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Dissecting the Heterogeneity of China's Regional Housing Markets

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Abstract

Using data from 29 regional housing markets in China, we estimate the long-run relationship between housing prices and key macroeconomic variables. Our findings suggest that the conventional cointegration framework can be misleading, as the estimated coefficients often contradict standard demand and supply theory even when statistical tests confirm the presence of cointegration. Among the variables considered, only real income consistently explains regional housing price dynamics. In contrast, factors such as the real interest rate and real building cost fail to account for price movements in a consistent manner across regions. We identify region-specific models that are both statistically valid and economically meaningful, revealing substantial heterogeneity across markets. These results call for more tailored, region-specific housing policies rather than uniform national strategies.

Keywords: Housing Market; Cointegration; Dynamic Ordinary Least Squares; Disaggregated Regional Data

JEL Classification: R30; E00; C51

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1 Introduction

The dynamics of housing prices in China have received considerable academic attention, reflecting the sector's pivotal role in driving the country's economic expansion. Over the past few decades, China's real estate sector has experienced a sustained housing boom, triggering debates on price misalignments and regional supply-demand imbalances.

Building on earlier research, numerous studies have studied the distinctive features of China's housing market, particularly regarding its susceptibility to asset bubbles.[1] For instance, Fang et al. (2015) claim that the observed housing price appreciation is largely supported by robust household income growth, thereby reducing the likelihood of a financial crisis akin to that of the 2008 U.S. subprime mortgage market crisis. In contrast, by estimating supply-demand fundamentals, Chivakul et al. (2015) identify potential mismatches in China's real estate markets. Chen and Wen (2017) also interpret China's housing boom as a rational bubble that emerged during the country's economic transition, highlighting a phenomenon where housing prices have grown substantially faster than disposable income despite high vacancy rates and sustained returns to capital. According to Jiang et al. (2022), rapid increases in housing prices in China may provide short-run benefits by stimulating infrastructure investment. However, Rogoff and Yang (2021) caution that an extended housing boom may expose China to macroeconomic vulnerabilities due to persistent supply-demand imbalances. More recently, Xu et al. (2024) highlight systemic vulnerabilities in the Chinese housing sector, emphasizing the potential for negative information to propagate across regional housing networks.

We recognize that understanding the potential mismatch issues highlighted in the existing literature requires a careful assessment of the fundamental drivers of housing prices and the extent to which macroeconomic variables—such as income, interest rates, and construction costs—can fully account for regional housing market dynamics. In particular, we focus on the heterogeneity of housing markets across China's diverse regions. Nationally aggregated models often obscure substantial regional variation arising from structural, demographic, and institutional differences. This concern is particularly relevant in the Chinese context, where local governments play a critical role in land allocation and the implementation of housing policies (see, among others, Deng et al. 2012). Moreover, regional disparities in income levels and credit market conditions further contribute to differentiated housing market behaviors that may elude detection in national-level analyses.

Our study seeks to fill this gap by utilizing a panel of annual data from 1994 to

[1] See Piazzesi and Schneider (2016) for a survey of the literature on housing markets in macroeconomics.

2021 for 29 Chinese regions to examine the long-run relationship between real housing prices and key macroeconomic variables, including real GDP per capita (as a proxy for income), real interest rates, and real construction costs. We apply cointegration test frameworks across alternative model specifications, followed by dynamic ordinary least squares (DOLS) estimation, to assess whether these variables are jointly cointegrated and whether the estimated coefficients are consistent with standard economic theory. In particular, we demonstrate that cointegration tests alone may lead to misleading inferences, underscoring the need for balanced evaluations that incorporate both statistical evidence and theoretical expectations.

A key contribution of our analysis lies in the identification of statistically and economically valid models at the regional level, which uncover substantial heterogeneity across regions. In contrast to earlier studies that typically impose a common model specification across regions, our approach allows for structural variation in the underlying cointegrating vectors. This enables a more nuanced understanding of regional housing market dynamics and carries important implications for the design of region-specific housing policies. Our findings suggest that while income consistently plays a dominant role in explaining housing prices, the effects of real interest rates and construction costs are generally limited and display considerable variation across regions.

The remainder of the paper is organized as follows. Section 2 presents the data and preliminary analysis, followed by the cointegration tests and DOLS estimations for the benchmark model. In Section 3, we explore and identify the model specifications that best fit each regional housing market. Section 4 concludes.

2 The Empirics

2.1 Data Descriptions and Preliminary Analysis

We collected data on housing prices and key macroeconomic variables that are related to the housing market for China and its 29 regions. These variables include gross domestic product (GDP), construction costs of completed buildings, population, the consumer price index (CPI), and real interest rates. Observations are annual frequency, spanning from 1994 to 2021.[2] We obtained the data from the World Bank and National/Provincial Statistical Yearbooks of China.

[2] In addition to GDP, we also collected alternative income measures, including urban disposable income per capita and rural per capita net income. Our main findings are based on real GDP, as the empirical results are overall similar when using these alternative income variables.

Housing prices and construction costs are expressed in Chinese yuan per square meter. Income variables are also expressed in Chinese yuan. The CPI, originally reported as year-over-year percent changes, was adjusted to a common base year and converted into an index. All nominal variables, including housing prices, GDP, construction/building cost, and lending interest rates, were transformed into corresponding real variables using the regional CPI. Real GDP was further adjusted into per capita terms utilizing regional population data.

To analyze regional real housing price ($hp_{i,t}$) dynamics, we focus on three key housing market variables: regional real GDP per capita ($ry_{i,t}$) and the real interest rate (rr_t) as demand shifters, and real building cost (bc_t) as a supply shifter. Note that housing prices ($hp_{i,t}$) and real GDP per capita ($ry_{i,t}$) are regional variables, whereas the real interest rate (rr_t) and real building cost (bc_t) are national variables. These two national variables were deflated using the national CPI to obtain their real values. All quantity variables, housing prices, real GDP, and real building cost, were log transformed for consistency to capture percent changes.

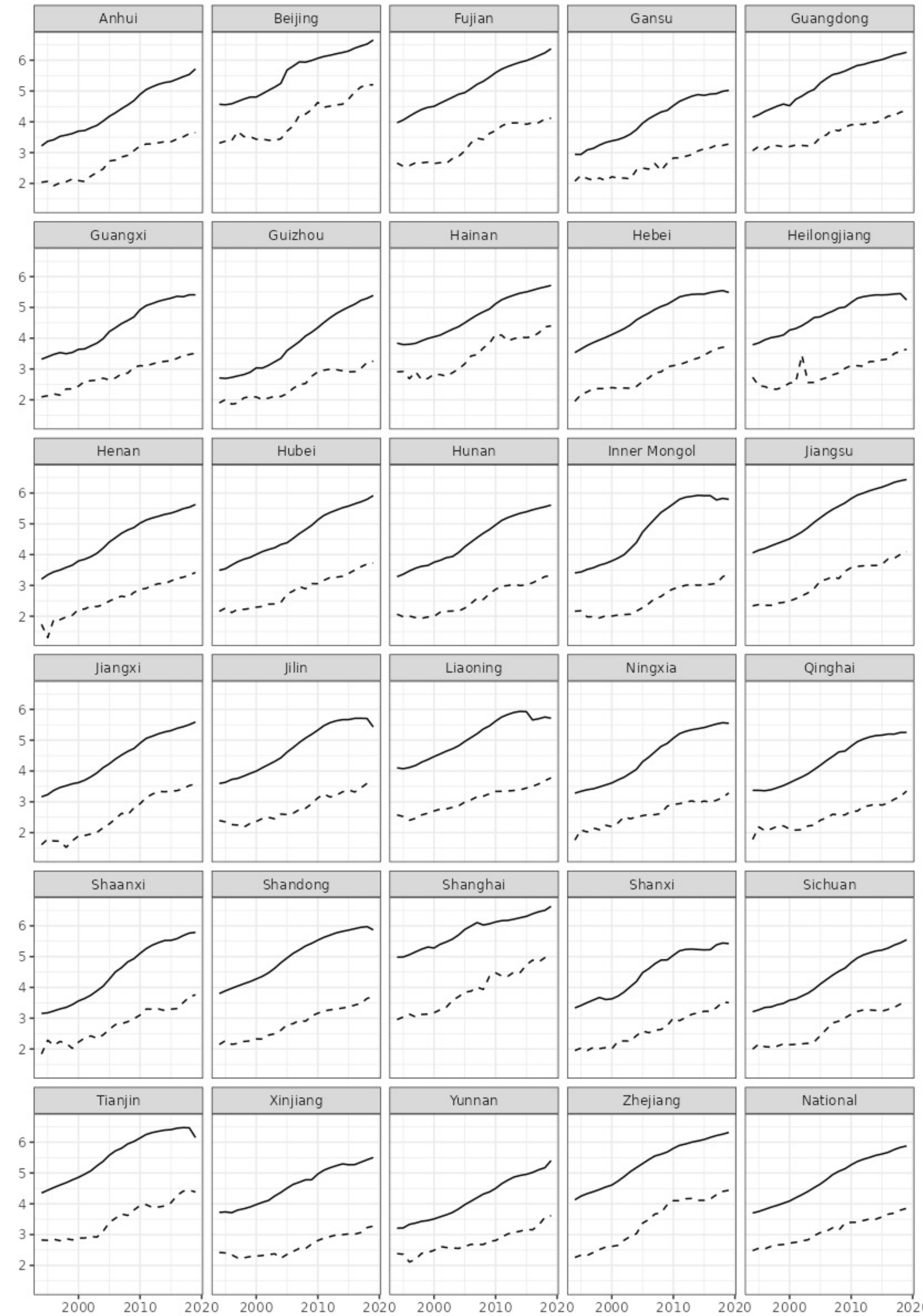
Figure 1 presents the graphs of housing prices $hp_{i,t}$ and real GDP per capita $ry_{i,t}$ for 29 regions, along with their respective national averages, hp_t and ry_t. Both $hp_{i,t}$ and $ry_{i,t}$ exhibit upward trends over time, suggesting the presence of stochastic trends. Moreover, the two variables tend to move together, with temporary short-run deviations, indicating potential cointegrating relationships.

To statistically test this possibility, we implemented the DF-GLS unit root test proposed by Elliott et al. (1996) with an intercept, which is asymptotically more powerful than the conventional augmented Dickey-Fuller test. The results, presented in Table 1, indicate that the null hypothesis of nonstationarity cannot be rejected at the 5% significance level for all 29 regional housing price series and for 27 of the regional real GDP per capita series. We also find strong evidence of nonstationarity in all national-level variables, including the real interest rate and real building cost. Given this strong evidence supporting the presence of integrated $I(1)$ processes, we proceed by modeling housing price dynamics within a cointegration framework.

2.2 Cointegration Analysis

Let $\mathbf{y}_{i,t}$ denote a $k \times 1$ vector of endogenous variables of region i which obey an integrated $I(1)$ process. In the presence of a cointegrating relationship among the variables in $\mathbf{y}_{i,t}$, we may consider the following vector error correction model.

Figure 1: Regional Housing Prices and Per Capital Real GDP



Note: The solid lines are regional housing prices $hp_{i,t}$, while the dashed lines are real GDP per capita $ry_{i,t}$. The last panel displays the national averages of these variables across 29 regions, hp_t and ry_t. All data are log transformed.

Table 1: DF-GLS Test Results

	$hp_{i,t}$		$ry_{i,t}$	
Region	DFGLS	p-value	DFGLS	p-value
Anhui	-0.023	0.499	0.003	0.804
Beijing	-0.025	0.670	-0.011	0.725
Fujian	-0.021	0.545	0.007	0.501
Gansu	0.035	0.639	-0.007	0.630
Guangdong	-0.001	0.980	-0.005	0.813
Guangxi	0.002	0.957	-0.013	0.500
Guizhou	-0.018	0.693	-0.017	0.240
Hainan	-0.026	0.658	-0.012	0.266
Hebei	0.000	0.998	-0.013	0.225
Heilongjiang	-0.090	0.592	-0.034	0.195
Henan	0.035	0.259	-0.002	0.865
Hubei	-0.017	0.664	0.003	0.800
Hunan	-0.011	0.776	-0.006	0.586
Inner Mongolia	-0.021	0.519	-0.025	0.085
Jiangsu	-0.005	0.887	-0.010	0.106
Jiangxi	-0.006	0.883	0.001	0.956
Jilin	-0.001	0.988	$-0.045^{\dagger}$	0.019
Liaoning	-0.019	0.566	-0.027	0.335
Ningxia	0.034	0.517	-0.021^{*}	0.091
Qinghai	0.050	0.359	-0.024^{*}	0.073
Shaanxi	0.019	0.725	-0.016	0.181
Shandong	-0.006	0.859	$-0.021^{\dagger}$	0.041
Shanghai	0.022	0.667	0.003	0.932
Shanxi	0.013	0.815	-0.014	0.563
Sichuan	-0.015	0.571	-0.005	0.643
Tianjin	-0.021	0.639	-0.042^{*}	0.052
Xinjiang	-0.001	0.988	-0.013	0.539
Yunnan	-0.004	0.957	0.016	0.349
Zhejiang	-0.017	0.548	-0.005	0.585
National Variables	DFGLS	p-value		
hp_t	0.008	0.839		
ry_t	-0.008	0.314		
bc_t	-0.901	0.264		
rr_t	-0.217	0.217		

Note: 'DFGLS' indicates the DF-GLS statistics proposed by Elliott et al. (1996). 'p-value' denotes the p values of the test with the null hypothesis of nonstationarity. $*$ and $\dagger$ denote a rejection of the null hypothesis at the 10% and 5% levels, respectively.

$$\Delta \mathbf{y}_{i,t} = \mathbf{a}_i + \mathbf{ff}_i \beta' \mathbf{y}_{i,t-1} + \sum_{j=1}^{k} \mathbf{B}_j \Delta \mathbf{y}_{i,t-j} + \mathbf{u}_{i,t}, \tag{1}$$

where $\mathbf{ff}_i$ is a $k \times 1$ vector of convergence rates, $\mathbf{fi}$ is a $k \times 1$ cointegrating vector, $\mathbf{fi}'\mathbf{y}_{t-1}$ denotes the error correction term. $\mathbf{B}_j$ is a $k \times k$ coefficient matrix. $\mathbf{a}$ is a $k \times 1$ vector of constants and $\mathbf{u}_t$ is a $k \times 1$ vector of error terms.

For our housing market analysis, consider $\mathbf{y}_{i,t} = \left[\mathbf{z}'_{i,t} \;\; hp_{i,t}\right]'$, where $hp_{i,t}$ denotes the log of housing price in region i at time t, while $\mathbf{z}_{i,t}$ is a 3×1 vector of key macroeconomic variables. Specifically, $\mathbf{z}_{i,t}$ includes the log of real per capita income ($ry_{i,t}$), the real interest rate (rr_t), and the log of the real building cost index (bc_t), where rr_t and bc_t are common factors across all regions.

We first employ the Johansen cointegration testing procedure, specifically the Johansen maximum eigenvalue test and the trace test. These are data-driven, sequential testing methods that allow for the possibility of multiple cointegrating relationship, which can make economic interpretation challenging. In what follows, we address this issue by applying an economic approach to interpret the estimated cointegrating relationship. We also supplement the testing procedure with the Engle-Granger test, which is based on a single equation specification for housing price.

Table 2 presents the cointegration test results with $\mathbf{y}_{i,t} = [ry_{i,t} \; rr_t \; bc_t \; hp_{i,t}]'$. The maximum eigenvalue test supports at least one cointegrating relationship for 28 out of 29 regions, except Heilongjiang, at the 10% significance level, while the trace test provides evidence of cointegration for all 29 regions. The Engle-Granger test, on the other hand, rejects the null of no cointegration for 21 out of 29 regions, possibly due to its weaker power relative to the Johansen procedure, which is based on a vector error correction model rather than a single equation framework. Overall, all tests indicate strong evidence of cointegrating relationships with the national average series. Taken together, the results provide robust evidence of a long-run relationship between $hp_{i,t}$ and $\mathbf{z}_{i,t}$, its demand and supply shifter variables.

In the next section, we critically examine the statistical evidence presented above that supports the conventional economic model based on demand and supply shifter variables by directly estimating the cointegration coefficients, highlighting the heterogeneity across the 29 regional housing markets in China.

Table 2: Cointegration Test Results
$\mathbf{y}_{i,t} = [ry_{i,t}\ rr_t\ bc_t\ hp_{i,t}]'$

Region	J_{MaxEig}	H_A	J_{Trace}	H_A	EG
Anhui	14.38^{*}	$r > 2$	18.23^{*}	$r > 2$	$-2.572^{\dagger}$
Beijing	8.89^{*}	$r > 3$	8.89^{*}	$r > 3$	-1.924^{*}
Fujian	$31.2^{\dagger}$	$r > 0$	33.73^{*}	$r > 1$	-1.739^{*}
Gansu	8.93^{*}	$r > 3$	8.93^{*}	$r > 3$	-1.835^{*}
Guangdong	8.46^{*}	$r > 3$	8.46^{*}	$r > 3$	-1.738^{*}
Guangxi	$37.37^{\ddagger}$	$r > 0$	$68.07^{\ddagger}$	$r > 0$	$-2.240^{\dagger}$
Guizhou	$26.28^{\dagger}$	$r > 1$	$39.48^{\dagger}$	$r > 1$	$-2.884^{\ddagger}$
Hainan	$30.94^{\dagger}$	$r > 0$	$62.90^{\ddagger}$	$r > 0$	$-2.622^{\dagger}$
Hebei	14.97^{*}	$r > 2$	$21.54^{\dagger}$	$r > 2$	-1.549
Heilongjiang	23.06	$r > 0$	52.75^{*}	$r > 0$	$-2.372^{\dagger}$
Henan	$36.23^{\ddagger}$	$r > 0$	$63.61^{\ddagger}$	$r > 0$	$-3.287^{\ddagger}$
Hubei	$23.81^{\dagger}$	$r > 1$	$40.80^{\dagger}$	$r > 1$	$-2.509^{\dagger}$
Hunan	$23.33^{\dagger}$	$r > 1$	$40.12^{\dagger}$	$r > 1$	$-2.720^{\dagger}$
Inner Mongolia	7.92^{*}	$r > 3$	7.92^{*}	$r > 3$	-0.259
Jiangsu	$25.28^{\dagger}$	$r > 1$	19.10^{*}	$r > 2$	$-3.071^{\ddagger}$
Jiangxi	20.38^{*}	$r > 1$	$35.05^{\dagger}$	$r > 1$	$-3.524^{\ddagger}$
Jilin	8.53^{*}	$r > 3$	8.53^{*}	$r > 3$	-0.378
Liaoning	$29.97^{\ddagger}$	$r > 1$	$42.43^{\ddagger}$	$r > 1$	-0.267
Ningxia	$29.48^{\dagger}$	$r > 0$	$56.97^{\dagger}$	$r > 0$	-1.752^{*}
Qinghai	14.12^{*}	$r > 2$	18.81^{*}	$r > 2$	-1.053
Shaanxi	26.79^{*}	$r > 0$	52.34^{*}	$r > 0$	$-2.632^{\dagger}$
Shandong	$17.30^{\dagger}$	$r > 2$	$22.31^{\dagger}$	$r > 2$	-0.466
Shanghai	13.78^{*}	$r > 2$	19.33^{*}	$r > 2$	$-2.833^{\ddagger}$
Shanxi	26.18^{*}	$r > 0$	32.21^{*}	$r > 1$	-1.294
Sichuan	7.74^{*}	$r > 3$	7.74^{*}	$r > 3$	$-2.579^{\dagger}$
Tianjin	$35.94^{\ddagger}$	$r > 0$	18.45^{*}	$r > 2$	-0.923
Xinjiang	14.25^{*}	$r > 2$	$19.97^{\dagger}$	$r > 2$	$-2.162^{\dagger}$
Yunnan	$46.66^{\ddagger}$	$r > 0$	32.84^{*}	$r > 1$	$-2.213^{\dagger}$
Zhejiang	$28.14^{\ddagger}$	$r > 1$	$43.52^{\ddagger}$	$r > 1$	-1.995^{*}
National	$22.15^{\dagger}$	$r > 1$	$39.72^{\dagger}$	$r > 1$	$-2.245^{\dagger}$

Note: J_{MaxEig} and J_{Trace} denote the Johansen maximum eigenvalue statistics and the Johansen trace statistics, respectively. H_A denotes the **last** alternative hypothesis considered when its associated null hypothesis is rejected in the sequential testing procedure. For example, statistically significant test results with $H_A : r > 0$ indicate the presence of one cointegrating relationship, whereas statistically insignificant results with $H_A : r > 0$ suggest no cointegrating relationship. EG denotes the Engle-Granger Test statistics, which tests the null of no cointegration against the alternative hypothesis of a single cointegration vector. $*, \dagger$, and $\ddagger$ indicates a rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively.

2.3 Dynamic Ordinary Least Squares Estimation

Given the strong evidence for cointegration, we employ the dynamic ordinary least squares (DOLS) regression proposed by Stock and Watson (1993) to estimate the cointegration relationship between $hp_{i,t}$ and $\mathbf{z}_{i,t}$. Abstracting from deterministic terms, consider the following regression equation:

$$hp_{i,t} = \mathbf{fi}'\mathbf{z}_{i,t} + \sum_{j=-p}^{q} \mathbf{fl}_j \Delta\mathbf{z}_{i,t+j} + \varepsilon_{i,t}, \tag{2}$$

where **fi** denotes the cointegration vector. Note that both past ($-p$) and future (q) values of $\Delta\mathbf{z}_{i,t}$ appear in this regression equation to ensure the strict exogeneity of $\mathbf{z}_t$, as shown by Stock and Watson (1993).[3]

Table 3 presents the DOLS estimation results with $\mathbf{y}_{i,t} = [ry_{i,t}\ rr_t\ bc_t\ hp_{i,t}]'$. Despite the strong statistical evidence of cointegration shown in the previous section, a surprising number of DOLS estimates, particularly those for rr_t and bc_t, are inconsistent with the prediction of the conventional economic model.

According to standard theory, stronger demand driven by higher real income should raise housing prices, while an increase in the real interest rate should shift the demand curve leftward, leading to lower housing prices. Similarly, higher building cost should shift the supply curve leftward, pushing the equilibrium price upward. Thus, the expected signs of the coefficients are positive for $ry_{i,t}$ and bc_t, and negative for rr_t.

Notably, the coefficient of $ry_{i,t}$ is statistically significantly positive at the 1% level for 28 out of 29 regions. The exception is Heilongjiang, where the coefficient is significant at the 5% level but has the wrong sign. Recall that Heilongjiang was the only case in which the Johansen maximum eigenvalue test failed to confirm cointegration. These findings, therefore, provide solid evidence of an income effect, supporting the existence of a long-run relationship between $hp_{i,t}$ and $ry_{i,t}$ in most regional housing markets.

Regarding the housing market effect of the real interest rate, the other demand shifter, its coefficient estimates are significantly negative at the 5% level for 16 out of 29 regions. In contrast, 10 regions show coefficients with the wrong (positive) sign, while 3 regions have correctly signed but statistically insignificant estimates. Thus, we find only limited evidence supporting the effect of rr_t.

As for the real building cost bc_t, its coefficient estimates are largely inconsistent with standard theory across many regions as well as at the national level. It is significantly

[3]The Bartlett kernel was used to estimate the long-run variance, with automatic bandwidth selection following Andrews (1991). The number of leads (q) and lags (p) was selected via the Akaike Information Criteria.

positive at the 10% level in only 13 out of 29 regions, with 2 additional regions showing the correct sign but statistically insignificant estimates. The remaining 14 regions and the national level data show significantly negative coefficients, with 11 of them including the national estimate being significant at the 1% level.

Taken all together, the DOLS estimation results provide solid evidence of an income effect but suggest a much weaker and inconsistent relationship between $hp_{i,t}$ and the other two variables, $rr_{i,t}$ and bc_t. In the next section, we examine a range of alternative models to identify the reasonable ones for each region, guided by both statistical and economic inferences.

3 Exploring Alternative Models for Regional Markets

3.1 Alternative Model Specifications

In addition to the benchmark (BM) model in the previous section with $\mathbf{y}_t = [ry_{i,t}\ rr_t\ bc_t\ hp_{i,t}]'$, we consider the following 5 alternative models.

- Model M1: $\mathbf{y}_{i,t} = [ry_{i,t}\ rr_t\ hp_{i,t}]'$
- Model M2: $\mathbf{y}_{i,t} = [ry_{i,t}\ bc_t\ hp_{i,t}]'$
- Model M3: $\mathbf{y}_{i,t} = [ry_{i,t}\ hp_{i,t}]'$
- Model M4: $\mathbf{y}_{i,t} = [rr_t\ hp_{i,t}]'$
- Model M5: $\mathbf{y}_{i,t} = [bc_t\ hp_{i,t}]'$

Table 4 presents a summary of the Johansen cointegration test results and the DOLS estimation outcomes. For detailed results, see Tables A1 through A8 in the Appendix.

The cointegration tests, based on J_{MaxEig} and J_{Trace} statistics, indicate strong evidence of cointegration for most models at the 10% significance level. Notably, the inclusion of the real interest rate, rr_t, seems to strengthen the cointegration relationship, showing over 98% of the tests exhibit cointegration even in the bivariate VECM specification $\mathbf{y}_{i,t} = [rr_t\ hp_{i,t}]'$ (Model M4).

However, interpreting the cointegration test results requires caution, particularly when evaluating the conformity of DOLS coefficients with economic theory. In Model M4, for instance, although DOLS estimates for rr_t were correctly signed across all regions, none were statistically significant, even at the 10% level. In contrast, the role of regional income, $ry_{i,t}$, appears robust. Whenever included in the model (Models BM,

Table 3: DOLS Cointegrating Regression Results
$\mathbf{y}_{i,t} = [ry_{i,t}\ rr_t\ bc_t\ hp_{i,t}]'$

Region	$ry_{i,t}$	s.e.	rr_t	s.e.	bc_t	s.e.
Anhui	0.747‡	0.003	0.045‡	0.005	-2.419‡	0.137
Beijing	0.748‡	0.007	0.000	0.002	-3.465‡	0.231
Fujian	0.873‡	0.016	0.011	0.015	-1.149	1.116
Gansu	0.403‡	0.013	-0.029‡	0.009	-3.345‡	0.746
Guangdong	0.463‡	0.070	-0.011	0.023	-2.791‡	0.777
Guangxi	0.485‡	0.021	-0.052‡	0.016	0.324	0.529
Guizhou	0.578‡	0.004	0.054‡	0.005	4.366‡	0.485
Hainan	0.402†	0.151	-0.528‡	0.108	13.016‡	2.399
Hebei	0.335‡	0.024	-0.053‡	0.007	-0.168	0.314
Heilongjiang	-0.568†	0.231	-0.492‡	0.093	66.685‡	9.497
Henan	0.292‡	0.044	-0.079‡	0.014	-4.406‡	0.799
Hubei	0.659‡	0.020	-0.011	0.008	-1.743‡	0.455
Hunan	0.516‡	0.011	-0.092‡	0.008	-0.244	0.292
Inner Mongolia	0.417‡	0.004	-0.020‡	0.002	0.711‡	0.063
Jiangsu	0.681‡	0.015	-0.022‡	0.006	0.159	0.227
Jiangxi	0.769‡	0.022	-0.102‡	0.017	0.942*	0.502
Jilin	0.642‡	0.063	-0.017	0.023	4.570‡	0.942
Liaoning	0.287‡	0.034	-0.040‡	0.007	-0.690‡	0.177
Ningxia	0.331‡	0.010	-0.089‡	0.005	0.681‡	0.169
Qinghai	0.627‡	0.000	0.081‡	0.000	-1.231‡	0.004
Shaanxi	0.154†	0.065	-0.166‡	0.023	-9.429‡	2.422
Shandong	0.540‡	0.009	-0.057‡	0.003	9.659‡	0.346
Shanghai	1.824‡	0.017	0.103‡	0.003	2.349‡	0.412
Shanxi	0.749‡	0.015	0.042‡	0.007	-1.672‡	0.270
Sichuan	0.689‡	0.004	-0.073‡	0.004	2.716‡	0.087
Tianjin	0.686‡	0.038	0.002	0.014	2.208‡	0.634
Xinjiang	0.632‡	0.005	-0.107‡	0.010	14.900‡	0.838
Yunnan	0.459‡	0.004	0.053‡	0.004	-2.017‡	0.233
Zhejiang	1.157‡	0.027	0.011	0.008	3.112‡	0.326
National	0.508‡	0.023	-0.013	0.008	-2.020‡	0.283

Note: We report the dynamic ordinary least squares (DOLS) coefficients along with the associated standard errors (s.e.). The long-run variance was estimated employing the Newey-West estimator. $*$, †, and ‡ indicate a rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively.

Table 4: Statistical and Economic Assessment of Competing Models

$\mathbf{y}_{i,t}$	J_{test} 5%	J_{test} 10%	Variables	Correct (%)	C&Sig (%)
BM: $[ry_{i,t}\ rr_t\ bc_t\ hp_{i,t}]'$	48.3	98.3	$ry_{i,t}$	96.7	96.7
			rr_t	66.7	53.3
			bc_t	50.0	43.3
M1: $[ry_{i,t}\ rr_t\ hp_{i,t}]'$	55.0	98.3	$ry_{i,t}$	100.0	100.0
			rr_t	60.0	30.0
M2: $[ry_{i,t}\ bc_t\ hp_{i,t}]'$	33.3	70.0	$ry_{i,t}$	100.0	100.0
			bc_t	70.0	50.0
M3: $[ry_{i,t}\ hp_{i,t}]'$	40.0	56.6	$ry_{i,t}$	100.0	100.0
M4: $[rr_t\ hp_{i,t}]'$	90.0	98.3	rr_t	100.0	0.0
M5: $[bc_t\ hp_{i,t}]'$	31.6	81.6	bc_t	0.0	0.0

Note: J_{test} p% denotes the rejection rate (in percent) of the null hypothesis of no cointegration at the p% significance level, based on J_{MaxEig} and J_{Trace} statistics. 'Correct (%)' refers to the percentage of cases in which the sign of the coefficient matches theoretical expectations, while 'C%Sig (%)' denotes the percentage of cases with a correct sign that is also statistically significant at the 10% level.

M1, M2, and M3), its DOLS coefficient estimates were consistently correctly signed and statistically significant across nearly all regions. The supply-side variable, real building cost, bc_t, contributes meaningful information only in a limited number of regions, and primarily when included in conjunction with other variables.

Table 5 provides the identified models based on these DOLS estimation results. In the selection procedure, we put the highest priority to models that yield theoretically correct and statistically significant coefficients. Models with correct signs but statistically insignificant estimates were given secondary priority. The greatest penalty was applied to cases in which coefficients were statistically significant but exhibited incorrect signs.

As emphasized earlier, real per capita income $ry_{i,t}$ consistently appears in all selected models, not only for all 29 regions but also at the national level. The income elasticity of housing prices, $\eta_{hp,ry}$, ranges from 0.331 for Ningxia to 1.414 for Shanghai. Notably, $\eta_{hp,ry}$ tends to be larger in urban regions such as Beijing (0.896), Fujian (0.834 or 0.914), Jiangxi (0.769), Shanghai (1.412), and Zhejiang (1.081).

In contrast, the real interest rate rr_t is included in fewer than 50% of the estimated models, and only 37% of the cases yield statistically significant at the 10% level. This suggests that real interest rates are not a key demand shifter in many regional housing markets in China. It is somewhat surprising that rr_t does not play an important role in large and rich urban areas such as Beijing, Guangdong, and Shanghai, indicating that liquidity constraints may not be binding in these regions.

The real building cost bc_t appears in 57% of the models, but only 43% cases show statistically significant coefficients. Once again, we find little evidence of a significant elasticity with respect to real building cost in major urban centers such as Beijing, Guangdong, and Shanghai.

Model BM, the most comprehensive specification, was selected for 10 regions: Guangxi, Hainan, Inner Mongolia, Jiangsu, Jiangxi, Jilin, Ningxia, Shandong, Sichuan, and Xinjiang. Notably, with the exceptions of Jiangsu and Shandong, these regions tend to have lower housing prices, lower levels of industrialization, and economies more reliant on agriculture or natural resources. In other words, their housing markets appear to be more closely aligned with fundamental supply and demand conditions, thereby exhibiting a lower likelihood of speculative bubbles.

Meanwhile, Model M3, the simplest specification incorporating only real income, was selected for 9 regions, including highly urbanized and affluent areas such as Beijing, Guangdong, and Shanghai. The remaining 6 regions in this group are mostly less urbanized, suggesting that rapid real estate booms have occurred not only in major metropolitan centers but also across a broader spectrum of regions in China. This pattern implies that rising housing prices in these areas may have emerged independently of changes in borrowing costs. The rest 10 regions are best described by models that include real income along with either the real interest rate or real building cost, indicating more nuanced housing market dynamics influenced by both demand- and cost-side factors.

These findings underscore the importance of designing housing policies that account for the idiosyncratic determinants specific to each region. They also highlight the need for further research into the potentially asymmetric dynamics of housing prices in more prosperous areas. In the next section, we present additional evidence of heterogeneous dynamics across regional housing markets.

3.2 Panel Evidence

This section examines further evidence regarding the heterogeneity in regional housing markets in China via panel cointegration tests developed by Westerlund (2007), applied to the benchmark model and 5 alternative specifications.

Table 5: Identified Models via Statistical and Economic Assessment

Region	Model #	$ry_{i,t}$	s.e.	rr_t	s.e.	bc_t	s.e.
Anhui	M3	$0.758^{‡}$	0.012				
Beijing	M3	$0.896^{‡}$	0.079				
Fujian	M1	$0.834^{‡}$	0.033	-0.032^{*}	0.016		
	M2	$0.914^{‡}$	0.033			$1.686^{†}$	0.645
Gansu	M3	$0.580^{‡}$	0.034				
Guangdong	M3	$0.543^{‡}$	0.019				
Guangxi	BM	$0.485^{‡}$	0.021	$-0.052^{‡}$	0.016	0.324	0.529
Guizhou	M2	$0.525^{‡}$	0.021			$2.120^{‡}$	0.437
Hainan	BM	$0.402^{†}$	0.151	$-0.528^{‡}$	0.108	$13.016^{‡}$	2.399
Hebei	M2	$0.601^{‡}$	0.022			$1.959^{‡}$	0.394
Heilongjiang	M3	$0.564^{‡}$	0.086				
Henan	M3	$0.632^{‡}$	0.022				
Hubei	M1	$0.682^{‡}$	0.024	-0.013	0.010		
	M2	$0.706^{‡}$	0.025			0.635	0.523
Hunan	M1	$0.593^{‡}$	0.017	-0.016^{*}	0.009		
	M2	$0.656^{‡}$	0.013			$1.621^{‡}$	0.249
Inner Mongolia	BM	$0.417^{‡}$	0.004	$-0.020^{‡}$	0.002	$0.711^{‡}$	0.063
Jiangsu	BM	$0.681^{‡}$	0.015	$-0.022^{‡}$	0.006	0.159	0.227
Jiangxi	BM	$0.769^{‡}$	0.022	$-0.102^{‡}$	0.017	0.942^{*}	0.502
Jilin	BM	$0.642^{‡}$	0.063	-0.017	0.023	$4.570^{‡}$	0.942
Liaoning	M1	$0.584^{‡}$	0.024	-0.001	0.007		
Ningxia	BM	$0.331^{‡}$	0.010	$-0.089^{‡}$	0.005	$0.681^{‡}$	0.169
Qinghai	M2	$0.439^{‡}$	0.025			0.434	0.422
Shaanxi	M1	$0.527^{‡}$	0.021	$-0.020^{†}$	0.009		
	M2	$0.559^{‡}$	0.022			$1.368^{‡}$	0.475
Shandong	BM	$0.540^{‡}$	0.009	$-0.057^{‡}$	0.003	$9.659^{‡}$	0.346
Shanghai	M3	$1.412^{‡}$	0.047				
Shanxi	M3	$0.655^{‡}$	0.027				
Sichuan	BM	$0.689^{‡}$	0.004	$-0.073^{‡}$	0.004	$2.716^{‡}$	0.087
Tianjin	M1	$0.589^{‡}$	0.048	-0.032^{*}	0.017		
	M2	$0.685^{‡}$	0.022			$2.058^{‡}$	0.409
Xinjiang	BM	$0.632^{‡}$	0.005	$-0.107^{‡}$	0.010	$14.900^{‡}$	0.838
Yunnan	M3	$0.529^{‡}$	0.035				
Zhejiang	M2	$1.081^{‡}$	0.015			$2.506^{‡}$	0.248
National	M2	$0.585^{‡}$	0.015			0.063	0.178

Note: We report the identified models based on dynamic ordinary least squares (DOLS) estimations for 5 alternative models in addition to the benchmark model. The highest priority was assigned to models that yield statistically significant coefficients with theoretically correct signs. On the other hand, the heaviest penalty was given to models that produce coefficients that were statistically significant but theoretically incorrect. Two models were chosen for 5 regions, Fukian, Hubei, Hunan, Shaanxi, and Tianjin. The long-run variance was estimated employing the Newey-West estimator. $*$, †, and ‡ indicate a rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively.

Westerlund's approach is based on error correction models. Let α_i denote the coefficient on the error correction term for region i, $i = 1, 2, ..., N$. The null hypothesis of no cointegration is specified as $H_0 : \alpha_i = 0$ for all i. Two group mean tests, G_τ and G_α, do not assume homogeneity in α_i and test the null against the alternative hypothesis $H_A : \alpha_i < 0$ for at least one i. In contrast, two panel test, P_τ and P_α, impose the homogeneity restriction, testing the null against $H_A : \alpha_i = \alpha < 0$ for all i. These tests account for cross-section dependence via bootstraps to avoid size distortion. The results for all models are presented in Table 6.

As shown in Table 2, Johansen's cointegration test for the benchmark model provides strong evidence of cointegration when applied to individual regions. Surprisingly, however, all panel cointegration tests fail to reject the null hypothesis of no cointegration for Model BM, which may reflect substantial heterogeneity in the cointegration relationships across regions. In contrast, all panel cointegration tests, G_τ, G_α, P_τ, and P_α, uniformly reject the null hypothesis at the 5% significance level for Model M3, which includes a scalar $\mathbf{z}_{i,t}$ with $ry_{i,t}$. This result suggests that the inclusion of additional variables, such as the real interest rate or real building cost, could introduce noise by imposing uniform model specifications that overlook heterogeneous housing market structures, potentially leading to misspecification problems.

4 Conclusion

This paper presents a comprehensive analysis of the long-run determinants of housing prices across 29 regional markets in China, using annual data from 1994 to 2021. By examining cointegration relationships between real housing prices and key macroeconomic fundamentals, including regional real income, real interest rates, and real building cost, we uncover substantial heterogeneity in housing market structures across regions. To ensure theoretical consistency, we exclude model specifications in which the estimated coefficients contradict standard economic predictions, thereby identifying region-specific models that more accurately reflect the distinct dynamics of each regional housing market.

Our findings indicate that real income is the most robust and consistent long-run determinant of housing prices across all regions. However, the estimated income elasticities vary widely, with wealthier urban regions such as Shanghai, Beijing, and Zhejiang exhibiting notably higher responsiveness. In contrast, the effects of real interest rates and construction costs are far less consistent and often yield estimates that are inconsistent with theoretical expectations. These discrepancies underscore the potential pitfalls

Table 6: Panel Cointegration Test Results with CSD

	Group Mean Cointegration Tests			
	G_τ	pv	G_α	pv
Model BM	-1.568	0.792	-3.773	0.780
Model M1	-1.816	0.466	-5.710	0.368
Model M2	-1.825	0.480	-7.821*	0.066
Model M3	-2.276†	0.022	-9.457‡	0.002
Model M4	-0.290	0.994	-0.263	1.000
Model M5	-0.173	1.000	-0.175	1.000
	Panel Cointegration Tests			
	P_τ	pv	P_α	pv
Model BM	-5.834	0.862	-2.859	0.748
Model M1	-7.819	0.528	-4.585	0.332
Model M2	-8.442	0.420	-6.245	0.124
Model M3	-10.729†	0.042	-8.485‡	0.000
Model M4	-2.007	0.978	-0.424	0.984
Model M5	-1.127	0.998	-0.226	1.000

Note: We report two panel cointegration test results that account for cross-sectional dependence. G_τ and G_α denote the group mean cointegration τ-test and α-test statistics, respectively. P_τ and P_α refer the panel cointegration τ-test and α-test statistics, respectively. pv denotes the robust p-value, computed under the null hypothesis of no cointegration while accounting for cross-section dependence (CSD). See Westerlund (2007) for detailed information about these panel tests. $*$, $\dagger$, and $\ddagger$ indicates a rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively.

of imposing uniform models on heterogeneous regional markets. We further demonstrate this through the failure of panel cointegration tests, which likely stem from model misspecification arising from the neglect of regional heterogeneity.

We identify region-specific models that align with both statistical rigor and economic theory. Notably, we find that relatively simple income-based models often outperform more complex specifications, particularly in urban regions where liquidity constraints are likely to be less binding and supply rigidities more pronounced. These findings suggest that a uniform, nationwide housing policy may be inefficient or even counterproductive. Instead, our results support the case for differentiated policies tailored to the structural characteristics and macroeconomic conditions of each region.

This study contributes to the literature by offering a methodologically rigorous, disaggregated framework for analyzing housing market dynamics. Future research could build on this approach by explicitly incorporating housing price expectations, demographic changes, or credit market frictions. In addition, China's ongoing policy experimentation in the property sector offers a promising avenue for causal identification, particularly through difference-in-differences or regression discontinuity designs.

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Appendix: Additional Tables

Table A1. Cointegration Test Results for Model M1
$\mathbf{y}_{i,t} = [ry_{i,t}\ rr_t\ hp_{i,t}]'$

Region	J_{MaxEig}	H_A	J_{Trace}	H_A	EG
Anhui	14.90^{*}	$r > 1$	$20.28^{\dagger}$	$r > 1$	$-2.833^{\ddagger}$
Beijing	7.64^{*}	$r > 2$	7.64^{*}	$r > 2$	-1.658
Fujian	$23.38^{\dagger}$	$r > 0$	$39.91^{\dagger}$	$r > 0$	-1.731^{*}
Gansu	8.63^{*}	$r > 2$	8.63^{*}	$r > 2$	-1.793^{*}
Guangdong	$11.06^{\dagger}$	$r > 2$	$11.06^{\dagger}$	$r > 2$	-1.348
Guangxi	$27.37^{\ddagger}$	$r > 0$	$44.27^{\ddagger}$	$r > 0$	$-2.133^{\dagger}$
Guizhou	$33.09^{\ddagger}$	$r > 0$	$47.55^{\ddagger}$	$r > 0$	$-2.967^{\ddagger}$
Hainan	7.56^{*}	$r > 2$	7.56^{*}	$r > 2$	$-2.347^{\dagger}$
Hebei	$10.21^{\dagger}$	$r > 2$	$10.21^{\dagger}$	$r > 2$	-1.481
Heilongjiang	15.61^{*}	$r > 1$	18.74^{*}	$r > 1$	$-2.490^{\dagger}$
Henan	8.54^{*}	$r > 2$	8.54^{*}	$r > 2$	$-3.315^{\ddagger}$
Hubei	$30.88^{\ddagger}$	$r > 0$	$44.61^{\ddagger}$	$r > 0$	$-2.599^{\dagger}$
Hunan	7.76^{*}	$r > 2$	7.76^{*}	$r > 2$	-2.053^{*}
Inner Mongolia	$19.88^{\dagger}$	$r > 1$	$26.68^{\ddagger}$	$r > 1$	-0.676
Jiangsu	$21.02^{\ddagger}$	$r > 1$	$27.76^{\ddagger}$	$r > 1$	$-3.030^{\ddagger}$
Jiangxi	$18.19^{\dagger}$	$r > 1$	$22.83^{\dagger}$	$r > 1$	$-3.144^{\ddagger}$
Jilin	7.99^{*}	$r > 2$	7.99^{*}	$r > 2$	-0.423
Liaoning	20.49^{*}	$r > 0$	33.33^{*}	$r > 0$	-0.296
Ningxia	21.77^{*}	$r > 0$	31.70	$r > 0$	-1.699
Qinghai	$25.72^{\dagger}$	$r > 0$	$42.04^{\ddagger}$	$r > 0$	-0.996
Shaanxi	$22.65^{\dagger}$	$r > 0$	$36.20^{\dagger}$	$r > 0$	$-2.627^{\dagger}$
Shandong	7.68^{*}	$r > 2$	7.68^{*}	$r > 2$	-0.776
Shanghai	$21.63^{\ddagger}$	$r > 1$	$27.05^{\ddagger}$	$r > 1$	$-2.591^{\dagger}$
Shanxi	$25.39^{\dagger}$	$r > 0$	$40.09^{\dagger}$	$r > 0$	-1.301
Sichuan	9.13^{*}	$r > 2$	9.13^{*}	$r > 2$	$-2.430^{\dagger}$
Tianjin	14.09^{*}	$r > 1$	19.31^{*}	$r > 1$	-0.597
Xinjiang	8.44^{*}	$r > 2$	8.44^{*}	$r > 2$	-1.619
Yunnan	$36.68^{\ddagger}$	$r > 0$	$47.86^{\ddagger}$	$r > 0$	$-2.547^{\dagger}$
Zhejiang	$32.49^{\ddagger}$	$r > 0$	$48.85^{\ddagger}$	$r > 0$	$-2.231^{\dagger}$
National	$28.44^{\ddagger}$	$r > 0$	$42.60^{\ddagger}$	$r > 0$	$-2.261^{\dagger}$

Note: J_{MaxEig} and J_{Trace} denote the Johansen maximum eigenvalue statistics and the Johansen trace statistics, respectively. H_A denotes the **last** alternative hypothesis considered when its associated null hypothesis is rejected in the sequential testing procedure. For example, statistically significant test results with $H_A : r > 0$ indicate the presence of one cointegrating relationship, whereas statistically insignificant results with $H_A : r > 0$ suggest no cointegrating relationship. EG denotes the Engle-Granger Test statistics, which tests the null of no cointegration against the alternative hypothesis of a single cointegration vector. $*, \dagger$, and $\ddagger$ indicates a rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively.

Table A2. Cointegration Test Results for Model M2
$\mathbf{y}_{i,t} = [ry_{i,t}\ bc_t\ hp_{i,t}]'$

Region	J_{MaxEig}	H_A	J_{Trace}	H_A	EG
Anhui	$29.67^{\ddagger}$	$r > 0$	$46.98^{\ddagger}$	$r > 0$	-2.025^{*}
Beijing	14.95	$r > 0$	31.53	$r > 0$	-1.683
Fujian	$22.19^{\dagger}$	$r > 0$	29.94	$r > 0$	-1.740^{*}
Gansu	18.44	$r > 0$	$20.15^{\dagger}$	$r > 1$	-1.979^{*}
Guangdong	$23.68^{\dagger}$	$r > 0$	19.56^{*}	$r > 1$	-1.327
Guangxi	15.80	$r > 0$	29.93	$r > 0$	$-2.241^{\dagger}$
Guizhou	7.57^{*}	$r > 2$	7.57^{*}	$r > 2$	$-2.455^{\dagger}$
Hainan	14.88	$r > 0$	30.62	$r > 0$	$-2.638^{\dagger}$
Hebei	$30.73^{\ddagger}$	$r > 0$	19.79^{*}	$r > 1$	-1.093
Heilongjiang	15.89	$r > 0$	26.65	$r > 0$	$-2.382^{\dagger}$
Henan	8.44^{*}	$r > 2$	8.44^{*}	$r > 2$	$-3.550^{\ddagger}$
Hubei	$15.78^{\dagger}$	$r > 1$	$22.83^{\dagger}$	$r > 1$	$-2.577^{\dagger}$
Hunan	21.71^{*}	$r > 0$	33.88^{*}	$r > 0$	$-2.824^{\ddagger}$
Inner Mongolia	8.16^{*}	$r > 2$	8.16^{*}	$r > 2$	0.051
Jiangsu	$16.15^{\dagger}$	$r > 1$	19.61^{*}	$r > 1$	$-3.020^{\ddagger}$
Jiangxi	18.4	$r > 0$	33.79^{*}	$r > 0$	$-3.515^{\ddagger}$
Jilin	8.33^{*}	$r > 2$	8.33^{*}	$r > 2$	-0.385
Liaoning	15.32^{*}	$r > 1$	19.76^{*}	$r > 1$	-0.883
Ningxia	14.83	$r > 0$	$19.98^{\dagger}$	$r > 1$	$-2.194^{\dagger}$
Qinghai	18.45	$r > 0$	18.38^{*}	$r > 1$	-0.596
Shaanxi	11.46	$r > 0$	23.67	$r > 0$	$-2.340^{\dagger}$
Shandong	15.35^{*}	$r > 1$	$21.85^{\dagger}$	$r > 1$	-0.177
Shanghai	$24.22^{\dagger}$	$r > 0$	$20.81^{\dagger}$	$r > 1$	$-2.730^{\dagger}$
Shanxi	15.18	$r > 0$	29.09	$r > 0$	-1.256
Sichuan	13.77^{*}	$r > 1$	$20.29^{\dagger}$	$r > 1$	$-2.296^{\dagger}$
Tianjin	14.88^{*}	$r > 1$	$20.53^{\dagger}$	$r > 1$	-0.979
Xinjiang	$23.89^{\dagger}$	$r > 0$	$41.00^{\dagger}$	$r > 0$	-1.560
Yunnan	$16.35^{\dagger}$	$r > 1$	$20.71^{\dagger}$	$r > 1$	$-2.143^{\dagger}$
Zhejiang	18.43	$r > 0$	32.51^{*}	$r > 0$	$-2.134^{\dagger}$
National	21.17^{*}	$r > 0$	$37.17^{\dagger}$	$r > 0$	$-2.193^{\dagger}$

Note: J_{MaxEig} and J_{Trace} denote the Johansen maximum eigenvalue statistics and the Johansen trace statistics, respectively. H_A denotes the **last** alternative hypothesis considered when its associated null hypothesis is rejected in the sequential testing procedure. For example, statistically significant test results with $H_A : r > 0$ indicate the presence of one cointegrating relationship, whereas statistically insignificant results with $H_A : r > 0$ suggest no cointegrating relationship. EG denotes the Engle-Granger Test statistics, which tests the null of no cointegration against the alternative hypothesis of a single cointegration vector. $*, \dagger$, and $\ddagger$ indicates a rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively.

Table A3. Cointegration Test Results for Model M3

$$\mathbf{y}_{i,t} = [ry_{i,t}\ hp_{i,t}]'$$

Region	J_{MaxEig}	H_A	J_{Trace}	H_A	EG
Anhui	$16.42^{\dagger}$	$r > 0$	$21.66^{\dagger}$	$r > 0$	$-2.523^{\dagger}$
Beijing	12.54	$r > 0$	16.96	$r > 0$	-1.618
Fujian	10.89	$r > 0$	14.26	$r > 0$	-1.719^{*}
Gansu	$12.87^{\dagger}$	$r > 1$	$12.87^{\dagger}$	$r > 1$	-2.070^{*}
Guangdong	$11.24^{\dagger}$	$r > 1$	$11.24^{\dagger}$	$r > 1$	-1.468
Guangxi	11.94	$r > 0$	16.05	$r > 0$	$-2.107^{\dagger}$
Guizhou	11.95	$r > 0$	18.80^{*}	$r > 0$	$-2.957^{\ddagger}$
Hainan	$18.34^{\dagger}$	$r > 0$	$22.98^{\dagger}$	$r > 0$	$-2.555^{\dagger}$
Hebei	10.84	$r > 0$	18.08^{*}	$r > 0$	-1.086
Heilongjiang	15.13^{*}	$r > 0$	19.18^{*}	$r > 0$	$-2.494^{\dagger}$
Henan	8.95^{*}	$r > 1$	8.95^{*}	$r > 1$	$-3.925^{\ddagger}$
Hubei	$17.06^{\dagger}$	$r > 0$	$22.21^{\dagger}$	$r > 0$	$-2.906^{\ddagger}$
Hunan	10.52	$r > 0$	16.54	$r > 0$	$-2.581^{\dagger}$
Inner Mongolia	$9.41^{\dagger}$	$r > 1$	$9.41^{\dagger}$	$r > 1$	-1.264
Jiangsu	$18.93^{\dagger}$	$r > 0$	$26.31^{\ddagger}$	$r > 0$	$-2.822^{\ddagger}$
Jiangxi	$17.79^{\dagger}$	$r > 0$	$24.63^{\ddagger}$	$r > 0$	$-3.899\ ^{\ddagger}$
Jilin	7.95^{*}	$r > 1$	7.95^{*}	$r > 1$	-0.939
Liaoning	9.08	$r > 0$	12.02	$r > 0$	-1.017
Ningxia	5.92	$r > 0$	11.30	$r > 0$	$-2.077^{\dagger}$
Qinghai	8.65	$r > 0$	16.12	$r > 0$	-0.510
Shaanxi	9.47	$r > 0$	16.20	$r > 0$	$-2.467^{\dagger}$
Shandong	$9.41^{\dagger}$	$r > 1$	$9.41^{\dagger}$	$r > 1$	-1.188
Shanghai	8.65^{*}	$r > 1$	8.65^{*}	$r > 1$	$-2.658^{\dagger}$
Shanxi	11.01	$r > 0$	15.12	$r > 0$	-1.255
Sichuan	$12.13^{\dagger}$	$r > 1$	$12.13^{\dagger}$	$r > 1$	$-2.759^{\dagger}$
Tianjin	$18.42^{\dagger}$	$r > 0$	$23.47^{\dagger}$	$r > 0$	-0.881
Xinjiang	$9.36^{\dagger}$	$r > 1$	$9.36^{\dagger}$	$r > 1$	-1.731^{*}
Yunnan	12.13	$r > 0$	15.70	$r > 0$	$-2.780^{\dagger}$
Zhejiang	9.95	$r > 0$	13.77	$r > 0$	$-2.258^{\dagger}$
National	8.42	$r > 0$	14.27	$r > 0$	$-2.210^{\dagger}$

Note: J_{MaxEig} and J_{Trace} denote the Johansen maximum eigenvalue statistics and the Johansen trace statistics, respectively. H_A denotes the **last** alternative hypothesis considered when its associated null hypothesis is rejected in the sequential testing procedure. For example, statistically significant test results with $H_A : r > 0$ indicate the presence of one cointegrating relationship, whereas statistically insignificant results with $H_A : r > 0$ suggest no cointegrating relationship. EG denotes the Engle-Granger Test statistics, which tests the null of no cointegration against the alternative hypothesis of a single cointegration vector. $*, \dagger$, and $\ddagger$ indicates a rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively.

Table A4. Cointegration Test Results for Model M4
$\mathbf{y}_{i,t} = [rr_t \; hp_{i,t}]'$

Region	J_{MaxEig}	H_A	J_{Trace}	H_A	EG
Anhui	$19.69^{\dagger}$	$r > 0$	$26.25^{\ddagger}$	$r > 0$	-0.190
Beijing	$20.60^{\ddagger}$	$r > 0$	$23.11^{\dagger}$	$r > 0$	-0.225
Fujian	$24.26^{\ddagger}$	$r > 0$	$27.29^{\ddagger}$	$r > 0$	-0.620
Gansu	$19.55^{\dagger}$	$r > 0$	$25.69^{\ddagger}$	$r > 0$	0.302
Guangdong	$21.24^{\ddagger}$	$r > 0$	$28.67^{\ddagger}$	$r > 0$	0.367
Guangxi	$12.38^{\dagger}$	$r > 1$	$12.38^{\dagger}$	$r > 1$	-0.542
Guizhou	$17.67^{\dagger}$	$r > 0$	$20.67^{\dagger}$	$r > 0$	-0.144
Hainan	$18.81^{\dagger}$	$r > 0$	$22.46^{\dagger}$	$r > 0$	-0.077
Hebei	$19.09^{\dagger}$	$r > 0$	$23.48^{\dagger}$	$r > 0$	-0.257
Heilongjiang	13.86^{*}	$r > 0$	15.93	$r > 0$	-0.719
Henan	$10.89^{\dagger}$	$r > 1$	$10.89^{\dagger}$	$r > 1$	-1.585
Hubei	$10.85^{\dagger}$	$r > 1$	$10.85^{\dagger}$	$r > 1$	0.310
Hunan	$24.44^{\ddagger}$	$r > 0$	$28.21^{\ddagger}$	$r > 0$	-0.117
Inner Mongolia	$19.46^{\dagger}$	$r > 0$	$24.16^{\dagger}$	$r > 0$	0.423
Jiangsu	$24.36^{\ddagger}$	$r > 0$	$31.51^{\ddagger}$	$r > 0$	-0.116
Jiangxi	$25.75^{\ddagger}$	$r > 0$	$32.29^{\ddagger}$	$r > 0$	0.029
Jilin	8.36^{*}	$r > 1$	8.36^{*}	$r > 1$	0.224
Liaoning	$9.88^{\dagger}$	$r > 1$	$9.88^{\dagger}$	$r > 1$	-0.049
Ningxia	$12.13^{\dagger}$	$r > 1$	$12.13^{\dagger}$	$r > 1$	0.037
Qinghai	$9.68^{\dagger}$	$r > 1$	$9.68^{\dagger}$	$r > 1$	1.122
Shaanxi	7.55^{*}	$r > 1$	7.55^{*}	$r > 1$	0.520
Shandong	$12.39^{\dagger}$	$r > 1$	$12.39^{\dagger}$	$r > 1$	0.331
Shanghai	$22.42^{\ddagger}$	$r > 0$	$28.92^{\ddagger}$	$r > 0$	-0.150
Shanxi	$9.39^{\dagger}$	$r > 1$	$9.39^{\dagger}$	$r > 1$	0.055
Sichuan	$22.49^{\ddagger}$	$r > 0$	$26.29^{\ddagger}$	$r > 0$	0.187
Tianjin	$19.54^{\dagger}$	$r > 0$	$22.79^{\dagger}$	$r > 0$	-0.448
Xinjiang	$18.17^{\dagger}$	$r > 0$	$20.86^{\dagger}$	$r > 0$	0.378
Yunnan	$16.41^{\dagger}$	$r > 0$	$22.08^{\dagger}$	$r > 0$	0.181
Zhejiang	$25.67^{\ddagger}$	$r > 0$	$30.36^{\ddagger}$	$r > 0$	-0.601
National	$10.04^{\dagger}$	$r > 1$	$10.04^{\dagger}$	$r > 1$	0.019

Note: J_{MaxEig} and J_{Trace} denote the Johansen maximum eigenvalue statistics and the Johansen trace statistics, respectively. H_A denotes the **last** alternative hypothesis considered when its associated null hypothesis is rejected in the sequential testing procedure. For example, statistically significant test results with $H_A : r > 0$ indicate the presence of one cointegrating relationship, whereas statistically insignificant results with $H_A : r > 0$ suggest no cointegrating relationship. EG denotes the Engle-Granger Test statistics, which tests the null of no cointegration against the alternative hypothesis of a single cointegration vector. $*$, $\dagger$, and $\ddagger$ indicates a rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively.

Table A5. Cointegration Test Results for Model M5
$\mathbf{y}_{i,t} = [bc_t \ hp_{i,t}]'$

Region	J_{MaxEig}	H_A	J_{Trace}	H_A	EG
Anhui	8.31^{*}	$r > 1$	8.31^{*}	$r > 1$	-1.110
Beijing	8.62	$r > 0$	13.81	$r > 0$	-0.766
Fujian	7.82^{*}	$r > 1$	7.82^{*}	$r > 1$	-1.065
Gansu	10.28	$r > 0$	16.12	$r > 0$	-0.207
Guangdong	$16.33^{\dagger}$	$r > 0$	$23.17^{\dagger}$	$r > 0$	-0.638
Guangxi	8.44^{*}	$r > 1$	8.44^{*}	$r > 1$	-1.010
Guizhou	$10.32^{\dagger}$	$r > 1$	$10.32^{\dagger}$	$r > 1$	-1.152
Hainan	11.46	$r > 0$	18.10^{*}	$r > 0$	-0.599
Hebei	11.02	$r > 0$	17.21	$r > 0$	-0.814
Heilongjiang	8.89	$r > 0$	11.39	$r > 0$	-0.700
Henan	8.99^{*}	$r > 1$	8.99^{*}	$r > 1$	-0.572
Hubei	$23.96^{\ddagger}$	$r > 0$	$29.95^{\ddagger}$	$r > 0$	-0.660
Hunan	8.46^{*}	$r > 1$	8.46^{*}	$r > 1$	-0.903
Inner Mongolia	7.58^{*}	$r > 1$	7.58^{*}	$r > 1$	-0.835
Jiangsu	7.69^{*}	$r > 1$	7.69^{*}	$r > 1$	-1.146
Jiangxi	8.88^{*}	$r > 1$	8.88^{*}	$r > 1$	-0.912
Jilin	7.65^{*}	$r > 1$	7.65^{*}	$r > 1$	-0.588
Liaoning	$35.18^{\ddagger}$	$r > 0$	$41.75^{\ddagger}$	$r > 0$	-1.331
Ningxia	9.17^{*}	$r > 1$	9.17^{*}	$r > 1$	-0.741
Qinghai	$11.33^{\dagger}$	$r > 1$	$11.33^{\dagger}$	$r > 1$	-0.257
Shaanxi	8.00^{*}	$r > 1$	8.00^{*}	$r > 1$	-0.544
Shandong	7.88^{*}	$r > 1$	7.88 *	$r > 1$	-0.879
Shanghai	15.04^{*}	$r > 0$	$21.3^{\dagger}$	$r > 0$	-0.669
Shanxi	$9.41^{\dagger}$	$r > 1$	$9.41^{\dagger}$	$r > 1$	-0.816
Sichuan	$19.01^{\dagger}$	$r > 0$	$25.84^{\ddagger}$	$r > 0$	-1.281
Tianjin	9.98	$r > 0$	13.98	$r > 0$	-1.074
Xinjiang	8.01^{*}	$r > 1$	8.01^{*}	$r > 1$	-0.435
Yunnan	$17.61^{\dagger}$	$r > 0$	$22.98^{\dagger}$	$r > 0$	-0.920
Zhejiang	$10.39^{\dagger}$	$r > 1$	$10.39^{\dagger}$	$r > 1$	-1.450
National	7.91^{*}	$r > 1$	7.91^{*}	$r > 1$	-0.825

Note: J_{MaxEig} and J_{Trace} denote the Johansen maximum eigenvalue statistics and the Johansen trace statistics, respectively. H_A denotes the **last** alternative hypothesis considered when its associated null hypothesis is rejected in the sequential testing procedure. For example, statistically significant test results with $H_A : r > 0$ indicate the presence of one cointegrating relationship, whereas statistically insignificant results with $H_A : r > 0$ suggest no cointegrating relationship. EG denotes the Engle-Granger Test statistics, which tests the null of no cointegration against the alternative hypothesis of a single cointegration vector. $*, \dagger$, and $\ddagger$ indicates a rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively.

Table A6. DOLS Regression Results for Model M1
$\mathbf{y}_{i,t} = [ry_{i,t}\ rr_t\ hp_{i,t}]'$

Region	$ry_{i,t}$	*s.e.*	rr_t	*s.e.*
Anhui	0.757‡	0.012	-0.009	0.006
Beijing	0.947‡	0.076	0.021	0.024
Fujian	0.834‡	0.033	-0.032*	0.016
Gansu	0.590‡	0.043	0.002	0.015
Guangdong	0.536‡	0.037	-0.001	0.013
Guangxi	0.521‡	0.022	-0.017	0.012
Guizhou	0.487‡	0.029	0.000	0.008
Hainan	0.859‡	0.058	-0.019	0.011
Hebei	0.395‡	0.101	-0.064†	0.026
Heilongjiang	0.501‡	0.113	-0.012	0.024
Henan	0.643‡	0.026	0.015	0.010
Hubei	0.682‡	0.024	-0.013	0.010
Hunan	0.593‡	0.017	-0.016*	0.009
Inner Mongolia	0.408‡	0.010	-0.019‡	0.005
Jiangsu	0.680‡	0.012	-0.020‡	0.005
Jiangxi	0.897‡	0.025	-0.017	0.012
Jilin	0.513‡	0.021	-0.020‡	0.007
Liaoning	0.584‡	0.024	-0.001	0.007
Ningxia	0.475‡	0.026	0.015†	0.006
Qinghai	0.446‡	0.040	0.000	0.013
Shaanxi	0.527‡	0.021	-0.020†	0.009
Shandong	0.592‡	0.014	-0.022‡	0.004
Shanghai	1.510‡	0.046	0.015	0.011
Shanxi	0.838‡	0.017	0.093‡	0.008
Sichuan	0.713‡	0.029	0.007	0.015
Tianjin	0.589‡	0.048	-0.032*	0.017
Xinjiang	0.670‡	0.037	0.034†	0.012
Yunnan	0.515‡	0.015	0.046‡	0.013
Zhejiang	1.062‡	0.042	-0.005	0.009
National	0.583‡	0.014	0.002	0.003

Note: We report the dynamic ordinary least squares (DOLS) coefficients along with the associated standard errors (s.e.). The long-run variance was estimated employing the Newey-West estimator. $*$, †, and ‡ indicate a rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively.

Table A7. DOLS Regression Results for Model M2

$\mathbf{y}_{i,t} = [ry_{i,t} \; bc_t \; hp_{i,t}]'$

Region	$ry_{i,t}$	*s.e.*	bc_t	*s.e.*
Anhui	0.763‡	0.014	0.032	0.319
Beijing	0.841‡	0.020	-0.769	0.630
Fujian	0.914‡	0.033	1.686†	0.645
Gansu	0.559‡	0.011	-1.044‡	0.283
Guangdong	0.552‡	0.017	0.390	0.312
Guangxi	0.492‡	0.021	-1.154†	0.466
Guizhou	0.525‡	0.021	2.120‡	0.437
Hainan	0.928‡	0.040	1.832‡	0.436
Hebei	0.601‡	0.022	1.959‡	0.394
Heilongjiang	0.556‡	0.094	0.647	1.217
Henan	0.590‡	0.016	-1.138‡	0.311
Hubei	0.706‡	0.025	0.635	0.523
Hunan	0.656‡	0.013	1.621‡	0.249
Inner Mongolia	0.463‡	0.003	1.092‡	0.073
Jiangsu	0.759‡	0.016	0.727‡	0.211
Jiangxi	0.946‡	0.018	1.255‡	0.337
Jilin	0.579‡	0.018	0.873†	0.330
Liaoning	0.530‡	0.010	-0.005	0.244
Ningxia	0.419‡	0.022	-0.144	0.435
Qinghai	0.439‡	0.025	0.434	0.422
Shaanxi	0.559‡	0.022	1.368‡	0.475
Shandong	0.639‡	0.012	0.493†	0.211
Shanghai	1.382‡	0.042	-1.505†	0.548
Shanxi	0.650‡	0.011	-2.234‡	0.291
Sichuan	0.748‡	0.019	2.255‡	0.369
Tianjin	0.685‡	0.022	2.058‡	0.409
Xinjiang	0.600‡	0.027	1.073†	0.468
Yunnan	0.459‡	0.019	-1.824‡	0.398
Zhejiang	1.081‡	0.015	2.506‡	0.248
National	0.585‡	0.015	0.063	0.178

Note: We report the dynamic ordinary least squares (DOLS) coefficients along with the associated standard errors (s.e.). The long-run variance was estimated employing the Newey-West estimator. $*$, †, and ‡ indicate a rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively.

Table A8. DOLS Regression Results for Model M3, M4, and M5

	Model 4		Model 5		Model 6	
Region	$ry_{i,t}$	*s.e.*	rr_t	*s.e.*	bc_t	*s.e.*
Anhui	0.758‡	0.012	-0.152	0.121	-4.864	5.752
Beijing	0.896‡	0.079	-0.078	0.114	-3.805	5.569
Fujian	0.856‡	0.036	-0.151	0.125	-2.961	3.776
Gansu	0.580‡	0.034	-0.060	0.073	-2.505	2.556
Guangdong	0.543‡	0.019	-0.062	0.073	-2.431	2.605
Guangxi	0.569‡	0.038	-0.076	0.088	-4.244	4.176
Guizhou	0.487‡	0.029	-0.064	0.082	-2.603	4.462
Hainan	0.863‡	0.067	-0.176	0.117	-3.440	6.062
Hebei	0.539‡	0.045	-0.057	0.094	-4.473	4.352
Heilongjiang	0.564‡	0.086	-0.011	0.052	-3.692	3.151
Henan	0.632‡	0.022	-0.092	0.099	-6.216	4.832
Hubei	0.685‡	0.023	-0.101	0.095	-4.982	4.804
Hunan	0.638‡	0.020	-0.073	0.088	-2.262	3.112
Inner Mongolia	0.445‡	0.011	-0.078	0.085	-1.630	3.143
Jiangsu	0.710‡	0.010	-0.147	0.117	-5.018	5.786
Jiangxi	0.930‡	0.019	-0.160	0.144	-5.570	7.230
Jilin	0.573‡	0.022	-0.068	0.083	-3.720	4.610
Liaoning	0.564‡	0.027	-0.091	0.073	-3.744	3.827
Ningxia	0.447‡	0.020	-0.081	0.074	-3.071	3.782
Qinghai	0.447‡	0.025	-0.049	0.066	-2.720	3.665
Shaanxi	0.536‡	0.023	-0.136	0.094	-3.394	5.346
Shandong	0.641‡	0.011	-0.088	0.098	-4.368	4.944
Shanghai	1.412‡	0.047	-0.163	0.120	-6.544	6.712
Shanxi	0.655‡	0.027	-0.094	0.094	-4.829	4.994
Sichuan	0.684‡	0.034	-0.138	0.114	-2.672	3.486
Tianjin	0.644‡	0.039	-0.147	0.120	-4.889	5.688
Xinjiang	0.568‡	0.041	-0.007	0.043	-1.145	2.186
Yunnan	0.529‡	0.035	-0.057	0.061	-5.145	3.668
Zhejiang	1.062‡	0.044	-0.201	0.141	-5.427	7.281
National	0.583‡	0.014	-0.067	0.083	-3.933	3.864

Note: We report the dynamic ordinary least squares (DOLS) coefficients along with the associated standard errors (s.e.). The long-run variance was estimated employing the Newey-West estimator. $*$, †, and ‡ indicate a rejection of the null hypothesis at the 10%, 5%, and 1% significance level, respectively.