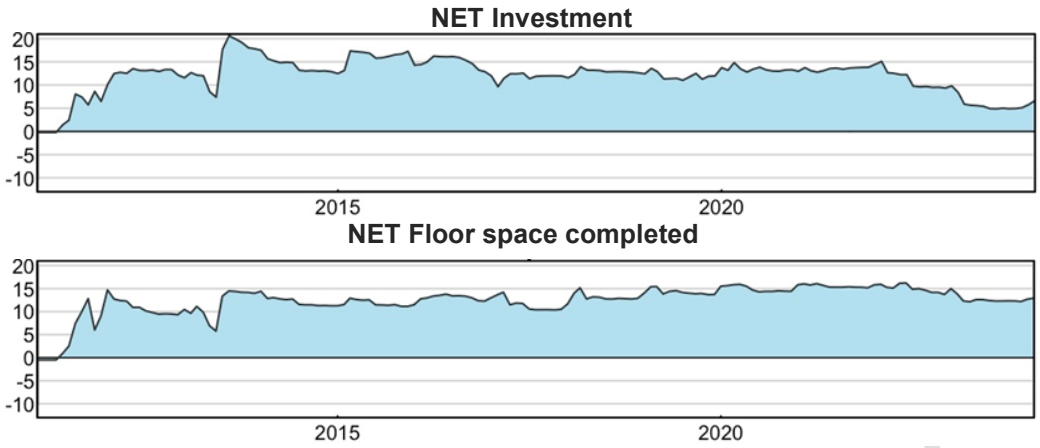
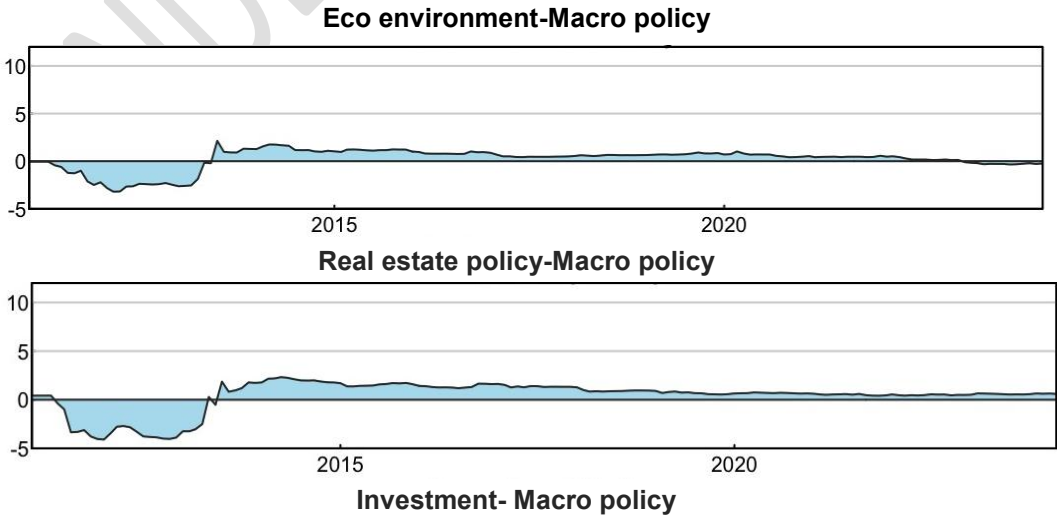


Fig. 22 Net spillover effects of macro policy, eco environment, real estate policy, investment and floor space completed

Figure 22 shows the net spillover effects for macro policy, economic environment, real estate, investment, and floor space completed. The results indicate that the three public attention indicators act as receivers of shocks, while investment and floor space completed act as emitters of shocks. The scale and speed of activities in these areas play a crucial guiding role for the entire real estate market and related economic variables. Furthermore, the trends in investment and floor space completed are highly consistent with the spillover effects, indicating their significant and stable role in the system.

d) Net pairwise spillover effects

According to the net pairwise spillover effects graph, as shown in Figure 23, investment and floor space completed have consistently played a dominant role in influencing the three variables of macro policy, economic environment, and real estate policy. This observation aligns with the understanding that investment and floor space completed are core indicators of the real estate industry and macroeconomic activities. Moreover, the fluctuations in these two variables reflect the supply and demand relationships in the real estate market. When market demand increases, investment and floor space completed typically rise accordingly, affecting the overall supply situation in the real estate market and attracting public attention.



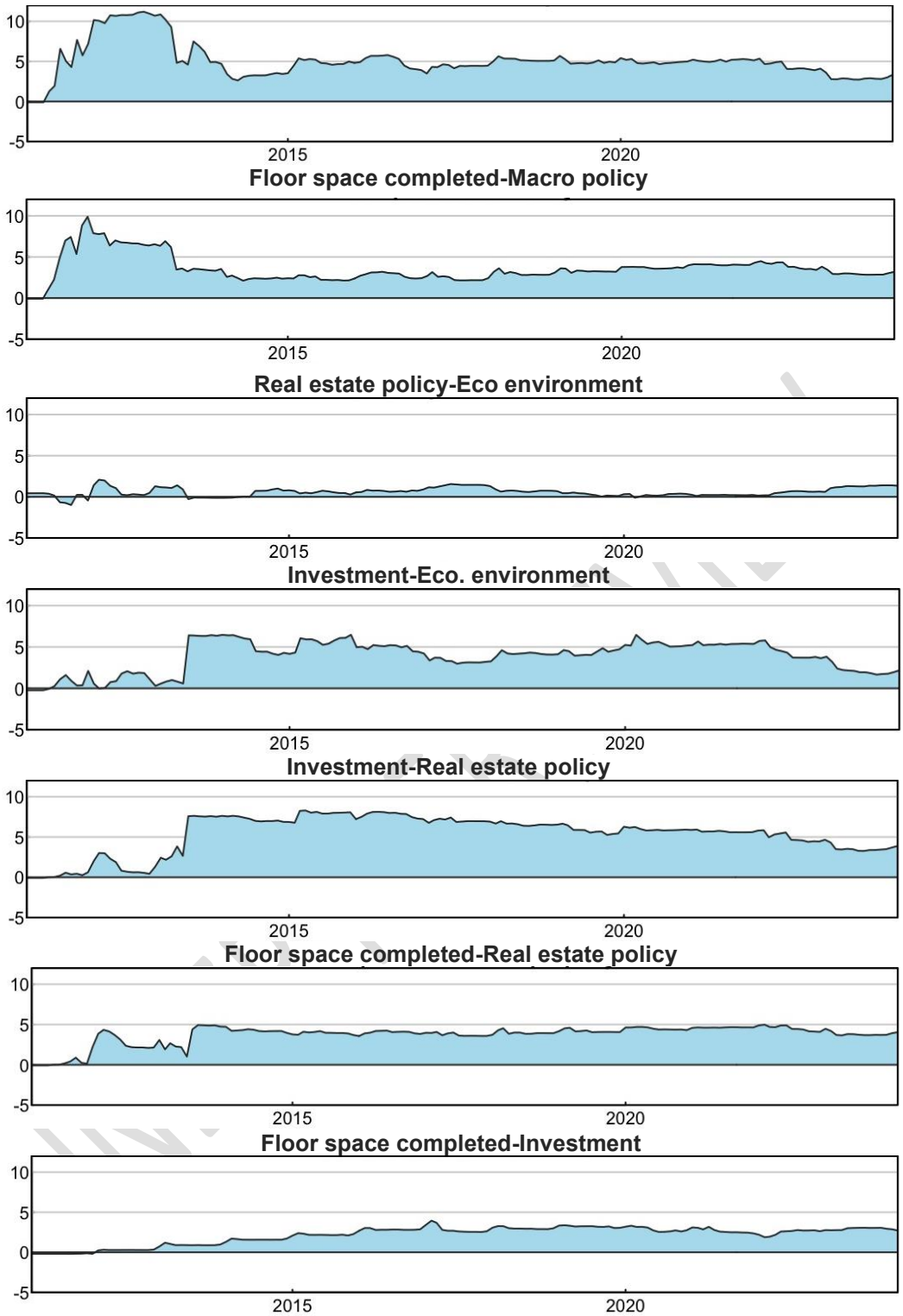


Fig. 23 Net pairwise spillover effects of macro policy, eco environment, real estate policy, investment and floor space completed

5 Conclusions

The real estate industry is closely related to the national economy, and changes in house prices are a hot topic of public attention (Dai et al. 2022). This paper collects extensive data, including 113 search index data and house prices, spanning from 2011 to 2024. Through correlation screening, principal component analysis for dimensionality reduction, and TVP-VAR model

measurement, it explores the relationship between public attention and house prices. The four experimental conclusions of the TVP-VAR model are consistent, and some align with initial data screening hypotheses. The spillover index of house prices on public attention is positive, with house prices acting as the transmitter of shocks. The sustained rise in house prices increases public attention, showing significant short- and medium-term effects, with long-term effects experiencing fluctuations from weak to strong and then weakening again. Additionally, the spillover index of public attention on house prices is negative, with public attention acting as the receiver of shocks.

From this study it has been observed that house prices influence public attention. Therefore, public attention should be included in the real estate market monitoring system. Due to the spillover effect of house prices on public attention, changes in public attention reflect both the public's views on the real estate industry and the trend of changes in the real estate market. Public attention can be used to predict changes in the real estate industry and adjust policies accordingly (Dai et al. 2022). Additionally, multiple indicators should be monitored in the real estate sector. Although house prices are typically the first aspect associated with real estate, our research indicates that the influence of house prices on public attention is gradually diminishing, while the impact of other real estate-related values is increasing. Therefore, to better understand how changes in the real estate market affect the public, it is necessary to monitor multiple indicators. Furthermore, efforts should be made to enhance the regulation of online media. As the public relies on online searches to understand real estate-related changes, and given the varying quality of online media, stricter regulation is needed to ensure that the public is informed about relevant policies and that these policies remain transparent.

In future research, we plan to explore and capture public sentiment towards the real estate market to understand the overall pessimistic or optimistic sentiment. This research will involve multiple data sources and analytical methods to comprehensively analyze public sentiment. By collecting data from social media, news reports, and articles, as well as government announcements and policy documents, we will use natural language processing (NLP) techniques to perform text mining and sentiment analysis on social media posts, news articles, and comments. Methods such as word frequency statistics and machine learning will be used to quantify emotional tendencies in the text. We will also use time-series analysis to analyze trends in sentiment over time and compare them with actual data of the real estate market to identify relationships between sentiment changes and market fluctuations, which will aid in market forecasting and policy formulation.

Disclaimer (Artificial intelligence)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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