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Do Increases and Decreases Matter Equally? Asymmetric and Regionally Heterogeneous Housing-Stock Interactions in Mainland China

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Abstract

This study examines the asymmetric relationship between housing prices and stock market returns across China's major economic regions. Specifically, it investigates whether positive and negative shocks exhibit different transmission dynamics and whether these dynamics vary across regions characterized by different levels of financial development and housing market maturity. Using monthly data from 2005 to 2024, the study employs region-specific asymmetric vector autoregression (VAR) models, asymmetric Granger causality tests, and generalized impulse response analysis based on asymmetric decompositions of housing prices and stock market returns. The results suggest that statistically significant housing-to-stock predictability is observed primarily following negative housing price shocks in selected regions, whereas positive shocks generally exhibit weaker or statistically insignificant predictive effects. Conversely, positive stock market shocks generally provide more consistent evidence of stock-to-housing predictability, particularly in the Eastern and Central regions, although the responses are more mixed in the Western region and vary in magnitude, statistical significance, and persistence across regional markets. Overall, the results provide evidence of heterogeneous dynamic transmission patterns across China's major economic regions and suggest that housing-related downside risk may represent an important source of regional macro-financial vulnerability.

Keywords: asymmetric VAR; asymmetric causality; housing-stock market; regional heterogeneity

MSC: 91B84; 91B82; 62M10; 62H20



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1. Introduction

Despite a growing literature on housing-stock market interactions, several important questions remain unresolved. Existing evidence provides conflicting conclusions regarding the nature and strength of the relationship between housing and stock markets. While some studies document strong and persistent interactions driven by wealth effects, collateral channels, and credit conditions [1–3], others report weak, unstable, or time-varying relationships that differ across periods and regions [4–6]. This lack of consensus is not merely an empirical issue. Misjudging the direction or magnitude of housing-stock market spillovers may lead to ineffective macroprudential policies and an underestimation of

systemic financial vulnerabilities, particularly in economies where housing markets play a central role in household wealth accumulation and credit creation.

The unresolved nature of this issue is particularly important in China. Over the past two decades, real estate has become the dominant component of household wealth and a key source of collateral within the financial system [7–9]. At the same time, substantial regional disparities exist in China's housing market maturity, financial development, demographic structure, and economic development, reflecting pronounced heterogeneity in regional macro-financial conditions [1,7]. Such regional differences imply that housing and financial shocks are unlikely to be transmitted uniformly across China but instead vary according to local institutional environments and market characteristics [3,4]. Nevertheless, most existing empirical studies rely on nationally aggregated data and implicitly assume homogeneous housing-stock market linkages across regions. Such aggregation may conceal important regional differences in financial vulnerability and obscure the mechanisms through which housing market fluctuations influence broader financial stability. Related evidence also links real-estate price fluctuations to financial stability in China [10].

A second limitation concerns the treatment of asymmetry. Theoretical perspectives from behavioral finance, collateral constraint models, and financial accelerator mechanisms suggest that negative asset-price shocks may generate disproportionately larger economic consequences than positive shocks [11–13]. Housing market downturns reduce collateral values, tighten borrowing constraints, weaken household and corporate balance sheets, and amplify financial stress [14,15]. This mechanism is further reinforced by the theory of credit rationing under asymmetric information. According to [16], declining collateral values not only reduce borrowers' pledgeable assets but also exacerbate information asymmetries, making it more difficult for lenders to distinguish between low- and high-risk borrowers. Consequently, financial institutions may restrict the supply of credit rather than simply increase lending rates, reducing credit availability even for otherwise creditworthy borrowers. This amplification mechanism further intensifies the economic consequences of adverse housing price shocks. By contrast, housing booms may generate comparatively weaker wealth effects and smaller financial responses. Despite these theoretical predictions, most empirical studies either employ linear frameworks or investigate asymmetry through single-equation approaches, making it difficult to assess how positive and negative shocks propagate through an interconnected housing-financial system. Consequently, existing evidence provides only limited insights into the role of downside housing risk as a source of macro-financial instability.

A third limitation relates to methodology. Although recent studies acknowledge nonlinear and asymmetric relationships [17,18], much of the evidence remains fragmented across alternative models and empirical settings. Existing approaches rarely examine positive and negative shocks within an integrated multivariate framework capable of simultaneously capturing feedback effects, dynamic transmission mechanisms, and regional heterogeneity. As a result, it remains unclear whether the documented asymmetries represent systematic features of housing-stock market interactions or are sensitive to specific model specifications.

This study argues that understanding housing-stock market spillovers requires the simultaneous consideration of two fundamental dimensions: asymmetric dynamics and regional heterogeneity. Ignoring asymmetry may underestimate the consequences of adverse housing market conditions, while ignoring regional heterogeneity may conceal important differences in financial vulnerability across regions. These issues are particularly relevant in China, where housing markets remain regionally segmented, while financial markets operate within a largely integrated national system. Under such con-

ditions, common financial shocks may generate heterogeneous regional responses, while localized housing disturbances may propagate through broader financial channels. To address these issues, this study investigates asymmetric housing-stock market interactions across China's four major macro-regions: Eastern, Central, Western, and Northeastern China. Using monthly data from 2005 to 2024, housing and stock returns are decomposed into positive and negative components and incorporated into region-specific asymmetric VAR models. The empirical framework combines asymmetric Granger causality tests with impulse response analysis under asymmetric decomposition analysis to identify heterogeneous transmission mechanisms across regions. Unlike conventional nationally aggregated or symmetric approaches, the analysis reveals how adverse and favorable shocks propagate differently across regional financial systems. The findings show that negative housing shocks generate disproportionately stronger spillover effects on stock markets, particularly in regions characterized by greater dependence on housing markets and credit conditions.

This study contributes to the literature in three ways. First, it provides new evidence on the asymmetric nature of housing-stock market spillovers by distinguishing between the effects of positive and negative shocks within an integrated dynamic framework. Second, it demonstrates that the magnitude and persistence of spillovers vary substantially across regions, highlighting the importance of regional financial heterogeneity in shaping transmission mechanisms. Third, it advances understanding of housing-related downside risk as a source of macro-financial vulnerability and provides insights into the design of region-specific macroprudential policies in China's evolving financial system.

The remainder of the paper is organized as follows: Section 2 reviews the relevant literature on housing-stock market linkages and methodological approaches. Section 3 describes the data and variable and econometric models. Section 4 presents the empirical results and discusses their implications. Section 5 concludes with policy recommendations and suggestions for future research.

2. Literature Review

2.1. Theoretical Review

The relationship between housing and stock markets has long been debated in both theoretical and empirical literature, with competing views regarding whether the two assets act as substitutes or complements. From a portfolio allocation perspective, housing and equities may serve as substitutes: when a larger share of household wealth is allocated to housing, participation in equity markets tends to decline due to limited liquidity and risk diversification constraints [19]. In contrast, the wealth and collateral channels suggest a complementary relationship. Rising housing prices increase household net worth and relax borrowing constraints, thereby facilitating access to credit and stimulating investment in financial assets, including equities [20,21]. Conversely, declining housing prices reduce collateral value, tighten credit conditions, and increase precautionary savings, leading to a contraction in equity investment [22]. These opposing mechanisms imply that the housing-stock nexus is inherently state-dependent and may vary across market conditions. These portfolio-allocation and participation mechanisms are also emphasized in foundational and applied asset-allocation studies [23,24].

Recent theoretical developments emphasize that such relationships are unlikely to be symmetric. Behavioral finance theory highlights that economic agents respond more strongly to losses than to gains, implying that negative shocks may generate disproportionately larger effects than positive shocks [11,25]. From an econometric perspective, the concept of hidden cointegration introduced by [26] suggests that long-run relationships

may differ between positive and negative components of economic variables. This idea has been extended in nonlinear frameworks such as the asymmetric ARDL model [27] and asymmetric causality tests [28], which demonstrate that positive and negative changes may propagate through distinct transmission mechanisms.

Applied to the housing-stock nexus, these insights imply that increases and decreases in asset prices are not mirror images. On the one hand, rising housing prices generate wealth effects and ease collateral constraints, encouraging risk-taking and participation in stock markets. On the other hand, housing price declines reduce collateral value, constrain borrowing capacity, and amplify financial fragility, leading to stronger contractionary effects on equity markets. Similarly, stock market expansions may stimulate housing demand through expectations, income prospects, and wealth accumulation, whereas stock market downturns primarily operate through confidence and liquidity channels, often with weaker and less persistent effects. In the context of China, these asymmetries are further amplified by institutional factors, including the dominance of real estate in household wealth portfolios, the strong linkage between housing collateral and bank lending, and regionally uneven financial development [29–31].

Based on these theoretical considerations, the transmission between housing and stock markets is expected to be both asymmetric and regionally heterogeneous. Negative housing shocks are likely to exert stronger short-run effects on stock markets through tightening credit conditions, declining collateral values, and balance-sheet deterioration, consistent with financial accelerator and collateral constraint theories [12–14]. In contrast, positive stock market shocks may have more persistent effects on housing prices through wealth accumulation, improved expectations, and increased borrowing capacity. Specifically, these transmission mechanisms operate within a broader macro-financial system in which housing markets are regionally segmented, while financial markets are largely nationally integrated. In China, substantial regional disparities in economic development, financial depth, and housing market conditions imply that housing dynamics are inherently local, whereas stock market movements reflect aggregate national conditions [7,8,32]. As a result, common financial shocks may propagate unevenly across regions, depending on differences in financial development, credit dependence, and housing market maturity. At the same time, region-specific housing fluctuations may feed back into the national financial system through aggregate wealth effects, banking sector exposure, and balance-sheet channels [12,14]. This interaction implies that both asymmetry and regional heterogeneity are fundamental features of the housing-stock nexus in China.

To examine these asymmetric and regionally heterogeneous transmission mechanisms, this study distinguishes between positive and negative movements in housing and stock markets within an integrated dynamic framework. This approach allows the analysis to evaluate how adverse and favorable shocks propagate differently across markets and regions. In this setting, stock market fluctuations are interpreted as common national financial disturbances, while housing market responses reflect region-specific economic and financial conditions. Figure 1 summarizes the conceptual framework linking housing and stock markets through wealth, collateral, credit, and a pattern consistent with wealth and expectations-related interpretations.

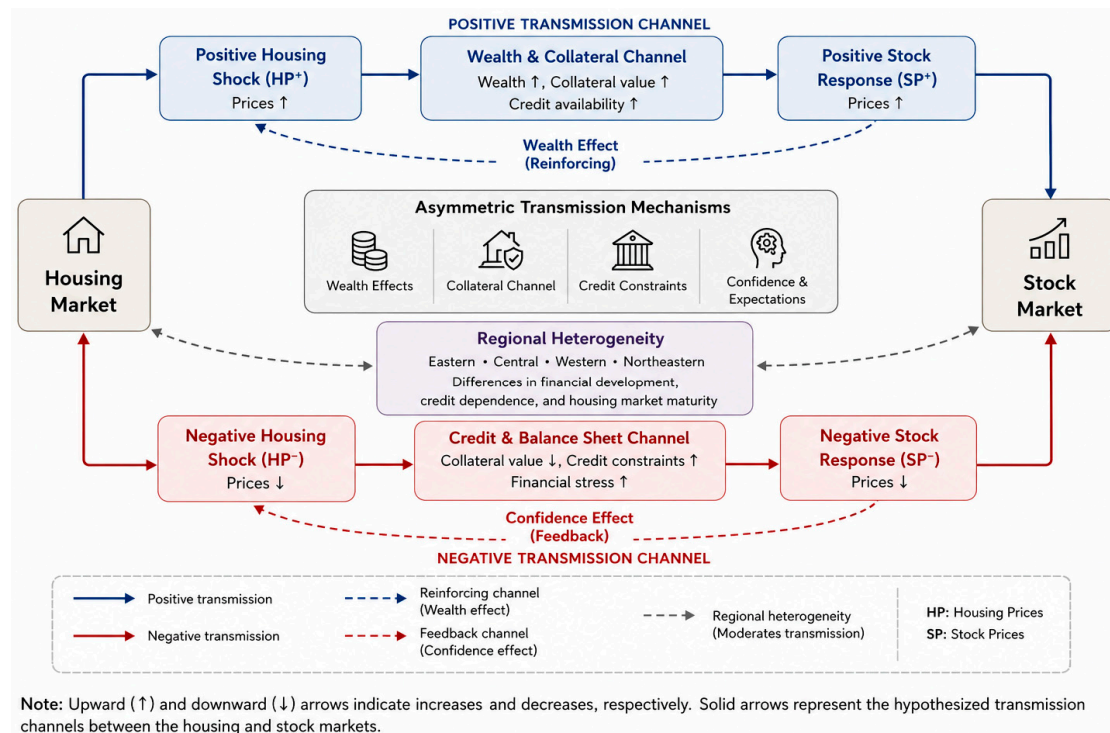


Figure 1. Conceptual Framework.

2.2. Housing-Stock Market Linkages

Empirical research on the housing-stock market nexus has evolved from conventional linear frameworks toward increasingly nonlinear and asymmetric approaches. Early studies based on vector autoregression (VAR), cointegration, and causality analyses generally reported weak, unstable, or time-varying relationships between housing and equity markets. For example, refs. [21,33] documented important interactions among housing prices, credit conditions, and financial cycles, although the magnitude and direction of these relationships were found to be highly sensitive to sample periods and macroeconomic environments. Similar evidence has been reported for the United States [34], Malaysia [35], Europe [36], and the G7 economies [37]. Overall, findings from linear models remain mixed and often inconsistent, suggesting that symmetric specifications may inadequately capture the complex dynamics linking housing and stock markets. Additional evidence from the United States and Asian markets likewise points to time-varying integration and information transmission [38–40].

Recognizing these limitations, a growing body of research has adopted nonlinear and asymmetric methodologies to investigate whether positive and negative shocks exert different effects across asset markets. For [17] documented asymmetric dependence between real estate and stock markets, while [18] reported that negative shocks generate stronger and more persistent transmission effects than positive shocks. Comparable evidence has been identified in OECD countries [41], Iran [42], and several European economies [43]. Collectively, these studies suggest that housing-stock market interactions are characterized by asymmetric adjustment processes, particularly during periods of financial stress, market uncertainty, and economic downturns.

2.3. Methodological Approaches and Research Gaps

Another influential strand of the literature employs the nonlinear autoregressive distributed lag (NARDL) framework proposed by [27]. By decomposing variables into positive and negative sign split, NARDL models enable researchers to examine whether increases and decreases in housing or stock prices generate asymmetric responses in the cor-

responding market. Although this approach has substantially advanced understanding of asymmetric adjustment mechanisms, most applications rely on separate-equation specifications that treat housing and stock markets independently. Such frameworks may overlook the joint determination of asset prices and the contemporaneous correlation of shocks across markets. Given that housing and stock market innovations are likely to interact simultaneously through wealth, collateral, and credit channels, separate-equation models may provide only partial insights into the persistence and transmission of cross-market spillovers [28]. More importantly, existing asymmetric studies rarely examine the dynamic propagation of shocks within an integrated multivariate framework. While asymmetric causality tests and NARDL models are effective in identifying nonlinear relationships, they do not naturally provide system-wide analyses of feedback effects, impulse responses, or the evolution of shocks through an interconnected housing-financial system. Consequently, the transmission mechanisms through which positive and negative shocks propagate across housing and stock markets remain incompletely understood. This limitation is particularly important in China, where housing markets are regionally segmented, whereas financial markets operate within a largely integrated national system. Under such conditions, adverse housing shocks may generate heterogeneous regional responses while simultaneously influencing broader financial conditions through wealth effects, collateral constraints, and credit-market adjustments.

To address these gaps, this study employs a region-specific asymmetric VAR framework that incorporates positive and negative housing and stock market returns within a unified multivariate system. By allowing favorable and adverse shocks to follow distinct transmission paths, the framework enables a comprehensive assessment of asymmetric spillovers, dynamic feedback effects, and shock propagation mechanisms. In addition, the use of regionally disaggregated data captures heterogeneity across Eastern, Central, Western, and Northeastern China, thereby providing insights into how differences in financial development, housing market maturity, and credit dependence influence transmission dynamics.

3. Research Methodology

3.1. Data Collection and Variable Selection

This study examines the dynamic linkages between China's housing and stock markets using a regionally aggregated dataset constructed from provincial-level information. Monthly data covering the period from January 2005 to December 2024 are collected for China's 31 provinces and subsequently aggregated into four macro-regions, Eastern, Central, Western, and Northeastern, following China's conventional regional classification. The provincial composition of each macro-region is provided in Appendix A. This aggregation reflects the view that each macro-region constitutes a distinct economic and financial regime, characterized by common patterns in housing market development, financial depth, migration dynamics, and exposure to national policy interventions. Table 1 summarizes the variables used in this study, together with their definitions, data sources, and corresponding references.

Regional housing price indices are constructed by averaging provincial residential housing prices within each macro-region. Prior to regional aggregation, nominal provincial housing prices are deflated by the corresponding provincial consumer price index (2015 = 100), following [1,3], to remove inflationary effects and obtain comparable real housing returns across provinces over time. This treatment is also consistent with evidence that house prices and inflation are closely related [44].

Table 1. Data description and formulation.

Variables	Definition	Sources	Ref.
<i>RHP</i>	Real housing price (HP) for China's 31 provinces (nominal housing prices deflated by the provincial CPI (2015 = 100)).	CEIC Database	[1–3]
<i>RSP</i>	Stock price index based on the Shanghai Stock Exchange (SSE) Composite Index. In the empirical analysis, we use $\Delta \ln(\text{SP})$ as monthly stock returns.	Yahoo Finance	[4,6]

The regional housing price index is computed as

$$HP_{r,t} = \frac{1}{N_r} \sum_{j=1}^{N_r} HP_{j,t}, \quad (1)$$

where $HP_{j,t}$ denotes the real housing price index of province j at month t , N_r is the number of provinces belonging to region r , and $HP_{r,t}$ represents the resulting regional housing price index.

Specifically, we employ a simple arithmetic average across provinces within each region (Table A1). This approach treats each province equally and is intended to capture the common directional movement of housing markets rather than their relative economic size. While major metropolitan areas such as Beijing and Shanghai exhibit higher price levels and volatility, the use of simple averages avoids over-weighting a small number of dominant markets and provides a balanced representation of regional housing dynamics. This approach is motivated by the strong co-movement of housing markets among provinces within the same region, arising from shared macroeconomic conditions and institutional environments. Aggregation at the regional level allows the analysis to capture the dominant housing market cycle within each macro-region while filtering out idiosyncratic provincial fluctuations that are not central to the study of systemic housing-stock market interactions. In addition, regional aggregation mitigates over-parameterization concerns inherent in asymmetric time-series models, thereby enhancing the reliability of statistical inference. This approach has been widely adopted in studies examining regional housing market dynamics, where the objective is to capture the common movement of housing prices across provinces rather than the relative economic importance of individual locations (e.g., [2,6,7]). In addition, following [1,3], nominal provincial housing prices are first deflated by the corresponding provincial consumer price index (2015 = 100) to remove inflationary effects before computing monthly real housing returns.

Stock market performance is measured using the Shanghai Stock Exchange (SSE) Composite Index, which serves as a national indicator of equity market conditions and has been widely adopted in empirical studies examining China's housing-stock market interactions [4,6]. The use of a single national stock market index reflects the institutional structure of China's equity market, which operates as a highly integrated national system rather than as regionally segmented markets, making the SSE Composite Index an appropriate proxy for nationwide financial conditions. The SSE Composite Index captures aggregate movements in equity prices, investor sentiment, and national financial conditions that are relevant for all regions. Employing a common stock market indicator therefore allows the analysis to examine how region-specific housing markets respond asymmetrically to national financial shocks and how regional housing price innovations feed back into overall stock market dynamics.

While alternative indices such as the Shenzhen Component Index or CSI 300 could also be considered, the SSE Composite Index provides a broad and widely used benchmark of overall market performance. Given the high degree of integration across China's equity markets, the use of alternative indices is unlikely to materially alter the main results. This

empirical design implies that stock market shocks are interpreted as common national financial disturbances, while housing market responses are allowed to vary across regions. This framework enables the analysis to capture how nationally integrated financial conditions transmit asymmetrically across heterogeneous regional housing markets, although it may abstract from localized micro-level interactions. Similar proxies have also been adopted in previous studies investigating housing-stock market interactions in China [4].

Table 2 reports descriptive statistics for SSE returns (RSP) and regional housing returns (RHP). For the stock market, RSP has a mean of 0.0043 and a standard deviation of 0.0726, with monthly changes ranging from -0.2828 to 0.2425 , indicating substantial short-run variability in equity returns. Across regions, housing returns are also positive on average: mean RHP ranges from 0.0045 (Northeast) to 0.0067 (East), while Central and West report mean returns of 0.0052 and 0.0055, respectively.

Table 2. Descriptive Statistics of SSE and Regional Housing returns.

Variable	Min	Max	Mean	SD	Skewness	Kurtosis
<i>RSP</i>	-0.2828	0.2425	0.0043	0.0726	-0.4892	2.6515
<i>RHP^{East}</i>	-0.1400	0.1405	0.0067	0.0272	1.6490	10.7531
<i>RHP^{Central}</i>	-0.0793	0.2190	0.0052	0.0294	3.0789	18.5927
<i>RHP^{West}</i>	-0.1221	0.1920	0.0055	0.0296	2.2673	15.2128
<i>RHP^{Northeast}</i>	-0.2118	0.3359	0.0045	0.0513	2.8401	14.3213

3.2. Empirical Model

3.2.1. Linear VAR and Granger Causality

We begin with a linear VAR model to establish the baseline dynamic relationship between provincial housing price returns and the national stock market return. Let $RHP_{i,t}$ denote the housing price return for region i , and let RSP_t denote the return on the Shanghai Stock Exchange (SSE) Composite Index, which represents national stock market conditions common to all regions. For each for i , the bivariate VAR(p) model is specified as

$$\begin{aligned} RSP_t &= a_{1,i} + \sum_{k=1}^p \alpha_{11,i,k} RSP_{t-k} + \sum_{k=1}^p \alpha_{12,i,k} RHP_{i,t-k} + \delta_{1,i} Crisis_t + \varepsilon_{1,i,t}, \\ RHP_{i,t} &= a_{2,i} + \sum_{k=1}^p \alpha_{21,i,k} RHP_{i,t-k} + \sum_{k=1}^p \alpha_{22,i,k} RSP_{t-k} + \delta_{2,i} Crisis_t + \varepsilon_{2,i,t}. \end{aligned} \quad (2)$$

The coefficients $\alpha_{11,i}$, $\alpha_{12,i}$, $\alpha_{21,i}$, $\alpha_{22,i}$ capture the lagged effects. The error terms ε_{1t} and ε_{2t} , are assumed to be i.i.d. with constant variance. where $Crisis_t$ is a dummy variable equal to 1 during major crisis periods, including the Global Financial Crisis (2008–2009), the Chinese stock market crash (2015–2016), and the COVID-19 pandemic (January 2020–January 2023), and 0 otherwise. The parameters $\delta_{1,i}$ and $\delta_{2,i}$ capture the effects of these crisis periods on stock returns and housing price returns, respectively. This linear VAR framework allows for the examination of bidirectional predictive relationships between housing and stock returns through standard Granger causality tests, while serving as a benchmark against which asymmetric dynamics can be evaluated. These crisis controls capture extraordinary equity-market disturbances documented during China's 2015 intervention and the COVID-19 shock [45–47].

3.2.2. Asymmetric VAR and Granger Causality

To examine asymmetric transmission mechanisms between housing and stock markets, we augment the conventional VAR framework by decomposing housing and stock returns into positive and negative components. This specification is motivated by the theoretical literature on loss aversion, collateral constraints, and financial accelerator effects,

which suggests that adverse asset-price movements may generate disproportionately larger economic and financial consequences than favorable movements. Consequently, treating positive and negative shocks symmetrically may conceal important nonlinear adjustment processes and lead to an incomplete characterization of housing-stock market interactions.

Unlike the cumulative partial-sum decomposition proposed by [26,28], which is designed to capture the accumulation of positive and negative innovations over time, the present study adopts a contemporaneous decomposition of return series as the baseline specification. This approach is more appropriate for the objective of the study, namely, to examine the short-run asymmetric transmission of monthly housing and stock market shocks while preserving the timing of individual return movements. The cumulative partial-sum decomposition of [28] is subsequently implemented as a robustness check to examine whether the empirical findings are robust to an alternative asymmetric decomposition framework.

Using these decomposed return series, we estimate a region-specific asymmetric VAR(q) model for each region i . Although the system consists of two behavioral equations, one for housing returns and one for stock returns, each equation includes the positive and negative components of both variables as separate regressors. Accordingly, the model is interpreted as an asymmetric bivariate VAR in which positive and negative return components follow distinct dynamic transmission paths. Similar decomposition-based VAR specifications have been employed to examine asymmetric interactions between housing and financial markets (e.g., [41,42]).

Formally, the positive and negative return components are defined as

$$SP_t^+ = \max(RSP_j, 0), \quad (3)$$

$$HP_t^+ = \max(RHP_j, 0), \quad (4)$$

$$SP_t^- = \min(RSP_j, 0), \quad (5)$$

$$HP_t^- = \min(RHP_j, 0), \quad (6)$$

Under this specification, a positive shock corresponds to a positive monthly return, whereas a negative shock corresponds to a negative monthly return. Observations equal to zero remain zero in both decomposed series. This decomposition treats positive and negative return innovations as separate state variables. By construction, $RSP_t = RSP_t^+ + RSP_t^-$ and $RHP_{i,t} = RHP_{i,t}^+ + RHP_{i,t}^-$. This allows the responses of housing (stock) markets to stock (housing) price increases and decreases to differ both in magnitude and persistence. Although the resulting VAR system remains linear in parameters, asymmetry arises from the piecewise nature of the sign decomposition, where positive and negative return components enter the system separately and are permitted to follow distinct transmission paths.

Using these decomposed return series, we specify a region-specific asymmetric VAR(q) system for each region i . Although the model consists of two behavioral equations, one for stock returns and one for housing returns, each equation includes the positive and negative components of both variables as separate state variables. Accordingly, the empirical specification is interpreted as an asymmetric bivariate VAR with four contemporaneous state variables corresponding to the positive and negative components of stock and housing returns. Formally, the model is specified as follows:

$$\begin{aligned} RSP_t &= c_{1,i} + \sum_{k=1}^q \beta_{1,i,k}^+ RSP_{t-k}^+ + \sum_{k=1}^q \beta_{1,i,k}^- RSP_{t-k}^- + \sum_{k=1}^q \alpha_{1,i,k}^+ RHP_{i,t-k}^+ + \sum_{k=1}^q \alpha_{1,i,k}^- RHP_{i,t-k}^- + \delta_{1,i} Crisis_t + u_{1,i,t}, \\ RHP_{i,t} &= c_{2,i} + \sum_{k=1}^q \beta_{2,i,k}^+ RHP_{i,t-k}^+ + \sum_{k=1}^q \beta_{2,i,k}^- RHP_{i,t-k}^- + \sum_{k=1}^q \alpha_{2,i,k}^+ RSP_{t-k}^+ + \sum_{k=1}^q \alpha_{2,i,k}^- RSP_{t-k}^- + \delta_{2,i} Crisis_t + u_{2,i,t}. \end{aligned} \quad (7)$$

where $\beta_{1,i,k}^+$ and $\beta_{1,i,k}^-$ capture the asymmetric autoregressive effects of positive and negative stock market returns on current stock returns, respectively, while $\alpha_{1,i,k}^+$ and $\alpha_{1,i,k}^-$ measure the effects of positive and negative housing price returns on stock returns. In the housing-price equation, $\beta_{2,i,k}^+$ and $\beta_{2,i,k}^-$ represent the asymmetric persistence of housing price movements under positive and negative regimes, whereas $\alpha_{2,i,k}^+$ and $\alpha_{2,i,k}^-$ quantify the effects of positive and negative stock market returns on provincial housing price returns. The error terms $u_{1,i,t}$ and $u_{2,i,t}$ are assumed to be serially uncorrelated with zero mean and finite variance, allowing for potentially different innovation processes across the two markets. The optimal lag length q is selected using standard information criteria, including the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC).

To evaluate asymmetric predictive relationships, we estimate the asymmetric VAR and conduct Wald tests on the joint significance of the lagged positive and negative components [28]. For each region i , asymmetric Granger causality is examined using the following hypotheses.

(1) Joint test for overall asymmetric Granger causality

Housing prices Granger-cause stock returns if the joint null hypothesis that both positive and negative housing components do not enter the stock return equation is rejected

$$H_0^{+/-} : \alpha_{1,i,1}^+ = \dots = \alpha_{1,i,q}^+ = \alpha_{1,i,1}^- = \dots = \alpha_{1,i,q}^- = 0$$

Similarly, stock returns Granger-cause housing prices if

$$H_0^{+/-} : \alpha_{2,i,1}^+ = \dots = \alpha_{2,i,q}^+ = \alpha_{2,i,1}^- = \dots = \alpha_{2,i,q}^- = 0$$

(2) Test for negative-shock causality only

To assess whether negative housing price movements possess predictive power for stock returns, we test:

$$H_0^- : \alpha_{1,i,1}^- = \dots = \alpha_{1,i,q}^- = 0 \text{ (No causality from negative shocks)}$$

Analogously, negative stock market movements Granger-cause housing prices if

$$H_0^- : \alpha_{2,i,1}^- = \dots = \alpha_{2,i,q}^- = 0 \text{ (No causality from negative shocks)}$$

(3) Test for positive-shock causality only

To examine predictive effects arising exclusively from positive movements, we test:

$$H_0^+ : \alpha_{1,i,1}^+ = \dots = \alpha_{1,i,q}^+ = 0$$

for housing-to-stock causality, and

$$H_0^+ : \alpha_{2,i,1}^+ = \dots = \alpha_{2,i,q}^+ = 0$$

for stock-to-housing causality. Rejection of these null hypotheses indicates that positive and negative shocks possess distinct predictive effects, providing evidence of asymmetric transmission between housing and stock markets.

3.2.3. Impulse Response Analysis

To examine the dynamic propagation of housing-stock market interactions, we compute generalized impulse response functions (GIRFs) from the estimated asymmetric VAR models. Following [48], GIRFs are adopted because they do not require orthogonalization

through a Cholesky decomposition and are invariant to the ordering of variables, making them particularly suitable for reduced-form VAR models.

Although the empirical model is estimated as the two-equation asymmetric VAR presented in Equation (7), where aggregate housing and stock returns are the dependent variables and their positive and negative components enter as explanatory variables, the computation of generalized impulse response functions requires the model to be expressed in an equivalent state-space form. Accordingly, for the purpose of deriving generalized impulse responses, the estimated asymmetric VAR is rewritten as the following four-dimensional state-space representation, in which the positive and negative return components are treated as state variables.

$$\mathbf{z}_{i,t} = \mathbf{c}_i + \sum_{k=1}^q \mathbf{A}_{i,k} \mathbf{z}_{i,t-k} + \mathbf{u}_{i,t}, \quad (8)$$

where

$$\mathbf{z}_{i,t} = \begin{pmatrix} RSP_t^+ \\ RSP_t^- \\ RHP_{i,t}^+ \\ RHP_{i,t}^- \end{pmatrix}.$$

and $\mathbf{u}_{i,t} = (u_{SP^+}, u_{SP^-}, u_{HP^+}, u_{HP^-})'$ denotes the four-dimensional vector of reduced-form innovations, and $\Sigma = E(u_{i,t} u_{i,t}')$ is the corresponding 4×4 covariance matrix. The innovations in the four-dimensional computational representation are obtained by decomposing the estimated reduced-form residuals from the two behavioral equations in Equation (7) into their contemporaneous positive and negative components. Therefore, the computational representation is algebraically equivalent to the estimated asymmetric VAR and is introduced solely for the computation of generalized impulse response functions.

Although the observed positive and negative return components are mutually exclusive by construction, the generalized impulse responses are computed from the covariance matrix of the estimated reduced-form innovations rather than from the covariance matrix of the observed decomposed variables. Consequently, provided that the residual covariance matrix is positive definite, the generalized impulse responses are well defined and should be interpreted as reduced-form asymmetric dynamic responses rather than structurally identified causal effects.

Following [48], the generalized impulse response of variable j at horizon h to a one-standard-deviation innovation in component k is defined as:

$$\text{GIRF}_{j,k,i}(h) = E \left[z_{j,i,t+h} \middle| u_{i,t} = \frac{\Sigma e_k}{\sqrt{\sigma_{kk}}}, \mathcal{F}_{t-1} \right] - E \left[z_{j,i,t+h} \middle| \mathcal{F}_{t-1} \right], \quad (9)$$

where Σ is the estimated residual covariance matrix, e_k is a selection vector with unity in the k -th position and zeros elsewhere, and $\mathcal{F}_{t-1}$ denotes the information set available at time $t - 1$.

To evaluate asymmetric transmission mechanisms, generalized impulse responses are computed separately for innovations to the positive and negative return components. Specifically, we examine the responses of provincial housing price returns to positive and negative innovations in the national stock market, together with the corresponding responses of the national stock market to positive and negative housing price innovations originating from each region. This produces four asymmetric transmission channels: positive stock-to-housing, negative stock-to-housing, positive housing-to-stock, and negative

housing-to-stock. Because the asymmetric VAR decomposes each observed return series into positive and negative components, the impulse responses are initially obtained for these decomposed state variables. For economic interpretation, the response of the observed housing (stock) return is reconstructed by aggregating the responses of its positive and negative components.

$$\text{IRF}_{RHP_i}(h) = \text{IRF}_{RHP_i^+}(h) + \text{IRF}_{RHP_i^-}(h), \quad (10)$$

$$\text{IRF}_{RSP}(h) = \text{IRF}_{RSP^+}(h) + \text{IRF}_{RSP^-}(h), \quad (11)$$

where $\text{IRF}_{RHP_i}(h)$ and $\text{IRF}_{RSP}(h)$ denote the reconstructed impulse responses of the observed housing and stock returns, respectively. This aggregation ensures that the reported impulse responses correspond to the total response of each market while preserving the asymmetric transmission captured by the decomposed positive and negative return components. Statistical inference is conducted using residual-based bootstrap confidence intervals with 1000 replications following [49], thereby accounting for parameter uncertainty while preserving the dependence structure of the estimated VAR system. The impulse responses are generated through Monte Carlo simulation, and region-specific confidence bands are reported for all estimated responses.

4. Empirical Results

4.1. Preliminary Tests

The stationarity properties of the monthly growth rates of housing prices and stock prices are examined using standard unit root tests. Specifically, the Augmented Dickey-Fuller test [50] and the Phillips-Perron test [51] are employed. The ADF test controls parametrically for serial correlation through lagged difference terms, whereas the PP test applies a nonparametric correction for serial correlation and heteroskedasticity in the disturbance process. Establishing stationarity is a necessary precondition for the validity of the subsequent VAR-based analysis.

As reported in Table 3, the null hypothesis of a unit root is decisively rejected for the stock price return series and for regional housing price return series across all four regions. The rejection holds at least at the 5% significance level for all tests and is predominantly significant at the 1% level. These results indicate that the transformed series are stationary and suitable for dynamic time-series modeling.

Table 3. Unit root tests for RSP and RHP returns.

Variable	ADF	PP	Variable	ADF	PP	Variable	ADF	PP
<i>RSP</i>	−5.4268 ***	−13.4883 ***	<i>RSP</i>	−2.9456 **	−3.941 ***	<i>RSP</i>	−3.1094 **	−3.2309 **
<i>RHP^{East}</i>	−4.3994 ***	−15.6139 ***	<i>RHP^{East},+</i>	−2.6793 **	−3.093 ***	<i>RHP^{East},−</i>	−3.395 **	−4.0925 ***
<i>RHP^{Central}</i>	−3.7363 ***	−17.4334 ***	<i>RHP^{Central},+</i>	−2.2960 *	−4.3951 ***	<i>RHP^{Central},−</i>	−2.6094 *	−3.8904 ***
<i>RHP^{West}</i>	−4.4293 **	−15.6586 ***	<i>RHP^{West},+</i>	−3.3056 **	−4.6090 ***	<i>RHP^{West},−</i>	−2.7042 *	−4.2004 ***
<i>RHP^{Northeast}</i>	−6.3243 ***	−20.0478 ***	<i>RHP^{Northeast},+</i>	−2.909 **	−5.3051 ***	<i>RHP^{Northeast},−</i>	−2.9835 **	−8.4467 ***

Note: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively.

4.2. Baseline Results

We begin by estimating baseline linear VAR models to provide benchmark evidence on the dynamic interactions between regional housing prices and the national stock market. These linear specifications serve as a reference point against which the subsequent asymmetric models can be evaluated. Prior to estimation, the optimal lag length was determined using the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). As reported in Appendix A Table A2, both information criteria consistently identify a first-order VAR specification ($q = 1$) as the optimal lag length for all regional

models. Accordingly, a one-lag specification is adopted for all linear VAR and nonlinear (asymmetric) VAR models throughout the empirical analysis. The estimated coefficients for the Eastern, Central, Western, and Northeastern regions are reported in Table 4.

Table 4. Linear VAR estimates.

Region	RHP				RSP			
	Intercept	RHP(−1)	RSP(−1)	Adj-R ²	Intercept	RHP(−1)	RSP(−1)	Adj-R ²
East	0.0139 (0.0111)	−0.3514 ** (0.1800)	0.1014 * (0.0663)	0.1086	0.0179 * (0.0041)	−0.0657 (0.0662)	0.0493 ** (0.0244)	0.1420
Central	0.0095 (0.0104)	−0.3452 *** (0.1690)	0.1048 * (0.0654)	0.1235	0.0144 * (0.0041)	−0.1463 ** (0.0660)	0.0661 ** (0.0255)	0.1706
West	0.0206 *** (0.0105)	−0.3230 ** (0.1688)	0.0983 (0.0665)	0.1025	0.0131 * (0.0042)	−0.0470 (0.0667)	0.0592 ** (0.0263)	0.1671
Northeast	0.0217 *** (0.0102)	−0.1768 ** (0.0959)	0.0108 * (0.0663)	0.1020	0.0125 *** (0.0070)	−0.1264 *** (0.0659)	0.1409 * (0.0455)	0.1631

Note: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All estimated models include a crisis-period dummy variable as an exogenous control. The estimated coefficient is omitted from the table for brevity.

Overall, the linear VAR results indicate the presence of dynamic linkages between housing and stock markets across regions; however, the estimated effects are generally modest in magnitude and exhibit considerable heterogeneity across regions. In several cases, the estimated responses differ in sign and statistical significance across regions, suggesting that the linear specification may reveal important nonlinear and asymmetric dynamics. Moreover, the explanatory power of the linear VAR models, as reflected in the adjusted R² values, remains limited, indicating that symmetric linear dynamics alone are insufficient to fully characterize housing-stock market interactions.

To further assess predictive linkages between regional housing returns and the national stock market, we conduct standard linear Granger causality tests based on the baseline VAR specifications. The results, reported in Table 5, provide preliminary evidence on the direction of predictability across China's four macro-regions.

Table 5. Granger Causality test.

Region	RHP → RSPF-Statistic	p-Value	RSP → RHPF-Statistic	p-Value
East	0.1723	0.7935	2.3369	0.0735
Central	2.6640	0.0414	3.1031	0.0395
West	0.6269	0.4056	1.8275	0.1204
Northeast	0.6678	0.3902	3.2775	0.0388

Note: All estimated models include a crisis-period dummy variable as an exogenous control. The estimated coefficient is omitted from the table for brevity.

Overall, the linear Granger causality results indicate that predictive relationships between housing and stock returns are limited and strongly heterogeneous across regions. Evidence of housing-led predictability ($RHP \rightarrow RSP$) is detected only in the Central region, while the null hypothesis cannot be rejected for the Eastern, Western, and Northeastern regions. In contrast, stock-led predictability ($RSP \rightarrow RHP$) appears more prevalent, with statistically significant effects observed in the Eastern, Central, and Northeastern regions, but not in the Western region. These findings suggest that, at the regional aggregate level, stock market information tends to be transmitted more systematically to housing markets than housing market development transmitted to the stock market.

4.3. Asymmetric VAR Results

Because the asymmetric VAR is estimated using decomposed positive and negative return components rather than the aggregate return series employed in the baseline linear VAR, the goodness-of-fit measures reported for the two models are not directly comparable. Accordingly, the asymmetric VAR is evaluated primarily for its ability to capture asymmetric transmission mechanisms rather than improvements in overall model fit.

To move beyond the weak and uneven relationships revealed in the baseline linear models, we estimate asymmetric VARs that explicitly account for asymmetric causality relationships. These models allow us to examine whether the housing-stock nexus differs when prices rise versus fall.

Table 6 reports the asymmetric VAR estimates for Chinese four major economic regions. The results highlight the presence of asymmetric interdependencies, where positive and negative shocks produce systematically different effects, and where stock and housing markets interact in a manner that varies by both sign and region. In the housing-to-stock transmission channel, negative housing price innovations are associated with larger subsequent responses in stock returns than positive housing price movements, with the strongest and most statistically robust effects observed in the Central region. This pattern is consistent with behavioral and macro-financial theories emphasizing loss aversion, balance-sheet effects, and collateral constraints, which predict that adverse wealth shocks trigger disproportionately strong financial responses [11,14,52].

The dominance of negative housing shocks is consistent with the potential importance of real estate collateral in China's financial system. Housing price declines may tighten borrowing constraints, reduce liquidity, and increase risk aversion in equity markets, generating asymmetric reduced-form spillovers from housing to financial markets. This pattern is consistent with financial accelerator and collateral constraint theories, which emphasize the amplification of downturns through balance-sheet channels [12,13], although the reduced-form VAR does not separately identify these structural channels. In contrast, housing price increases generate comparatively muted stock market responses, consistent with diminishing marginal wealth effects and precautionary behavior.

The reverse transmission from stock markets to housing prices exhibits a different form of asymmetry. Across the four regions, positive stock market shocks generally generate more persistent and, in most cases, larger responses in regional housing returns than negative stock market shocks, although both the magnitude and persistence of these responses vary across regions. This pattern suggests that equity market upturns influence housing demand primarily through wealth and a pattern consistent with wealth and expectations-related interpretations, whereas housing-driven balance-sheet effects dominate during downturns. Regional heterogeneity in these dynamics reflects differences in financial development, household portfolio composition, and reliance on property-backed credit.

Our results indicate that the asymmetric housing-stock nexus reflects structural features of China's macro-financial environment rather than short-lived anomalies. High household exposure to real estate, limited diversification, and strong dependence on housing collateral imply that housing market downturns constitute a key channel of systemic risk transmission. Symmetric linear models, by construction, fail to capture these nonlinear adjustment processes and therefore tend to underestimate the macro-financial consequences of adverse housing shocks [15,53]. Although the adjusted R^2 values of the stock return equations are relatively modest, the estimated asymmetric coefficients remain statistically significant and economically meaningful, indicating that the proposed framework is intended to identify asymmetric transmission mechanisms rather than maximize predictive performance.

Table 6. Asymmetric VAR estimates.

Region	Intercept	$RHP^+(-1)$	$RHP^-(-1)$	$RSP^+(-1)$	$RSP^-(-1)$	Adj-R ²
<i>RSP</i>						
East	0.0423 ** (0.0208)	0.0521 (0.1587)	−0.2806 (0.2359)	0.3068 ** (0.1153)	−0.1316 (0.1111)	0.0475
Central	0.0375 (0.0269)	0.1112 (0.1281)	−0.8443 ** (0.3840)	0.2921 *** (0.1122)	−0.0977 (0.1133)	0.0656
West	0.0510 *** (0.0195)	0.0025 (0.1169)	−0.1884 (0.4285)	0.3314 *** (0.1156)	−0.1590 (0.1150)	0.0664
Northeast	0.0347 * (0.0209)	0.0186 (0.0688)	−0.4348 *** (0.1509)	0.3205 *** (0.1067)	−0.1308 (0.1068)	0.0630
<i>RHP</i>						
East	0.0239 *** (0.0071)	−0.1662 *** (0.0447)	−0.0889 (0.1364)	0.0436 (0.0681)	0.0575 (0.0476)	0.1014
Central	0.0184 *** (0.0079)	−0.1141 *** (0.0353)	−0.3189 ** (0.1410)	0.1359 (0.0846)	0.0312 (0.0455)	0.1463
West	0.0118 *** (0.0069)	−0.1310 *** (0.0350)	0.0582 (0.0883)	0.0664 (0.0809)	0.0676 (0.0528)	0.1072
Northeast	0.0103 (0.0165)	−0.1629 *** (0.0447)	−0.2156 * (0.1314)	0.2192 * (0.1149)	0.1060 * (0.0584)	0.0956

Note: ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. All estimated models include a crisis-period dummy variable as an exogenous control. For brevity, the estimated coefficient of the crisis-period dummy variable is not reported in this table; the corresponding estimates are provided in Supplementary Table S1. Diagnostic results for the estimated asymmetric VAR models, including the VAR stability condition, residual serial correlation (Portmanteau test), multivariate ARCH effects, and verification of the positive definiteness of the residual covariance matrices, are reported in Appendix A Table A3.

4.4. Asymmetric Granger Causality Tests

Throughout this section, “Granger causality” refers to directional predictability and should not be interpreted as structural or policy-invariant causality. To further investigate asymmetric directional predictability between *RHP* and *RSP* across Chinese provinces, we apply the asymmetric Granger causality test. This approach enables us to go beyond linear associations and capture potential regime-dependent dynamics. In this section, we specifically examine three hypotheses: (i) whether *RHP* Granger-causes *RSP*, (ii) whether *RSP* Granger-causes *RHP*, and (iii) whether there exists a bidirectional causal relationship between *RHP* and *RSP*. The results of the Wald-tests corresponding to these hypotheses are reported in Table 7.

Table 7 reports the results of asymmetric Granger causality tests examining predictive linkages between housing and stock markets across China’s four macro-regions. The asymmetric causality evidence reveals a clear and systematic pattern that contrasts sharply with the weak and heterogeneous results obtained under linear specifications. First, the results provide evidence of housing-led predictability of stock market returns, although the effects are heterogeneous across regions and depend on the sign of shocks. The joint asymmetric tests indicate statistically significant housing-to-stock causality in several regions, particularly in the Central, Western, and Northeastern regions. This relationship is primarily driven by negative housing price shocks, which exhibit stronger and more consistent predictive power for stock returns compared to positive shocks. These findings suggest that housing market dynamics may contain relevant predictive information for stock market movements under certain regional and downside conditions, although such effects are not uniformly observed across all regions [3,8]. On the other hand, stock-to-

housing predictability emerges as both economically meaningful and statistically robust across regions. The joint causality tests indicate that stock market innovations Granger-cause regional housing returns in all four macro-regions, suggesting that equity market movements contain leading information for housing market dynamics. Importantly, this predictive relationship is driven primarily by positive stock market shocks. Positive stock returns consistently improve forecasts of housing price growth, a finding that is consistent with wealth, confidence, and income-expectation channels emphasized in the literature [20,21,54].

Table 7. Asymmetric Granger Causality tests for the 4 Regions.

Region	RHP($\pm$) $\rightarrow$ RSPF (<i>p</i> -Value)	RHP(+) $\rightarrow$ RSPF (<i>p</i> -Value)	RHP(−) $\rightarrow$ RSPF (<i>p</i> -Value)
East	0.6155 (0.5432)	0.1951 (0.8237)	0.9008 (0.4098)
Central	2.0479 (0.0092)	0.4580 (0.6334)	2.6763 (0.0410)
West	5.1685 (0.0864)	1.0938 (0.3378)	7.7103 (0.0349)
Northeast	1.9729 (0.0088)	0.1723 (0.8421)	3.2225 (0.0482)
Region	RSP($\pm$) $\rightarrow$ RHPF (<i>p</i> -Value)	RSP(+) $\rightarrow$ RHPF (<i>p</i> -Value)	RSP(−) $\rightarrow$ RHPF (<i>p</i> -Value)
East	2.9301 (0.0568)	3.0327 (0.0475)	2.9778 (0.0496)
Central	3.9261 (0.0584)	2.1780 (0.0086)	5.0774 (0.0715)
West	2.3771 (0.0461)	2.8440 (0.0427)	1.5825 (0.1829)
Northeast	2.5178 (0.0436)	2.8145 (0.0398)	3.1285 (0.0454)

Note: The table reports Wald (F) statistics with the corresponding exact *p*-values (shown in parentheses) for the asymmetric Granger causality tests. All estimated models include a crisis-period dummy variable as an exogenous control. The estimated coefficient on the crisis-period dummy is omitted for brevity.

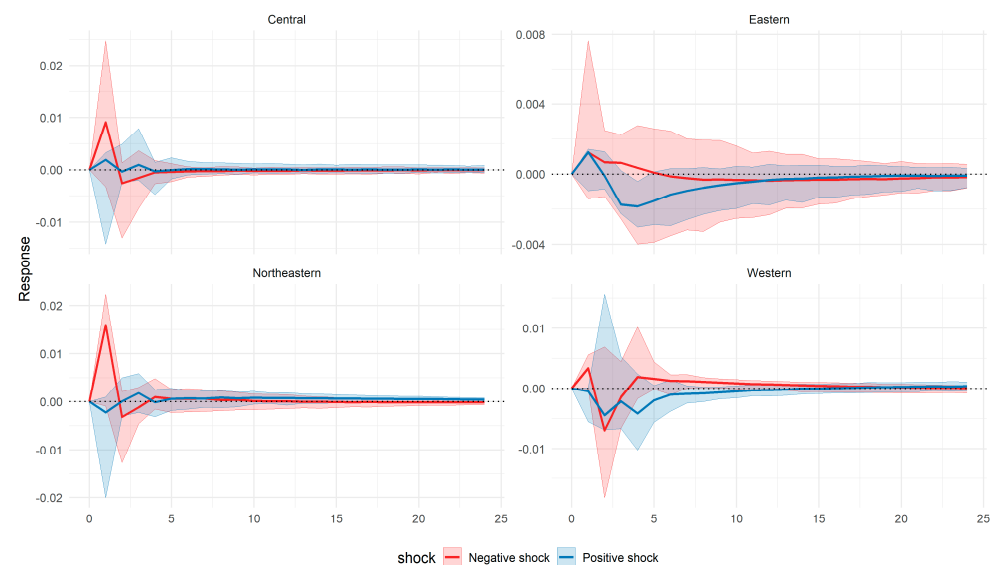
By comparison, negative stock market shocks exhibit weaker and more region-specific predictive power for housing markets. While downside stock movements contribute to housing market adjustments in some regions, their effects are neither uniform nor dominant. This asymmetry suggests that housing markets adjust more strongly during favorable financial conditions than during equity market downturns, possibly reflecting institutional features such as mortgage rigidities, policy stabilization measures, and the relatively slow adjustment of housing prices during periods of financial stress [15,53].

4.5. Impulse Responses to Positive and Negative Housing and Stock Price Shocks

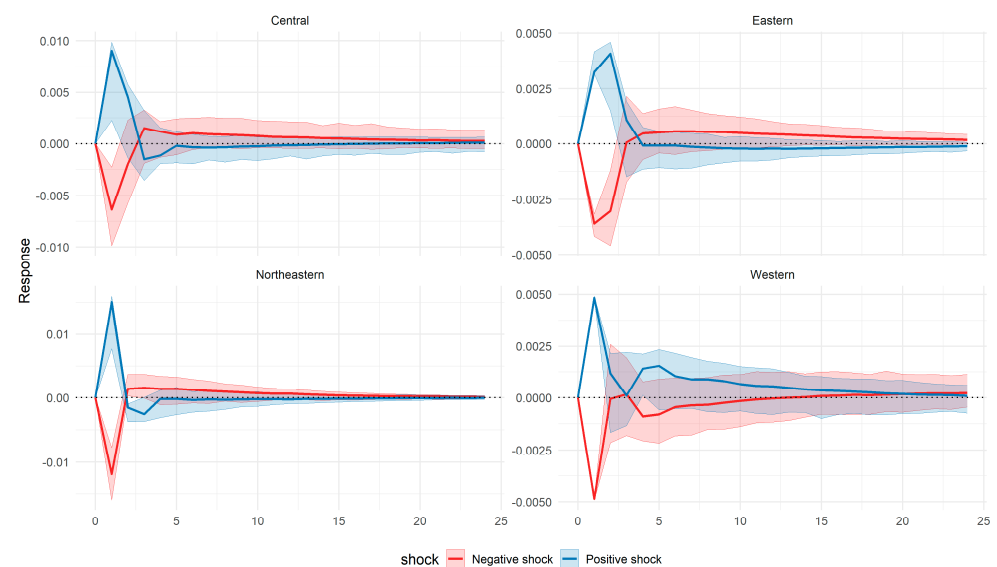
As housing and stock returns are decomposed into positive and negative components, the impulse response analysis distinguishes between shocks associated with positive price movements and shocks associated with negative price movements. Accordingly, a positive (negative) shock represents an unexpected increase in the corresponding positive (negative) return component, allowing us to examine whether upward and downward price movements in one market generate different dynamic responses in the other market. These shocks should therefore be interpreted as unexpected upward or downward movements in observed asset-price returns rather than as distinct structural economic or policy shocks. Consequently, the generalized impulse responses characterize reduced-form asymmetric transmission conditional on the direction of price movements, rather than structurally identified causal mechanisms.

Based on this interpretation, we estimate generalized impulse response functions for positive and negative shocks in both the housing and stock markets. This approach allows us to move beyond average dynamic relationships and examine whether the transmission of shocks differs according to their direction, consistent with theories of asymmetric adjustment and loss aversion [11,28].

Figure 2A reports the generalized impulse responses of stock returns to positive and negative housing price shocks across China's four major economic regions. Overall, the impulse responses suggest asymmetric transmission patterns, with negative housing shocks generally producing stronger stock market responses than positive housing shocks, although the magnitude and persistence of these responses vary across regions. Statistically significant responses are concentrated within approximately the first two to three forecast horizons, after which the confidence intervals generally include zero, indicating that the effects are largely transitory.



(A)



(B)

Figure 2. (A). Impulse response analysis under asymmetric decomposition of stock returns to housing shocks. (B). Impulse response analysis under asymmetric decomposition of housing returns to stock shocks. Note: Shaded areas denote 95% residual-based bootstrap confidence intervals based on 1000 replications.

Negative housing shocks generate relatively stronger stock market responses in the Central and Western regions, where stock returns decline more sharply than following comparable positive housing shocks. However, the coefficient equality tests reported in

Table A4 indicate statistically significant asymmetry only for selected regional equations. The observed response patterns are consistent with collateral-based transmission mechanisms, whereby declines in housing prices tighten borrowing constraints and amplify balance-sheet stress, particularly in regions with less diversified financial systems [1,14]. By contrast, positive housing shocks generally generate relatively modest and short-lived stock market responses, suggesting that, within the sample period, housing booms are associated with weaker stock market responses than housing market downturns.

In the Eastern region, where financial markets are deeper and more developed, housing-induced stock market responses are comparatively smaller and dissipate more rapidly, indicating greater capacity for risk sharing and shock absorption [37,55]. The Northeastern region exhibits weaker and less stable dynamic responses, reflecting structural and demographic constraints that may limit financial amplification [56]. Across all regions, the statistically significant responses are concentrated during the early forecast horizons, indicating that housing-driven stock market spillovers are economically meaningful but predominantly short-lived. This finding is consistent with previous evidence that asset-price spillovers tend to diminish relatively quickly under macroprudential and policy stabilization frameworks [4,57].

Figure 2B presents the generalized impulse responses of regional housing returns to positive and negative stock market shocks under the asymmetric decomposition framework. Overall, the impulse responses suggest that positive stock market shocks are associated with relatively stronger housing market responses in several regions, although both the magnitude and persistence of these responses differ across regional markets. The relatively stronger responses following positive stock market shocks are particularly evident in the Central, Eastern, and Northeastern regions, where positive stock market innovations generate larger housing market responses than comparable negative shocks during approximately the first two to four forecast horizons. Thereafter, the confidence intervals generally include zero, indicating that the responses are no longer statistically distinguishable from zero.

However, the Western region exhibits a more balanced response pattern, with relatively small differences between positive and negative stock market shocks over most forecast horizons. These findings are broadly consistent with the asymmetric VAR estimates reported in Table 6 and the asymmetric Granger causality results presented in Table 7, which indicate that stock-to-housing transmission is primarily associated with positive stock market innovations in several regions.

4.6. Robustness Check

To further evaluate the robustness of the empirical findings, we conduct three complementary robustness check that examine the sensitivity of the results to alternative constructions of the regional housing price index and alternative representations of asymmetric shocks.

First, following the reviewer's suggestion, we reconstruct the regional housing price index using population-weighted provincial housing price indices. This approach accounts for differences in the relative economic importance of provinces within each region by assigning weights according to provincial population shares. Specifically, the regional housing price index is constructed as

$$RHPI_{r,t}^{PW} = \sum_{i \in r} w_i HPI_{i,t}, \quad (12)$$

where $HPI_{i,t}$ denotes the housing price index of province i at time t , and

$$w_i = \frac{Population_i}{\sum_{j \in r} Population_j}, \quad (13)$$

with w_i representing the population share of province i within region r . Regional housing returns are then computed as logarithmic first differences in the reconstructed index.

Second, to address the possibility that averaging provincial price indices may be influenced by differences in index scales across provinces, we reconstruct the regional housing price index using normalized provincial housing price indices. Each provincial housing price index is normalized by its initial observation,

$$\tilde{HPI}_{i,t} = \frac{HPI_{i,t}}{HPI_{i,0}}, \quad (14)$$

where $HPI_{i,0}$ denotes the initial observation for province i . The normalized regional housing price index is then obtained as

$$RHPI_{r,t}^N = \frac{1}{N_r} \sum_{i \in r} \tilde{HPI}_{i,t}, \quad (15)$$

where N_r denotes the number of provinces in region r . Regional housing returns are subsequently calculated from the reconstructed normalized indices using logarithmic first differences.

Third, we evaluate whether the estimated asymmetric relationships depend on the specification of nonlinear shocks by replacing the baseline contemporaneous positive-negative return decomposition with the cumulative partial-sum decomposition proposed by [28]. Unlike the baseline approach, the cumulative partial-sum decomposition accumulates positive and negative innovations over time and therefore captures longer-run asymmetric adjustments. The qualitative similarity of the estimated coefficients, impulse responses, and causality results across the two decompositions indicates that the observed asymmetry reflects a robust feature of housing-stock market interactions rather than an artifact of a particular nonlinear decomposition.

The estimation results are reported in Table 8. Overall, the results obtained from both alternative constructions of the regional housing price index are highly consistent with the baseline findings reported in Table 6. Across all four economic regions, negative housing market shocks continue to exert stronger effects on stock market returns than positive housing market shocks, while positive stock market shocks remain the dominant driver of housing market dynamics. Moreover, the cumulative partial-sum decomposition yields qualitatively similar asymmetric transmission patterns and impulse responses.

Table 9 reports asymmetric VAR estimates based on cumulative partial-sum decompositions, which emphasize longer-run asymmetric adjustments rather than contemporaneous shock transmission. While the cumulative specification yields weaker housing-to-stock predictability in the stock return equations, it reveals a robust and persistent stock-to-housing channel across all regions. Taken together with the baseline results, these findings indicate that housing market downturns primarily affect stock markets through short-run nonlinear mechanisms, whereas stock market movements exert more persistent cumulative effects on housing prices.

Finally, to assess the robustness of the results to the choice of stock market proxy, we re-estimate the asymmetric VAR model using the CSI 300 Index as an alternative measure of equity market performance. The CSI 300 provides broader coverage of both the Shanghai and Shenzhen exchanges and is widely used as a benchmark for China's stock market. The results reported in Table 10 are qualitatively consistent with those obtained using the SSE Composite Index. In particular, the main asymmetric transmission patterns remain robust across specifications. Negative housing price shocks continue to exert stronger effects on stock returns than positive shocks, while the stock-to-housing transmission continues to exhibit regional heterogeneity, with broadly similar patterns across the Eastern, Central,

Western, and Northeastern regions. Although some differences in statistical significance are observed across specifications, the overall direction, magnitude, and asymmetry of the relationships remain broadly consistent.

Table 8. Robustness Check Using Alternative Constructions of Regional Housing Returns.

Panel A. Population-Weighted Regional Housing Return						
Region	Intercept	<i>RHP</i>⁺(−1)	<i>RHP</i>[−](−1)	<i>RSP</i>⁺(−1)	<i>RSP</i>[−](−1)	Adj-<i>R</i>²
<i>RSP</i>						
Eastern	−0.0097 (0.0073)	0.1832 (0.2415)	−0.7245 (0.5685)	0.2930 ** (0.1170)	−0.0598 (0.1076)	0.1170
Central	−0.0086 (0.0070)	0.0861 (0.1951)	−1.0026 ** (0.4458)	0.2439 ** (0.1174)	−0.0237 (0.1086)	0.1299
Western	−0.0068 (0.0072)	0.0238 (0.2092)	−0.1575 (0.3858)	0.2868 ** (0.1169)	−0.0728 (0.1081)	0.1096
Northeastern	−0.0105 (0.0074)	0.0122 (0.1051)	−0.4377 * (0.2392)	0.2897 ** (0.1161)	−0.0682 (0.1069)	0.1230
<i>RHP</i>						
Eastern	0.0046 ** (0.0023)	−0.0403 (0.0756)	0.0255 (0.1780)	0.0893 ** (0.0366)	0.0037 (0.0337)	0.1134
Central	0.0006 (0.0027)	−0.0294 (0.0741)	−0.2882 * (0.1694)	0.1406 *** (0.0446)	0.0049 (0.0413)	0.1492
Western	0.0033 (0.0027)	−0.0034 (0.0789)	−0.0490 (0.1456)	0.0877 ** (0.0441)	0.0162 (0.0408)	0.0959
Northeastern	0.0002 (0.0052)	−0.0804 (0.0748)	−0.1341 (0.1702)	0.2299 *** (0.0826)	0.0662 (0.0761)	0.1383
Normalized Provincial Housing Indices						
Region	Intercept	<i>RHP</i>⁺(−1)	<i>RHP</i>[−](−1)	<i>RSP</i>⁺(−1)	<i>RSP</i>[−](−1)	Adj-<i>R</i>²
<i>RSP</i>						
Eastern	−0.0097 (0.0074)	0.1835 (0.2202)	−0.5751 (0.5490)	0.2926 ** (0.1172)	−0.0605 (0.1077)	0.1153
Central	−0.0088 (0.0071)	0.0864 (0.2088)	−1.0447 ** (0.4726)	0.2501 ** (0.1171)	−0.0326 (0.1080)	0.1292
Western	−0.0077 (0.0071)	0.0470 (0.1799)	−0.3136 (0.3312)	0.2816 ** (0.1169)	−0.0707 (0.1077)	0.1127
Northeastern	−0.0102 (0.0073)	0.0155 (0.0956)	−0.3270 * (0.1903)	0.2930 ** (0.1162)	−0.0751 (0.1069)	0.1213
<i>RHP</i>						
Eastern	0.0044 * (0.0025)	−0.0449 (0.0755)	−0.0284 (0.1883)	0.0942 ** (0.0402)	0.0010 (0.0369)	0.1105
Central	0.0009 (0.0025)	−0.0215 (0.0741)	−0.3521 ** (0.1678)	0.1287 *** (0.0416)	0.0060 (0.0383)	0.1539
Western	0.0025 (0.0031)	−0.0232 (0.0773)	0.0677 (0.1424)	0.1461 *** (0.0502)	0.0127 (0.0463)	0.1264
Northeastern	0.0002 (0.0059)	−0.0953 (0.0764)	−0.1475 (0.1522)	0.2361 ** (0.0930)	0.0856 (0.0855)	0.1371

Note: Standard errors are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels. N = 238 per equation.

Table 9. Asymmetric VAR using cumulative partial-Sum Decomposition.

Region	Intercept	$RHP^+(-1)$	$RHP^-(-1)$	$RSP^+(-1)$	$RSP^-(-1)$	Adj-R ²
<i>RSP</i>						
East	0.0410 ** (0.0199)	0.0103 (0.0782)	−0.0402 (0.0504)	0.0429 * (0.0254)	−0.0335 (0.0401)	0.1156
Central	0.0155 (0.0260)	0.0114 (0.0669)	−0.1329 (0.1433)	0.0594 ** (0.0260)	−0.0380 (0.0359)	0.1164
West	0.0405 ** (0.0188)	−0.0930 (0.0747)	−0.0006 (0.1120)	0.0264 (0.0271)	−0.0648 (0.0401)	0.1201
Northeast	0.0284 (0.0176)	−0.0314 (0.0364)	−0.0843 (0.0774)	0.0478 * (0.0270)	−0.0355 (0.0338)	0.1168
<i>RHP</i>						
East	0.0150 ** (0.0058)	−0.0951 *** (0.0190)	−0.0605 *** (0.0205)	0.0241 *** (0.0067)	0.0037 (0.0058)	0.1663
Central	0.0067 (0.0073)	−0.0740 ** (0.0316)	−0.0536 (0.0423)	0.0131 (0.0091)	0.0061 (0.0074)	0.1277
West	0.0071 * (0.0039)	−0.0805 *** (0.0265)	−0.0518 (0.0428)	0.0187 ** (0.0088)	0.0031 (0.0080)	0.1390
Northeast	0.0045 (0.0087)	−0.1367 ** (0.0545)	−0.1670 *** (0.0608)	0.0181 * (0.0099)	0.0038 (0.0142)	0.1565

Note: Standard errors (time-clustered) are reported in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively. All estimated models include a crisis-period dummy variable as an exogenous control. The estimated coefficient is omitted from the table for brevity.

Table 10. Asymmetric VAR estimates using alternative stock market (CSI300).

Region	Intercept	$RHP^+(-1)$	$RHP^-(-1)$	$RSP^+(-1)$	$RSP^-(-1)$	Adj-R ²
<i>RSP</i>						
East	0.0194 * (0.0103)	0.0353 (0.0495)	−0.0923 (0.1034)	0.2944 *** (0.0924)	−0.0945 * (0.0510)	0.0502
Central	0.0202 (0.0189)	0.2043 * (0.1145)	−0.4095 (0.5096)	0.1924 *** (0.0735)	−0.0834 (0.064)	0.1093
West	0.044 *** (0.0102)	0.0094 (0.0245)	−0.0340 *** (0.0124)	0.2229 *** (0.0823)	−0.1029 * (0.0593)	0.1339
Northeast	0.0289 ** (0.0142)	0.0034 (0.0045)	−0.0234 (0.0345)	0.2538 ** (0.1238)	−0.0294 (0.0823)	0.1934
<i>RHP</i>						
East	0.0105 (0.0230)	−0.0943 ** (0.0405)	−0.0475 (0.0734)	0.0498 (0.0596)	0.0439 (0.0304)	0.1103
Central	0.0324 *** (0.0034)	−0.0695 * (0.0024)	−0.2094 * (0.1209)	0.0834 (0.0535)	0.0221 (0.0402)	0.1443
West	0.0109 *** (0.0043)	−0.045 ** (0.027)	0.1034 * (0.0593)	0.0330 (0.0443)	0.0389 (0.0189)	0.0934
Northeast	0.0223 ** (0.0102)	−0.0934 (0.0596)	−0.1034 *** (0.0348)	0.1039 (0.1090)	0.0395 (0.405)	0.1204

Note: ***, ** and * indicate significantly at the 1%, 5%, and 10% levels, respectively. All estimated models include a crisis-period dummy variable as an exogenous control. The estimated coefficient is omitted from the table for brevity.

5. Conclusions

This study examines asymmetric housing-stock market interactions across China's four major economic regions using an integrated empirical framework combining asymmetric VAR models, asymmetric Granger causality tests, and generalized impulse response

analysis under asymmetric decomposition analysis. By distinguishing between positive and negative shocks, the analysis provides evidence of asymmetric and regionally heterogeneous transmission patterns that may be obscured in conventional linear frameworks.

The empirical findings suggest that housing market downturns tend to be associated with stronger adverse stock market responses than housing market expansions in selected regions. These effects are particularly pronounced in the Central and Western regions, where household balance sheets, local credit systems, and economic activity remain more closely linked to real estate markets. The results are broadly consistent with collateral constraint and financial accelerator theories. Specifically, the observed asymmetric transmission patterns are consistent with the view that housing price declines may reduce collateral values, tighten borrowing conditions, weaken balance sheets, and amplify financial stress, although these structural channels are not separately identified within the reduced-form VAR framework. In the reverse direction, positive stock market shocks provide more consistent evidence of stock-to-housing predictability across several regions, although the magnitude, statistical significance, and persistence of the responses vary across regional markets. This pattern is consistent with interpretations based on wealth accumulation, improved market expectations, and stronger borrowing capacity, although these channels are not directly identified in the empirical model. Taken together, the findings suggest that housing-related downside risk may represent an important source of regional macro-financial vulnerability in China.

The results also suggest meaningful regional differences in the estimated transmission patterns. In the Eastern region, where financial systems are deeper and more diversified, stock-to-housing transmission is stronger and adjustment processes are relatively more stable. By contrast, the Central and Western regions exhibit stronger housing-to-stock spillovers, reflecting greater dependence on real estate markets and property-backed credit. The Northeastern region displays weaker and less persistent interactions, likely reflecting structural economic challenges, demographic decline, and comparatively limited financial dynamism. These findings are consistent with the view that differences in financial development, credit dependence, and housing market maturity contribute to regional differences in macro-financial transmission mechanisms.

Beyond the Chinese context, this study contributes to the broader literature on asset-market interdependence in three important ways. First, it demonstrates that the direction and magnitude of housing-stock market spillovers depend critically on the nature of shocks, with adverse housing shocks generating substantially stronger transmission effects than favorable shocks. Second, it shows that housing-related financial risks cannot be fully understood without accounting for regional heterogeneity in financial structures and market development. Third, the findings highlight the importance of analyzing housing and financial markets within an integrated framework that captures asymmetric transmission, dynamic feedback effects, and spatial variation in vulnerability. These results contribute to a growing body of evidence suggesting that housing markets play an important role in the propagation of macro-financial risks, particularly during periods of economic uncertainty and financial stress. The findings provide useful empirical evidence for understanding regional differences in housing-financial interactions. However, because the estimated relationships are obtained from a reduced-form VAR model and may depend on the policy and institutional environment prevailing during the sample period, they should not be interpreted as policy-invariant structural parameters. Consequently, the policy implications should be interpreted as suggestive rather than prescriptive.

From this perspective, the findings suggest that uniform nationwide macroprudential policies may not fully account for regional differences in housing and financial systems. Likewise, measures aimed at mitigating housing market downturns may warrant particular attention in regions where real estate markets appear to play a more prominent role in credit creation and financial transmission. More broadly, the results suggest that region-specific macroprudential monitoring frameworks incorporating asymmetric housing-related risks may provide a useful basis for assessing regional financial vulnerabilities, although further research using structurally identified models would be required to establish causal policy effects.

Several limitations warrant attention. First, the use of provincial-level data may conceal important heterogeneity across city tiers and local housing markets within each region. Future research using more disaggregated city-level data could provide a richer understanding of regional transmission mechanisms. Second, although the reduced-form VAR framework effectively captures dynamic interdependence, asymmetric transmission, and directional predictability, it is not designed to identify the underlying structural mechanisms through which shocks are transmitted. Consequently, the estimated impulse responses should be interpreted as reduced-form dynamic responses rather than structurally identified causal effects. Identifying structural shocks would require additional identifying restrictions, such as recursive ordering assumptions or structural VAR specifications, which are beyond the scope of the present study. Future research could investigate whether the asymmetric transmission mechanisms identified here remain robust under alternative structural identification strategies, including Cholesky decomposition or structural VAR approaches based on stronger theoretical identification schemes. Third, the parsimonious bivariate VAR focuses exclusively on housing and stock market interactions and therefore excludes other macroeconomic and financial factors, such as monetary policy, credit conditions, investor sentiment, and external shocks, that may also influence market dynamics. Consequently, the explanatory power of the stock return equations is relatively modest, which is common in financial return models. Future research could incorporate additional macroeconomic variables or higher-dimensional VAR specifications to provide a more comprehensive understanding of housing-stock market interactions.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/math14152814/s1>, Table S1: Estimated coefficients of the crisis dummy variable in Asymmetric VAR estimates (Table 6).

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Appendix A

Table A1. Provincial classification used for regional aggregation.

Region	Provinces
Eastern China	Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan
Central China	Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan
Western China	Inner Mongolia, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang
Northeastern China	Liaoning, Jilin, Heilongjiang

Note: The regional classification follows the conventional four-region classification widely adopted in studies of the Chinese economy and by the National Bureau of Statistics of China.

Table A2. VAR lag length selection results.

Lag	AIC				BIC			
	East	West	Central	Northeast	East	West	Central	Northeast
1	−12.433	−12.333	−12.394	−11.210	−12.351	−12.193	−12.276	−11.123
2	−12.423	−12.314	−12.371	−11.203	−12.275	−12.168	−12.224	−11.062
3	−12.395	−12.296	−12.375	−11.193	−12.186	−12.081	−12.171	−10.982
4	−12.401	−12.329	−12.386	−11.205	−12.135	−12.055	−12.110	−10.948

Note: Bold number indicates the optimal lag.

Table A3. Diagnostic tests for the estimated asymmetric VAR models.

Region	Portmanteau Test (<i>p</i> -Value)	Multivariate ARCH (<i>p</i> -Value)	Stability
East	0.502	0.340	Stable
Central	0.673	0.440	Stable
West	0.233	0.345	Stable
Northeast	0.394	0.498	Stable

Note: VAR stability is evaluated using the companion matrix eigenvalue criterion (all characteristic roots lie inside the unit circle). Residual serial correlation is examined using the asymptotic Portmanteau test, and residual heteroskedasticity is assessed using the multivariate ARCH test. The residual covariance matrices are verified to be positive definite using the eigenvalue criterion.

Table A4. Wald tests of coefficient equality between positive and negative shocks.

Region	Variable	Null Hypothesis	$\beta^+ - \beta^-$	Wald χ^2	<i>p</i> -Value
East	RSP	$H_0 : \beta_{RHP}^+ = \beta_{RHP}^-$	0.3327	2.74	0.098
	RHP	$H_0 : \beta_{RSP}^+ = \beta_{RSP}^-$	−0.0139	0.02	0.892
Central	RSP	$H_0 : \beta_{RHP}^+ = \beta_{RHP}^-$	0.9555	4.22	0.040
	RHP	$H_0 : \beta_{RSP}^+ = \beta_{RSP}^-$	0.1047	0.84	0.364
West	RSP	$H_0 : \beta_{RHP}^+ = \beta_{RHP}^-$	0.1909	1.37	0.181
	RHP	$H_0 : \beta_{RSP}^+ = \beta_{RSP}^-$	−0.0012	0.14	0.995
Northeast	RSP	$H_0 : \beta_{RHP}^+ = \beta_{RHP}^-$	0.4534	4.80	0.028
	RHP	$H_0 : \beta_{RSP}^+ = \beta_{RSP}^-$	0.1132	0.36	0.556

Notes: The table reports Wald χ^2 tests of the null hypothesis that the coefficients associated with positive and negative shocks are equal within each estimated VAR equation. The reported coefficient difference equals $\hat{\beta}^+ - \hat{\beta}^-$. *p*-values correspond to Wald χ^2 tests with one degree of freedom.

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