The Non-linear Ripple Effect of House Prices in Taiwan – A Smooth Transition Regressive Model

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Abstract

Different from past research of regional house prices, this paper employs the smooth transition regression (STR) model to investigate the ripple effects among regional house prices in Taiwan. The aim of this paper is to test whether a smooth transition regression model, which is capable of capturing this non-linear behaviour, shows a better characterisation of regional house prices than a linear model. Our main findings are as follows. First, the results reveal that there is a mixture of linear and smooth non-linear ripple effects in Taiwan's regional house prices. If there is enough time to adjust, then the non-linear behavior in house prices will exist, causing a non-linear ripple effect for the regional house prices. Second, a large portion of the variance in Taiwan's overall house price changes is associated with Taipei's house price changes, and Kaohsiung's house price changes do not effectively impact Taiwan's overall house price changes. Third, strong evidence shows that the STR models capture the smooth non-linear ripple effects of regional house prices in Taipei and Taichung, and several features identify the superiority of the non-linear estimation. When compared with Taichung, there is a faster speed of transition between the regimes in Taipei. Fourth and finally, the estimated transition parameter value, revealing the halfway point between two regimes, is lower in Taipei and implies that a change in Taipei's house prices can more easily cause a non-linear "ripple out" change in Taiwan's overall house prices.

Keywords: STR model, Non-linear ripple effect, Regional house prices, Taiwan's house market, Transition variable

JEL Classification R11, R21

1. Introduction

There is a voluminous amount of literature examining the interrelationships between regional house prices, which are empirical works based on the hypothesis for shocks to regional house prices "rippling out" across the economy. If a ripple effect indeed exists, then it is predicated on a degree of long-run relative constancy between regional house prices. Many papers (Millington, 1994; Johns et al., 2003, 2004, 2005; Johns and Leishman, 2006) have stressed the role of migration as the mechanism for showing differential price adjustments. Meen (1999) indicates that four factors cause a ripple effect of regional house prices: migration, equity transfer, spatial arbitrage, and spatial patterns in the determinants of house prices.

Most of these empirical studies have employed the unit root and cointegration analysis to examine the existence of equilibrium between regional house prices. In the first of these two closely related lines of research, which apply Engle and Granger (1987) or Johansen (1988) cointegration tests, some papers explore the notion of a causal relationship between different regional house prices, but there lacks a consensus about the existence of a ripple effect. After finding the cointegration between regional house prices in the UK, MacDonald and Taylor (1993) and Alexander and Barrow (1994) confirm a ripple effect is present. Conversely, the empirical results of Ashworth and Parker (1997) reject the existence of a ripple effect by employing the ECM (error correction model) and the Lagrange multiplier test. Berg (2002) uses the Granger causality test to examine house markets in Sweden, showing that the Stockholm region leads price changes in other Swedish house markets. Johns and Leishman (2006) indicate that house price dynamics in the Ayr cluster are independent of the Glasgow local house market, while the results of the Paisley cluster presents the opposite. There are more papers that have discussed the existence of long-run relationships between regional house prices within a country, including Luo et al. (2007), Oikarinen (2008), etc.

Moving on from cointegration and ECM model analysis, investigators have tested for ripple effects in different regional house prices using unit root analysis. The motivation underlying these studies is that a rejection of the unit root hypothesis in regional/national house price ratios, which implies the phenomenon that shocks to regional house prices "ripple out" across the economy, can be taken as evidence of the presence of convergence. After revising the model with spatial correlations in house prices, Meen (1999) employs the ADF (of Dickey and Fuller, 1979) unit root test and finds evidence to support the existence of ripple effects in the UK. Cook (2005) applies the joint application of two tests, the DF-GLS test of Elliot et al. (1996) and the KPSS test of Kwiatkowski et al. (1992), with the results finding supportive evidence of stationarity in regional house price ratios in the UK.

Many studies lately indicate an asymmetric adjustment of economic variables that could lower the power of the DF test. Using the threshold regression method with an asymmetric adjustment process about the stationary attractor, Cook (2003) re-examines the stationarity of regional house price ratios and supports that stationarity exists in a number of regions of the UK. Hereafter, Chien (2010) and Canarella et al. (2012) use the Lagrange multiplier (LM) unit root tests with one and two structural breaks of Lee and Strazicich (2003, 2004) to examine the existence of ripple effects. Chien (2010) is unable to reject the existence of the ripple effect in regional house prices in Taiwan, while the empirical results of Canarella et al. (2012) show that the tests of the 'ripple effect' have conflicting evidence in the U.S.

Many recent papers have tested for non-linearity in other economic and financial variables, with some researchers focusing on the non-linearity of house markets. Kim and Bhattacharya (2009) indicate, "*it is clearly plausible that market behavior differs across expansion and contraction phases of the swings that characterize the real estate market.*" Seslen (2004) also points out that "*households exhibit rational responses to returns on the upside of the market but do not respond symmetrically to downturns.*" Households exhibit forward looking behavior and are more likely to move when prices are on the upswing, while households are less likely to move as prices are on the downside (Seslen, 2004). What causes this? To avoid a delay that results in paying even higher prices, buyers are eager to get into the house market when prices are increasing, while sellers are often unwilling to cut prices when markets are flat (Abelson et al., 2005). The existence of lumpy transaction costs in the house market can cause important non-linearities or threshold effects in a house market's aggregate demand (Kim and Bhattacharya, 2009), but if house prices are characterized by non-linear properties, then this implies that linear models are not an appropriate tool to analyze house prices.

Reviewing the past relative literature, some empirical papers have examined the non-linear relationship between economic variables and house prices. Studying the changes of real house prices in Australia, Abelson et al. (2005) estimate a cointegration and the asymmetric error correction model and find that there are significant lags in adjustment to equilibrium. Their results suggest that the speed of adjustment (α) during boom periods is somewhat greater when compared to non-boom periods. Posedel and Vizek (2010) apply a non-linear framework to discuss house price determinants and their adjustment properties. An asymmetric house price adjustment is present in four transition countries and the U.S., while no threshold effects are detected in developed European countries.

The above empirical literature has examined the non-linearity of house markets, with some using unit root tests of MTAR or employing structural breaks to explore the ripple effects of regional house prices (Cook, 2003; Chien, 2010; Canarella et al., 2012), and some applying threshold cointegration and asymmetric ECM to examine the non-linearity of house prices (Abelson et al. 2005; Posedel and Vizek, 2010). However, all of these papers apply non-linear methods with instantaneous adjustment between regimes, not a continuum of states between the two extremes. Using the Smooth Transition Autoregressive (STAR) model as a regime-switching model allowing for two regimes where the transition from one regime to the other is smooth, Kim & Bhattacharya (2009) examine non-linear properties of house prices for the entire U.S. and for four regions. The empirical results display non-linearity for house prices of the entire U.S. and for all regions except the Midwest.

This current paper employs the smooth transition regression (STR, Chan and Tong, 1986; Teräsvirta and Anderson, 1992; Granger and Teräsvirta, 1993; Teräsvirta, 1994) model to investigate non-linear ripple effects among regional house prices in Taiwan. The foremost advantage of the STR model, allowing the transition from one regime to the other to be smooth, is that it can capture all agents reacting separately to a given economic signal when changes in economic aggregates are influenced by changes in the behavior of many different agents. In house markets, a smooth transition or a continuum of states between the extremes appears more realistic, because heterogeneity in investors might switch at different times. According to Peters (1994), heterogeneity in investors' objectives is caused by different investment horizons, geographical locations, and various types of risk profiles. Therefore, when considering house prices, the time path of any structural change is liable to be better captured by a model whose dynamics are gradual, rather than instantaneous adjustment between regimes. The STR model accurately measures this kind of continuing change while being flexible enough that the conventional change arises as a special case (Aslanidis et al., 2002).

The STR or STAR model has so far mainly been applied to macroeconomic time series.[1] From the papers listed above, a few applications have applied the STR or STAR model on the convergence of regional house prices, except Kim & Bhattacharya (2009). In order to examine a potential smooth non-linear relationship of ripple effects among different regional house prices in Taiwan, this paper employs the STR model. In this paper we contribute to the existing literature on regional house prices in the following. First, the aim of this paper is to test whether the STR model, which is capable of capturing this non-linear behavior, shows a better characterisation of regional house prices than a linear model. This empirical analysis applies three regional house prices of Taiwan: the capital of Taiwan, Taipei City, and the other two mega cities of Taichung City and Kaohsiung City. Our results reveal that there is a mixture of linear and smooth non-linear ripple effects in these regional house prices. Second, strong evidence shows that the STR model captures the smooth non-linear ripple effects of regional house prices in the case of Taipei City and Taichung City. Changes in Taipei's house prices can more easily cause a smooth non-linear "ripple out" change in Taiwan's overall house prices than the other cities. The remainder of the paper is set up as follows. Section 2 introduces Taiwan's house market, Section 3 describes the methodology, Section 4 presents the empirical findings, and Section 5 offers some conclusions.

2. The House Market and Housing Policy in Taiwan

Taiwan has a high home ownership rate caused by traditional practices involving intergenerational transfers and self-built??? housing. In recent decades a pre-sale housing system has contributed to the growth of private sector housing construction (Chang and Ward, 1993). State intervention and housing subsidies have also risen, helping drive home ownership rates up further. According to the 2010 Population and Housing Census, Taiwan's average home ownership rate is 79.2% and the average housing unit vacancy rate in the country is 19.6%, both of which are far above the average rates of most other countries. For Taiwan, home ownership is the most entrenched in the housing system and a more fundamental function of family welfare, with domestic housing policies supporting home ownership as the mainstream residence.

Taiwan's housing policy has been reactive to changing economic and political

[1] For example, Granger and Teräsvirta (1993) apply STAR to discuss a non-linear relationship between U.S. GNP growth and leading indicators. Öcal and Osborn (2000) employ STAR models to investigate non-linearities between consumption and industrial production in the UK. Others using STAR include Skalin and Teräsvirta (1999), McMillan (2003), Sarantis (2001), Franses and van Dijk (2000), Mills (1999), etc.

pressures at different stages of the country' development (Chen and Li, 2010). As the level of housing intervention is relatively low in Taiwan, private housing developers have more freedom and face less competition from the public sector[2] (Yip and Chang, 2003). Although the housing policy has fulfilled a particular role in social and economic development as in most industrialized Asian economies, Taiwan has used more selective state intervention with subsidies that ensure the housing needs of low income groups are met within a market framework. In other words, the government of Taiwan has a much minor role in the housing sector, causing the house market to work on free market principles. The market orientation of the housing policy encompasses intense privatisation in terms of public/private partnerships and non-state provisions.

Taiwan's house market has gone through five boom periods, experiencing more peaks than most other countries over the same period. From 1986-1991, Taiwan's house prices rose sharply, increasing by over 300% in major cities, but house prices on the island then began a long fall during the mid-1990s. The 1997 Asian financial crisis had a significant impact on currency and stock market values, and there was also a deep crash in house markets. Taiwan's house market witnessed a slower decline of about 12% between 1998 and 2002 (Chiu, 2006). After plunging and bottoming out in 2003, Taiwan's house prices began to rise higher, reflecting the global explosion in 2007. The beginning of the global financial crisis in late 2008 caused Taiwan's house prices to decrease 11% by the first quarter of 2009, while house prices showed a strong upturn of 9.4% by the third quarter of 2009.

Geographical and regional economic circumstances are very different in Taiwan, which is revealed in the value of house prices. The major cities are Taipei City in the northern area, Taichung City in the central area, and Kaohsiung City in the southern area, and these cities are heterogeneous. On the back of the global trend in free trade and the rise of low-wage Asian countries, especially among China's coastal cities, many Taiwanese industrial firms have moved a part of their labor-intensive manufacturing plants overseas. The impact of globalization has caused Taiwan's traditional manufacturing industries, centered around Kaohsiung's metropolitan area, to lose their competitiveness and jobs. Being different from Kaohsiung, the core competitive advantage of Taipei City is not from traditional industries, but from its strategic node position in transnational flows that have resulted in many corporate headquarters and

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[2] Yip and Chang (2003) indicate, "*Unlike Hong Kong, where state monopolizes land supply, and also in Singapore, where the powerful Land Acquisition Act enables the state to control land, land in Taiwan is mostly privately owned. Contrary to private housing development in South Korea, private developers in Taiwan enjoy supplementary credits from the state for bailing them out during a market slump*."

advanced service industries to be located there. Taipei City is also a nodal city in cross-border connections, causing house prices in Taipei City to be much higher.

Table 1 shows the average house price and the ratio of house price to income in these three cities. Comparing these three cities in the third quarter of 2010, Taipei City's average house price is NT$20,396,000, much higher than the other cities - indeed at least 200% higher. As to the ratio of house price to income, the ratio for Taipei City is 14 or at least 50% higher elsewhere. Comparing the vacancy rate among these cities for 2010 (as Table 2), the lowest rate, 9.4%, is Taipei City where land costs are much higher than others. However, being a unique regional global city in Taiwan, house price fluctuations in Taipei City significantly differ from the other cities. Therefore, these characteristics of Taiwan's house market offer an interesting case study of non-linear convergence of regional house prices.

Table 1. Average house price and the ratio of house price to income

Area	Average house price	Ratio of house price income	Average home ownership rate
Taipei City	NT$20,396,000	14.0	71.4
Taichung City	NT$6,191,000	6.1	76.1
Kaohsiung City	NT$6,608,000	7.0	76.5
Taiwan Area	NT$9,254,000	9.1	79.2

Source: (1) Housing Demand Survey of the Third Quarter 2011, the Council for Economic Planning and Development, Taiwan. (2) 2010 Population and Housing Census, General of Budget, Accounting and Statistics, Taiwan.

Table 2. Vacant housing rate in Taiwan

Area	End of 1990	End of 2000	End of 2010
Taipei City	9.40%	12.20%	13.4%
Taichung City	19.70%	26.00%	26.2%
Kaohsiung City	16.20%	16.50%	19.3%
Taiwan Area	13.30%	17.60%	19.3%

Source: 2010 Population and Housing Census, General of Budget, Accounting and Statistics, Taiwan.

3. Smooth Transition Models

In order to examine for a potential non-linear relationship of ripple effects among different regional house prices in Taiwan, we apply the class of smooth transition regression models (STR, Chan and Tong, 1986; Teräsvirta and Anderson, 1992; Granger and Teräsvirta, 1993; Teräsvirta, 1994, 1998). The main feature of the smooth transition models is to allow for different types of market behaviour depending on the nature of the transition function, which can describe the dynamics of house prices to evolve with a smooth transition between regimes that depends on the changes of relative regional house prices.

We present the smooth transition model of Teräsvirta (1998)[3] by:

$$y_t = \phi_0' x_t + \phi_1' x_t \; G(s_t;\gamma,c) + \varepsilon_t \tag{1}$$

where y_t is the dependent variable, $x_t = (1, \mathrm{y}_{t-1},..., \mathrm{y}_{t-p}; z_{1t}, z_{2t},..., z_{kt})'$ and is the vector consisting of lagged endogenous and exogenous variables z_{it}[4], and $\phi_i = (\phi_{i,0}, \phi_{i,1}, \cdots, \phi_{i,p+k})'$, , $i = 0,1$. The transition function $G(s_t;\gamma,c)$, controlling the regime-shift mechanism, is a continuous function and usually is bounded from 0 to 1. The transition variable s_t can be a lagged endogenous variable, an exogenous variable, or a function of lagged endogenous and exogenous variables. The parameter c is the threshold and gives the location of the transition function, while γ defines the slope of the transition function. The residual ε_t is assumed to be a martingale difference sequence with respect to the history of the time series, which is denoted as $\Omega_{t-1} = \{y_{t-1}, y_{t-2}, \cdots, y_{t-P}\}$, and $\mathrm{E}[\varepsilon_t \mid \Omega_{t-1}] = 0$, $\mathrm{E}[\varepsilon_t^{\,2} \mid \Omega_{t-1}] = \sigma^2$. The STR model can be taken as a regime switching model, which allows for two regimes having the

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[3] Our empirical specification procedures for the smooth transition model are based on elements of Ter¨asvirta (1994) and Eitrheim and Ter¨asvirta (1996). A review of the smooth transition model is similar in spirit to a chapter of Ter¨asvirta (1998).

[4] In the STAR model as discussed in Teräsvirta (1994), the transition variable is assumed to be the lagged dependent variable. In our work, the model is called the smooth transition regression (STR) model (Teräsvirta, 1998), which allows the transition variable to be either a past value of the dependent variable or of some exogenous variables.

extreme values of the transition function, $G(st; \gamma; c) = 0$ and $G(st; \gamma; c) = 1$, while the transition process is gradual.

We give the transition function $G(s_t; \gamma; c)$ as equation (2):

$$G(s_t;\gamma,c_j) = \left(1+\exp\{-\gamma\prod_{j=1}^{K}(s_t - c_j)\}\right)^{-1}, \gamma > 0 \qquad (2)$$

There are two forms of the transition functions, including the logistic function and the exponential function. Equation (2) is the logistic function when K=1, and the full model is thus referred to as the logistic STR (LSTR) model. The logistic function changes monotonically from 0 to 1 as s_t increases. The parameter γ determines the smoothness of the change in the value of the logistic function. As $\gamma \to \infty$, Equation (1) reduces to the threshold model (Tong, 1983). When $\gamma \to 0$, Equation (1) becomes a linear model. When K=2, Equation (2) is an exponential function, and the resulting model is referred to as the exponential STR (ESTR) model.

For checking whether there is non-linearity of the STR type in the model and whether LSTR or ESTR should be used, we apply the following auxiliary regression if s_t is an element of x_t:

$$y_t = \beta_0' x_t + \sum_{j=1}^{3} \beta_j' \tilde{z}_t \, s_t^j + \varepsilon_t^* \qquad (3)$$

where $x_t = (1, \tilde{x}_t)'$. The null hypothesis of linearity is H_0: $\beta_1 = \beta_2 = \beta_3 = 0$. Accepting the null hypothesis implies that the appropriate model is a linear model against a non-linear STAR alternative. If linearity is rejected, then one has to choose whether an LSTR or an ESTR model should be specified. The choice can be based on the following test sequence:

test H_{04}: $\beta_3 = 0$.

test H_{03}: $\beta_2 = 0 \mid \beta_3 = 0$. (4)

test H_{02}: $\beta_1 = 0 \mid \beta_2 = \beta_3 = 0$.

As suggested by Teräsvirta and Anderson (1992), the test of linearity as specified in Equation (3) can be used again to provide a sequence of nested hypothesis tests H_{04}, H_{03}, and H_{02} for the choice between LSTR and ESTR alternatives.

4. Data and Empirical Results

In this section we first illustrate the data and the conclusions drawn from unit root tests for stationarity. Next, we perform the Lagrange Multiplier Smooth Transition (LM-STR) test for linearity of house price changes. We then conduct hypothesis tests to choose the appropriate STAR model (LSTAR vs. ESTAR). This section concludes with the estimation of models to explain the regional house price ripple in Taiwan.

4.1. Data and the results of the unit-root test

This empirical work employs four house price indices for Taiwan, including the national house price index for the overall Taiwan area (TW) and three regional house price indices for Taipei City (TC) and the other two mega cities of Taichung (TA) and Kaohsiung (KA), from the first quarter of 1998 to the fourth quarter of 2012. The housing index data are published by Sinyi Real Estate Development Company. The nominal house prices are used just like Kim and Bhattacharya (2009) indicate, "*sellers are averse to realizing nominal losses (not real losses) and therefore it is nominal house price changes that cause asymmetric effects on mobility and on the house market.*"

Table 2. Descriptive statistics (Levels)

	TC	TA	KA	TW
Mean	150.3535	147.689	120.1349	143.7415
Std. Dev.	54.75221	43.51057	26.56766	44.60733
Skewness	54.75221	43.51057	26.56766	44.60733
Kurtosis	2.401017	2.988985	3.938261	2.70441
Jarque-Bera	8.041072	9.296178	17.97935	8.724572
Probability	0.017943	0.00958	0.000125	00.012749

Table 2 summarizes the descriptive statistics of the series in levels. The standard deviations show that TC has the highest volatility, while KA has the lowest variation. These preliminary statistics suggest that the house prices of TC are more sensitive to changing economic conditions than the other three regional house prices. As shown in Figure 1 to Figure 4, the trending lines for the four house prices help draw out some important points. First, all house prices for these regions in Taiwan fell for a long time until 2003. After plunging and then bottoming in 2003, the house prices began to climb higher until 2008. Second, the beginning of the global financial crisis in late 2008 caused all regional house prices in Taiwan to slump. The house prices of Taiwan decreased 11% by the first quarter of 2009, while they strongly upturned, rising 9.4% by the third quarter of 2009.

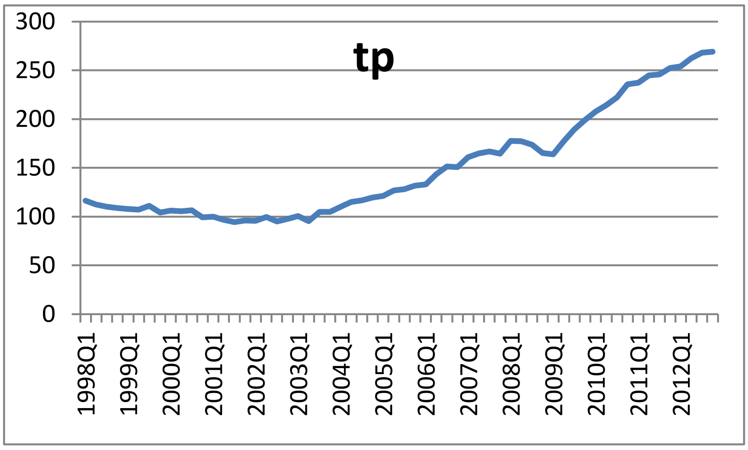

Figure 1. House price movement of Taipei City

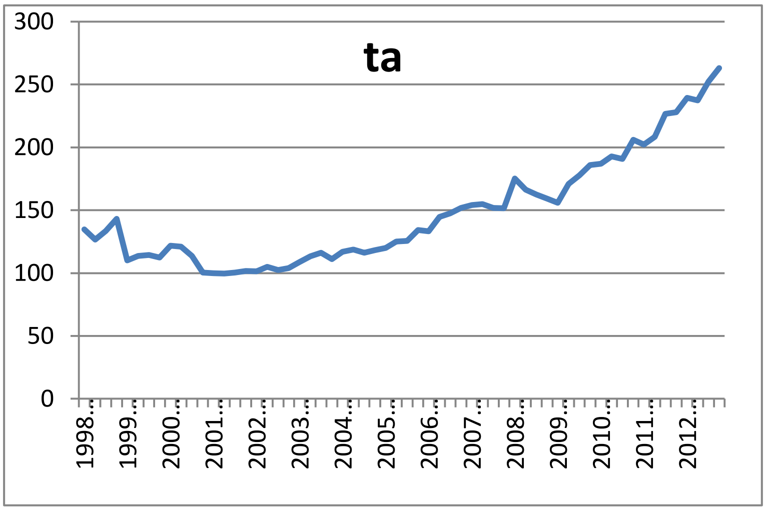

Figure 2. House price movement of Taichung

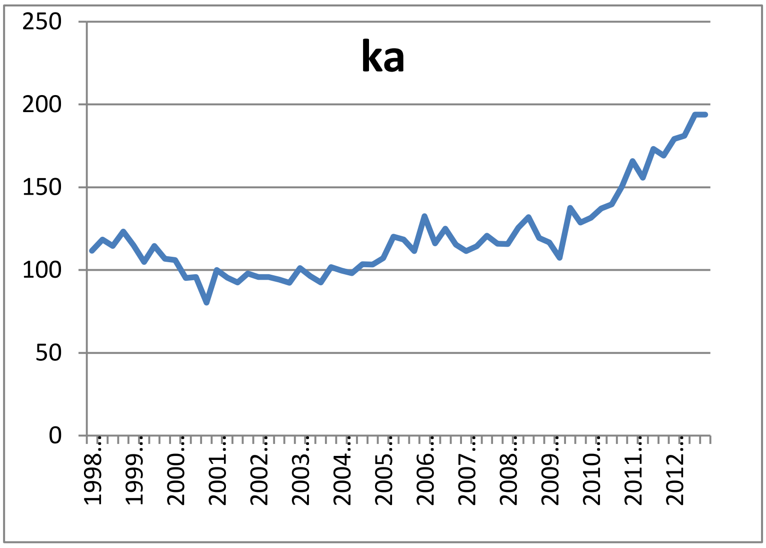

Figure 3. House price movement of Kaohsiung

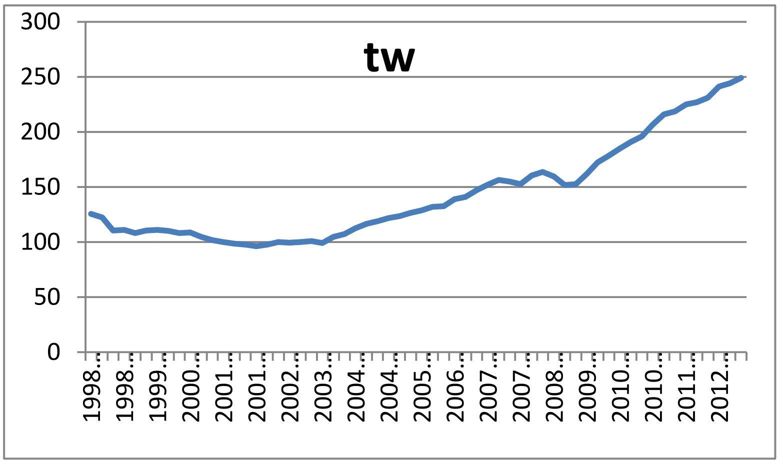

Figure 4. House price movement of Taiwan

We start by testing for the presence of a unit root. Table 3 reports the results of these univariate unit root tests with intercept and trend. All data are tested for the presence of unit roots in regional house prices using the ADF (Dickey and Fuller, 1979), DF-GLS (Elliott et al., 1996), PP (Phillips and Perron, 1988), and KPSS (Kwiatkowski et al., 1992). The results of Table 3 show that all variables follow I(1) processes, where a unit root exists in each level of all house prices, and thus all regional house prices are differenced to ensure stationarity.

Table 3. Results of unit-root tests

Variable	ADF	DF-GLS	PP	KPSS
Levels				
TC	-1.655 (0)	-0.402 (0)	-1.165 (2)	0.236** (6)
TA	-1.292 (0)	-0.623 (0)	-0.769 (9)	0.235** (6)
KA	-0.634 (1)	-0.596 (1)	-1.091 (2)	0.224** (5)
TW	-1.671(1)	-0.582 (1)	-1.667 (3)	0.230**(6)
First differences				
dTC	-7.389** (0)	-7.339**(0)	-7.398** (2)	0.058 (3)
dTA	-9.980** (0)	-9.685** (0)	-14.317** (18)	0.105 (14)
dKA	-13.176** (0)	-11.745** (0)	-14.713** (3)	0.097 (5)
dTW	-5.912** (0)	-5.995** (0)	-5.7582(7)	0.064 (3)

Notes: The regressions include an intercept and trend. All variables are in natural logs, while the lag lengths are determined via the Schwarz information criterion (SIC) and are in parentheses. The numbers in parentheses are the lag order in the ADF and DF-GLS tests. The bandwiths are for the Newey-West method of the PP and KPSS tests in parentheses. The nulls for all tests except for the KPSS test are unit roots. The superscripts * and ** indicate significance at the 10% and 5% levels, respectively.

4.2 The Choice Between Linear Model and Non-linear Model

The ripple effect describes the manner in which a price shock in one area ripples out to other areas. There are many relative papers, such Holmes and Grimes (2005) and Cook (2005), etc., that confirm the existence of stationarity in regional to national house price ratios by using the unit root test. To discuss the smooth non-linear ripple effect among regional house prices in Taiwan, we specify the following STR model of order p to capture the non-linearities characterized by asymmetries in price changes dynamics.

$$DTW_t = (\varphi_0 + \sum_{i=1}^{p} \varphi_{1i} DTW_{t-i} + \sum_{i=0}^{p} \varphi_{2i} X_{t-i}) + (\rho_0 + \sum_{i=1}^{p} \rho_{1i} DTW_{t-i} + \sum_{i=0}^{p} \rho_{2i} X_{t-i})\, G(s_t;\gamma,c) + \varepsilon_t \quad (5)$$

The difference of the house price index for the overall Taiwan area (DTW) is the dependent variable in equation (5). To separately discuss each relationship of Taiwan's overall house price and each regional house price, each time we will use one of these three differences of regional house price indices - DTC, DTA, or DKA - to be the exogenous independent variable X_{t-i} and transition variable s_t.

Table 4 presents the results of the Lagrange Multiplier Smooth Transition (LM-STR) Test for Linearity of Equation (5). We follow the standard procedure in the selection of the LSTR vs the ESTR model as discussed in Teräsvirta and Anderson (1992). The first test is to examine H_{04}, with a rejection of H_{04} implying the selection of the LSTR model. If H_{04} is not rejected, then we move to the second part of the sequential test H_{03}. A rejection of H_{03} implies the selection of the ESTR model. However, if H_{03} is not rejected, then we move to the last part of the sequential test H_{02}. A rejection of H_{02} implies the selection of the LSTR model (Kim & Bhattacharya, 2009).

Table 4. Linearity tests: Linear model versus STR model

Exogenous independent variable	Transition variable	Lag	H_0	H_{04}.	Selection of model
Taipei City	DTC_t	1	0.401	0.623	linear
	DTC_{t-1}	1	0.025**	0.018**	LSTR
Taichung	DTA_t	1	0.597	0.314	linear
	DTA_{t-1}	1	0.049**	0.099*	LSTR
Kaoshung	DKA_t	1	0.335	0.372	linear
	DKA_{t-1}	1	0.352	0.140	linear

Notes: $H_0 : \beta_1 = \beta_2 = \beta_3 = 0$; $H_{04} : \beta_3 = 0$. The values for the nested tests H04, H03, H02 have probability p values. The superscripts * and ** indicate significance at the 10% and 5% levels, respectively. The selection of the optimal lag, p, is made using the Akaike Information Criterion (AIC) over a range of lags from 1 through 4.

In Table 4, except for using each contemporaneous variable, DTC_t, DTA_t and DKA_t, as a transition variable, we also use one lag of each regional house price as a transition variable for considering the time lag effect of the house market.[5] Our results reveal that there is a mixture of linear and non-linear ripple effects in these regional house prices in Taiwan. If a contemporary variable is the transition variable, then all of cases are the linear model. When using one lag variable as the transition variable, the results of the test for linearity are very different. If one lag variable is the transition variable, then all the cases, except for Kaohsiung, are the non-linear model. In other words, when we discuss whether each regional house price in Taiwan can "ripple out" across Taiwan's overall area, if a time lag effect is not considered, then all cases have linear ripple effects. On the contrary, if we consider time lag effects, then all cases, except for Kaohsiung, have non-linear ripple effects. This phenomena means if there is enough time to adjust, then the non-linear behavior in house prices

[5] As to the question of a time lag in the house market, please see De Leeuw & Ekanem (1973).

will exist, causing a non-linear ripple effect of regional house prices in Taiwan.

In light of the cases that have non-linear ripple effects, we now identify a proper STR model, making a choice between ESTR and LSTR models, to capture the non-linear dynamics of regional house markets. The results of DTC_{t-1} show that a rejection of H_{04} implies selecting the LSTR model at the 10% level, while the results of DTA_{t-1} show a selection of the LSTR model, because H_{04} is accepted, but H_{03} is rejected at the 10% level.

4.3. Empirical Results of the STR Models

According to the results of the last section, if there is enough time to adjust, then the non-linear behavior in house prices will exist (except for the case of Kaohsiung), causing a non-linear ripple effect of regional house prices in Taiwan. Hence, this section estimates the time lag models that use one lag regional house prices, DTC_{t-1} and DTA_{t-1}, as transition variables. For comparative purposes, this section also presents the estimating results of the linear model. Tables 5 and 6 report the estimated coefficients of the linear model and the non-linear LSTR model, respectively, where the linear estimation is conducted with OLS. We employ the AIC and BIC to determine appropriate lag lengths, and the lags are eliminated on the basis of the individual significance test.

The estimated results for the linear relationship between the three regional house prices and adjusted R^2 are 0.6934, 0.4208, and 0.2164, respectively, for the three models of Taipei, Taichung, and Kaohsiung. The adjusted R^2 of Taipei's model is the highest, which implies that a large portion of variance in Taiwan's overall house price changes is associated with Taipei's house price changes. Second, in Taipei's model, the value of coefficients φ_{21} and φ_{22} are significant at the 10% level and higher than the other models, indicating Taiwan's overall house price changes are highly sensitive to Taipei's house prices changes. Third, in the Kaohsiung's model the coefficients φ_{21} and φ_{22} are insignificant at the 10% level, indicating Kaohsiung's house price changes do effectively impact Taiwan's overall house price changes.

What does cause the different results between Taipei and Kaohsiung? Since the 1990s, the global trends of free trade and low-wage Asian countries' development have caused Taiwan's traditional manufacturing industries to lose competitiveness.

These traditional manufacturing industries, located around Kaohsiung, moved their labor-intensive manufacturing plants overseas, resulting in higher unemployment in Kaohsiung. On the contrary, Taipei has gained the status of a regional global city (Wang, 2003). Hence, Taipei's economic strength results in a much higher influence on Taiwan's overall house price changes.

Table 5. Estimation of the linear model

	Model 1 (Taipei)		Model 2 (Taichung)		Model 3 (Kaohsiung)	
Coefficient	Variable	Coefficient	Variable	Coefficient	Variable	Coefficient
φ_0	constant	-0.133(0.727)	constant	0.633(0.207)	constant	1.195(0.037)**
φ_{11}	DTW_{t-1}	-0.279(0.033)**	DTW_{t-1}	0.366(0.003)**	DTW_{t-1}	0.487(0.001)***
φ_{21}	DTC_t	0.629(0.000)***	DTA_t	0.234(0.000)***	DKA_t	0.029(0.679)
φ_{22}	DTC_{t-1}	0.454(0.000)***	DTA_{t-1}	0.121(0.048)**	DKA_{t-1}	-0.030(0.651)
Adjust R^2		0.6934		0.4208		0.2164
AIC		4.6629		5.2987		5.6012
SC		4.8050		5.4408		5.7432

Notes: The probability value is reported in parenthesis, and the superscripts ** and *** indicate significance at the 5% and 1% levels, respectively.

We next specify an LSTR model as in equation (5) to discuss non-linear ripple effects, using the house prices of Taipei and Taichung respectively as the exogenous independent variable, and one lag regional house price, DTC_{t-1} or DTA_{t-1}, as the transition variable. Table 6 presents the estimating results of the LSTR models. Comparing the results of the linear and LSTR models across Tables 5 and 6, several features identify the superiority of the non-linear estimation.

First, the improvements of adjusted R^2 in the non-inear LSTR estimation, as compared to the linear estimation, display that a great portion of variations in the changes of house prices in the long run is related to non-linear dynamics. Second, the non-linear coefficients ρ_{21} of both models, Taipei and Taichung, are significant at the 10% level. Third, the parameter of γ, which implies the speed of transition between regimes, is significant at the 10% level. The statistical significance of γ again confirms the existence of non-linearity as in Equation (5). These results together show strong evidence that the STR models capture the non-linear ripple effects of regional house prices in the case of Taipei and Taichung.

Table 6. Estimation of the LSTR model in Equation (5)

Regime		Model 1 (Taipei)		Model 2 (Taichung)	
	Coefficient	Variable	Coefficient	Variable	Coefficient
Linear part	φ_0	constant	-0.117(0.749)	Constant	-2.416(0.384)
	φ_{11}	DTW_{t-1}	-0.293(0.022)**		
	φ_{21}	DTC_t	0.653(0.000)***	DTA_t	0.390(0.000)***
	φ_{22}	DTC_{t-1}	0.516(0.000)***	DTA_{t-1}	-0.0349(599)
Non-linear part	ρ_0	constant	-73.382(0.000)***	Constant	54.149(0.093)*
				DTW_{t-1}	2.109(0.141)
				DTA_t	-1.012(0.103)
	ρ_{21}	DTC_{t-1}	5.520(0.000)***	DTA_{t-1}	-2.830(0.008)***
	γ		8.398(0.048)**		1.375(0.065)*
	C		11.313(0.000)***		18.119(0.000)***
	Adjust R^2		0.7554		0.5185
	AIC		1.8086		2.5202
	SC		2.0928		2.8399
Diagnostics Test	Normality		65.040(0.000)***		76.032(0.000)***
	ARCH(4)		1.204(0.877)		1.926(0.749)
	Autocorrelation(4)		0.507(0.730)		0.810(0.526)

Notes: The probability value is reported in parenthesis, and the superscripts *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively. Normality refers to the test of Jarque and Bera (1980), and autocorrelation (4) is the test of Godfrey (1988), which has been discussed in its application to STR models in Ter¨asvirta (1998).

Other points are worth noting from the estimation of the LSTR models, as presented in Table 5. First, the parameter γ takes the values of 8.398 for Taipei's model and 1.275 for Taichung's model. The higher γ for Taipei's model shows a faster speed of transition between regimes in Taipei as compared to Taichung's model. Second, the estimated transition parameter c, revealing the halfway point between two regimes, is 11.313 and 18.119, respectively, for Taipei's and Taichung's models, and both are statistically significant at 10% level. The c value of Taipei is lower, which implies that a lower value of Taipei's house price changes triggers a shift in regimes for the non-linear ripple effect. In other words, the change in Taipei's house price can more easily cause a non-linear "ripple out" change in Taiwan's overall house price, which implies Taipei, as the most important economic center in Taiwan, has a much higher influence on Taiwan's overall house market than the other cities. Table 6 also shows the residual diagnostic tests of the LSTR modes, which present no evidence of any remaining serial correlation and ARCH for any model.

5. Conclusions

In house markets, a smooth transition or a continuum of states between the extremes appears more realistic, because investors might switch their heterogeneity at different times. Hence, this paper employs the STR model to investigate the smooth non-linear ripple effects among regional house prices in Taiwan. The aim of this paper is to test whether a STR model, which is capable of capturing this non-linear behavior, shows a better characterisation of regional house prices than a linear model. Our main findings are as follows.

First, our results reveal that there is a mixture of linear and smooth non-linear ripple effects in regional house prices in Taiwan. If we consider time lag effects, then all of the cases, except for Kaohsiung, have non-linear ripple effects. This phenomena mean that if there is enough time to adjust, then the non-linear behavior in house prices exists, causing a non-linear ripple effect of regional house prices in Taiwan.

Second, a large portion of variance in Taiwan's overall house price changes is associated with Taipei's house price changes. Kaohsiung's house price changes cannot effectively impact Taiwan's overall house price changes.

Third, strong evidence shows that the STR models capture the smooth non-linear ripple effects of regional house prices in the cases of Taipei and Taichung. Comparing the results of the linear and LSTR models of Taipei and Taichung, several features identify the superiority of the non-linear estimation. Comparing with Taichung, there is a faster speed of transition between regimes in Taipei.

Fourth and finally, the estimated transition parameter value, revealing the halfway point between two regimes, is lower in Taipei, which implies that a change in Taipei's house prices can more easily cause a non-linear "ripple out" change in Taiwan's overall house prices and have a much greater influence on Taiwan's overall house market than the other cities.

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