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THE HOUSING PRICE DYNAMICS AND MACROECONOMIC FACTORS: EVIDENCE OF TAIWAN HOUSING MARKET

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Abstract. The housing price in Taiwan has seen a sharp increase since 2020 after a long period of stability from 2011 to 2019. To provide a more granular analysis on this substantial rise of the housing prices since 2020 in Taiwan, we applied the hedonic pricing model to analyze the completed and presale residential housing across four types of houses: luxury, first-class, second-class and suite. By incorporating relevant macroeconomic variables from 2014 to 2022, we try to capture the demand of homebuyers across the three biggest cities in Taiwan. In the completed housing market, we find that the suite prices in Taipei and Taichung cities are more significantly affected by Taiwan's continuing economic growth, whereas the suite prices in Kaohsiung city are hindered by its historically stagnant employment market. Notably, suite prices in Kaohsiung display greater sensitivity to construction cost changes and broader economic cycles compared to the suite prices in Taipei and Taichung. These findings highlight the unique dynamics of real estate markets in northern, central, and southern Taiwan, providing valuable insights for housing investors, prospective homebuyers in different regions and policymakers in their decision making.

Keywords: hedonic price model, housing price index, macroeconomic variables, completed residential property, presale residential property.

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1. Introduction

According to the latest international statistics, Taiwan has one of the lowest fertility rates in the world. In 2024, Taiwan's total fertility rate was estimated at 1.09 children per woman–well below the replacement level of 2.1 needed to maintain a stable population (worldpopulationreview.com). This low fertility rate has led to population decline and aging, significantly affecting education, the labor market, and economic development. Due to Taiwan's declining population growth rate, people will increasingly move to and concentrate in several major cities–an almost certain trend for the future. As a result, to measure its impact on housing market, we focused on the three major cities in Taiwan to examine the changes in the housing market, as this can reflect shifts in real estate supply and demand and their impact on the value of different tiers of housing.

Based on the hedonic pricing models, this study also aims to highlight the recent sharp increase in 2020 in Taiwan housing prices by developing separate indices for existing and presale homes across Taiwan's three largest cities–Taipei, Taichung, and Kaohsiung. By considering the macroeconomic variables such as consumer price indices (CPI), construction cost indices (CCI), national income (NI), money supply, mortgage interest rates, and Taiwan Stock Exchange Market (TAIEX) performance, this research seeks to uncover distinct relationships between these factors and housing prices in different market segments. To better account for the slight changes in the period prior to 2020, we collected the data from 2014Q2 to 2022Q1. The findings will contribute to a deeper understanding of the dynamics of Taiwan's real estate market and provide timely information for policy makers to constrain the overheating housing market.

Real estate in Taiwan holds both economic and cultural significance. Beyond serving as a hedge against inflation for investors, property ownership symbolizes wealth and social status in Taiwanese society. According to Taiwan 2020 Population and Housing Census, the average rate of homeownership was 78.6%, of which Taipei city and Changhua county were 72% and 87%, the lowest and highest in Taiwan island, respectively. In this study, we select three cities, Taipei, Taichung, and Kaohsiung, as the focus of analysis by highlighting their geographical and economic differences, which can be better reflected in their respective real estate markets. Taipei is the traditional political center; Taichung is a hub for traditional, emerging, and electronics industries, and Kaohsiung is a center for traditional industries and tourism.

From a historical perspective, Taiwan government had employed various macroeconomic policies to stabilize housing markets in the periods of economic recession. For instance, during the Asian financial crisis (1997) and the dot-com bubble (2000), interest rate cuts and housing subsidies helped to support the housing and construction industry. Similarly, after the 2008 global financial crisis, policies such as inheritance tax reductions and monetary easing spurred capital inflows into luxury real estate, leading to a recovery in housing market. The COVID-19 pandemic in the beginning of 2020 also pushed Taiwan government to ease the monetary supply to boost its economic growth, which in turn helped to prosper the housing market as well.

Figure 1 shows the annualized GDP quarterly growth rate and TAIEX index from 2015 to 2024. After a minor recession in 2020Q1, the economy of Taiwan has seen a strong recovery in 2021 followed by a substantial dip in 2022. Despite a record low of negative GDP growth rate in 2023Q3, the average annual economic growth rate in 2023 was still maintained at a positive rate of 1.2%, the lowest in the past 14 years. The opposite direction of annualized GDP growth rate and Taiwan stock market index from 2022Q3 to 2023Q3 also confirmed that the stock market index, a leading economic indicator, can reflect its positive relationship with rising housing prices more promptly than the economic growth rate. Laurinavičius et al. (2022) also provided evidence that after the hit of 2008 financial crisis on OMX Vilnius GI stock price index, stock prices are a good leading indicator to anticipate economic recovery including housing prices in the following years.

However, the housing price in Taiwan has seen a sharp increase since 2020 after a long period of stable rise from 2011 to 2019. Figure 2 presents the Cathay House Price Indices showing the housing prices of the seven largest cities in Taiwan. The global financial market has also faced unprecedented challenges in recent years due to factors such as the Trump's tariff war, the Russia-Ukraine war, and supply chain disruptions, all of which have driven material costs and inflation to new heights. To combat inflation, central banks worldwide, including the U.S. Federal Reserve, have implemented aggressive interest rate hikes.

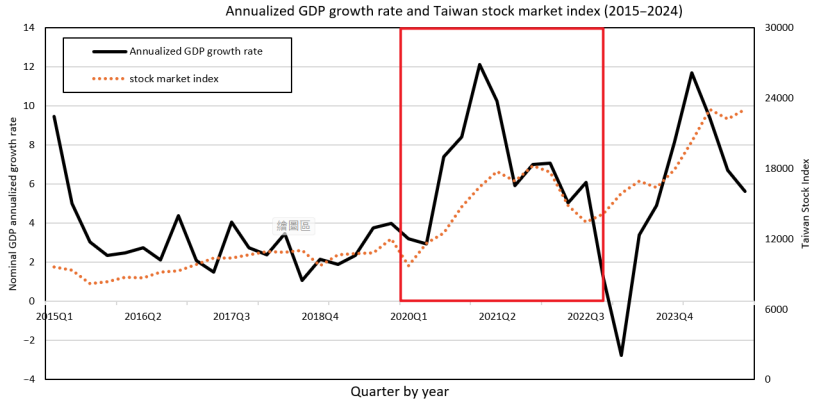
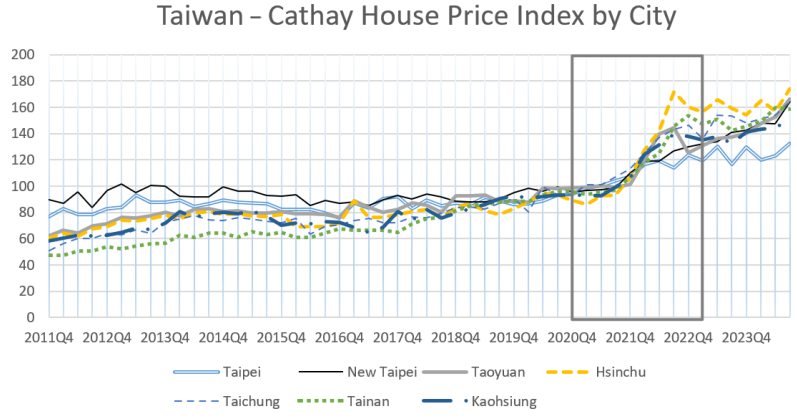


Figure 1. Annualized GDP growth rate and the index of Taiwan stock market index (TWSE)



Note: The Cathay House Price Index is developed by Cathay Real Estate, the Center for Real Estate Research at National Chengchi University, and scholars in the field of real estate research in Taiwan. Released quarterly, the index is mainly based on prices of presold and new homes. Since 2022 Q1, the base year of index has been set at 2021 (benchmark = 100).

Figure 2. Cathay House Price Index by cities in Taiwan (2011Q4–2024Q3)

These macroeconomic shifts have significantly impacted real estate markets globally. However, the interest rate policy of Taiwan central bank and tax policy on housing seem not able to curb the already-booming housing market since 2022, which is consistent with the Wang et al. (2022) that increases in housing prices were likely driven by factors such as supply and expected returns, rather than by government policies.

In view of the fast increase and even speculation in the housing prices since 2020, the housing policy of Taiwan government seemed to lag behind the volatile housing market. Recent controversies on the presale homes, which are often criticized for speculative trading practices in Taiwan, highlight the need for more granular analysis of how the macroeconomic policy can affect the housing prices. In Taiwan housing market, the presale house transfer to arbitrage profits from price difference has been quite popular especially in the housing bull market. Existing indices like the Cathay Housing Price Index and Sinyi Housing Price Index[1] provide valuable insights but fail to distinguish the differences between existing and presale home prices. This gap underscores the necessity of reconstructing housing price indices to closely track the housing market dynamics.

In the past, numerous studies have demonstrated the impact of macroeconomic variables on housing prices. Lai (2019) indicated that variables such as stock prices, money supply, savings rate, inflation, interest rates, and income affect the prices of existing and presale home in Taiwan. The study concluded that there is a bidirectional feedback relationship between money supply and the prices of existing and presale homes. Lai also pointed out that variables such as the housing price index, interest rates on housing loans by major banks, gross domestic product, consumer price index, and money supply growth rate influence the housing prices in Taiwan and exhibit a stable long-term equilibrium relationship.

Furthermore, Feng et al. (2010) argued that housing prices are determined by both simultaneous and lagged macroeconomic variables, indicating a stable equilibrium relationship between macroeconomic factors and housing prices in the long run. In addition, in 2022, Taiwan Semiconductor Manufacturing Company's (TSMC) announcement of its expansion into Kaohsiung led to a surge in housing prices. The prices of presale homes also increased accordingly. In recent years, presale homes have been a subject of controversy due to their futures trading nature. Speculators in Taiwan housing market often exploit its leverage feature of futures trading to speculate on presale homes.

[1] The Sinyi housing index is another key indicator of the Taiwan real estate market. Developed by Sinyi Realty Inc., a listed company in Taiwan stock market specializing in the housing sales and brokerage service, this index provides valuable data on the fluctuations in property prices, helping to gauge market demand and supply. The main difference between the Cathay House Price Index and the Sinyi House Price Index is that the latter is based on second-hand residential units and excludes presold homes.

2. Literature review

2.1. House price index

Wallace and Meese (1997) addressed the issues related to assumptions in the repeat sales and hedonic pricing methods used to construct housing price indices. They developed a new hybrid model combining elements of repeat sales and hedonic pricing. Analyzing housing sales data from 18 years in Auckland and Fremont, California, they found that the repeat sales method was affected by selection bias and violated the time-invariance assumption of implicit housing attributes. The repeat sales method was highly sensitive to influential observations. In contrast, the hedonic pricing method was better suited for solving index problems as it could adapt to changing prices over time. Anomalous observations had a smaller impact on the estimated price indices, leading to more useful estimates of price indices.

Englund et al. (1999) analyzed housing sales data from Sweden over the past decade. They investigated the impact of temporal aggregation on price estimation and volatility. Comparing the traditional Weighted Repeat Sales (WRS) model with a strategy based on housing sales data, they concluded that time disaggregation significantly affected price estimation and volatility, regardless of the model used. The differences in price variations were largely attributed to inherent data limitations in the repeat sales method. By using the hedonic price method, Hill and Melser (2008) emphasized the importance of using different model formulas for different variables when estimating prices, employing models by Fisher and Törnqvist. The study utilized three years of housing price data from three regions in Sydney, highlighting the significance of these factors in the housing environment.

Lin and Lin (2010) employed the Laspeyres index, Paasche index, and median price by utilizing extensive estimation calculations to establish monthly housing price indices from a well-known commercial bank database in Taiwan, incorporating data from various counties and cities. The results indicated that the median index without quality control exhibited significant fluctuations, whereas the index with quality control showed smaller fluctuations. Therefore, the Laspeyres and Paasche index were found to most accurately reflect the actual housing price fluctuations. However, it is worth noting that the indices for each county and city might be influenced by factors such as time, space, and quality, leading to varying degrees of fluctuations.

On the other hand, Shimizu et al. (2010) proposed a new method called "Overlap Period Hedonic Model" (OPHM), which calculated monthly hedonic price indices based on the data from the past year. The results of OPHM revealed that the housing market structure continually changes over time, and ignoring these changes led to significant errors in housing price indices. Their study suggested that OPHM could provide valuable insights for countries developing housing price indices.

Additionally, Paredes (2011) combined quasi-experimental methods, hedonic pricing, and the Fisher Spatial price index using the housing price data from Chile National Socioeconomic Characterization Survey (CASEN 2006). They found that employing the Mahalanobis metric (Mahalanobis metric within propensity score calipers, MMWPS) method helped to reduce biases. By matching specific area attributes with similar attributes in the reference area, they calculated the hedonic price model. The study concluded that there were price differences for homogeneous houses in different regions of Chile.

2.2. Macroeconomic impact on housing price

The strong contemporaneous and lagged wealth effect of macroeconomic factors on property prices in U.S. has been proposed and verified in the literature (Jud & Winkler, 2002). They found that real housing price appreciation was influenced by population growth, income, construction costs, and interest rates. Stock market appreciation also has a significant wealth effect on housing price growth. Laurinavičius et al. (2022) found that higher GDP per capita, lower unemployment, and inflation correlate with increased nominal house prices in Vilnius. Ahn et al. (2024) examined the impact of the 2016 policy tightening on the Chinese housing market, questioning its effects on price expectations and regime changes. They found that that the tightening policy did not trigger a market crash but shifted the market to a soft landing. It suggests that timely government policies can stabilize housing prices and improve market conditions.

In addition, Chen and Lin (2019) conducted regression analysis to explore the impact of monetary policy on asset prices and how quantitative easing policies affect asset prices in U.S. market. The study revealed simultaneous effects between short-term interest rates, monetary supply, and the S&P 500 index. Duan et al. (2021) proposed that both macroeconomic and hedonic factors significantly influence housing prices in Beijing. Their results revealed that increases in money supply and decreases in mortgage rates lead to long-term rises in housing prices, indicating the importance of monetary policies. Furthermore, Ding (2022) used a multiple linear regression model to discover a positive correlation between the housing price index over the past 15 years and stock price growth and economic growth. Housing prices were negatively correlated with mortgage interest rates and unemployment rates. This study provides valuable insights into estimating the short-term major macroeconomic variables' impact on future housing price indices.

In the European market, Panagiotidis and Printzis (2016) used a two-stage VECM estimation method to examine the long-term determinants of the Greek real estate market. Dynamic analysis showed that the property price index responded to impacts on mortgage loans, CPI, and retail trade, whereas the impact of industrial production on house price index was not significant. On the other hand, Gasparėnienė et al. (2016) confirmed significant interdependencies between four major macroeconomic factors (GDP, inflation rate, interest rate, and bank loan availability) and the annual average prices of apartments in Lithuania from 2008 to 2015. Among these factors, interest rate dynamics and bank loan availability were the most significant, explaining 49.23% and 79.03% of the variations in the country's property prices, respectively. In comparison, inflation rate accounted for 39.35% of the fluctuations, and GDP had the smallest impact on property prices in Lithuania.

Beltratti and Morana (2010) examined the relationship between macroeconomic conditions in the G-7 countries and the real estate market. The study revealed that the United States serves as a significant source of global volatility, influencing not only real activity, variables, and stock prices but also real estate prices. The connection between real estate prices and macroeconomic development is bidirectional, with investment having a stronger impact on house price shocks than consumption and output. Gueye (2021) also found that there is strong evidence for cross-section dependence in international housing prices across 20 OECD countries, which is crucial for analyzing housing price panels. The research emphasizes the importance of robust methodologies for estimating impulse-response functions in the presence of cross-section dependence. Additionally, it addresses the impact of the Great Recession on cointegration results, finding no evidence of distortion. The findings have critical policy implications for economic decision-making related to housing markets.

Kishor and Marfatia (2017) modeled the dynamic relationships between short-term and long-term property prices, income, and interest rates across 15 OECD countries. The empirical analysis revealed a positive correlation between individual income and property prices in most countries over the long term. However, there was a negative relationship between interest rates and property prices. Among the 15 countries, ten countries exhibited common trends among the variables. Short-term deviations returned to equilibrium with subsequent property price changes, indicating that most variations were temporary compared to permanent changes in income and interest rates. This suggested that short-term fluctuations in property prices were independent of changes in income and interest rates.

Gao (2009) employed a Vector Error Correction Model (VECM) to examine the long-term equilibrium and short-term volatility relationship between housing price indices and CPI in China. The results indicated a significant impact of housing price indices on CPI, suggesting a correlation between the rising housing prices and short-term or long-term CPI inflation in the country. Feng et al. (2010) also analyzed the relationship between macroeconomic factors and the Chinese real estate cycle. Their study presented that housing prices are determined by both contemporaneous and lagged macroeconomic variables, demonstrating a stable equilibrium relationship between macroeconomic factors and housing prices in the long term.

Li (2020) also studied the interaction between China's macroeconomy and property prices and found that under policy interventions, there was a close relationship between the trend of the macroeconomy and property price fluctuations. He quantitatively studied the macroeconomic determinants of China's property prices using multiple linear regression. The analysis revealed positive correlations between GDP, CPI, FAI, and property prices, with CPI having the most significant impact. The study indicated that the substantial influence of CPI on property prices could lead to fluctuations in the real estate market due to inflation.

In the studies on Taiwan real estate market, Mo (2009) analyzed the factors affecting the transaction prices of second-hand houses in Kaohsiung city, one of the three biggest cities in Taiwan. The research indicated that macroeconomic variables had limited explanatory power over housing prices in Kaohsiung city, a result consistent with Fernández-Kranz and Hon (2006) by estimating the income elasticity of housing demand in Spain from 1996 to 2002 using price and income data from 50 provinces.

However, Cheng (2012) investigated the impact of supply growth rate, mortgage interest rates offered by the five major banks, CPI, and unemployment rate on housing prices in Taiwan. They found that mortgage interest rates were the primary factor influencing housing price fluctuations in various regions. Housing prices were positively correlated with the CPI. The study revealed that real estate possesses a hedge against inflation, as during periods of inflation, the public tends to invest their funds in the real estate market. The CCI was found to be positively correlated with both Cathay and Sinyi housing price indices. An increase in construction costs was reflected in the selling prices of new houses, and rising prices of new houses subsequently drove up the prices of pre-owned houses (Mei & Lin, 2017). Therefore, these factors exhibited a positive impact on both Cathay and Sinyi housing price indices.

The aforementioned studies shed light on the macroeconomic factors influencing real estate price indices, including interest rates, GDP, CPI, monetary supply growth rates, and construction costs. Therefore, this study aims to incorporate these factors for analysis, exploring how different types of real estate price indices are affected by macroeconomic conditions. Additionally, this research delves into the existing literature on the relationship between overseas real estate prices and macroeconomic factors, aiming to integrate the macroeconomic factors explored in this study further.

3. Methodologies

3.1. Hedonic price method

The hedonic price method, proposed by Rosen (1974), combines utility theory with bid price theory. This approach evaluates the implicit prices of various attributes in a market characterized by perfect competition, quantifiable attribute properties, maximization of utility in production and consumption for producers and consumers, a wide variety of heterogeneous goods in the market, and the absence of resale issues. It uses the equilibrium price function of a differentiated market to assess the implicit prices of goods' attributes, considering that values vary with different market characteristics. Therefore, implicit prices represent the equilibrium prices in the market.

The hedonic price method is employed to estimate the impact of various factors on house prices. Regression models can be utilized to determine the importance of individual factors on house prices, including the positive or negative correlation between housing features and prices. This method provides a better understanding of buyers' preferences for certain properties. The functional forms of the hedonic price model are categorized into three models: linear-linear, semi-logarithmic (semi-log), and double-logarithmic (log-log). Previous literature (Chang et al., 2008) suggests that the semi-logarithmic model has advantages over other models, as it allows for easier interpretation of the percentage change in prices caused by a one-unit change in features. Therefore, the semi-logarithmic model is more suitable for constructing price indices. In this study, we will use the semi-logarithmic model to establish the house price index. The hedonic price model (1) is presented below.

$$\ln\left(HPI_i\right) = a_{i0} + \sum_{i=1}^{n} \beta_{ik} \cdot X_{ik} + \varepsilon_i, \quad (1)$$

where: HPI_i – trading price of i^{th} sold house; X_{ik} – k^{th} feature of the i^{th} sold house (features including total number of floors, current floor level, registered floor area, building age, parking spaces, and location); β_{ik} – coefficient of X_{ik}; a_{i0} – intercept term; ε_i – error term, $\varepsilon_i \sim N\left(0, \sigma\right)$.

Table 1 shows the feature variables in the hedonic price model (Chang et al., 2008).

Table 1. Features of completed and presale houses

	Feature	Unit	Expected sign	Note
Completed houses	Total number of floors	floor	+	
	Current floor level	floor	–	
	Registered floor area	ping	+	
	Building age	year	–	
	Parking lot	number	+	
	Location	dummy	+	City center = 1, suburbs = 0
Presale houses	Total number of floors	floor	+	
	Current floor level	floor	–	
	Registered floor area	ping	+	
	Parking lot	number	+	
	Location	dummy	+	City center = 1, suburbs = 0

3.2. Housing price index

Based on the housing price index model by Chang et al. (2008), the base year and current year housing prices were determined through index conversion, coupled with the use of the logarithmic formula. By employing a semi-logarithmic model, we calculated the current housing price index as follows:

$$HPI_{t,o} = \frac{\hat{Y}_{to}}{\hat{Y}_{oo}} = \frac{exp\left(\sum_{i=0}^{n} \beta_{it} \bar{X}_{io}\right)}{exp\left(\sum_{i=0}^{n} \beta_{io} \bar{X}_{io}\right)}, \quad (2)$$

where: o – base period; t – calculated period; $\hat{Y}_{to}$ – estimated standard residential price in calculated period (base period weighted); $\hat{Y}_{oo}$ – estimated standard residential price in base period (base period weighted); β_{io}, β_{it} – coefficients of base and calculated period (including intercept term); $\bar{X}_{io}$ – median or average of feature variables in base period (for standard residential houses with generally accepted qualities).

By Chang et al. (2008), housing price index based on Laspeyres index is:

$$HPI_{t,a} = \frac{\hat{P}_{ta}}{\hat{P}_{aa}} = \frac{exp\left(\sum_{i=0}^{n} \beta_{it} \bar{P}_{it}\right)}{exp\left(\sum_{i=0}^{n} \beta_{ia} \bar{P}_{it}\right)}, \quad (3)$$

where: a – base period; t – calculated period; $\hat{P}_{ta}$ – estimated standard residential price in calculated period (weighted by calculated period); $\hat{P}_{aa}$ – estimated standard residential price in base period (weighted by the calculated period); β_{ia}, β_{it} – coefficients of base and calculated period (including intercept term); $\bar{P}_{it}$ – median or average of feature variables in calculated period (for standard residential houses with generally accepted qualities).

3.3. Macroeconomic indicators

The prices in the real estate market are influenced by the supply and demand dynamics, and the housing market is also affected by the changes in economic conditions. Therefore, macroeconomic indicators are one of the main factors affecting housing prices. This study explores literature related to the relationship between macroeconomics and housing prices. The explanation of macroeconomic indicators is as follows:

- Consumer Price Index (CPI)

The price index is an indicator that measures the price level of goods and services purchased by residents. It is calculated by comparing the prices of a fixed basket of goods and services in different periods to measure the extent of inflation.

- Construction Cost Index (CCI)

The Construction Cost Index reflects the changes in materials and labor costs required for construction projects. It directly impacts housing prices; when construction costs rise, housing prices tend to increase. This index measures the price fluctuations of materials and labor inputs in construction projects.

- Gross National Income (GNI)

The total value of goods and services produced by the nation, including wages, rent, interest, and profits, calculated at market prices, is known as Gross National Income.

- Mey supply

As per the current definition by the central bank:

(1) Monetary aggregate M1A:

M1= Currency in circulation (money held by the public) + Checkable deposits and demand deposits held by corporations, individuals, and non-profit organizations in banks and grassroots financial institutions.

(2) Monetary aggregate M1B:

M1B = M1A + Savings deposits (currently, only individuals and non-profit organizations can open savings accounts).

(3) Monetary aggregate M2:

M2 = M1B + Quasi-money (Quasi-money refers to certain monetary assets, such as fixed-term deposits, foreign currency deposits, and postal savings, that can be unconditionally and immediately converted into narrow money. It has relatively lower liquidity and is generally used for the purpose of value storage).

- Arage mortgage interest rates of five major banks

T ctral bank compiles and publishes the monthly new housing loan interest rates oered by five major banks in Taiwan, including Taiwan Bank, Cooperative Bank, Land Bank, Hua Nan Bank, and First Bank.

- Taiwan Weighted Stock Price Index (TAIEX)

The weighted index is compiled by the Taiwan Stock Exchange and is used to evaluate the overall performance of stocks listed in Taiwan. It is considered a crucial indicator reflecting Taiwan's economic trends.

3.4. Unit root test

Macroeconomic indicators and housing price indices are time series data that can be stationary or non-stationary. Non-stationary series exhibit long-term trends and deviations from the mean over time, while stationary series revert to the mean after shocks, maintaining stable statistical properties (Granger & Newbold, 1974). Non-stationary data can lead to spurious regressions, making it essential to test for stationarity using unit root tests. Nelson and Plosser (1982) found many macroeconomic series to be non-stationary with random trends. This study employs the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests to examine the stationarity of the data.

4. Empirical results and analysis

4.1. Data and variables

The sample period for this study covers quarterly residential trading data from April 2014 to March 2022 for Taipei, Taichung and Kaohsiung cities, the three largest cities in Taiwan. In addition, according to the Real Estate Brokerage

Management Regulations of Taiwan, the "existing properties" and "pre-sale properties" are defined as follows:

- Existing properties

Existing properties refer to the buildings that have obtained a usage permit or were completed before the implementation of building management regulations.

- Pre-sale properties

Pre-sale properties refer to properties that have been issued a construction permit but have not been completed yet. These properties can also be traded based on buildings that will be completed in the near future.

Classifications of residential buildings are listed in the Table 2. Trading data are obtained from the quarterly statistics provided by the Ministry of the Interior, Taiwan. There are four categories of residential houses: luxury homes, first class, second class and suite. Suite is defined as the house with total floor area below 25 pings and it also includes studio apartment. Luxury homes are housing prices in the top 20% of the total transaction volume. Excluding luxury homes and suites, residential properties priced above the average trading price for elevator buildings are classified as the first-class housing, and those below the average trading price are classified as the second-class housing.

Table 2. Classifications of residential buildings

Category	Definition
Luxury homes	Housing prices in the top 20% of the total transaction volume
First-class	Excluding luxury homes and suites, residential properties priced above the average for elevator buildings are classified as the first-class housing
Second-class	Excluding luxury homes and suites, residential properties priced below the average for elevator buildings (by the quarterly statistics from the Ministry of the Interior) are classified as the second-class housing
Suite	Total floor area below 25 pings (1 ping = 3.3 square meter)

Note: Data source: Quarterly statistics provided by the Ministry of the Interior, Taiwan.

This study utilizes quarterly data spanning eight years of macroeconomic variables which are used as independent variables. The data sources for the macroeconomic variables are presented in the Table 3.

This study involves the screening and removal of transactions that deviate from normal market prices and special real transaction information. The quarterly data for residential property prices of existing and pre-sale buildings in Taipei, Taichung, and Kaohsiung cities over the eight-year period is then transformed into an index, serving as the dependent variable. The trading data sources of the existing and pre-sale buildings are listed in the Tables 4 and 5.

Table 3. Macroeconomic variables and data sources

Independent variables	Data source
CPI for Taipei city	Taipei City Government's Directorate of Budget, Accounting and Statistics
CPI for Taichung city	Taichung City Government's Directorate of Budget, Accounting and Statistics
CPI for Kaohsiung city	Kaohsiung City Government's Directorate of Budget, Accounting and Statistics
CCI for Taipei city	Taipei City Government's Directorate of Budget, Accounting and Statistics
CCI for Taichung city	Taichung City Government's Directorate of Budget, Accounting and Statistics
CCI for Kaohsiung city	Kaohsiung City Government's Directorate of Budget, Accounting and Statistics
National Income (NI)	Statistical information website of the Republic of China (Taiwan)
Money Supply (M2)	Statistical information website of the Republic of China (Taiwan)
Average mortgage rate of the five major banks (AMR)	Real Estate Information Platform of the Ministry of the Interior
Taiwan Stock Price Index (TAIEX)	Taiwan Economic Journal

Table 4. Existing housing prices and data sources

Price index of residential buildings (dependent variables)	Data source
Price index of existing residential building – luxury	Taiwan Economic Journal
Price index of existing residential building – first-class	Taiwan Economic Journal
Price index of existing residential building – second-class	Taiwan Economic Journal
Price index of existing residential building – suite	Taiwan Economic Journal

Table 5. Pre-sale housing prices and data sources

Price index of residential buildings (dependent variables)	Data source
Price index of existing residential building – luxury	Taiwan Economic Journal
Price index of existing residential building – first-class	Taiwan Economic Journal
Price index of existing residential building – second class	Taiwan Economic Journal
Price index of existing residential building – suite	Taiwan Economic Journal

4.2. Descriptive statistics

By Chang et al. (2008), we screened the data by removing the transactions deviating from normal market prices, and special real estate registration data, followed by the consolidation of standardized housing information for each category. Tables 6 and 7 are the feature statistics according to the four categories of standard housing, i.e., luxury homes, the first-class housing, the second-class housing, and suite in Taipei city. Note that the data of 2016Q4 and 2019Q3 in Table 7 are not shown due to the incomplete data.

Table 8 shows the basic statistics of Taipei city existing home price indices across four different categories of housing. We observed that the standard deviation of the luxury home and the second-class home price indices in Taipei are relatively high. This suggests greater fluctuation over the eight-year period. Moreover, the maximum and minimum values of the luxury home index exhibit the largest difference, indicating the greatest magnitude of variation.

Table 9 shows the basic statistics of Taichung city existing home price indices across four different categories of housing. We noted that the standard deviation of the suite index exhibits the highest variability, followed by the second-class housing index. The difference between the maximum and minimum values of the luxury home index is the smallest, indicating the least fluctuation.

Table 10 shows the basic statistics of Kaohsiung city existing home price indices across four different categories of housing. We noted that the standard deviation and maximum value of the suite index are the highest compared to other housing categories. Conversely, the standard deviation of the first-class index is the smallest, indicating less fluctuation.

Table 6. The existing luxury and the first-class housing in Taipei city

Category	Feature	Stats	2014Q2	2014Q3	2014Q4	2015Q1	2015Q2	2015Q3	2015Q4	2016Q1	2016Q2	2016Q3	2016Q4
Luxury homes	total number of floors	mean	14.24	15.16	16.22	16.89	18.15	18.35	17.36	15.31	15.88	15.88	16.61
	sampled floor	mean	8.14	8.69	8.70	9.14	9.37	9.57	9.79	9.15	9.48	8.71	9.73
	registered total area	median	77.01	79.54	90.46	75.15	79.85	83.27	97.31	87.78	87.29	82.03	93.73
	housing age (year)	median	2.85	3.80	2.60	4.30	4.60	5.60	3.05	3.15	3.90	1.45	4.30
	parking lot	mean	1.61	1.71	1.99	1.35	1.68	1.60	1.88	1.58	1.62	1.55	1.88
	location	mean	0.47	0.63	0.47	0.74	0.66	0.67	0.65	0.59	0.64	0.73	0.72
	number of quarterly data	# obs.	108	249	463	328	326	263	348	130	146	56	190
	Feature	Stats	2017Q1	2017Q2	2017Q3	2017Q4	2018Q1	2018Q2	2018Q3	2018Q4	2019Q1	2019Q2	2019Q3
	total number of floors	mean	16.41	16.85	18.50	17.23	16.86	18.94	17.43	19.81	18.97	17.79	17.97
	sampled floor	mean	9.56	9.78	10.59	10.02	9.12	12.54	9.17	10.66	10.40	9.71	10.58
	registered total area	median	92.39	94.48	93.26	92.29	87.15	104.99	84.51	91.92	95.80	86.22	75.85
	housing age (year)	median	4.45	5.00	3.60	4.00	2.35	3.50	3.80	4.00	5.30	6.10	4.00
	parking lot	mean	1.83	1.87	1.87	1.89	1.58	2.01	1.78	1.80	1.83	1.72	1.58
	location	mean	0.80	0.48	0.45	0.50	0.59	0.68	0.67	0.69	0.55	0.63	0.83
	number of quarterly data	# obs.	176	211	205	218	90	99	147	134	108	155	101
	Feature	Stats	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4	2021Q1	2021Q2	2021Q3	2021Q4	2022Q1	
	total number of floors	mean	16.26	18.62	17.48	17.75	17.80	20.49	18.27	16.83	21.63	16.83	
	sampled floor	mean	9.65	10.32	10.25	10.26	9.65	11.46	10.49	9.56	13.45	9.04	
	registered total area	median	83.33	74.25	85.57	80.44	89.37	95.29	76.36	74.52	129.56	69.13	
	housing age (year)	median	7.95	5.30	7.00	7.10	7.80	6.65	7.90	7.60	6.15	8.30	
	parking lot	mean	1.46	1.71	1.61	1.47	1.69	1.95	1.48	1.36	2.64	1.23	
	location	mean	0.33	0.74	0.53	0.58	0.56	0.60	0.73	0.66	0.78	0.74	
	number of quarterly data	# obs.	72	91	181	204	203	312	208	249	64	297	

End of Table 6

Category	Feature	Stats	2014Q2	2014Q3	2014Q4	2015Q1	2015Q2	2015Q3	2015Q4	2016Q1	2016Q2	2016Q3	2016Q4
The first-class housing	total number of floors	mean	12.69	13.96	14.08	14.15	14.17	14.21	14.11	14.26	17.22	18.49	18.14
	sampled floor	mean	9.22	8.26	8.18	8.07	8.17	8.11	8.41	8.58	9.94	10.27	10.23
	registered total area	median	39.59	47.11	45.20	45.51	41.71	41.37	42.92	44.03	41.35	39.25	38.55
	housing age (year)	median	6.40	6.40	6.10	6.40	6.70	8.30	8.10	8.20	5.20	3.30	3.40
	parking lot	mean	0.63	0.85	0.78	0.78	0.66	0.59	0.60	0.62	0.76	0.82	0.77
	location	mean	0.56	0.42	0.53	0.54	0.66	0.64	0.65	0.66	0.71	0.73	0.73
	number of quarterly data	# obs.	197	515	967	931	769	490	607	553	736	532	624
	Feature	Stats	2017Q1	2017Q2	2017Q3	2017Q4	2018Q1	2018Q2	2018Q3	2018Q4	2019Q1	2019Q2	2019Q3
	total number of floors	mean	15.66	15.58	15.58	15.57	15.73	15.78	14.20	14.35	14.53	14.64	14.57
	sampled floor	mean	8.99	8.91	8.80	9.12	9.40	9.85	8.35	8.34	8.53	8.79	8.90
	registered total area	median	42.08	42.32	43.80	42.79	42.78	41.51	42.67	41.61	41.37	40.86	40.21
	housing age (year)	median	7.40	8.00	8.10	8.85	9.00	9.20	8.75	9.90	8.90	9.40	9.80
	parking lot	mean	0.71	0.70	0.73	0.67	0.65	0.62	0.70	0.67	0.64	0.60	0.59
	location	mean	0.66	0.58	0.51	0.51	0.53	0.60	0.40	0.44	0.46	0.49	0.46
	number of quarterly data	# obs.	496	724	723	752	486	281	176	275	455	529	620
	Feature	Stats	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4	2021Q1	2021Q2	2021Q3	2021Q4	2022Q1	
	total number of floors	mean	14.83	15.00	15.08	14.91	14.76	14.78	14.74	15.12	14.84	14.71	
	sampled floor	mean	9.18	9.15	8.85	8.59	8.52	8.67	8.53	8.61	12.22	11.75	
	registered total area	median	40.10	40.28	40.74	42.02	41.56	40.67	39.68	39.42	40.94	40.63	
	housing age (year)	median	8.90	8.90	8.80	9.80	10.15	10.80	11.30	13.80	13.70	13.80	
	parking lot	mean	0.64	0.66	0.70	0.67	0.68	0.65	0.65	0.61	0.67	0.66	
	location	mean	0.45	0.44	0.46	0.49	0.50	0.51	0.49	0.51	0.57	0.57	
	number of quarterly data	# obs.	664	622	704	729	770	662	559	519	1008	1099	

Table 7. The existing second-class housing and suite in Taipei city

Category	Feature	Stats	2014Q2	2014Q3	2014Q4	2015Q1	2015Q2	2015Q3	2015Q4	2016Q1	2016Q2	2016Q3
The second-class housing	total number of floors	mean	13.51	14.00	14.44	14.57	14.97	14.77	13.99	14.07	14.25	14.07
	sampled floor	mean	7.70	7.67	8.07	8.16	8.04	7.79	7.60	7.68	7.58	7.71
	registered total area	median	55.83	50.03	48.36	49.23	48.83	48.19	47.65	48.25	47.79	48.16
	housing age (year)	median	5.10	5.80	5.10	5.80	6.50	6.40	7.00	8.35	7.70	6.60
	parking lot	mean	1.00	0.95	0.91	0.96	1.02	0.94	0.89	0.95	0.93	0.95
	location	mean	0.35	0.38	0.33	0.38	0.41	0.38	0.40	0.28	0.26	0.26
	number of quarterly data	# obs.	524	1285	1875	1925	1713	1590	991	462	411	271
	Feature	Stats	2017Q1	2017Q2	2017Q3	2017Q4	2018Q1	2018Q2	2018Q3	2018Q4	2019Q1	2019Q2
	total number of floors	mean	14.38	14.25	14.17	14.23	14.56	14.46	14.31	14.53	14.35	14.06
	sampled floor	mean	7.53	7.72	7.58	7.53	7.80	7.90	7.69	7.87	7.76	7.90
	registered total area	median	49.48	49.55	51.49	50.87	49.68	49.28	48.32	48.89	48.84	49.81
	housing age (year)	median	8.95	9.10	9.10	9.80	10.00	10.50	11.00	10.80	11.50	12.10
	parking lot	mean	0.93	0.87	0.93	0.92	0.90	0.88	0.84	0.86	0.86	0.87

End of Table 7

Category	Feature	Stats	2014Q2	2014Q3	2014Q4	2015Q1	2015Q2	2015Q3	2015Q4	2016Q1	2016Q2	2016Q3
	location	mean	0.32	0.34	0.32	0.35	0.38	0.39	0.34	0.35	0.33	0.32
	number of quarterly data	# obs.	480	477	548	639	547	428	467	417	626	486
	Feature	Stats	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4	2021Q1	2021Q2	2021Q3	2021Q4	2022Q1
	total number of floors	mean	14.31	14.29	14.20	14.37	14.30	14.35	14.48	14.55	14.65	14.99
	sampled floor	mean	7.93	7.69	7.59	7.77	7.59	7.75	7.94	7.91	8.12	8.29
	registered total area	median	47.29	45.77	45.66	47.48	48.74	48.21	44.63	43.33	43.76	44.09
	housing age (year)	median	11.45	12.20	12.70	12.70	13.25	15.00	14.55	14.00	13.85	14.80
	parking lot	mean	0.88	0.82	0.81	0.85	0.85	0.83	0.82	0.81	0.81	0.72
	location	mean	0.34	0.40	0.39	0.35	0.39	0.43	0.42	0.38	0.36	0.45
	number of quarterly data	# obs.	464	436	477	575	522	437	430	513	288	241
Category	Feature	Stats	2014Q2	2014Q3	2014Q4	2015Q1	2015Q2	2015Q3	2015Q4	2016Q1	2016Q2	2016Q3
Suite	total number of floors	mean	12.82	13.25	13.43	13.26	13.42	13.60	13.67	13.78	16.17	17.21
	sampled floor	mean	8.30	7.88	7.62	7.86	8.58	8.45	8.51	8.58	8.87	9.18
	registered total area	median	17.43	18.04	18.76	19.51	19.51	19.41	20.20	20.07	19.43	19.92
	housing age (year)	median	18.45	17.45	14.45	16.50	18.70	18.70	18.95	18.80	8.70	7.80
	parking lot	mean	0.07	0.09	0.14	0.13	0.07	0.06	0.08	0.09	0.08	0.07
	location	mean	0.78	0.75	0.74	0.69	0.62	0.62	0.62	0.62	0.74	0.80
	number of quarterly data	# obs.	196	304	258	245	227	205	190	175	203	147
	Feature	Stats	2017Q1	2017Q2	2017Q3	2017Q4	2018Q1	2018Q2	2018Q3	2018Q4	2019Q1	2019Q2
	total number of floors	mean	14.43	13.89	13.90	16.10	16.69	14.94	14.29	13.99	14.13	14.13
	sampled floor	mean	8.70	8.55	8.42	9.26	9.79	9.18	8.58	8.11	8.64	8.52
	registered total area	median	19.55	19.43	19.43	19.07	19.58	19.85	19.27	19.63	19.21	19.47
	housing age (year)	median	19.30	13.60	20.50	10.30	9.30	11.50	14.55	20.85	20.50	20.40
	parking lot	mean	0.08	0.09	0.06	0.04	0.04	0.04	0.04	0.05	0.09	0.08
	location	mean	0.78	0.79	0.72	0.78	0.81	0.75	0.73	0.70	0.73	0.74
	number of quarterly data	# obs.	169	163	173	279	264	187	180	122	127	220
	Feature	Stats	2019Q4	2020Q1	2020Q2	2020Q3	2020Q4	2021Q1	2021Q2	2021Q3	2021Q4	2022Q1
	total number of floors	mean	15.10	15.08	14.12	14.31	14.38	14.28	14.24	14.25	14.13	14.15
	sampled floor	mean	9.45	9.54	9.10	9.33	9.17	8.82	8.60	8.64	8.59	8.62
	registered total area	median	19.70	19.56	18.20	16.27	15.50	15.50	15.35	15.36	15.36	15.25
	housing age (year)	median	14.90	22.25	23.30	22.60	23.80	24.40	24.90	25.20	25.10	26.20
	parking lot	mean	0.09	0.09	0.12	0.10	0.07	0.06	0.08	0.08	0.07	0.08
	location	mean	0.70	0.70	0.77	0.73	0.71	0.75	0.75	0.76	0.80	0.78
	number of quarterly data	# obs.	185	182	244	381	406	358	328	397	569	579

Table 8. Statistics of Taipei city existing home price indices across four different categories of housing*

Categories	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	J-B	Probability	# obs.
Luxury home	101.21	100.99	108.62	97.79	2.10	1.29	6.12	21.84	0.0000	32
First-class	98.27	98.23	100.00	96.57	0.90	0.04	2.25	0.75	0.6867	32
Second-class	99.98	99.37	105.63	96.65	2.43	0.91	2.79	4.44	0.1088	32
Suite	100.42	100.50	103.67	97.07	1.99	–0.07	1.79	1.98	0.3724	32

Note: *The base period to compute the index in this study is the second quarter of 2014 (2014Q2).

Table 9. Statistics of Taichung city existing home price indices across four different categories of housing*

Categories	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	J-B	Probability	# obs.
Luxury home	100.28	100.35	102.23	96.45	1.28	–0.93	4.22	6.56	0.0376	32
First-class	101.49	101.25	104.90	98.26	1.55	0.28	2.52	0.73	0.6935	32
Second-class	102.69	102.71	109.96	98.25	2.42	0.54	4.08	3.12	0.2101	32
Suite	108.72	108.04	163.73	59.38	18.03	0.65	6.18	15.70	0.0004	32

Note: *The base period to compute the index in this study is the second quarter of 2014 (2014Q2).

Table 10. Statistics of Kaohsiung city existing home price indices across four different categories of housing*

Categories	Mean	Median	Max	Min	Std. dev.	Skewness	Kurtosis	J-B	Probability	# obs.
Luxury home	102.48	102.48	106.79	99.14	1.73	0.11	2.83	0.11	0.9469	32
First-class	100.65	100.54	103.81	98.28	1.17	0.63	3.62	2.63	0.2691	32
Second-class	101.99	100.87	108.14	99.84	2.29	1.22	3.48	8.24	0.0162	32
Suite	111.82	114.17	120.35	97.44	5.88	–0.76	2.82	3.12	0.2105	32

Note: *The base period to compute the index in this study is the second quarter of 2014 (2014Q2).

Table 11. Summary statistics of macro and construction factors across three cities*

Variables	Mean	median	Max	Min	Std. dev.	Skewness	Kurtosis	J-B	Probability	# obs.
Taipei CPI	97.52	97.56	101.31	94.11	1.82	0.20	2.42	0.66	0.7195	32
Taichung CPI	97.24	97.51	101.45	93.48	2.01	0.18	2.32	0.78	0.6759	32
Kaohsiung CPI	97.12	97.37	101.25	92.94	2.20	0.02	2.22	0.80	0.6694	32
Taipei CCI	88.13	86.32	105.40	81.54	6.45	1.41	4.13	12.34	0.0021	32
Taichung CCI	86.85	84.65	105.99	80.07	7.02	1.49	4.27	13.98	0.0009	32
Kaohsiung CCI	88.31	86.45	104.25	81.32	6.25	1.29	3.79	9.77	0.0076	32
M1B	18021118	16972986	25389297	13716369	3397258	0.80	2.52	3.75	0.1536	32
M2	44103120	43445430	55006759	36443453	5033015	0.55	2.45	2.03	0.3616	32
NI	4057689	3990863	5066643	3469291	395478	0.86	2.95	3.91	0.1414	32
AMR	0.0165	0.0163	0.0199	0.0135	0.0021	0.12	2.04	1.29	0.5255	32
TAIEX	11333	10518	18219	8181	2986	1.30	3.36	9.15	0.0103	32

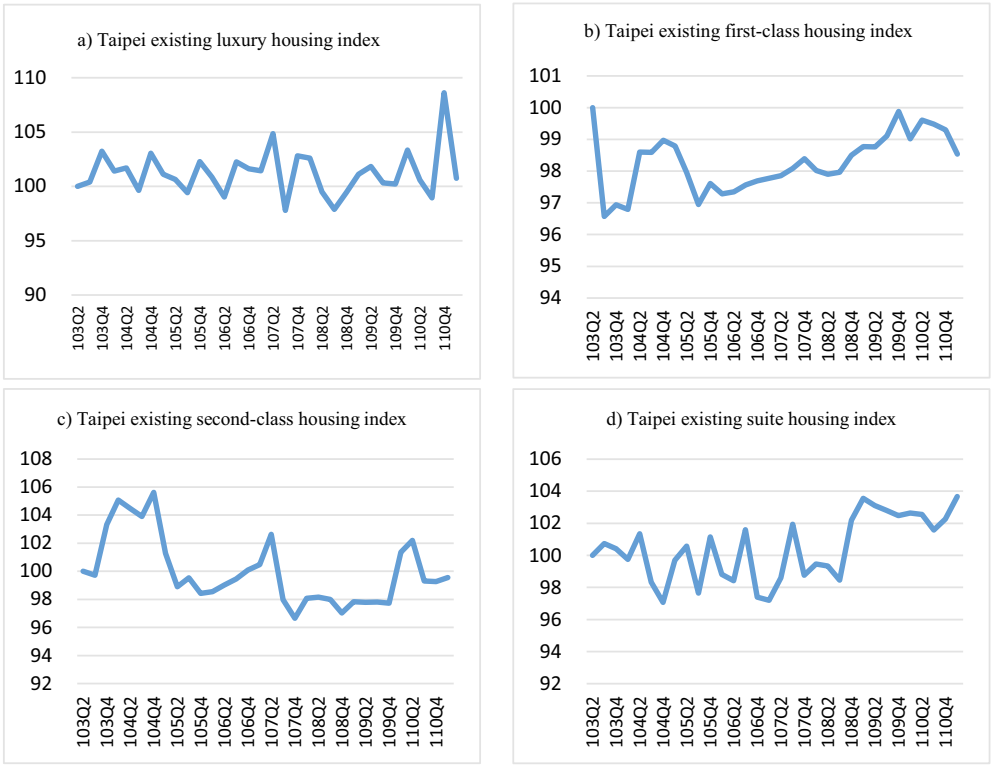
Note: *The base period to compute the index in this study is the second quarter of 2014 (2014Q2).

From Table 11, it is observed that the standard deviation of the construction cost index in Taichung city is relatively higher compared to other cities, indicating a larger fluctuation range. Conversely, Kaohsiung city exhibits the smallest fluctuation range in the construction cost index. However, Kaohsiung city has the highest standard deviation in consumer price levels, suggesting the greatest degree of index variation.

4.3. Analysis of housing index

Based on the results of the calculated residential price indices for various tiers over eight years in Taipei, Taichung, and Kaohsiung using the house price index model (Chang et al., 2008), Figures 3a to 5d present the existing housing index charts for the three biggest cities in Taiwan.

Figures 3a to 3d contains four subplots of the four tiers of housing index for the existing housing property. Figure 3a shows the existing luxury residential index in Taipei, which exhibits significant fluctuations but generally remains within a certain range over the long term. This indicates periodic implementation of government policies aimed at controlling luxury home prices. Figure 3d illustrates the suite index in Taipei, which has shown a recent upward trend. This suggests an increasing demand for rental suites driven by the influx of population, particularly from other regions. Consequently, there is also an increase in demand from investors purchasing suites, leading to a rise in the apartment price index. In view of the sensitivity of the housing price index, the existing suite housing index seems to be the most sensitive to the changes in housing market, which showed a strong rebound as early as 2020Q1, and then the first- and second-class housing indices (Figures 3b and 3c) began to rise accordingly. The existing suite housing index, therefore, should become an important signal for the government housing policy makers to monitor closely so as to make timely reaction curb the speculation in housing market.



Note: The X axis is using the Republic of China (ROC) calendar which is the method of numbering years currently used in ROC (including the islands of Taiwan, Kinmen and Matsu). To find out the ROC year equivalent to any Gregorian calendar year, we can add 1911 to the ROC year. For example: 103 + 1911 = 2014 year of the Gregorian calendar.

Figure 3. Taipei existing housing indices across four tiers of housing from 2014Q2 to 2021Q4

Figures 4a to 4d depict the luxury, the first-class, the second-class and suite housing indices of the existing property in Taichung city. Over the past eight years, the luxury, the first-class and the second-class housing indices have all shown a trend of moderate growth. This indicates that in recent years, an increasing number of people have been moving to Taichung. According to statistics from the Ministry of the Interior, despite the serious issue of declining birth rates in the past seven years, the population of Taichung has increased by more than 100,000 people. Consequently, there has been an increased demand for housing, leading to a growth in price indices. In view of the sensitivity of the housing price index, the existing luxury and the first-class housing price indices seem to be more sensitive to the housing market than the second- and suite housing indices which are more stable in completed housing market.

Figures 5a to 5d depict the luxury, the first-class, the second-class and suite housing indices of the existing property in Kaohsiung city. By the Figure 5d of the suite housing index, it has consistently remained around the mean value in recent years. This suggests that there may be relatively fewer job opportunities in Kaohsiung compared to Taipei. As a result, the increase in demand for studio apartments or suites among office workers has been relatively small, and there is also less demand from investors in the suite market. Therefore, this price index has shown a stable trend in recent years. On the other hand, the existing second-class housing price has risen much earlier than other indices and cities since 2019Q2, indicating possible potential speculators from the market. This can also be an important signal for local government to monitor in the future.

Due to insufficient data on pre-sale housing, the calculation of the eight-year pre-sale housing price index is not feasible. We only calculated and showed the results of the pre-sale housing price indices for Taipei, Taichung and Kaohsiung for a three-year period in Figures 6a–8d.

Figure 6a shows the luxury pre-sale housing index in Taipei, reaching its peak in the Q1 of 2019, and entering a consolidation phase after a decline in the Q2 of 2019. Figure 6b illustrates the first-class pre-sale housing index in Taipei, showing an upward trend reaching its peak in the Q1 of 2022. Figure 6c represents the second-class presale housing index in Taipei, reaching its highest point in the Q2 of 2021 with the index consolidating before reaching the peak. Figure 6d depicts the suite presale housing index in Taipei that remains in a consolidation phase over three years.

Figure 7a depicts the luxury pre-sale housing index in Taichung, reaching its peak in the Q1 of 2020. Following a decline in the subsequent year, it then demonstrates an upward trend. Figure 7b illustrates the first-class presale housing index in Taichung, showing an upward trend over

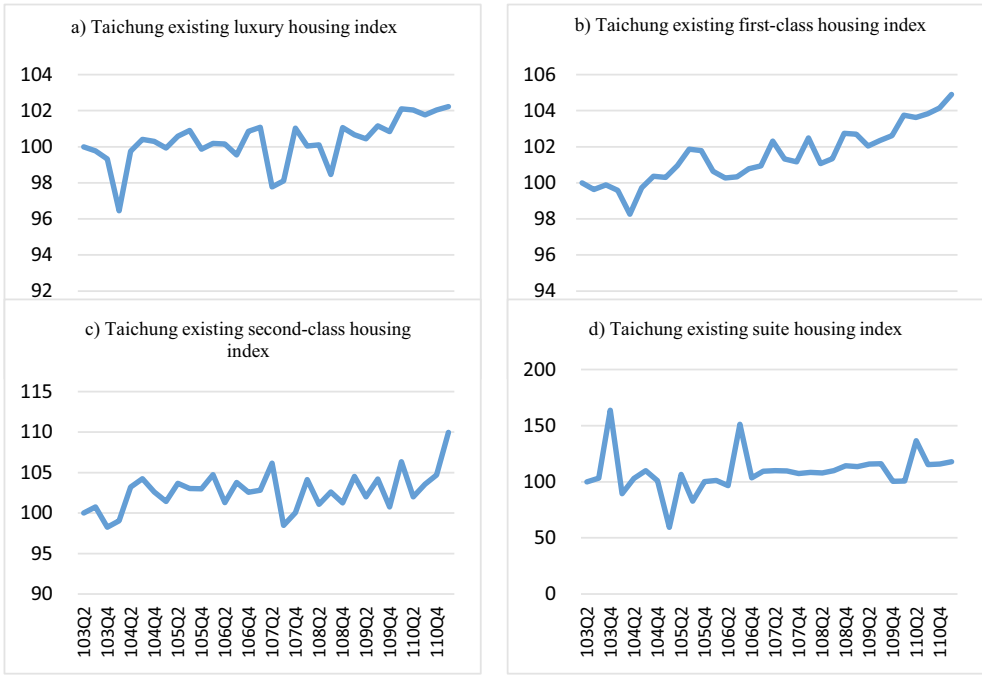


Figure 4. Taichung existing housing indices across four tiers of housing from 2014Q2 to 2021Q4

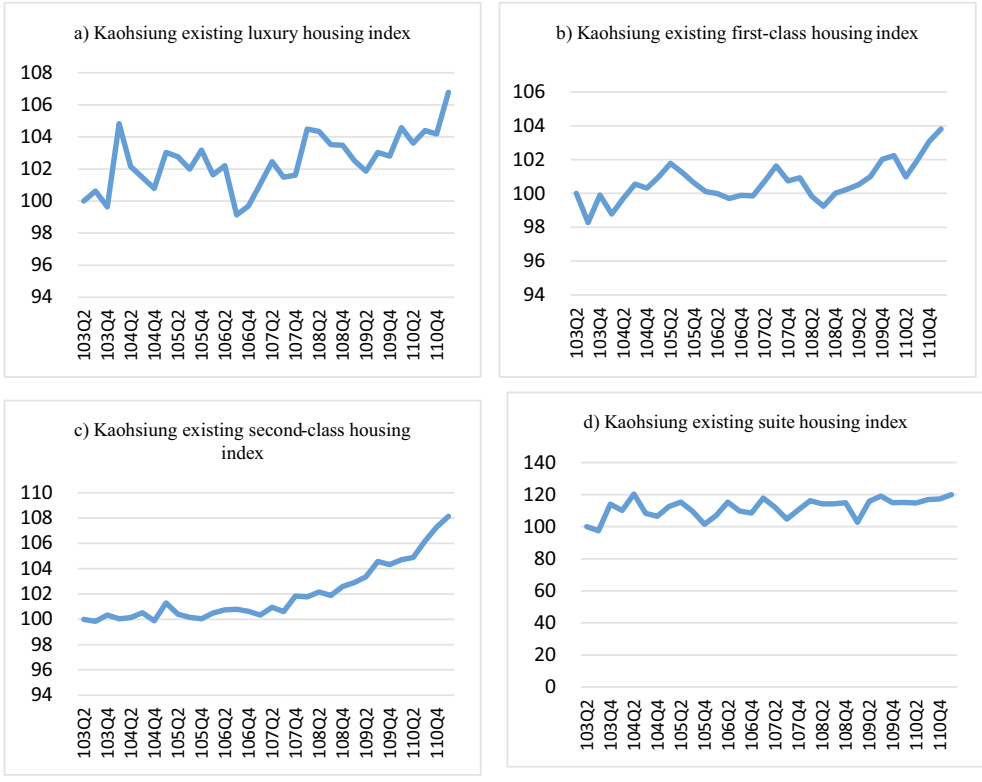


Figure 5. Kaohsiung existing housing indices across four tiers of housing from 2014Q2 to 2021Q4

Figure 6. Taipei presale housing indices across four tiers of housing from 2019Q2 to 2022Q1

Figure 7. Taichung presale housing indices across four tiers of housing from 2019Q2 to 2022Q1

Figure 8. Kaohsiung presale housing indices across four tiers of housing from 2019Q2 to 2022Q1

three years. Figures 7c and 7d represent the second-class and suite housing indices in Taichung respectively, both maintaining a consolidation phase over three years.

Figure 8a shows the luxury pre-sale housing index in Kaohsiung, reaching its lowest point in the Q2 of 2019, followed by an upward trend. Figure 8b illustrates the first-class presale housing index in Kaohsiung, peaking in the Q3 of 2019. After a decline the following year, it shows an upward trend. Figure 8c represents the second-class presale housing index in Kaohsiung, exhibiting an upward trend over three years. Figure 8d depicts the suite presale housing index in Kaohsiung, peaking in the Q2 of 2019, declining until the Q4 of 2019, and then entering a consolidation phase.

4.4. Unit root test

In the context of unit root tests for variables such as price indices and money supply, the test with a single intercept term performs better than the test with both intercept and trend terms (Elliott et al., 1996; Culver & Papell, 1997; Leybourne & Newbold, 1999; Ng & Perron, 2001). Therefore, the study adopted the Augmented Dickey-Fuller (ADF) test with a single intercept term to confirm whether the macroeconomic variables are stationary data. Table 12 above presents the tests before and after differencing. The results reveal that the first-order differencing CPI, money supply (M2), average mortgage interest rates of the five major banks, TAIEX, as well as the second-order differencing of the construction cost index and national income in Taipei, Taichung, and Kaohsiung, which reject the presence of a unit root. Therefore, this study employs the differenced macroeconomic variables for regression analysis.

Table 12. Unit root test of macroeconomic variables using ADF test

Macroeconomic variables	Level	First difference τ-stat	Second difference τ-stat
Taipei CPI	0.5349	–7.2165***	–7.2361***
Taichung CPI	0.1165	–4.9485***	–6.5187***
Kaohsiung CPI	–0.4335	–5.8720***	–6.5726***
Taipei CCI	0.7294	–1.9685	–6.2356***
Taichung CCI	1.0966	–1.9904	–6.2546***
Kaohsiung CCI	3.1752	–2.4651	–6.3955***
M2	3.2084	–3.2987**	–6.3022***
NI	3.3628	–2.2260	–7.3865***
AMR	–0.7222	–4.5898***	–8.1799***
TAIEX	0.4984	–6.0249***	–11.6901***

Note: ***and ** denote the unit root test with 1% and 5% significance level, respectively.

4.5. Regression results

The hses in Taiwan are categorized into the primary four types: luxury homes, the first-class, the second-class and suites as shown in the following:

- Luxury homes: high-income groups;
- First-class: middle- and high-income groups;
- Second-class: young couple or people earning the average-income groups;
- Suite: owner-occupiers and investors.

After calculating the house price indices for each category using the index model, the regression analysis is conducted with macroeconomic variables to examine the positive or negative correlations and the extent of their impact. Tables 13, 15 and 17 show the correlation coefficients between the house price indices of various levels and macroeconomic variables for Taipei, Taichung, and Kaohsiung over eight years. Tables 14, 16 and 18 present the regression results of the house price indices of various levels and macroeconomic indicators for Taipei, Taichung and Kaohsiung over eight years.

Existing property in Taipei city

- Taipei city luxury housing index for completed homes

Model (1) in Table 14 shows the regression results of the Taipei city luxury housing index for completed homes and macroeconomic variables. There is no significant impact between the luxury housing index and macroeconomic variables, indicating that high-income groups are not influenced by any macroeconomic variables when purchasing homes.

- Taipei city first-class housing index for completed homes

Model (2) in Table 14 shows the regression results of the Taipei city first-class housing index for completed homes and macroeconomic variables. The first-class housing index is positively and significantly influenced by the Taipei city CPI and the money supply, while it is negatively and significantly influenced by mortgage rates. This indicates that when the market is active and interest rates are lower, middle- and high-income groups are likely to use the benefits from their investments to purchase homes due to reduced interest costs.

- Taipei city second-class housing index for completed homes

Model (3) in Table 14 shows the regression results of the Taipei city second-class housing index for completed homes and macroeconomic variables. There is no significant impact between the second-class housing index and macroeconomic variables, indicating that young people and average-income earners have an urgent need for housing, and therefore changes in macroeconomic indicators are less likely to affect housing prices.

Table 13. Correlation between the Taipei housing indices of existing property and macroeconomic variables

	Luxury	First-class	Second-class	Suite	Taipei CPI	Taipei CCI	M2	NI	AMR	TAIEX
Luxury										
First-class	0.0908									
Second-class	0.2575	–0.0925								
Suite	0.0523	0.5278***	–0.2921							
Taipei CPI	–0.1314	0.2850	–0.0870	0.0550***						
Taipei CCI	–0.2514	0.1988	–0.0493	0.3334*	0.0217					
M2	0.2645	0.5050***	–0.0187	0.4651***	–0.2217	0.0205				
NI	0.0175	0.0224	–0.0696	–0.0688	0.4962***	–0.2277	–0.1964			
AMR	–0.0033	–0.0984	0.0838	–0.0915	0.0609	0.0581	0.1640	–0.1827		
TAIEX	0.1444	0.1869	–0.0903	0.1968	–0.0323	0.0103	0.3438*	0.0817	–0.2294	

Note: *** and * denote 1% and 10% significance level, respectively.

Table 14. Regression of Taipei housing index and macroeconomic variables across four housing categories

	Luxury	First-class	Second-class	Suite
	(1)	(2)	(3)	(4)
Intercept	100.5442***	97.2415***	100.3078***	98.4118***
Taipei CPI	–0.3353	0.6406***	–0.3470	0.6251
Taipei CCI	–0.5667	0.1502	–0.1541	0.7264
M2	1.29E-06	1.37E-06***	–2.15E-07	2.81E-06***
NI	3.76E-07	–2.62E-07	–2.21E-07	–1.34E-07
AMR	2.2027	–467.0859*	398.6749	–921.4761
TAIEX	0.0001	–7.48E-05	–0.0001	–8.33E-05
adj R^2	–0.077	0.396	–0.229	0.229
# obs.	32	32	32	32

Note: *** and * denote 1% and 10% significance level, respectively.

- Taipei city suite index for completed homes

Model (4) in Table 14 shows the regression results of the Taipei city suite index for completed homes and macroeconomic variables. The suite index is positively and significantly influenced by the Taipei city construction price index and the money supply. This indicates that when construction costs increase, housing prices also rise, leading to an increased demand for renting suite apartments. Consequently, investors are likely to use their investment returns to purchase real estate.

Existing property in Taichung city

- Taichung city luxury housing index for completed homes

Model (1) in Table 16 shows the regression results of the Taichung city luxury housing index for completed homes and macroeconomic variables. There is a significant and positive impact between the luxury housing index and both the Taichung city CPI and the money supply. This indicates that when the market is more active, capital more easily flows into the luxury housing market, reflecting that there is both residential and investment demand for luxury homes in Taichung.

- Taichung city first-class housing index for completed homes

Model (2) in Table 16 shows the regression results of the Taichung city first-class housing index for completed homes and macroeconomic variables. There is a significant and positive impact between the first-class housing index and the money supply. This suggests that middle- and high-income groups are likely to use the benefits from their investments to purchase higher-quality homes.

- Taichung city second-class housing index for completed homes

Model (3) in Table 16 shows the regression results of the Taichung city second-class housing index for completed homes and macroeconomic variables. There is a significant and positive relationship between the second-class housing index and the Taichung CPI, and a significant and negative relationship with national income. This indicates that when prices rise and national income decreases, young people and average-income earners tend to buy houses below the average price.

- Taichung city suite index for completed homes

Model (4) in Table 16 shows the regression results of the Taichung city suite index for completed homes and

Table 15. Correlation between the Taichung housing indices of existing property and macroeconomic variables

	Luxury	First-class	Second-class	Suite	Taichung CPI	Taichung CCI	M2	NI	AMR	TAIEX
Luxury										
First-class	0.5777***									
Second-class	0.4216***	0.4652**								
Suite	0.2178	0.3188*	0.2422							
Taichung CPI	0.2944	0.1463	0.2817	0.3115						
Taichung CCI	0.2175	–0.0056	–0.2026	–0.1562	0.1287					
M2	0.3991***	0.5750***	0.1897	0.0754	–0.1367	–0.1563				
NI	–0.1106	–0.0981	–0.3936**	0.1678	0.2120	–0.0173	–0.1931			
AMR	–0.0309	0.1023	0.1046	0.0669	0.1636	–0.2589	0.1516	–0.1803		
TAIEX	0.1530	0.2493	–0.1226	–0.0429	–0.1014	0.1773	0.3476	0.0821	–0.2311	

Note: ***, ** and * denote 1%, 5% and 10% significance level, respectively.

Table 16. Regression of Taichung housing index and macroeconomic variables across four housing categories

	Luxury	First-class	Second-class	Suite
	(1)	(2)	(3)	(4)
Intercept	99.1064***	100.1698***	101.8984***	102.2586***
Taichung CPI	0.8018*	0.5782	1.7055**	8.2996
Taichung CCI	0.2711	0.0593	–0.5949	–2.6463
M2	1.66E-06**	2.22E-06***	9.96E-07	5.39E-06
NI	–4.84E-07	–2.05E-07	–3.64E-06**	5.95E-06
AMR	–375.5697	–21.2252	–803.0944	–1354.89
TAIEX	–6.20E-05	1.03E-04	–0.0002	–7.40E-04
adj R^2	0.195	0.224	0.241	–0.069
# obs.	32	32	32	32

Note: ***, ** and * denote 1%, 5% and 10% significance level, respectively.

macroeconomic variables. There is no significant relationship between the suite index and macroeconomic variables. This suggests that Taichung has attracted many residents from other counties and cities in recent years, and these new residents have a stable demand for suite apartments. Therefore, their demand for purchasing suite apartments is less affected by macroeconomic changes.

Existing property in Kaohsiung city

- Kaohsiung city luxury housing index for completed homes

Model (1) in Table 18 shows the regression results of the Kaohsiung city luxury housing index for completed homes and macroeconomic variables. There is no significant impact between the luxury housing index and macroeconomic variables, indicating that the high-income group in Kaohsiung city views real estate has a stable demand. Therefore, changes in macroeconomic indicators do not affect luxury housing prices.

- Kaohsiung city first-class housing index for completed homes

Model (2) in Table 18 shows the regression results of the Kaohsiung city first-class housing index for completed homes and macroeconomic variables. There is a significant and positive relationship between the first-class housing index and both the Kaohsiung CPI and the money supply. This suggests that when the economy is active, middle- and high-income groups are likely to use the benefits from their investments to purchase higher-quality homes.

- Kaohsiung city second-class housing index for completed homes

Model (3) in Table 18 shows the regression results of the Kaohsiung city second-class housing index for completed homes and macroeconomic variables. There is a significant and positive relationship between the second-class housing index and both the Kaohsiung CPI and the money supply. This indicates that when young people and average-income earners purchase homes, their limited funds lead them to use the profits from their investments to buy houses. Compared to the home-changing, middle- and high-income groups, the average-income group is more affected by the money supply.

- Kaohsiung city suite index for completed homes

Model (4) in Table 18 shows the regression results of the Kaohsiung city suite index for completed homes and macroeconomic variables. There is a significant and nega-

Table 17. Correlation between the Kaohsiung housing indices of existing property and macroeconomic variables

	Luxury	First-class	Second-class	Suite	Kaohsiung CPI	Kaohsiung CCI	M2	NI	AMR	TAIEX
Luxury										
First-class	0.4792***									
Second-class	0.6340***	0.7284***								
Suite	0.3965**	0.2822	0.5046***							
Kaohsiung CPI	0.0019	0.2390	0.1233	0.0080						
Kaohsiung CCI	0.0775	0.1414	–0.0227	–0.1532	–0.0367					
M2	0.3442*	0.4158**	0.6245***	0.2408	–0.2326	0.0790				
NI	–0.2588	–0.1378	–0.0602	–0.2085	0.3981**	–0.4152**	–0.1964			
AMR	0.1927	0.0040	0.0937	–0.0066	0.1503	0.0757	0.1640	–0.1827		
TAIEX	0.1337	0.1763	0.2267	0.3827**	–0.1037	0.0828	0.3438*	0.0817	–0.2294	

Note: ***, ** and * denote 1%, 5% and 10% significance level, respectively.

Table 18. Regression of Kaohsiung housing index and macroeconomic variables across four housing categories

	Luxury	First-class	Second-class	Suite
	(1)	(2)	(3)	(4)
Intercept	101.8043***	99.6302***	99.3691***	110.9012***
Kaohsiung CPI	0.4161	0.7513**	1.0824*	1.7546
Kaohsiung CCI	–0.1250	0.0229	–0.2435	–1.8221**
M2	1.18E-06	1.39E-06**	3.99E-06***	1.01E-06
NI	–1.67E-06	–9.76E-07	–9.46E-07	–8.11E-06**
AMR	323.9451	–434.592	–369.9859	–171.7181
TAIEX	1.96E-04	3.73E-05	6.12E-05	2.36E-03**
adj R^2	–0.007	0.205	0.349	0.192
# obs.	32	32	32	32

Note: ***, ** and * denote 1%, 5% and 10% significance level, respectively.

tive relationship between the suite index and both the Kaohsiung city CCI and national income, and a significant and positive relationship with the stock price index. In a city facing a prolonged economic depression, a decline in national income is likely to shift homebuyers' demand from second-class housing to suites as well as studio apartments, where prices will see an increase. However, the inflexibility of rising rental prices of suites in Kaohsiung, coupled with the escalation in CCI, will in turn reduce the demand of investors for the apartment studios. On the other hand, the increase in stock market will also boost the demand of investors for apartment studios, which is a popular investment that can generate minimum required return for investors in Kaohsiung.

5. Conclusions

This study compiles price indices for completed and pre-sale homes across four categories in the three biggest cities in Taiwan, i.e., Taipei, Taichung, and Kaohsiung, and examines the extent to which macroeconomic variables impact the price indices of completed homes in each category. The results are summarized as follows.

- Analysis of the completed home price index

The real estate market price indices in Taiwan have shown different trends. Although the luxury home price index in Taipei fluctuates significantly, its long-term trends indicate that prices remain within a certain range, suggesting that the government periodically implements policies to control housing market prices. Due to the increasing population of people moving to Taipei, the demand for suites has also increased, which in turn drove up the demand from investors, resulting in a rising trend in the suite price index in recent years. On the other hand, Taichung's growing population has led to increased housing demand, resulting in a moderate growth trend in its housing price index. In contrast, Kaohsiung has seen fewer people moving there for work compared with Taipei and Taichung, leading to lower demand for suites and subsequently a more stable suite price index that stays around the average value.

- Analysis of the pre-sale home price index

Between 2015 and 2018, the government implemented policies to regulate housing prices, causing a 10% drop in prices and transaction volumes. In 2020, the pandemic prompted the government to lower the home purchase interest rate to 1.35%. At the end of 2020, the central bank implemented selective credit control policies to curb housing prices, increasing the cost of home purchases for the public and reducing the leverage used in real estate investments to curb speculative behavior. After the regulatory period from 2015 to 2018, the housing market began to recover in 2019. The pre-sale luxury home indices in Taipei and Taichung reached their peak in the first quarter of 2020. In March 2020, the pandemic led to a drop in the home purchase interest rate to 1.35%, combined with rising construction costs, resulting in an upward trend in Taipei's second-class and suite pre-sale home indices in the second quarter of 2020. The first-class pre-sale home indices in Taipei and Taichung started to rise after the third quarter of 2020. Due to the Kaohsiung government's promotion of the Qiaotou Science Park and TSMC's investment announcement of a new Kaohsiung plant, Kaohsiung's first-class pre-sale home index began to rise early in the second quarter of 2020. To suppress housing prices, the government introduced four rounds of credit control and the Housing and Land Tax 2.0 policies starting to take effect from the end of 2020. Taichung's luxury home index began to decline in the first quarter of 2021, while Taipei's first and second-class home indices saw a significant downward trend in the third quarter of 2021. Kaohsiung's pre-sale home market however remained largely unaffected.

- Analysis of the impact of macroeconomic variables on completed home indices by category

In Taipei, high income homebuyers for the luxury homes are not affected by economic changes. Middle to high income homebuyers are more interested in buying higher quality housing when the market interest rate is low. Young people and average wage earners have an urgent demand for renting suites irrespective of economic conditions. Despite the rising construction costs driving up suite and home prices in recent years, the strong demand for suites has attracted more investors in buying suite apartments.

When the market is active, capital flows into Taichung's luxury home market, indicating that high-income groups have both residential and investment demand for luxury homes. Middle- and high-income groups also use investment gains to purchase higher-quality homes in Taichung. When prices rise and national income decreases, young people and average-income earners tend to buy houses below the average price. In recent years, Taichung has attracted many residents from other counties and cities, leading to a strong demand for suites from the migrating population, making them less affected by macroeconomic indicators.

Compared to central and northern Taiwan, high-income groups in Kaohsiung view real estate as a rigid demand, making luxury home prices less affected by macroeconomic indicators. During active economic periods, young people and average-income earners, who have limited funds, use investment gains to purchase homes, making them more affected by the money supply compared to middle- and high-income groups who buy higher-quality homes with their investment profits. When the stock market is active and national income decreases, the high cost of entering the stock market drives investors to allocate funds to suite apartments. As the construction price index increases, suite investors seek to raise rental income. However, southern homebuyers tend to be conservative, preferring to purchase second-class homes rather than renting suites or studio apartments, leading to decreased investor demand for suites and studio apartments.

In different cities and among different groups, homebuyers' employment and economic status vary, leading to different decision-making processes. Consequently, changes in macroeconomic variables impact housing prices differently. For instance, homebuyers in Taichung use real estate not only for personal residence but also as an investment. In contrast, buyers in southern regions tend to view real estate as a rigid demand rather than an investment. Therefore, if the government aims to regulate housing prices for specific groups, policies must be tailored accordingly. For example, high-income groups in Taipei are not influenced by macroeconomic variables when purchasing homes, so adjusting mortgage rates may not effectively control luxury home prices. When mortgage rates rise, the demand for housing from home-changers, and middle- and high-income groups in Taipei decreases. Therefore, when implementing policies, the government needs to consider whether the housing market policies will affect those who genuinely need housing.

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