5. DOES HOUSING COST AFFECT BIRTH RATES IN TAIWAN? THE ADL TEST FOR THRESHOLD CO-INTEGRATION[1]

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Abstract

This study applied the ADL threshold co-integration model to investigate the relationship between fertility and housing cost in Taiwan. Our empirical results were in favor of the threshold co-integration relationship between crude birth rate and cost of childbearing, such as housing cost and opportunity cost. The asymmetric adjustment process of fertility toward the long-run equilibrium was verified. In general, the effects of housing cost and opportunity cost on fertility in the regime of upper threshold were more significant than that in the regime of lower threshold. Recognizing that housing cost is a major cost of childbearing in terms of family formation, the housing price policy should not be managed from the perspective of the equity of housing affordability but from the perspective of how to maintain the social security.

Keywords: ADL test, threshold co-integration; house price, low fertility

JEL Classification: C32, I15, J11

1. Introduction

Taiwan has one of the lowest fertility rates in the world. In 1984, the total fertility rate, a measure of the average number of babies born to each woman in her lifetime, was below the population replacement level (2.1) for the first time in Taiwan, and the rate continuously declined to 1.065 in 2012 (Ministry of Interior, 2012), leading to Taiwan being the lowest fertility country in the world (Population Reference Bureau, 2012). While the total fertility rate decreased, the house price continuously increased during the same period. This condition worsened Taiwanese housing affordability due to a

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loss of labor force leading to imposition of heavier burden of social security on current workers. The house price to annual household income ratio, a basic measure of housing affordability, was 3.14 during 1981-1986 in Taiwan (Hsueh, 1996), and the ratio continuously increased to 9.1 in 2012 (Construction and Planning Agency, 2012), meaning that the cost for a representative house is approximately 9.1 times that of annual household income in Taiwan. In addition, the mean age of the individual who purchases a house is around 28.5-35.3 years old, and this age is a major life-time period for childbearing (Chen,Chou, Lin, and Chen, 2013). Recognizing that housing cost is a major cost associated with childbearing in terms of family formation (Chen,Chou, Lin, and Chen, 2013; Hui, Zheng, Hu, 2012; Shuya and Shinichiro, 2012; Dettling and Kearney, 2011; Yi and Zhang, 2010; Simon and Tamura, 2009), the upward trend of the housing affordability measure suggested the cost of childbearing is rising significantly in Taiwan.

Previous studies investigating the determinants of female fertility focused on the cost and preference of childbearing for women (Becker, 1991). For example, Narayan (2006) used Taiwanese fertility data over the period from 1966 to 2001 to examine the structural hypothesis and the ideational hypothesis of fertility transition. The former hypothesis emphasizes that the conventional socioeconomic factors (mostly reflecting the opportunity cost of childbearing for women, such as female labor force participation and income) are essential for an initial decline in fertility and the latter hypothesis highlights the preference change of childbearing for women (resulting from some family planning policies, and an increase in female education level) brings an initial decline in fertility. The results from his research suggested that female education and female labor force participation are the key determinants of female fertility in Taiwan. In fact, female education and female labor force participation are the most frequently cited factors to affect the decision of childbearing all over the world. These two factors are refered to as important determinants of female fertility in Taiwan (Chen, Chou, Lin, and Chen, 2013; Narayan, 2006; Cheng and Nwachukwu, 1997); China (Narayan and Peng, 2006), Thailand (Masih and Masih, 1999), India (Masih and Masih, 2000), OECD countries (Ahn and Mira, 2002), Czech Republic (Klasen and Launov, 2006), and Japan as well as some European countries (Feyrer, Sacerdote, Stern, 2008).

Nevertheless, the growth of female education level and female labor force participation rate had slowed down in the past decades around the world (World Bank, 2012), and it followed that the female fertility became less responsive to female education level and female labor force participation (Yi and Zhang, 2010). Therefore, many recent studies tried to identify some key factors (other than female education and female labor force participation) that determine the decision of childbearing. Because the housing cost is a major cost of childbearing in terms of family formation, some recent studies have tried to construct both theoretical and empirical frameworks to investigate the relationship between fertility and housing cost (measured by house price). For example, Yi and Zhang (2010) was the first study to provide a theoretical model to predict the effect of house price on fertility. The empirical evidence from their study suggested a negative relationship between fertility and house price. Following this line of research, Chen, Chou, Lin, and Chen (2013) applied the same model proposed by Yi and Zhang (2010) to investigate the impact of housing affordability (measured by house price to annual household income ratio) on total fertility rate in the Taipei municipal area. The negative impact of housing affordability on the total fertility rate was validiated in the Taipei municipal area. The evidence supporting a negative link between house price and fertility can also be found in Hong Kong (Hui, Zheng, Hui, 2012; Yi and Zhang, 2010), Japan (Shuya and Shinichiro, 2012), the US (Mumford and Lovenheim, 2012; Dettling and Keatney, 2011; Simon and Tamura, 2009), and the UK (Ermisch, 1988).

One should notice that many previous studies applied time series models to explore the determinants of female fertility. Some studies used Johansen and Juselius's co-integration approach (Johansen and Juselius, 1990) to construct a long-run relationship between fertility and some socioeconomic factors such as female education level, female labor force participation, and housing cost (Chen, Chou, Lin, and Chen, 2013; Yi and Zhang, 2010; Narayan and Peng, 2006; Ahn and Mira, 2002; Masih and Masih, 2000; Masih and Masih, 1999; Cheng and Nwachukwu, 1997). Other studies used the bound testing approach proposed by Pesaran, Shin, Smith (2001) to analyze the factors influencing female fertility in the long run (Hui, Zheng, Hu, 2012; Narayan, 2006). The results generated from those studies based on Johansen and Juselius's co-integration approach suffered from two problems. First, Johansen and Juselius's co-integration approach requires all variables in the model to be I(1) series. It is particularly problematic to pre-test the order of integration of the variables in the unit-root and co-integration literature, since the power of unit root tests is typically low (Narayan, 2006). Second, size distortion of type I error in Johansen and Juselius's co-integration test (based on the maximum-likelihood estimation method) was well documented in the literature due to a small sample size of time series data (Palm, Smeekes, Urbain, 2010).

On the other hand, the bound testing approach has two advantages. First, it does not depend on pre-testing the order of integration of the variables. Second, its co-integration test remains reliable in a small sample size of time series data (Pesaran, Shin, Smith, 2001). Although these two advantages solve the problems of Johansen and Juselius's co-integration approach, the bound testing approach remains problematic. This is because the co-integration relationship remains inconclusive under the condition that the F-statistic of the bound test falls into the middle of upper and lower critical bounds (Pesaran, Shin, Smith, 2001). In addition, the underlying assumption of the co-integration relationship in the bound testing approach is that the adjustment process of fertility toward the long-run equilibrium is always symmetric. A growing literature demonstrated asymmetric adjustments toward the long-run equilibrium in many socioeconomic time series due to various policy interventions (Li and Lee, 2010). Various family planning policies to influence fertility were frequently found in some Asian countries such as Taiwan (Chen, Chou, Lin, Chen, 2003) and China (Narayan and Peng, 2006), so there is no reason to assume to the adjustment process of fertility toward long-run equilibrium is symmetric.

In this study, we used the autoregressive distributed lag (hereafter, ADL) threshold co-integration model proposed by Li and Lee (2010) to investigate the long run relationship between housing cost and fertility, given that the opportunity cost of childbearing for women was controlled. The ADL threshold co-integration model not only can solve a possibly inconclusive result obtained from the bound testing approach but can also release the assumption of the symmetric long-run fertility adjustment process underlying the bound testing approach proposed by Pesaran, Shin, Smith (2001). This research contributed to the literature on the study of determinants of female fertility in two ways. First, different from other studies investigating a linear co-integration relationship between fertility and its determinants (Chen, Chou, Lin, Chen, 2013; Hui, Zheng, Hu, 2012; Yi and Zhang, 2010; Narayan, 2006; Narayan and Peng, 2006; Ahn and Mira, 2002; Masih and Masih, 2000; Masih and Masih, 1999; Cheng and Nwachukwu, 1997), this study is the first to explore the nonlinear co-integration relationship between fertility rate and housing cost. Second, it adopted the most sophisticated time series approach, the ADL threshold co-integration model proposed by Li and Lee (2010) to provide reliable evidence for the existence of an asymmetric long-run relationship between fertility and housing cost. Two appealing features of the ADL threshold co-integration model are worth being addressed. First, the test statistics generated from the ADL threshold co-integration model can be obtained, regardless of whether non-stationary or stationary time series are used to estimate the model (Li and Lee, 2010). Second, the ADL threshold co-integration model prevents an inconclusive result on the co-integration relationship from the bound testing approach. Low fertility rate will lead to a reduced labor force, and impose a heavier burden of providing care and welfare expenditure on the young generation. The results generated from this study can provide a connection between housing policies and demographic policies in order to main social security.

This study was organized as follows. Section 2 describes data. Section 3 presents empirical models. Section 4 displays the empirical results of the ADL threshold co-integration model. Section 5 provides the conclusion and policy implications from this study.

2. Data

Based on the standard Beckerian model of fertility behavior to formulate the effect of housing cost on fertility proposed by Yi and Zhang (2010), we need data for fertility, housing cost, and the opportunity cost of childbearing. The fertility rate was measured by the monthly crude birth rate (live births per thousand people), and the opportunity cost of childbearing was measured by the relative wage rate of the female to male, computed by the female wage divided by the male wage per month. The house price index was taken to measure housing cost in previous studies (Hui, Zheng, Hu, 2012; Yi and Zhang, 2010). Nevertheless, there is no official (or government authorized) house price index available in Taiwan. Therefore, the construction cost index, measuring the construction cost of real estate, served as a proxy variable for the housing cost. Those data were obtained from macroeconomic and interior statistics databases administrated by the Directorate-General of Budget, Accounting and Statistics (DGBAS), and the Ministry of Interior in Taiwan, respectively. The whole sample period starts in January 1994 and ends in October 2012, resulting in a total of 226 monthly observations.

3. Empirical Model

3.1. Unit Root test

The Taiwanese government implemented several interventions to influence the fertility in Taiwan, and the preference for childbearing would also be changed during the auspicious months (ghost month in July) or years (such as years of the dragon and tiger) in the Chinese Lunar calendar. In addition, the transition of economic development in Taiwan also impacted the housing cost and income so that it is reasonable to find some structural breaks in our time series data. Therefore, our time series data should be tested for unit roots in the presence of structural breaks. To this end, two NP-ADF tests (i.e., M1 and M2 tests) proposed by Narayan and Popp (2010) were adopted in this study in order to identify unknown structural breaks. There are several appealing features in these two NP-ADF tests. First, these tests can incorporate two unknown structural breaks under both the null hypotheses of the presence of unit root and the alternative hypotheses of stationary series (Narayan and Popp, 2010). It follows that the coefficients in these two NP-ADF model specifications are nonlinearly related to each other. Second, the Monte Carlo simulations reported in Narayan and Popp (2010) suggested that the NP-ADF tests have stable power and can accurately identify true break dates even for small breaks. Specifically, the data generation process under the null hypotheses of the presence of unit root in the NP-ADF tests (i.e., M1 and M2 tests) can be described as follows:

$$x_t^{M1} = \rho x_{t-1} + \phi_1 + \beta^* t + \theta_1 D(T_B)_{1,t} + \theta_2 D(T_B)_{2,t} + \delta_1 DU_{1,t-1} + \delta_2 DU_{2,t-1} + \sum_{j=1}^{k} \gamma_j \Delta x_{t-j} + u_t \quad [1]$$

$$x_t^{M2} = \rho x_{t-1} + \phi^* + \beta^* t + \kappa_1 D(T_B)_{1,t} + \kappa_2 D(T_B)_{2,t} + \delta_1^* DU_{1,t-1} + \delta_2^* DU_{2,t-1} + \omega_1^* DT_{1,t-1} + \omega_2^* DT_{2,t-1} + \sum_{j=1}^{k} \gamma_j \Delta x_{t-j} + u_t \quad [2]$$

where: x_t were the observed data at time *t*.

The regressors used in the equations [1]-[2] were defined as follows: *t* represents time trend, $D(T_B)_{i,t} = 1(t = T_{B,i})$, and $DU_{i,t-1}$ ($DT_{i,t-1}$) is one lag of $DU_{i,t} = 1(t > T_{B,i})$ ($DT_{i,t} = 1(t > T_{B,i})(t - T_{B,i})$). $T_{B,i}$, *i*=1,2 denotes the structural break dates. Δx_{t-j} represents the *j*th difference of x_{t-j}. u_t is the stochastic disturbance term. ρ, ϕ^*, ϕ_1, β^*, θ_i, δ_i κ_i, δ_i^*, ω_i^* (*i*=1,2), and γ_j (j=1,2,..,*k*) are parameters needed to be estimated. The M1 and M2 types of model specification test the unit root under the null hypotheses of $\rho = 1$ against the alternative hypotheses of $\rho < 1$. Since the *t* statistics of ρ does not follow a standard t distribution, critical values at the 1% (5%) level of significance for M1, and M2 tests were obtained from

Narayan and Popp (2010) to determine whether the time series are stationary or not. The time breaks were selected via a sequential procedure comparable to Kapetanios (2005).

3.2. ADL threshold co-integration model

In this study, the ADL threshold co-integration model proposed by Li and Lee (2010) was employed to test for co-integration for an asymmetric adjustment of the crude birth rate toward long-run equilibrium in Taiwan. According to the empirical framework of Li and Lee (2010), the estimation of the ADL threshold co-integration model included two steps: First, we estimated the linear co-integration vector as follows:

$$y_t = \alpha_0 + \alpha_1 H_t + \alpha_2 R_t + e_t \quad [3]$$

where: y_t, H_t and R_t represents monthly crude birth rate, construction cost index, and relative wage of the female to male at time *t*, respectively. These three variables were converted into in a natural logarithm scale. e_t is the stochastic disturbance term. α_0, α_1, and α_2 denoted the coefficients associated with the constant, H_t and R_t, respectively. The model specification in equation [3] was suggested by a standard Beckerian model of fertility behavior to capture the effect of housing cost on fertility as proposed by Yi and Zhang (2010).

Second, the threshold type of unrestricted error correction model was specified as follows:

$$\begin{aligned} \Delta y_t = {} & \beta_0 + \beta_1 t + \beta_2 y_{t-1} I_t^j + \beta_3 y_{t-1}(1 - I_t^j) + \beta_4 H_{t-1} I_t^j + \beta_5 H_{t-1}(1 - I_t^j) + \beta_6 R_{t-1} I_t^j + \\ & \beta_7 R_{t-1}(1 - I_t^j) + \beta_8 \Delta H_t + \beta_9 \Delta R_t + \beta_{10} \Delta y_{t-1} + \beta_{11} \Delta H_{t-1} + \beta_{12} \Delta R_{t-1} + \varepsilon_t \end{aligned} \quad [4]$$

where the definitions for y_t, H_t and R_t are the same as in equation [3], and *t* represents the time trend. Δy_t, ΔH_t, and ΔR_t denote the first difference of y_t, H_t, and R_t, respectively. Δy_{t-1}, ΔH_{t-1}, and ΔR_{t-1} are one lag of Δy_t, ΔH_t, and ΔR_t, respectively. One lag of Δy_{t-1}, ΔH_{t-1}, and ΔR_{t-1} was selected in equation [4] in accordance with the parsimony principle. I_t^j (*j*=*A*, *B*) represents indicator *A* (given by $I_t^A = I(e_{t-1} < e_{t-1}^*(\tau))$) or indicator *B* ($I_t^B = I(\Delta e_{t-1} < \Delta e_{t-1}^*(\tau))$). $e_{t-1}^*(\tau)$, and $\Delta e_{t-1}^*(\tau)$ are threshold values, referred to as the τ^{th} percentile element of the empirical distribution of $e_{t-1}^*(\tau)$ and $e_{t-1}^*(\tau)$, respectively. Akaike Information criteria (AIC) or Schwartz criteria (SC) were suggested by Li and Lee (2010) to choose whether indicator *A* or indicator *B* should enter equation [4]. ε_t is the stochastic disturbance term. β_j (*j*=0,1,2,3..,12) are the parameters needed to be estimated, and β_j (*j*=2,3,4,5,6,7) measure the adjustment speed toward the long-run equilibrium. These parameters are allowed to vary in the ADL threshold co-integration model. In the case of $\beta_2 = \beta_3$, $\beta_4 = \beta_5$, and $\beta_6 = \beta_7$, the ADL threshold co-integration model reduces to the ADL model (i.e., the co-integration model based on the bound testing approach proposed by Pesaran, Shin, Smith, 2001).

Two statistics generated from the estimation of equation [4] were suggested by Li and Lee (2010) to test the threshold co-integration of fertility. The first one is called a BO statistic and is used to test H_0: no co-integration relationship ($\beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = 0$) against H_1: threshold co-integration relationship. The second one is designated the BDM statistic and is used to test H_0: no co-integration relationship ($\beta_2 = \beta_3 = 0$) against H_1: threshold co-integration relationship. Li and Lee (2010) indicated that the BO statistic performs better than the BDM statistic for testing the threshold co-integration relationship in terms of size and power. Therefore, the threshold co-integration relationship was mainly determined by the BO statistic. In the long-run equilibrium, we set $\Delta y_t = \Delta H_t = \Delta R_t = \Delta y_{t-1} = \Delta H_{t-1} = \Delta R_{t-1} = 0$ in equation [4]. The long-run relationship among crude birth rate, construction cost index, and relative wage of female to male can be derived by the equations [5]-[6] below:

[5] $y_{t-1} = (-\beta_0/\beta_2) + (-\beta_1/\beta_2)TR + (-\beta_4/\beta_2)H_{t-1} + (-\beta_6/\beta_2)R_{t-1} + \varepsilon_t/\beta_2$, if I_t^j =1

[6] $y_{t-1} = (-\beta_0/\beta_3) + (-\beta_1/\beta_3)TR + (-\beta_5/\beta_3)H_{t-1} + (-\beta_7/\beta_3)R_{t-1} + \varepsilon_t/\beta_3$, if I_t^j =0

Equation [5] (equation [6]) represents the long-run relationship among crude birth rate, construction cost index, and relative wage of the female to male below (above) the threshold values. Since the coefficients in equations [5]-[6] are nonlinear parameters composed of the estimated parameters from equation [4], the exact standard error of these coefficients in equations [5]-[6] cannot be calculated directly. Therefore, the Krinsky and Robb's simulation technique with 20,000 replications was used to construct the 95% confidence intervals (Krinsky and Robb, 1991) for these coefficients in equations [5]-[6].

4. Empirical Results

4.1. Descriptive Statistics

Table 1 summarizes the descriptive statistics of crude birth rate (live births per thousand people, CBR), construction cost index (CCI), and relative wage of the female to male (RW). The mean and standard deviation of each variable with 5 periods (beginning with 1994:01-1997:09, and ending with 2009:01-2010:10) are displayed in Table 1. In order to better present these data, we provide a graph based on Table 1. Figure 1 displays the trends of crude birth rate (CBR), construction cost index (CCI), and relative wage of the female to male (RW) over the period from 1994:01 to 2010:10. Figure 1 shows that the crude birth rate (CBR) continuously decreased from 1994:01 to 2010:10, and meanwhile, the construction cost index, CCI (used to measure housing cost), and relative wage of the female to male (RW) continuously increased during the same period. This finding suggests a negative relationship between crude birth rate (CBR) and cost of childbearing (such as hosing cost measured by the construction cost index, CCI and opportunity cost measured by relative wage of the female to male, RW).

Table 1

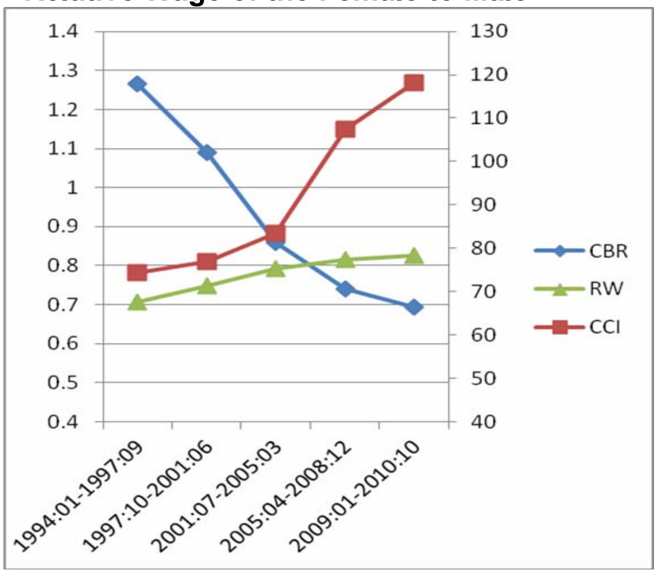
Descriptive Statistics*

	Crude Birth Rate (CBR; ‰)		Construction Cost Index (CCI)		Relative Wage (RW)		Sample Size
Time Period	MEAN	SD	MEAN	SD	MEAN	SD	N
1994:01-1997:09	1.266	0.092	74.421	0.734	0.706	0.014	45
1997:10-2001:06	1.090	0.120	76.844	0.639	0.748	0.011	45
2001:07-2005:03	0.860	0.096	83.398	7.091	0.792	0.008	45
2005:04-2008:12	0.741	0.067	107.482	12.260	0.815	0.008	45
2009:01-2010:10	0.695	0.110	118.036	3.559	0.826	0.006	46
1994.01-2010.10	0.929	0.238	92.151	18.735	0.778	0.046	226

* The whole sample period starts from January 1994 and ends in October 2012, resulting in a total of 226 monthly observations.

Figure 1

Trends of Crude Birth Rate, Construction Cost Index, and Relative Wage of the Female to Male



4.2. Unit Root Test

Table 2 presents the results of two NP-ADF (M1 and M2) tests proposed by Narayan and Popp (2010). As indicated in Table 2, no matter which test was used to test the null hypothesis of unit root against the alternative hypothesis of stationarity for construction cost index (CCI) and relative wage of the female to male (RW), the testing results based on both M1 and M2 tests all suggest these two variables to be

I(1) series. In the case of construction cost index (CCI), both M1 and M2 tests identified the first and second breaks at 2004:01, and 2008:08, respectively. As for the relative wage of the female to male (RW), the first and second breaks were found by both M1 and M2 tests at 2001:06, and 2005:01, respectively. Contrarily, the M1 and M2 tests suggested different orders of integration for the crude birth rate (CBR). The crude birth rate (CBR) was found to be an I(1) series based on the M1 test, but it was identified to be an I(0) series based on the M2 test. The M1 test identified the first and second breaks of crude birth rate (CBR) at 2009:03 and 2010:01, respectively and the M2 test identified the first and second breaks of crude birth rate (CBR) at 1997:12 and 2009:03, respectively. The ambiguous conclusions in determining the order of the crude birth rate (CBR) from the M1 and M2 tests suggest the validity of using the ADL threshold co-integration model to investigate the relationship between fertility and cost of childbearing.

Table 2

New ADF Tests with Structural Breaks*

		Level			Difference			
		T statistics	TB1	TB2	T statistics	TB1	TB2	Order
	Log(CBR)	-3.918	2009.03	2010.01	**-8.429**	2009.03	2010.01	I(1)
M1	Log(CCI)	0.009	2004.01	2008.08	**-8.935**	2004.01	2008.08	I(1)
	Log(RW)	-1.832	2001.06	2005.01	**-12.640**	2001.06	2005.01	I(1)
	Log(CBR)	**-5.337**	1997.12	2009.03	**-8.290**	1997.12	2009.03	I(0)
M2	Log(CCI)	-3.431	2004.01	2008.08	**-9.105**	2004.01	2008.08	I(1)
	Log(RW)	-4.115	2001.06	2005.01	**-12.750**	2001.06	2005.01	I(1)

*The whole sample period starts from January 1994 and ends in October 2012, resulting in a total of 226 monthly observations. Bold fonts represent 5% or better significance level, respectively. Critical values at 1% (5%) level of significance for M1, and M2 are -4.731(-4.136), and -5.318(-4.741) in Table 3 of Narayan and Popp (2010), respectively.

4.3. ADL Threshold Co-Integration Model

Table 3 displays the estimated results of the ADL threshold co-integration models with indicator A and indicator B. Previous studies (such as Li and Lee, 2010; Chang, Lee, Hung, 2012) recommended that the AIC or SC should serve as criteria to select the ADL threshold co-integration model with indicator A or indicator B. In general, the lower the values of AIC or SC are, the better the model fits our data. As indicated in Table 3, no matter which criterion was used to select the best model, the ADL threshold co-integration model with indicator B should be chosen. The BO and BMD statistics (derived from the model and used to test the null hypotheses of no co-integration relationship) were 45.960, and 44.211, respectively. These two values were higher than the 1% critical values for BO and BMD statistics obtained from Li and Lee (2010). These results support the threshold co-integration relationship between fertility (measured by crude birth rate, CBR) and cost of childbearing such as housing cost (measured by construction cost index, CCI) and opportunity cost (measured by the relative wage of the female to male, RW).

Table 3

ADL Tests for Threshold Co-integration Relationship*

	Indicator A		Indicator B	
	Coef	T-ratio	Coef	T-ratio
LNCBRt-1*It	-0.430	-4.702***	-0.280	-3.515***
LNCBRt-1*(1-It)	-1.491	-3.748***	-0.767	-5.751***
LNCCIt-1*It	-0.322	-2.555**	-0.255	-2.034**
LNCCIt-1*(1-It)	-2.095	-3.531***	-1.574	-2.563**
LNRWt-1*It	-0.506	-3.394***	-0.344	-2.729***
LNRWt-1*(1-It)	-5.693	-3.857***	-3.082	-4.456***
ΔLNCCIt	-2.144	-2.174**	-1.971	-2.013**
ΔLNRWt	-5.108	-4.882***	-5.429	-5.200***
ΔLNCBRt-1	-0.213	-3.156***	-0.270	-3.148***
ΔLNCCIt-1	0.991	0.984	0.830	0.827
ΔLNRWt-1	0.400	0.361	0.117	0.107
Constant	0.001	1.693*	0.001	1.511
Trend	0.732	1.723*	0.598	1.434
BO Statistics	44.021***		45.960***	
5% Critical Values	24.670		24.670	
1% Critical Values	30.090		30.090	
BMD Statistics	34.858***		44.211***	
5% Critical Values	18.660		18.660	
1% Critical Values	23.72		23.72	
Threshold value	0.115		0.076	
% of Threshold value	0.841		0.743	
AIC	177.461		175.765	
SBC	221.813		220.117	

*Y_{t-1}=LNCBRt-1,H_{t-1}=LNCCIt-1,R_t=LNRWt-1,ΔY_{t-1}=ΔLNCBRt-1,ΔH_{t-1}=ΔLNCCIt-1,ΔR_{t-1}=ΔLNRWt-1, ΔH_t=ΔLNCCIt, ΔR_t=ΔLNRWt. "***", "**", and "*" represents 1%, 5%, and 10% significance levels, respectively. The 1% and 5% critical values for BO and BMD statistics are obtain from Table 1 in Li and Lee (2010).

4.4. Long-run Relationship

The rejection of the null hypotheses of no co-integration relationship obtained from BO and BMD statistics in Table 3 validates the existence of the long-run relationship between crude birth rate (CBR) and cost of childbearing such as housing cost (measured by construction cost index, CCI) and opportunity cost (measured by relative wage of the female to male, RW). Note that the estimated coefficients of construction cost index (CCI) and relative wage of the female to male (RW) are statistically significant at the 1% significance level in both regimes of lower and upper threshold. This finding suggests that the adjustment process of fertility toward the long-run equilibrium is asymmetric. To verify the asymmetric effects of the construction cost index (CCI) and relative wage of the female to male (RW) on the crude birth rate (CBR), the asymmetric long-run relationship between crude birth rate (CBR) and cost of childbearing such as housing cost (measured by construction cost index, CCI) and opportunity cost (measured by the relative wage of the female to male, RW) was evaluated by the estimated coefficients (and their 95% confidence intervals) in equations [5]-[6]. Since the coefficients in equations [5]-[6] are nonlinear in turn, the exact standard error of these coefficients in equations [5]-[6] cannot be calculated directly. Therefore, the Krinsky and Robb's simulation technique with 20,000 replications was used to construct the 95% confidence intervals (Krinsky and Robb, 1991) for these coefficients in equations [5]-[6].

Table 4

Threshold Long-Run Relationship*

	Lower Threshold			Upper Threshold		
	Coef	95% Confidence		Coef	95% Confidence	
LNCCIt-1	-0.910	-2.634	-0.041	-2.051	-4.182	-0.500
LNRWt-1	-1.227	-3.207	-0.331	-4.016	-7.003	-2.099
Trend	2.135	-0.774	6.846	0.779	-0.269	2.036
Constant	0.004	-0.001	0.013	0.001	-0.0004	0.004

* H_{t-1}=LNCCIt-1,R_t=LNRWt-1. 95% confidence intervals were obtained using Krinsky and Robb's parametric bootstrapping technique with 20,000 replications (Krinsky and Robb, 1991). Bold fonts represent significance at 5% significant level.

In the case of regime of lower threshold indicated in Table 4, we found that a 1% increase of the construction cost index (CCI) will decrease by 0.910% (95% CI=[-2.634%, -0.041%]) the crude birth rate (CBR) in the long-run, and a 1% increase in relative wage of the female to male (RW) will decrease the crude birth rate (CBR) by 1.227% (95% CI=[-3.207%, -0.331%]) in the long-run. As for the case of the regime of higher threshold indicated in Table 4, the estimated results show a 1% increase in construction cost index (CCI) will lead to a 2.051% (95% CI=[-4.182%, -0.500%]) reduction in crude birth rate (CBR) in the long-run, and a 1% increase in relative wage of the female to male (RW) will decrease by 4.016% (95% CI=[-7.003%, -2.099%]) the crude birth rate (CBR) in the long-run. The impacts of construction cost index (CCI) and relative wage of the female to male (RW) on crude birth rate (CBR) were different between the regimes of lower threshold and upper threshold. In general, the construction cost index (CCI) and relative wage of the female to male (RW) impact the crude birth rate (CBR) in the regime of upper threshold more than that in regime of lower threshold.

5. Conclusions

Low fertility and high house prices are two serious issues in Taiwanese society. The former issue will accelerate population aging, and in turn there will be a loss of labor force, and a heavier burden of social security will be imposed on those who are in the labor market. The latter issue will deteriorate housing affordability. Therefore, the purpose of this study is to explore, for the first time, a link between fertility and housing cost in Taiwan using the ADL threshold co-integration model proposed by Li and Lee (2010).

Our empirical results based on BO and BMD statistics from the ADL threshold co-integration model supported the threshold co-integration relationship between fertility (measured by crude birth rate) and cost of childbearing such as housing cost (measured by construction cost index) and opportunity cost (measured by the relative wage of the female to male). The asymmetric adjustment process of fertility toward the long-run equilibrium was verified in that the impacts of housing cost and opportunity cost of childbearing on crude birth rate were different between the regimes of upper threshold and low threshold. In general, the effects of housing cost and opportunity cost on fertility in the regime of upper threshold are more significant than that in regime of lower threshold.

The housing cost is considered a major cost associated with childbearing (Chen, Chou, Lin, Chen, 2013; Hui, Zheng, Hu, 2012; Shuya and Shinichiro, 2012; Dettling and Kearney, 2011; Yi and Zhang, 2010; Simon and Tamura, 2009), and most Taiwanese will apply for the mortgage loan from banks when they purchase a house. It is the prevailing thought that the payment for the mortgage loan is the substitution of rent for a house (that could be considered the price of living space) in Taiwanese society. Our results echo the empirical findings from previous studies in developed countries that the childbearing decisions seems to be more sensitive to changes in the user cost of house, as well the existence of a negative correlation between the price of living space (as measured by rent per room) and fertility as indicated in Simon and Tamura (2009). Therefore, the housing price policy should not be managed only from the perspective of the equity of housing affordability but also from the perspective of how to maintain social security.

Finally, the childbearing decision could be traced back to the date for the conception decision, in order to delineate the relationship between fertility and the housing cost, future study could impose some explanatory variables that clarify economic conditions existing at the conception decision point (as opposed to the economic conditions in place at the time when the birth actually occurs) in a more sophisticated time series model.

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