

# Asymmetric Inflation Hedge of Housing Return: A Non-linear Vector Error Correction Approach

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Conclusions of past work on the inflation hedging ability of real estate investment are not consistent. The reason for this perplexity might be the neglect of separation between high and low state of inflation, which has a great influence on empirical results. In order to examine the inflation hedging effectiveness of real estate with Taiwanese monthly housing returns and inflation, this paper uses the inflation as the threshold variable to create the nonlinear vector correction model that divides the inflation rates into high and low regime. We find robust evidence that when inflation rates are higher than 0.83% threshold value, housing returns are able to hedge against inflation, and, otherwise, they are unable. Using new methodology to discover new implications is main contribution of this study.

## Keywords

Housing prices; Inflation; Nonlinear VECM; Taiwan

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## 1. Introduction

The economic literature has yielded a large number of in-depth studies concerning the relationship between real estate returns and inflation. It is a commonplace cognizance that real estate returns hedge against inflation when the raise in real estate returns could compensate for the costs added by the shrink in wealth and purchasing power. Sirmans and Sirmans (1987), Brueggeman, Chen and Thibodeau (1984), Miles and McCue (1984), Hartzell et al. (1987), Gyourko and Linneman (1988) and Bond and Seiler (1998) early use the U.S. samples to discover that real estate investment effectively dodges inflation. Furthermore, Real Estate Investment Trusts (REITs) are found to have the same characteristic by Goebel and Kim (1989), Park, Mullineaux and Chen (1990), Chen, Hendershott and Sanders (1990) and Liu, Hartzell and Hoesli (1997). However, Lu and So (2001) and Glascock, Lu and So (2002) recently argue that REITs are unable to directly hedge against inflation. The explanations for the indirect inflation hedge presented by Lu and So (2001) are the spurious regression and the improper causality. The correlation between these two variables, therefore, should be established through other economic variables.

Earlier studies employed many simple as well as veteran statistical models to explore the inflation hedging ability of real estate. Simple methods such as the ordinary least squares (OLS) and the capital asset pricing model (CAPM) are used by Fama and Schwert (1977) and Chen and Tzang (1988). Afterward, other methods, such as the vector error correction model (VECM) used by Lu and So (2001), Glascock, Lu and So (2002), Apergis (2003), and the vector autoregressive (VAR), applied by Glascock, Lu and So (2000) and Ewing and Payne (2005), appear on real estate forum. The conclusions can be roughly grouped into three main categories; (1) the investment on real estate or REITs can hedge against inflation, (2) the investment on real estate or REITs can not hedge against inflation, (3) the relation between real estate returns and inflation is linked by some macroeconomic variables or proxy variables.

However, all above-mentioned studies utilize the linear models to examine the relation between real estate returns and inflation, revealing the disregard of nonlinear relationship. We consider that the high or low state of inflation probably influence the inflation hedging effectiveness of real estate. Thus, the inflation hedge of real estate should be asymmetric along states of inflation. Ignoring this characteristic might lead to the improper models, which consequently invert the inflation hedging ability of real estate or REITs. The major obstacles to research on the inflation hedge of Taiwan REITs have been the lack of data and the incomplete response to the dynamic adjustment of real estate prices, because Taiwan REITs are still at an early stage of operation. This study, therefore, uses the housing index to investigate if Taiwan housing returns are able to hedge against its inflation.

In this study, the Johanson cointegration test is first employed to explore the stable long-run relationship between housing index and consumer price index. After verifying this relationship, the inflation is adopted as the threshold variable to estimate the appropriate threshold value which divides inflation rates into two

regimes, high and low inflation. Finally, the relationship between housing returns and the inflation under each regime is examined with the nonlinear VECM.

The key issues we address in this study are the availability of asymmetric inflation hedge of housing return within nonlinear VECM framework and the evidence that help housing market participants better evaluate the real estate investment. Our main research questions are: (1) whether the relationship between housing index and consumer price index is stable and long-run, (2) whether the short-run relationship between housing returns and inflation is nonlinear, (3) how the housing returns hedge against inflation under high and low inflation respectively when nonlinear relation exists.

The empirical results demonstrate that there exists a cointegration between housing index and consumer price index when allowing for the influence of time trend. The impact of consumer price index on housing index is positive and the effect of time trend on housing index is negative. Employing inflation rate as the threshold variable, we discover that the nonlinear adjustment between housing returns and inflation emerges when the inflation variable delays 10 periods. In other words, the inflation hedge of housing return consequently is asymmetric along inflation states, high or low. According to the causal analysis on short-run adjustment, when the inflation rates are greater than the threshold value, the effect of inflation on housing returns is positive, which means that the housing returns are able to hedge against the inflation. However, when the inflation rates are equal to or lower than the threshold value, the effect of inflation on housing returns is not significant, or the housing returns are unable to hedge against the inflation.

The paper is organized as follows. In Section I we present the research motive and purpose. Section II briefly reviews the literature relating to the inflation hedge of real estate in Taiwan as well as abroad. Section III introduces the research procedure. Section IV describes the data and analyzes the empirical results. Finally, Section V concludes.

## **2. Related Literature Using the Nonlinear Model**

With regard to methodology, the existing studies on REITs early use the ordinary least squares (OLS), and recently apply the multivariate models such as the vector autoregressive (VAR) and the vector error correction model (VECM) which help improve greatly the estimations and the empirical results as well as present new findings. Focusing on the inflation hedging ability of REITs, Lu and So (2001) utilize the vector error correction model (VECM) and four variables- REITs return, CPI, Federal fund rate, industrial production index- to examine the relationship among U.S. REITs returns, real production, monetary policy and inflation. They conclude that the relation between inflation and REITs returns is not the direct causality and that REITs returns are unable to compensate for inflation.

Similarly, Glascock, Lu and So (2002) employ VECM and these four variables to scrutinize the inflation hedge of REITs along with the influence of real production and monetary policy. They find that the relation between REITs returns and expected inflation or unexpected inflation are indirect. They further show that the negative relation between REITs and inflation is merely effected by the monetary policy.

Using the error correction vector autoregressive (ECVAR) model, Apergis (2003) analyses the dynamic effects of specific macroeconomic variables (i.e. housing loan rates, inflation and employment) on the price of new houses sold in Greece. This study indicates that the housing loan rate is the variable having the highest explanatory power over the variation of real housing prices, followed by inflation and employment.

The generalized impulse response analysis is applied by Ewing and Payne (2005) to explore the relationship between REITs return and macroeconomic variables, such as monetary policy, default risk premium, real output growth and inflation, over the period 1980-2000. They find that the volatility of Federal fund rate and the default risk premium are the determinants influencing REITs returns. Besides, monetary policy, real output growth and inflation cause the lower expected return, and default risk premium induces the higher expected return.

Additionally, relating to Taiwan real estate, Lin and Lai (2003) use the time series analysis to compare two saving models, the traditional one and the one with forced saving over the period from 1981 to 2000. Their three main findings are: First, the negative wealth effect of housing price appreciation on saving is smaller in the forced saving model than in the traditional saving model. Secondly, by the estimated ECMs, ignoring the impact of housing price appreciation on forced saving, the speed of short-run adjustment in total saving would be significantly slower. Third, for forecasting purpose, the forecast errors in ECM of the forced saving model are smaller than that in the total saving model.

To focus on the inflation hedging characteristics of residential property in five markets: Hong Kong, Tokyo, Singapore, Taipei and London, Chen and Sing (2006) find that the inflation hedging characteristics vary across different market and that Taipei residential property is the most effective in hedging long-term inflation. They also suggest that investor should have to adopt different timing strategies to minimize their exposure to different inflation risks in individual markets.

The above mentioned study, *cetera paribus*, just applies the linear model while real estate data having the asymmetric adjustment seems to be ignored. To replenish the existing studies with nonlinear approach, we use a new econometric method to create an asymmetric model and provide new finding on inflation hedge of housing return.

### 3. Nonlinear Vector Error Correction Model

Tong (1978) and Tong and Lim (1980) develop the threshold autoregressive (TAR) model which is based on an optimal threshold value to divide the dynamic status of one economic indicator into two regimes. Taking the present of cointegration between HPI and CPI into consideration, we create the threshold vector error correction model (TVECM) to carry out the estimation. To adjust the short-run disequilibrium, TVECM, relative to TVAR, just has one discrepancy in the error correction term (ECT).

$$r_t = \begin{cases} \alpha_{10} + \sum_{i=1}^p \alpha_{1,1i} r_{t-i} + \sum_{i=1}^p \alpha_{1,2i} \pi_{t-i} + \omega_1 ECT_{t-1} + \varepsilon_{11,t} & \pi_{t-d} > \gamma \\ \alpha_{20} + \sum_{i=1}^p \alpha_{2,1i} r_{t-i} + \sum_{i=1}^p \hat{\alpha}_{2,2i} \pi_{t-i} + \omega_2 ECT_{t-1} + \varepsilon_{12,t} & \pi_{t-d} \leq \gamma \end{cases} \quad (1)$$

$$\pi_t = \begin{cases} \beta_{10} + \sum_{i=1}^p \beta_{1,1i} r_{t-i} + \sum_{i=1}^p \beta_{1,2i} \pi_{t-i} + \omega_{21} ECT_{t-1} + \varepsilon_{21,t} & \pi_{t-d} > \gamma \\ \beta_{20} + \sum_{i=1}^p \beta_{2,1i} r_{t-i} + \sum_{i=1}^p \beta_{2,2i} \pi_{t-i} + \omega_{22} ECT_{t-1} + \varepsilon_{22,t} & \pi_{t-d} \leq \gamma \end{cases} \quad (2)$$

where the housing return  $r_t = \log(HPI_t / HPI_{t-1}) \times 100$ ,  $HPI_t$  is the housing index. The inflation  $\pi_t = \log(CPI_t / CPI_{t-1}) \times 100$ ,  $CPI_t$  is the consumer price index.  $\alpha, \beta$  are parameters,  $\varepsilon_{1t}, \varepsilon_{2t}$  are error terms.  $ECT_{t-1}$  is the correction term of period t-1 in long-run equilibrium:

$$ECT_{t-1} = HPI_{t-1} - \theta_0 - \theta_1 t - \theta_2 CPI_{t-1} \quad (3)$$

$t$  represents the time trend.  $\theta_0, \theta_1, \theta_2$  are the parameters of cointegration equation.  $\omega_{11}, \omega_{12}, \omega_{21}$  and  $\omega_{22}$  are the parameters of ECT, being namely the adjusting coefficients.

In order to confirm the causality of short-run dynamic effect, we employ the *Wald* coefficient test to check the causality between variables (strong exogeneity). According to the TVECM in equation (1) and (2), the null hypothesis of causality test is  $H_0 : \alpha_{1,2i} = 0, i = 1, \dots, p$  ( $H_0 : \alpha_{2,2i} = 0$ ) along with the upper (lower) regime, expressing that  $\pi$  does not Granger cause  $r$ . The rejection of this null hypothesis means that inflation Granger cause return. Observing coefficient and  $\sum_{i=1}^p \alpha_{1,2i}$  ( $\sum_{i=1}^p \alpha_{2,2i}$ ), we are able to determine the interaction between variables within the upper (lower) regime to be positive or negative. When the null hypothesis is rejected and the coefficient sum is

positive, it indicates inflation hedging effectiveness of housing return in the short run. Besides, the test of null hypothesis,  $H_0 : \beta_{1,li} = 0, i = 1, \dots, p (H_0 : \beta_{2,li} = 0)$ , shows that  $r$  does not Granger cause  $\pi$ . The rejection of this null hypothesis means that housing returns do not Granger cause inflation. According to coefficient and  $\sum_{i=1}^p \beta_{1,li} (\sum_{i=1}^p \beta_{2,li})$ , we can ascertain that the effect of housing returns on inflation within the upper (lower) regime is negative or positive in the short run. In addition, we could verify if the consumer price index has the weak exogeneity on housing index through the significance of adjusting coefficients  $\omega_{11}$ ,  $\omega_{12}$ ,  $\omega_{21}$ , and  $\omega_{22}$  of error correction term under different regimes. Based on the causality test and the lag parameter, we examine if investing in Taiwan housing could nicely avoid the inflation.

#### 4. Empirical Results

Our analysis is based on the monthly data of housing index (HPI) and consumer price index (CPI). The housing index is obtained from Taiwan Sinyi Realty Commercial Brokerage, and the consumer price index is obtained from Taiwan AREMOS database for the period from July 1991 to June 2006.<sup>1</sup> The sample includes 180 observations which are used for examining the inflation hedging effectiveness of Taiwan housing investment. When carrying out the test as well as the estimation, both variables are formed in natural logarithm.

Figure 1 illustrates the historical trend of HPI and CPI in natural logarithm form. It also exhibits the trend of their relative returns and inflation. It is clearly seen that housing prices present a slide over 1991 to 2002 and a lift over 2002 to 2006. Consumer price index displays an increase from 1991 to 2006. Approximately, CPI and HPI have gone oppositely before 2000 and turned into increasing trend synchronally since then. Additionally, it is observed that the volatility of housing returns are larger than of inflation, implying the higher risk of housing returns.

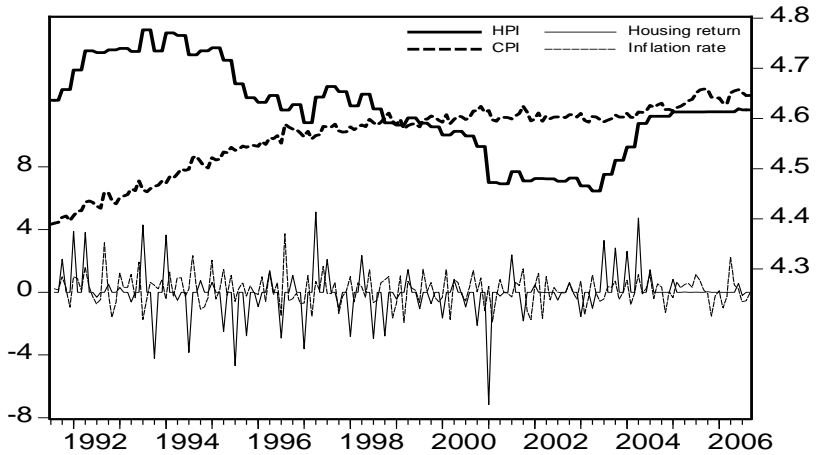
Table 1 reports the statistic description of housing returns and inflation. The negative mean of housing returns and positive mean of inflation display the negative growth

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1 Sinyi housing index is established by Sinyi Realty Company that presently is the biggest real estate brokerage in Taiwan. Using the transaction database of existing homes in four biggest metropolises, Taipei city, Taipei County, Taichung City and Kaohsiung City, its housing index is built up by the Hedonic Price Theory. Sinyi housing index came into effect in 1991, being the earliest index in Taiwan relative to two other indices including the north area housing index and Cathay housing index. Hence, the data that is provided by Sinyi housing index is not only the longest but also widely referenced as the representative benchmarking. It amply reflects the variational trend of the whole Taiwan's housing prices. Additionally, the housing price index is published daily and adjusted monthly or quarterly based on the actual transactions of housing market.

of HPI and positive growth of CPI during the sample period. The risk represented by standard deviation shows that the risk of housing returns is higher than that of inflation, being consistent with observation from figure 1. In addition, the negative skewness of housing returns signifies the left skewed distribution and the positive skewness of inflation indicates the right skewed distribution. The kurtosis values of both housing returns and inflation are higher than 3, demonstrating the leptokurtic distributions. The Jarque-Bera statistics show the rejection of normal distribution of both variables.

**Figure 1 Historical Trend of HPI and CPI and Their Growth (%)**



**Table 1 Statistic Description of Housing Returns and Inflation**

	Housing return	Inflation rate
Mean	-0.01	0.15
Maximum	5.12	3.73
Minimum	-7.17	-1.92
Standard deviation	1.41	0.91
Skewness	-0.37	0.30
Kurtosis	9.74	4.23
Jarque-Bera statistic	342.6***	13.92***

Housing return is denoted by  $r_t = \log(HPI_t / HPI_{t-1}) \times 100$ , and inflation by  $\pi_t = \log(CPI_t / CPI_{t-1}) \times 100$ ,  $HPI$  and  $CPI$  are housing price index and consumer price index respectively. Jarque-Bera is the statistic of Jarque-Bera normal distribution test. \*\*\* represents 1% significant level.

This study mainly utilizes the nonlinear model to test for the causality between dynamic housing prices and consumer prices. The empirical process is divided in two steps. First, the unit root test is applied to housing index and consumer price

index for identifying their stationarity. It is then followed by the cointegration test. Second, if the cointegration between variables is clarified, the rejection of linear hypothesis allows the nonlinear vector error correction model, or TVECM, to be estimated for examining the causality between variables. If the cointegration, or the long-run relationship, between variables does not exist, and the nonlinearity is significant, the causality between variables is tested with the nonlinear vector autoregressive model, or TVAR.

The ADF unit root test results are reported in Table 2. The ADF regressive equation is separated into two ADF sub-equations; one includes constant and the other one includes constant and time trend. The optimal lag length is selected according to the Akaike information criterion (AIC). The test results show that the ranks of both variables are I(1).

**Table 2 ADF Unit Root Test**

Variables	Levels		First differences	
	Constant	Constant plus Time trend	Constant	Constant plus Time trend
HPI	-1.06	-1.35	-13.27**	-13.23**
CPI	-3.77**	-2.60	-12.27**	-6.91**

HPI denotes the housing price index; CPI denotes the consumer price index. The regression of ADF test covers two sub-regressions; one includes the constant, the other includes the constant and the time trend. The optimal lag is selected according to the Akaike information criterion (AIC).

\*\* represents the 5% significant level. The 5% critical values are -2.87 and -3.43.

Table 3 presents the results of optimal lag-lengths for which we select the maximum of 18 periods for testing. In order to have alternative selections for the optimal lag, we apply five criteria including LR (sequential modified LR test statistic), FPE (Final prediction error), AIC (Akaike information criterion), SC (Schwarz information criterion), and HQ (Hannan-Quinn information criterion). These criteria, except LR, choose the longest lag as 1 period, which seems too short for monthly data to respond to the causality between housing prices and consumer prices, not conforming the intuition on economics. Furthermore, the lag period of 12, determined by LR criterion, not only nicely forms one yearly variation, tallying with the economic implication, but also wipes out the seasonal interference of monthly data itself. Therefore, this study adopts the lag length of 12 to test for cointegration as well as to estimate model.<sup>2</sup>

<sup>2</sup> Additionally, one period of VAR lag is unable to satisfy the condition that residuals are not auto-correlation. Only with 12 lags, the residuals of the estimated model are white noise.



**Table 3 Tests for Lags**

Lags	LR	FPE	AIC	SC	HQ
0	NA	1.57	6.13	6.16**	6.14
1	12.92	1.52**	6.09**	6.21	6.14**
2	4.99	1.55	6.11	6.30	6.19
3	2.62	1.60	6.15	6.41	6.25
4	2.52	1.65	6.18	6.52	6.32
5	7.27	1.66	6.18	6.60	6.35
6	2.47	1.71	6.21	6.71	6.42
7	5.74	1.73	6.22	6.80	6.46
8	0.85	1.81	6.27	6.92	6.53
9	5.88	1.83	6.28	7.00	6.57
10	8.56	1.81	6.26	7.07	6.59
11	1.69	1.88	6.30	7.18	6.66
12	<b>13.88**</b>	1.78	6.25	7.21	6.64
13	2.65	1.84	6.28	7.31	6.70
14	6.56	1.84	6.28	7.39	6.73
15	2.36	1.91	6.31	7.50	6.79
16	4.06	1.94	6.33	7.59	6.84
17	7.44	1.93	6.32	7.66	6.86
18	4.04	1.97	6.34	7.75	6.91

LR represents the sequential modified LR test statistic, FPE expresses the final prediction error, AIC is the Akaike information criterion, SC denotes the Schwarz information criterion, HQ indicates the Hannan-Quinn information criterion.

\*\* denotes the 5% significant level.

We report the results of Johanson cointegration test in Table 4. According to these results, the relation between housing index and consumer price index can not get rid of the long-run time trend. This paper, hence, considers involving the time trend in long-run equation when carrying out the test on cointegration. The null hypothesis is:

$$H^*(\theta) : \Pi y_{t-1} + Bx_t = \alpha(\beta' y_{t-1} + \rho_0 + \rho_1 t) + \alpha_{\perp} \zeta_0 \quad (4)$$

In equation (4),  $y_t$  denotes the endogenous variable,  $x_t$  denotes the exogenous variable,  $\theta$  is the cointegration vector,  $t$  represents the time

trend,  $\alpha_{\perp}$  is the deterministic term, guarantying  $\alpha' \alpha_{\perp} = 0$ .  $\Pi = \alpha \beta'$  is the cointegration vectors.

We use two statistic methods, the Trace of Johanson methodology and the Maximum-eigenvalue ( $\lambda$ ), for testing:

$$\lambda_{trace}(\tau) = -T \sum_{i=\tau+1}^k \log(1 - \hat{\lambda}_i) \quad (5)$$

$$\lambda_{max}(\tau, \tau + 1) = -T \log(1 - \hat{\lambda}_{\tau+1}) \quad (6)$$

where  $\hat{\lambda}_i$  is the estimated value of the characteristic root (also called eigenvalue), obtained from the estimated  $\Pi$  matrix.  $T$  is the number of usable observations. When the appropriate values of  $\tau$  are clear, these statistics are simply referred to as  $\lambda_{trace}$  and  $\lambda_{max}$ .

**Table 4 Test for Cointegration**

VAR lags = 12			
Null Hypothesis	Alternative Hypothesis	Statistics	5% Critical Value
$\lambda_{trace}$ tests			
$\tau = 0$	$\tau > 0$	29.15**	25.87
$\tau \leq 1$	$\tau > 1$	5.44	12.52
$\lambda_{max}$ tests			
$\tau = 0$	$\tau = 1$	23.72**	19.39
$\tau = 1$	$\tau = 2$	5.44	12.52

The lag length is determined by the sequential LR test.

\*\*denotes the 5% significant level.

Under the 5% significant level, the cointegration test results shown in Table 4 provide evidence that there is at least one cointegration between housing index and consumer price index, this long-run relation is expressed as follows:

$$HPI_t = 1.619 - 0.001t + 0.675CPI_t \quad (7)$$

It is informed by equation (7) that there is a stable long-run relationship between housing index and consumer price index. Although the housing prices

fall along with times, yet, still present a small stable raise, revealing the reserve capability for the fundamental value of housing. Particularly, once the consumer price index rises, the housing index grows, too. However, the rising ratio is not equal 1, indicating that the increase of consumer price is just partly reflected in housing returns. In other words, housing returns partly hedge against inflation.

Because of the presence of cointegration, when building the vector error correction model to test for causality between housing index and consumer price index, we add the error correction term in the model for analyzing the adjustment of short-run disequilibrium and further confirming the dynamic relation between these two variables. Besides, in order to realize the existence of nonlinearity, the linear test is applied to each mono-regime model to verify the optimal framework adopted. During the process of linear test, we follow the testing model of Tsay (1998) whose null hypothesis is the linear VECM and alternative hypothesis is the nonlinear VECM. The variant rate of consumer prices ( $\pi_{t-d}$ ), known as inflation, is used as the threshold variable.

Table 5 shows the results of linear test represented by the p-value of statistic Chi-squared test. When the threshold variable (inflation) delays 10 periods ( $d=10$ ), the testing result significantly reject the linear hypothesis, confirming the nonlinearity of model. This phenomenon implies that the dynamic volatility of consumer price index in 10 periods before reflects the asymmetric adjustment between housing index and consumer price index. Therefore, utilizing just the linear model to explore the relationship between two variables might lead to biased results.

Table 5 Test for Linearity

$d \backslash q$	1	2	3	4	5	6	7	8	9	10	11	12
1	0.06	0.63	0.57	0.62	0.24	0.21	0.42	0.40	<b>0.02**</b>	0.06	0.07	0.15
2		0.85	0.84	0.78	0.69	0.84	0.95	0.59	0.39	0.35	0.42	0.58
3			0.47	0.65	0.73	0.79	0.90	0.80	0.60	0.60	0.20	0.22
4				0.85	0.88	0.71	0.74	0.69	0.89	0.78	0.89	0.96
5					0.55	0.52	0.43	0.56	0.50	0.58	0.33	0.61
6						0.25	0.47	0.60	0.76	0.68	0.71	0.95
7							0.67	0.69	0.56	0.41	0.36	0.17
8								0.27	0.46	0.42	0.50	0.88
9									0.13	0.15	0.23	0.51
10										0.31	<b>0.03**</b>	<b>0.04**</b>
11											0.81	0.69
12												0.09

The above values are the p-values of Chi square test for linearity.  
 \*\* denotes the 5% significant level.

According to the test results in Table 5, the two regimes, high and low inflation, are separated based on the threshold value of inflation.  $\pi_{t-10}$  being higher than the threshold value belongs to the upper regime,  $\pi_{t-10}$  being lower (equal) than the threshold value belongs to the lower regime. The main purpose of using the regressive threshold model is to seek for the factor influencing the benchmark of distinct regimes. By the estimations of TVECM, it can be observed if the change of consumer price index has effect on the change of housing index at any time. The estimations of TVECM are:

$$r_t = \begin{cases} -0.014 + \sum_{i=1}^{12} \hat{\alpha}_{1,1i} r_{t-i} + \sum_{i=1}^{12} \hat{\alpha}_{1,2i} \pi_{t-i} + 0.051 ECT_{t-1} & \pi_{t-10} > 0.83\% \\ (0.036) & (0.065) \\ R^2 = 0.93, \quad LM = 0.75 \quad (0.38), \quad ARCH(d.f = 1) = 2 \quad (0.16) \\ \\ -0.001 + \sum_{i=1}^{12} \hat{\alpha}_{2,1i} r_{t-i} + \sum_{i=1}^{12} \hat{\alpha}_{2,2i} \pi_{t-i} - 0.033 ECT_{t-1} & \pi_{t-10} \leq 0.83\% \\ (0.546) & (0.224) \\ R^2 = 0.86, \quad LM = 1.02 \quad (0.31), \quad ARCH(d.f = 1) = 2 \quad (0.16) \end{cases} \quad (8)$$

$$\pi_t = \begin{cases} -0.003 + \sum_{i=1}^{12} \hat{\beta}_{1,1i} r_{t-i} + \sum_{i=1}^{12} \hat{\beta}_{1,2i} \pi_{t-i} + 0.022 ECT_{t-1} & \pi_{t-10} > 0.83\% \\ (0.706) & (0.524) \\ R^2 = 0.23, \quad LM = 0.51 \quad (0.47) \quad ARCH(d.f = 1) = 2.29 \quad (0.12) \\ \\ 0.005 + \sum_{i=1}^{12} \hat{\beta}_{2,1i} r_{t-i} + \sum_{i=1}^{12} \hat{\beta}_{2,2i} \pi_{t-i} + 0.045 ECT_{t-1} & \pi_{t-10} \leq 0.83\% \\ (0.000) & (0.005) \\ R^2 = 0.35, \quad LM = 0.04 \quad (0.83) \quad ARCH(d.f = 1) = 0.03 \quad (0.84) \end{cases} \quad (9)$$

Equations (8) and (9) are the estimated results of TVECM. The optimal threshold value, also known as the “watershed”, is 0.83%. When  $\pi_{t-10} > 0.83\%$ , the inflation state belongs to the upper regime, referred to as the high inflation period. When  $\pi_{t-10} \leq 0.83\%$ , the inflation state belongs to the lower regime, referred to as the low inflation period. Additionally, in order to fully spell out the location of threshold value relative to lower and upper regime, Figure 2 describes the relation between Taiwan’s historical trend of the monthly inflation rate and the threshold value. It is clearly seen that the high inflation periods (inflation  $> 0.83\%$ ) in the sample do not often appear. Therefore, inflation  $> 0.83\%$  being considered as high inflation regime is appropriate.

Further, figures in parentheses denote the p-values resulted by the LM serial correctional test and the ARCH heteroskedasticity test. Analyzing the effect of error correction terms under different regimes, we discover, in equation (8), that the parameter  $\hat{\omega}_{11} = 0.051$  with 10% significant level is obviously higher than 0, showing the presence of weak exogeneity in influence of inflation on housing returns under high inflation period. In other words, the inflation influences housing returns through the short-run adjustment. Differently, in equation (9), the parameter  $\hat{\omega}_{22} = 0.045$  is significantly higher than 0, indicating the existence of weak exogeneity in influence of housing returns on inflation under low inflation period. In other words, the changes of housing prices influence the inflation through the short-run adjustment.

**Figure 2 The trend of inflation and the threshold value**

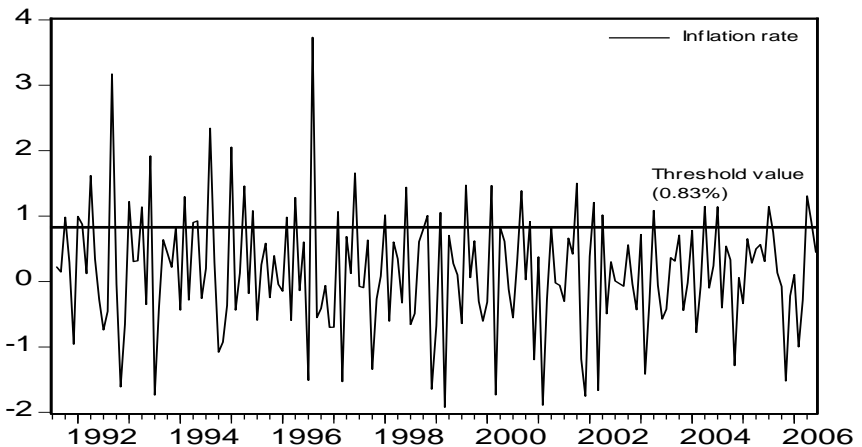


Table 6 reports the results of causality test on nonlinear model. The presence of threshold value implies that the respond of consumer prices to housing prices is the adjustment relation of asymmetric momentum. Accordingly, as soon as the consumer prices have the discrepant degree in variation (higher, equal and lower than 0.83%), the interaction between consumer prices and housing prices has to change. As the adjustment of short-run momentum is asymmetric, the causality under the upper and lower regime is not consistent. There is only the one-way causal relationship from inflation to housing returns being significant under high inflation. This study is based on the sum of coefficient values to determine the influence direction of relation between variables. It is found in the upper regime that the impact of the changes in consumer price index on housing returns is positive, and the impact of the variation in housing index on inflation is negative, yet, not specifically significant. Particularly, under the lower regime, the effect of the changes in consumer price index on housing returns is positive, and the effect of the

variation in housing index on inflation is negative. However, these causalities are not obvious.

The above results provide a detail insight into the inflation hedging ability of housing returns, particularly in the context of nonlinear model. Due to the asymmetric adjustment of housing returns relative to consumer price variation, there exists an incomplete pass-through from consumer prices to housing prices in the long run. Therefore, in the short run, when the rise in housing prices is caused by the broad margin of increase in consumer price index, the demand for housing raises just because of the expectation of investors rather than the need of habitants. We find the evidence that investing in Taiwan housing can partly hedge against inflation only when the increasing margin of monthly inflation rate is higher than 0.83%.

**Table 6 Results of Causality Test**

Dependent Variable		$r$	$\pi$
Null Hypothesis		$H_0: \pi \times \rightarrow r$	$H_0: r \times \rightarrow \pi$
High inflation period	Sum of coefficients	$\sum_{i=1}^{12} \hat{\alpha}_{1,2i} = 1.60$	$\sum_{i=1}^{12} \hat{\beta}_{1,1i} = -1.18$
	Chi-square test	52.4 (0.00) ***	14.4 (0.27)
Low inflation period	Sum of coefficients	$\sum_{i=1}^{12} \hat{\alpha}_{2,2i} = 0.44$	$\sum_{i=1}^{12} \hat{\beta}_{2,1i} = -0.12$
	Chi-square test	9.26 (0.68)	13.4 (0.33)

The inflation is used as the threshold variable, the optimal threshold value  $\gamma = 0.83\%$ , the lag length of TVECM  $p=12$ , and the threshold variable optimal lag  $d=10$ .  $\pi \times \rightarrow r$  presents the null hypothesis that the (deferred) consumer price changes (inflation) can not explain the (current) housing returns,  $r \times \rightarrow \pi$  indicates the null hypothesis that the (deferred) housing returns can not explain the (current) consumer price changes (inflation).

The values in “(.)” are the p-values of Chi-square statistic of Join test, \*\*\*denotes the 1% significant level.

## 5. Conclusions

This study aims to empirically investigate the inflation hedging ability of Taiwan housing investment. The methodology allows for the possible presence of nonlinear adjustment between housing returns and inflation as well as the time trend of long-run relationship. We set up the threshold vector error correction model (TVECM) for examining the inflation hedge. The empirical findings show that investing in Taiwan housing can only partly hedge against inflation when the inflation rate is higher than 0.83%. This study, relative to the related literatures, has some innovations and contributions: (1) with regard to the research motivation, this is the first paper using the nonlinear model to explore the inflation hedging effectiveness of Taiwan housing investment, (2) with regard to the methodology,

ours differs from the models used by the exiting studies such as the linear VAR and VECM which just focus on the symmetric relation between variables and overlook the asymmetric effect.

Real estate has been widely regarded as one of the best inflation hedge for a long time in Taiwan. Therefore, it is considered as one of ideal assets for risk diversification and for reservation, especially in high inflation period. Over the past 15 years, inflation has moderated considerably in Taiwan *vis-à-vis* abroad. Beside, Taiwan real estate prices have dropped drastically since 1994. Since then, demand for resident houses is not strong enough to fuel a run-up in prices. Desire for real estate investment is very low unless the signals of high inflation period emerge. Thus, when high inflation is unexpected or in the low regime (negative or lower than 0.83%), the housing prices seem unchangeable. When high inflation period (higher than 0.83%) is expected and the deposit interest rate can not compensate for this expected inflation rate, the capital flows back to real estate market, pushing up the prices. This phenomenon shows that the domestic housing market is swayed by speculators rather than by real demand.

The findings of this study do hope to provide Taiwan Government with some perspectives on the characteristic of housing demand, the determination of people on the possible capital costs, the evaluation of real estate and asset allocation. When regulating real estate policies, the asymmetric adjustment between housing price changes and inflation should be particularly taken care, this could influence the potential external costs generated by the inflation hedge. Along with increasing prices, inflation heavily pressures on Taiwan economy day by day. Our findings also do hope to supply a valuable suggestion on valuation and determination of one housing investment for investors, consumers and banks. On the academic perspective, we employ the methodology and model that have never been used before in the same topic and contribute new discoveries to the existing literatures.

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