9. ON THE RELATIONSHIP BETWEEN BUSINESS CYCLE AND FERTILITY RATE IN TAIWAN: EVIDENCE FROM THE NONLINEAR COINTEGRATION METHODOLOGY

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Abstract

This study employs, for the first time, the nonlinear ARDL cointegration methodology to examine the potentially asymmetric responses of fertility rate to business cycle after extensively controlling for prevalence of education, crude marriage and crude death rates in Taiwan over the period from 1950 to 2015. Our results suggest that there is an asymmetric effect of business cycles on total fertility rate. Both economic boom (in terms of an increase in real GDP per capita) and recession (in terms of a decrease in real GDP per capita) will decrease fertility rate. The effect of economic recession dominates that of economic boom. Policy implications generated from our results include the ideas that intervention designed to increase female fertility should put more emphasis on reducing the substitution effect of childbearing (such as the provision of care for children) during economic boom periods, while subsidies for childbearing and care for children that could sufficiently reduce the income effect of childbearing should be given during economic recession periods.

Keywords: low fertility; business cycle; NARDL; ARDL; asymmetry

JEL Classification: C32, I15, J11.

Introduction

Taiwan's fertility rate has declined over the past few decades. The total fertility rate (a measure of the average number of babies born to a woman over her lifetime) in Taiwan was lower than the population replacement level (two births per woman) in 1984 (Ministry of Interior, 2015). Since then, the total fertility rate continuously declined, to reach a low rate of

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below one birth per woman in 2010, and then rose marginally to one birth per woman during the period of 2011-2015 (Ministry of Interior, 2015). These vital statistics allow Taiwan to claim one of the lowest rates in the world, and thus, investigating determinants of fertility is an important research agenda in Taiwan (National Development Council, 2015).

Previous studies investigating determinants of fertility have emphasized the childbearing preference and cost of childbearing for women (Becker, 1991). The key factors associated with the childbearing preference change for women include family planning policies (Miller and Singer Babiarz, 2016) and education (Fabian *et al*., 2016). The important factors relating to the cost of childbearing for women consist of female employment status (Sobotka *et al*., 2011; Matysiak and Vignoli, 2008), and housing price (Chen, 2013; Hui *et al*., 2012; Yi and Zhang, 2010). Owing to the recent global financial crises occurring in 2007-2009, there have been a number of contributions investigating fertility fluctuations alongside business cycles. Some found that fertility rate is counter-cyclical with respect to business cycles (Aksoy, 2016; Ermisch, 1988; Butz and Ward, 1979), while most studies suggested that fertility is pro-cyclical with respect to business cycles (Bellido and Marcén, 2016; Cazzola *et al*., 2016; Jones and Schoonbroodt, 2016; Cherry and Wang, 2015; Comolli and Bernardi, 2015; Schneider, 2015; Currie and Schwandt, 2014; Percheski and Kimbro, 2014; Cherlin *et al*., 2013; Goldstein *et al*., 2013; Lanzieri, 2013;Neels *et al*., 2013; Sobotka *et al*., 2011; Őrsal and Goldstien, 2010). Only limited studies indicated a mixed or changing relationship between fertility rate and business cycles (Lagerborg, 2015; Hashimoto, and Kondo, 2012; Adsera and Menendez, 2011; Engelhard *et al*., 2004; Ahn and Mira, 2002; Mocan, 1990).

It is important to state that an ambiguous relationship between fertility and business cycles is consistent with the fact that the New Home Economic theory of fertility behavior developed by Becker (1991) and its extensions predicts an unclear relationship between fertility and business cycles (measured by the fluctuation in unemployment rate and other economic indicators). Economic recession (in terms of either an increase of unemployment rate or a decrease of parental income) will depress fertility due to the income effect (reflecting the nature of the normal goods consumption of raising children). Nevertheless, economic recession would encourage fertility because of the substitution effect (reflecting a conflict between the roles of mother and employee). In addition, economic recession also reduces the opportunity cost of childbirth (Butz and Ward, 1979), a condition possibly leading to an increase of fertility. It is crucial to note that one implicit assumption that prevails in theoretical and empirical studies on fertility (such as studies cited in the aforementioned paragraph) is that the impact of business cycles on fertility is symmetric. Nevertheless, one may expect that economic fluctuation may have an asymmetric effect on fertility. The effect of a positive economic shock on fertility may differ from the effect of a negative economic shock on fertility. Failure to accommodate for asymmetric fertility cycles in the model specification is likely to create an unclear relationship between fertility and business cycles.

In fact, the potential asymmetric response of various behaviors and its policy implications has long been focused on various domains of socioeconomic analyses such as suicide (Chang and Chen, 2016; Lin and Chen, 2018), crime (Mocan and Bali, 2010), and cigarette smoking (Harris and López-Valcárcel, 2008). Nevertheless, the research incorporating asymmetric fertility cycles in the determinants of fertility is limited in the literature. To the authors' best knowledge, Chen (2013), which deals with the possibility of an asymmetric response of birth rate to the fluctuation in wage income, could be the only published study that could partially reveal the asymmetric effects of business cycles on fertility. By estimating the autoregressive distributed lags threshold (ADL threshold) cointegration model, Chen (2013) identified the asymmetric effect of the female to male relative wage rate on birth rate.

Nevertheless, his results are restricted to the long-run relationship and fail to provide precautionary information in terms of the propagation mechanism of an economic shock across a period of time.

In order to establish an empirical model with a strong theoretical foundation that can simultaneously test for the existence of short- and long-run asymmetric effects of business cycles on fertility rate, we first apply the newly developed nonlinear autoregressive distributed lags (NARDL) model (first proposed by Shin *et al*., 2014, and then extended by Chang and Chen, 2016) to investigate the relationship between fertility and business cycles in Taiwan from 1950 to 2015 and then estimate the dynamic multipliers to capture the propagation mechanism of an economic shock across a period of time. There are several advantages in the specification of the NARDL model. First, it provides a dynamic error-correction specification that is able to estimate asymmetric responses of fertility rate to positive and negative fluctuations in GDP per capita (used to measure business cycles in this study). Second, the long-run cointegrating relationship between fertility and business cycles is decided by means of a bound test regardless of whether the series are integrated of order zero or one ($I(0)$ or $I(1)$). Third, the bound test remains reliable in a small sample size of time series data (Pesaran *et al*., 2001). Fourth, the asymmetric propagation mechanism of an economic shock on fertility across a period of time can easily be captured by the dynamic multipliers generated from the dynamic error-correction specification of the NARDL model (Chang and Chen, 2016).

This study makes several contributions beyond those of the existing research on the socio-economic determinants of fertility in two respects. First, although asymmetric cycles in socioeconomic indicators have been studied extensively in the fields of finance (Katrakilidis *et al*., 2012), macroeconomics (Shin *et al*., 2014), energy price (Greenwood-Nimmo, and Shin, 2013), housing price (Katrakilidis and Trachanas, 2012), suicide (Chang and Chen, 2016; Lin and Chen, 2018), crime (Mocan and Bali, 2010), and cigarette smoking (Harris and López-Valcárcel, 2008), this study employed the NARDL model to investigate the asymmetric responses of fertility to business cycles in Taiwan over the period of 1950-2015 for the first time, contributing to the literature on socio-economic determinants of fertility. Second, unlike the many prior studies examining factors influencing female fertility in which the responses of fertility to an unexpected economic shock across a period of time are not available, this study transformed total fertility rate and GDP per capita into cumulative positive and negative changes in total fertility rate and GDP per capita, which allowed us to estimate the impulses to an asymmetric innovation. Our NARDL model specification incorporating asymmetric fertility cycles will provide a more complete picture of the relationship between fertility and business cycles than have previous studies.

The rest of this study is organized as follows: Section 2 describes data used in this study, Section 3 presents the linear and nonlinear ARDL models, and Section 4 discusses the empirical results. Section 5 offers some policy implications and the conclusions of this study.

1. Data and Variables

Based on the New Home Economic theory of fertility behavior developed by Becker (1991) and its extensions, to formulate the asymmetric effect of business cycles on fertility, we need data for the female fertility rate, the preference for and opportunity cost of childbearing. The total fertility rate, defined as the average number of babies born to a woman over her lifetime, is used to measure the female fertility rate. As suggested by previous studies on the determinants of female fertility (Chen, 2013; Narayan and Peng, 2007; Narayan, 2006; Ahn and Mira, 2002), prevalence of education, marriage, and mortality rates could be used to measure the preference for childbearing, and macroeconomic indicators such as unemployment rate and real GDP per capita could serve as proxy variables to measure the opportunity cost of childbearing. Due to the restriction of historical data availability, the prevalence of education, marriage, and mortality rates are measured by the student-teacher ratio (calculated by the average number of students per teacher at all levels of schools), crude marriage rate (computed by the number of marriage couple per 1,000 people), and crude death rate (defined as the total number of deaths per year per 1,000 people), respectively. In addition, the real GDP per capita is chosen to measure the opportunity cost of childbearing because the historical unemployment data are not available. The whole sample period starts in 1950 and ends in 2015, resulting in a total of 66 annual observations.

The data for total fertility rate, crude marriage, and crude death rates were obtained from the historical database for the interior statistics administrated by the Ministry of Interior in Taiwan. The student-teacher ratio was obtained from the historical database for the educational statistics administrated by the Ministry of Education in Taiwan. In addition, Taiwanese historical real GDP per capita data from the periods of 1950-2010 were obtained from the Maddison Project database, and we recreated the real GDP per capita data from 2011 to 2015 using a compound growth formula ($GDP_t=GDP_{t-1}\times(1+$ economic grow rate$)$). The data for economic growth rate were obtained from the macroeconomic statistics databases administrated by the Directorate-General of Budget, Accounting and Statistics (DGBAS). The Maddison Project database is consistently maintained by a group of well-reputed academic researchers and covers the longest time period in the study of world historical data, and the way that we recreated the consistent real GDP per capita data has been used in the previous study (Chen, 2016; Bolt and van Zanden, 2014).

2. The Empirical Model

This study employs the multivariate NARDL model introduced by Chang and Chen (2006) to evaluate the asymmetric response of fertility rate to business cycles. This model is an extension of the bivariate NARDL model developed by Shin et al. (2014). In order to link the concept of asymmetric responses of fertility rates to business cycles, we first present the symmetric ARDL model developed by (Pesaran *et al*., 2001) as follows:

$$\Delta F_t = \mu + \rho F_{t-1} + \omega y_{t-1} + \theta x_{t-1} + \gamma z_{t-1} + \lambda w_{t-1} + \sum_{j=1}^{p-1}\alpha_j \Delta F_{t-j} + \sum_{j=0}^{q-1}\pi_j \Delta y_{t-j} + \sum_{j=0}^{r-1}\kappa_j \Delta x_{t-j} + \sum_{j=0}^{s-1}\phi_j \Delta z_{t-j} + \sum_{j=0}^{m-1}\varphi_j \Delta w_{t-j} + u_t \tag{1}$$

Equation (1) is the standard linear ARDL(*p,q,r,s,m*) cointegration model with five variables. u_t is an *iid* stochastic process. Δ is the difference operator. F_t, y_t, x_t, z_t, and w_t (t = 1,2, …, T) represents the total fertility rate, real GDP per capita, crude marriage rate, crude death rate, and education level, respectively. *p, q, r, s,* and *m* represent the optimal lags selected by the following lag selection procedures: we first use the Akaike Information Criterion (AIC) to obtain the lag lengths by estimating the ARDL specification of the long run relationship among F_t, y_t, x_t, z_t and w_t (namely,

$y_t = \lambda_0 + \sum_{j=1}^{p-1}\lambda_{1j}F_{t-j} + \sum_{j=0}^{q-1}\lambda_{2j}y_{t-j} + \sum_{j=0}^{r-1}\lambda_{3j}x_{t-j} + \sum_{j=0}^{s-1}\lambda_{4j}z_{t-j} + \sum_{j=0}^{s-1}\lambda_{5j}w_{t-j} + \varepsilon_t$), and then the goodness of fit for residuals u_t (given by the lag lengths from the ARDL specification) in equation (1) is examined by testing of residuals correlation, heteroskedasticity, and normality. The optimal lags were determined if there was no violation of the independence, homoscedasticity, and normality assumptions in residuals u_t. The maximal lag lengthen was set as four due to a small sample size in this study. The lag selection procedures and the diagnostics of the goodness of fit for equation (1) have been used in previous studies such as Chang and Chen (2016) and Narayan (2006). Once the optimal lags are determined, the existence of a stable long-run relationship can be tested by the modified *F*-test (denominated F_{PSS}) for the joint null hypothesis of no cointegration $\rho = \omega = \theta = \gamma = 0$ (Pesaran *et al.*, 2001). The relevant bound testing procedure suggested by (Pesaran *et al.*, 2001) consists of two critical bounds: the upper and lower bounds. If the value of the F_{PSS} statistics is higher than the upper critical bound, then the null is rejected; if it is lower than the lower critical bound, the null hypothesis cannot be rejected; and if it lies between the critical bounds, the test is inconclusive.

The ARDL model specification described in equation (1) implies symmetric adjustment in the long and the short-run and thus it is irrelevant when the relationship between the total fertility rate ($\mathbf{F_t} = [F_1, F_2, ..., F_T]'$) and its explanatory variables ($\mathbf{x_t} = [x_1, x_2, ..., x_T]'$, $\mathbf{y_t} = [y_1, y_2, ..., y_T]'$, $\mathbf{z_t} = [z_1, z_2, ..., z_T]'$, $\mathbf{w_t} = [w_1, w_2, ..., w_T]'$) is asymmetric. In order to model the asymmetric long-run and short-run relationship and the pattern of dynamic adjustment simultaneously in a coherent way, we now introduce the NARDL model developed by Shin et al. (2014). The vector of explanatory variables (written by $\mathbf{X}_t = [\mathbf{y_t}, \mathbf{x_t}, \mathbf{z_t}, \mathbf{w_t}]'$) is decomposed into positive and negative partial sums:

$$\mathbf{X_t} = \mathbf{X_0} + \mathbf{X_t^+} + \mathbf{X_t^-} \tag{2}$$

where:

$$\mathbf{X}_t^+ = \sum_{j=1}^{t}\Delta\mathbf{X}_{t-j}^+ = \sum_{j=1}^{t}\max(\Delta\mathbf{X}_t, 0) \quad \text{and} \quad \mathbf{X}_t^- = \sum_{j=1}^{t}\Delta\mathbf{X}_{t-j}^- = \sum_{j=1}^{t}\min(\Delta\mathbf{X}_t, 0) \tag{3}$$

Thus, the long-run equilibrium relationship can be given by

$$\mathbf{F_t} = \mathbf{X}_t^+\boldsymbol{\beta}^+ + \mathbf{X}_t^-\boldsymbol{\beta}^- + \mathbf{u}_t \tag{4}$$

where: $\boldsymbol{\beta}^+$ and $\boldsymbol{\beta}^-$ are the vectors of asymmetric long-run parameters associated with positive and negative changes in $\mathbf{X}_t$, respectively. Based on the definitions from equations (2)-(4), we can construct the NARDL(**p**,**q**) model as follows:

$$\Delta\mathbf{F}_t = \boldsymbol{\mu} + \mathbf{F}_{t-1}\boldsymbol{\rho} + \mathbf{x}_t^{+}\boldsymbol{\theta}^{+} + \mathbf{x}_t^{-}\boldsymbol{\theta}^{-} + \sum_{\mathbf{j=1}}^{\mathbf{p-1}}\Delta\mathbf{F}_{\mathbf{t-j}}\boldsymbol{\alpha}_{\mathbf{j}} + \sum_{\mathbf{j=0}}^{\mathbf{q-1}}(\Delta\mathbf{x}_{t-j}^{+}\boldsymbol{\Pi}_j^{+} + \Delta\mathbf{x}_{t-j}^{-}\boldsymbol{\Pi}_j^{-}) + \mathbf{u_t} \quad (5)$$

where: $\boldsymbol{\theta}^{+} = \left(-\boldsymbol{\rho}/\boldsymbol{\beta}^{+}\right)$ and $\boldsymbol{\theta}^{-} = \left(-\boldsymbol{\rho}/\boldsymbol{\beta}^{-}\right)$. $\boldsymbol{\Pi}_j^{+}$ and $\boldsymbol{\Pi}_j^{-}$ are the vectors of asymmetric short- run parameters associated with positive and negative changes in $\Delta\mathbf{x}_t$, respectively.

The empirical procedures to capture both the short- and long-run asymmetries in the transition mechanism in the NARDL model include four steps. First, we estimate (5) by using the standard OLS method. Since the NARDL model specification would increase the number of regressors and our sample size is relative small (66 observations), we intend to have a parsimonious specification in order to save some degrees of freedom. In addition, the inclusion of insignificant lags is likely to lead to inaccuracies in the NARDL estimation and may introduce noise into the dynamic multipliers (Chang and Chen, 2016). Therefore, the lag length in equation (5) was initially selected by the so-called *general-to-specific* approach (e.g., Greenwood-Nimmo and Shin, 2013; Shin *et al.*, 2014), and we checked the goodness of fit by verifying whether or not the residuals in equation (5) were consistent with the assumptions regarding residuals imposed in equation (5). Specifically, the preferred specification was selected by starting with *max* **q** = *max* **p**=1+**g** (**g**=0,1,2,….) and dropping all the insignificant regressors with a 5% unidirectional decision rule. **g** was determined based on whether or not the residuals in equation (5) were consistent with the assumptions of independence, homoscedasticity, normality, and functional forms imposed in equation (5). This lag selection process was used in Chang and Chen (2016). Second, we used the modified *F*-test (denominated F_{PSS}) to verify the asymmetric cointegrating relationship between total fertility rate ($\mathbf{F_t}$) and positive and negative partial sums of explanatory variables ($\mathbf{X}_{\mathbf{t}}^{+}$ and $\mathbf{X}_{\mathbf{t}}^{-}$). As with the symmetric ARDL model, the null hypothesis of no cointegration $\boldsymbol{\rho} = \boldsymbol{\theta}^{+} = \boldsymbol{\theta}^{-} = \mathbf{0}'$ can be tested using the F_{PSS} statistic. Third, we adopted a standard F test to test for long-run symmetry, and the relevant null hypothesis took the form $\boldsymbol{\beta}^{+} = \boldsymbol{\beta}^{-}$ (*i.e.*, $-\boldsymbol{\rho}/\boldsymbol{\theta}^{+} = -\boldsymbol{\rho}/\boldsymbol{\theta}^{-}$). As for short-run symmetry, we also applied a standard F test to test for the *additive* (weak-form) symmetric restriction in parameters given by the null hypothesis of $\sum_{\mathbf{j=0}}^{\mathbf{p-1}}\boldsymbol{\Pi}_{\mathbf{j}}^{+} = \sum_{\mathbf{j=0}}^{\mathbf{q-1}}\boldsymbol{\Pi}_{\mathbf{j}}^{-}$. Fourth, Given that asymmetry is justified either in the long run or in the short-run or in both, the asymmetric dynamic multiplier effects on $\mathbf{F_t}$ associated with unit changes in positive and negative partial sums of explanatory variables ($\mathbf{X}_{\mathbf{t}}^{+}$ and $\mathbf{X}_{\mathbf{t}}^{-}$) can be calculated from the coefficients of the NARDL model in equation (5). These positive and negative dynamic multipliers are written by:

$$\mathbf{m}_h^{+} = \sum_{i=0}^{h}\frac{\partial\mathbf{F_{t+i}}}{\partial\mathbf{X}_{\mathbf{t}}^{+}} \text{ and } \mathbf{m}_h^{-} = \sum_{i=0}^{h}\frac{\partial\mathbf{F_{t+i}}}{\partial\mathbf{X}_{\mathbf{t}}^{-}} \text{ with } h=0,1,2,\ldots.. \quad (6)$$

where: $\lim_{h\to\infty}\mathbf{m}_h^{+} \to \boldsymbol{\beta}^{+}$, $\lim_{h\to\infty}\mathbf{m}_h^{-} \to \boldsymbol{\beta}^{-}$, and the aggregate effects of the positive and negative dynamic multipliers is given by the sum of the positive and negative dynamic multipliers (*i.e*, $\mathbf{m}_h^+ + \mathbf{m}_h^-$). The plots of equation (6) allow us to track the path and time interval needed to form a new long-run stead-state from an initial equilibrium after an unexpected shock to an explanatory variable.

3.Results

3.1. Descriptive Statistics

Table 1 displays the descriptive statistics for all variables used in this study from 1950 to 2015. The total fertility rate rates ranged from 0.895 to 7.040, and the average number of babies born to a woman over her lifetime was around three during our study period. Real GDP per capita ranged from GK$916 to GK$27,363, and its mean value was approximately GK$9,250. The means of crude marriage and crude death rates were about 7.70 couples and 6.00 deaths per 1,000 people, respectively. The mean of the student-teacher ratio at all levels was 27.57, meaning that in general, each teacher taught approximately 28 students over the period of 1950-2015. To present these data more clearly, we display the time evolution of all variables used in this study in Figures 1 (a)-(d). As indicated in Figures 1(a) and 1(b), the total fertility rate was negatively associated with the real GDP per capita, suggesting that total fertility is mostly likely to be counter-cyclical with respect to the business cycle. In addition, a negative relationship between total fertility rate and crude death rate was observed in Figure 1(a) and 1(c). Figure 1(a) and 1(d) indicate a positive linkage between prevalence of education and total fertility, since a higher student-teacher ratio represents a lower prevalence of education. Nevertheless, Figures 1(a) and 1(e) suggested an unclear relationship between total fertility rate and crude marriage rate. Finally, as shown in Figures 1(b)-(e), the time plots of our explanatory variables suggested that real GDP per capita was most likely to be correlated with prevalence of education, crude death, and crude marriage rates. As a result, prevalence of education, crude death, and crude marriage rates may serve as possible confounders that should be controlled for when we investigate the relationship between fertility and business cycles.

Table 1

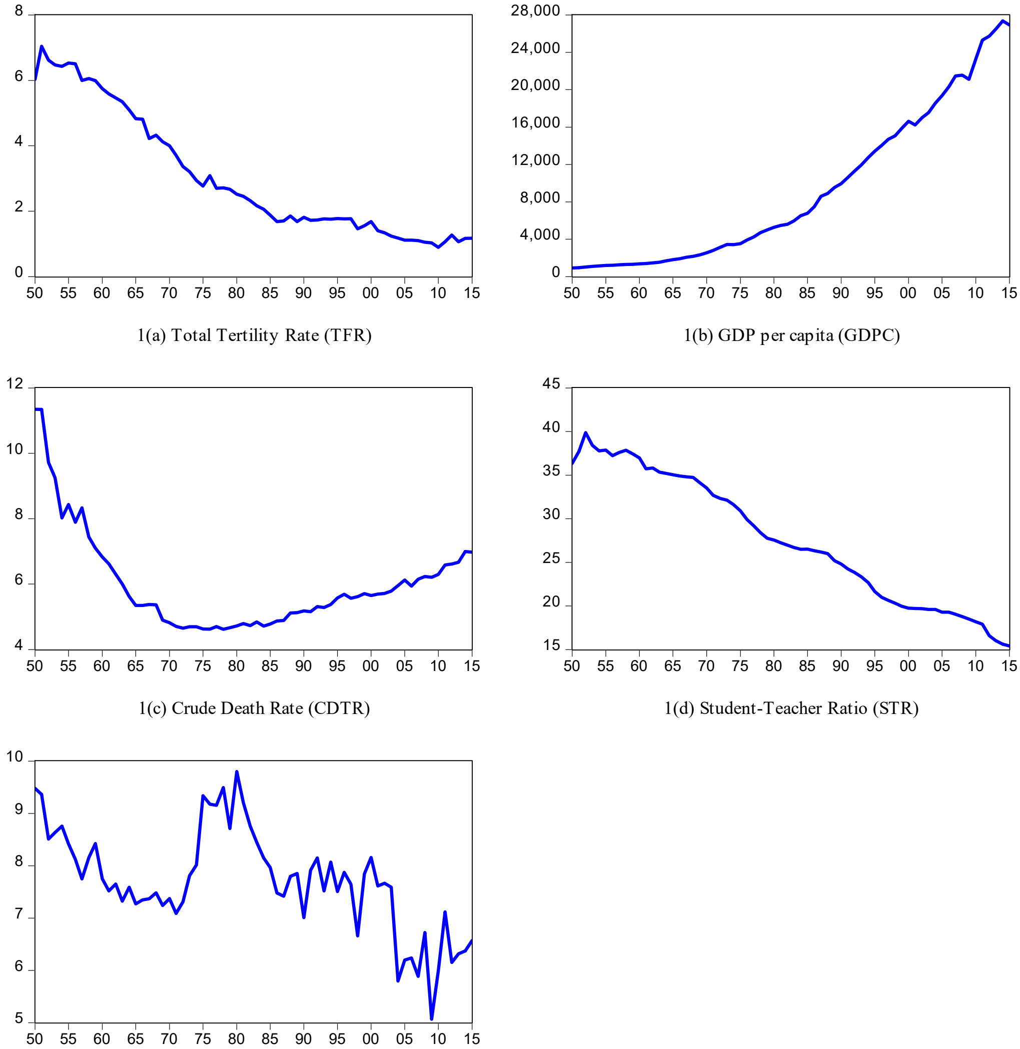
Descriptive Statistics

Variables	Mean	Median	SD	Min	Max
TFR (Total Fertility Rate)	3.040	2.245	1.914	0.895	7.040
GDPC (GDP per capita)	9249.944	5784.540	8255.098	915.773	27363.07
CMR (Crude Marriage Rate)	7.697	7.658	0.990	5.065	9.800
CDR (Crude Death Rate)	6.000	5.618	1.498	4.613	11.349
STR (Student-Teacher Ratio)	27.568	26.831	7.369	15.391	39.868

Notes: SD represents standard deviation. Total fertility is the average number of children that would be born to a woman over her lifetime. Crude marriage and crude death rates are defined as the number of married couples per 1,000 people, and the total number of deaths per year per 1,000 people, respectively. Student-Teacher ratio is the average number of students per teacher at all levels of schools.

Figure 1

Time Plots for Variables Used in this Study



1(a) Total Tertility Rate (TFR)

1(b) GDP per capita (GDPC)

1(c) Crude Death Rate (CDTR)

1(d) Student-Teacher Ratio (STR)

1(e) Crude Marriage Rate (CMR)

3.2. Unit Root Tests

Table 2 presents the results of the conventional ADF and structural break unit test proposed by Perron (1997). 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 all variables used in this study, the total fertility rate, real GDP per capita, crude death rate, and student-teacher ratio were confirmed to be integrated of order one (I(1)) series, and crude marriage rate was suggested to be integrated of order zero (I(0)). It is worth addressing that the symmetric ARDL and the NARDL cointegration models do not require the restrictive assumption that all series are integrated of the same order in order to proceed with the further cointegration analyses. Specifically, the examined series are either integrated of order one (I(1)) or zero (I(0)) and can be used for the cointegration analyses under the symmetric ARDL and the NARDL cointegration models. Therefore, our unit root tests suggest the validity of using the ARDL type of cointegration model to investigate the relationship between fertility rate and business cycles.

Table 2

Unit Root Tests

Variables	ADF Unit Root		Perron Unit Root		Order
	Level	1st Differences	Level	1st Differences	
ln(*TFR*)	-2.293	-10.515**	-2.980	-11.917**	I(1)
ln(*GDPC*)	0.272	-5.922**	-3.026	-7.220**	I(1)
ln(*CMR*)	-3.489*	-8.792**	-6.044*	-12.277**	I(0)
ln(*CDR*)	-2.901	-10.915**	-4.995	-12.901**	I(1)
ln(*STR*)	-1.301	-6.246**	-3.335	-6.821**	I(1)

Notes: De-trended series were used to test the unit root property. The optimal lag structure of the unit root tests was chosen based on the Schwarz Information Criterion. "**" and "*" denote rejection of the null hypothesis at 1 and 5%, significance levels, respectively.

3.3. ARDL Co-integration Tests

Since we confirmed the order of integration of the variables used in this study, we were then able to proceed and initially test for symmetric and asymmetric cointegrating relationships between total fertility rate and four socio-economic determinants of fertility (namely, real GDP per capita, crude marriage rate, crude death rate, and prevalence of education). Table 3 presents the symmetric and asymmetric ARDL cointegration test results. As shown in Table 3, both the symmetric and asymmetric ARDL specification are satisfied with the assumptions of goodness of fit (such as independence, homogeneity, normality, and functional form) in the residuals. Besides, the F_{PSS} statistics used to test for the null hypothesis of no cointegration against symmetric cointegration and for the null hypothesis of no cointegration against asymmetric cointegration are 6.159 and 7.785, respectively. The upper and lower bounds of critical values for the symmetric cointegration were obtained from Pesaran *et al.* (2001) by setting the number of explanatory variables to be four (k=4). As for the upper and lower bounds of critical values for the asymmetric cointegration, we adopted a conservative approach to the choice of critical values for the F_{PSS} statistics by employing $k = 1$ in testing for the null (*i.e.*, a higher critical value). This approach to choose the upper and lower bounds of critical values is recommended by Shin et al. (2014). Note that the empirical values of the F_{PSS} statistics generated by both the symmetric and asymmetric ARDL (*i.e.*, NARDL) are higher than the upper bound of critical values at the 5% or better significance level, and hence, both symmetric and asymmetric cointegration are strongly confirmed. In order to select the best model specification in this study, we followed the model selection procedure used in Yu *et al.* (2013). The model generating the smaller values of both Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) was chosen for our final model specification. From the empirical values of the AIC and BIC reported in Table 3, both AIC and BIC values obtained from the NARDL model are lower than those generated from the ARDL model. Therefore, our empirical analyses for the effect of business cycles on fertility are based on the results obtained from the NARDL model.

Table 3

Cointegration Tests

		ARDL			NARDL	
	Statistics [*p*-value]	5% I(0)/ I(1)	1% I(0)/ I(1)	Statistics [*p*-value]	95% I(0)/ I(1)	99% I(0)/ I(1)
F_{pss}	6.159**	2.86/4.01	3.74/5.06	7.785*	4.94/5.73	6.84/7.84
SC	1.305 [0.28]			1.401 [0.26]		
HET	1.874 [0.10]			0.606 [0.86]		
BJ	0.493 [0.78]			0.136 [0.93]		
FF	1.339 [0.25]			1.591 [0.21]		
AIC	-2.537			-3.123		
BIC	-2.303			-2.583		

Notes: *SC*, *HET*, *BJ*, and *FF* denote LM statistics for the tests of residuals correlation, heteroskedasticity, normality, and functional form (misspecification). F_{PSS} denotes the Pesaran *et al*. (2001) *F* statistics testing the joint null hypotheses H_0: $\rho=\theta==0$, and H_0: $\rho=\theta^+=\theta^-=0$ for the ARDL and NARDL cointegration, respectively. These values can be found in Pesaran *et al.* (2001). "**" and "*" denote rejection of the null hypothesis of no cointegration at the 1 and 5% significance levels, respectively.

3.4. NARDL Estimation Results

Table 4 reports detailed estimation results for the NARDL model. According to the results presented in Table 4, the F statistics are able to firmly reject the null hypothesis of joint long-run symmetry (*i.e.*, H_0: $\boldsymbol{\beta}^+=\boldsymbol{\beta}^-$) and joint short-run symmetry (*i.e.*, H_0: $\sum_{\mathbf{j=0}}^{\mathbf{p-1}}\boldsymbol{\Pi}_{\mathbf{j}}^{+}=\sum_{\mathbf{j=0}}^{\mathbf{q-1}}\boldsymbol{\Pi}_{\mathbf{j}}^{-}$). For the individual symmetry tests (i.e., H_0: $\beta_j^+ = \beta_j^-$ and H_0: $\sum\Pi_j^+=\sum\Pi_j^-$), the asymmetric responses of total fertility rate to business cycles and crude death rate are proved in the long-run but only the asymmetric relationship between total fertility rate and crude marriage rate is justified in the short-run.

Table 4

NARDL estimation results

Variables	Coefficient	*t* Statistics
Constant	0.852	3.26**
$ln(TFR)_{t-1}$	-0.364	-2.85**
$ln(GDPC)_{t-1}^{+}$	-0.327	-2.38*
$ln(GDPC)_{t-1}^{-}$	5.842	3.32**
$ln(CMR)_{t-1}^{+}$	0.765	4.28**
$ln(CMR)_{t-1}^{-}$	0.388	3.08**
$ln(CDR)_{t-1}^{+}$	1.357	4.00**
$ln(CDR)_{t-1}^{-}$	0.104	1.23

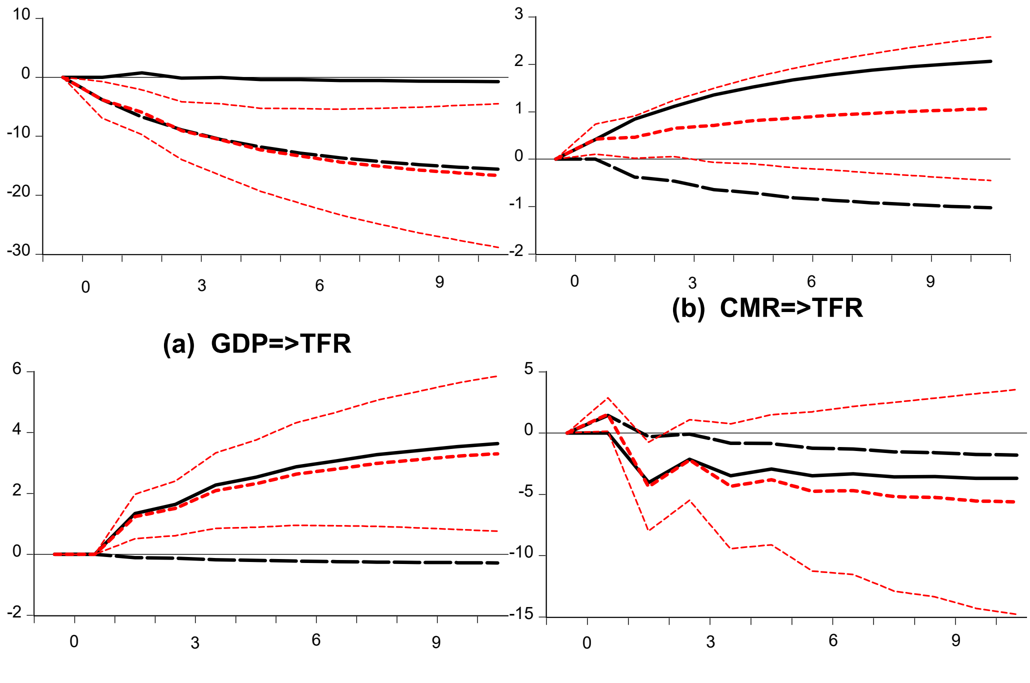
Variables	Coefficient	*t* Statistics
$ln(STR)^{+}_{t-1}$	-1.289	-1.08
$ln(STR)^{-}_{t-1}$	0.587	1.22
$\Delta ln(TFR)_{t-1}$	-0.409	-3.53**
$\Delta ln(GDPC)^{+}_{t-1}$	1.099	4.53**
$\Delta ln(GDPC)^{-}_{t}$	3.879	2.46**
$\Delta ln(CMR)^{+}_{t}$	0.415	2.63**
$\Delta ln(STR)^{+}_{t-1}$	-2.792	-2.70**
$\Delta ln(STR)^{-}_{t}$	-1.458	-2.11*
Long-run Symmetric tests	F Statistics	*p* value
H0: $\beta^{+}_{GDP} = \beta^{-}_{GDP}$	6.952	0.01*
H0: $\beta^{+}_{CMR} = \beta^{-}_{CMR}$	1.823	0.18
H0: $\beta^{+}_{CDR} = \beta^{-}_{CDR}$	5.226	0.03*
H0: $\beta^{+}_{STR} = \beta^{-}_{STR}$	1.355	0.25
Joint Test: H0: $\boldsymbol{\beta}^{+}_{j} = \boldsymbol{\beta}^{-}_{j}$ *j*=1,2,3,4	4.202	<0.01**
Short-run Symmetric tests	F Statistics	*p* value
H0: $\sum \Pi^{+}_{GDP} = \sum \Pi^{-}_{GDP}$	2.975	0.09
H0: $\sum \Pi^{+}_{CMR} = \sum \Pi^{-}_{CMR}$	6.905	0.01*
H0: $\sum \Pi^{+}_{CDR} = \sum \Pi^{-}_{CDR}$	--------	--------
H0: $\sum \Pi^{+}_{STR} = \sum \Pi^{-}_{STR}$	1.425	0.24
Joint Test: H0: $\sum \boldsymbol{\Pi}^{+}_{j} = \sum \boldsymbol{\Pi}^{-}_{j}$ *j*=1,2,3,4	3.415	0.02*
Asymmetric long-run coefficients	Coefficient	*t* Statistics
$ln(GDPC)^{+}_{t-1}$	-0.898	-5.71**
$ln(GDPC)^{-}_{t-1}$	16.037	2.50*
$ln(CMR)^{+}_{t-1}$	2.101	2.13*
$ln(CMR)^{-}_{t-1}$	1.066	2.24*
$ln(CDR)^{+}_{t-1}$	3.724	2.52*
$ln(CDR)^{-}_{t-1}$	0.285	1.17
$ln(STR)^{+}_{t-1}$	-3.539	-0.99
$ln(STR)^{-}_{t-1}$	1.6111	0.93

Notes: Δ is the first difference operator. “**” and “**” denote significance at the 1 and 5%, levels, respectively.

The estimated asymmetric long-run coefficients for real GDP per capita (*i.e.*, β^{+}_{GDP} and β^{-}_{GDP}) are all significantly positively at the 5% (or better) significance level. Specifically, an increase in real GDP per capita by 1% will decrease total fertility rate by approximately 0.90%. However, a decrease in real GDP per capita by 1% will decrease total fertility rate by approximately 16.04%. In other words, the negative change of real GDP per capita ultimately has a considerably more significant effect on total fertility rate than the positive one. The estimated asymmetric long-run coefficient for negative change in crude death rate (β^{-}_{CDR}) is not significant, but the estimated asymmetric long-run coefficient for positive change in crude death rate (β^{+}_{CDR}) is significantly positive at the 5% significance level. Particularly, a positive change in the crude death rate (β^{+}_{CDR}) will increase total fertility rate by 3.72%. We will skip any interpretation of the estimated asymmetric long-run coefficients for the changes in crude marriage rate and prevalence of education because we failed to identify asymmetric responses of total fertility rate to crude marriage rate and student-teacher ratio.

Figure 2

Dynamic Multipliers



(a) GDP=>TFR **(b) CMR=>TFR**

(c) CDR=>TFR **(d) STR=>TFR**

Note: Black-thick and black-dot lines represent positive and negative dynamic multipliers, respectively. Red-dot lines represent aggregate effects of positive and negative dynamic multipliers and their 95% confidence intervals.

In order to gauge the asymmetric effect of our measures of the socio-economic determinants of fertility (namely, real GDP per capita, crude marriage rate, crude death rate, and prevalence of education on the total fertility rate) we performed analyses of the dynamic relationships between total fertility rate and these socio-economic determinants by computing the dynamic multipliers of the NARDL model, as presented in Table 4. Figure 2 presents the dynamic multipliers for up to 10 years, from which we can trace the evolution of the total fertility rate following positive and negative changes in real GDP per capita, crude marriage rate, crude death rate, and prevalence of education. In this way, the asymmetric adjustment path and the duration of the disequilibrium due to an unexpected shock can be identified in a coherent manner. Several results obtained from Figure 2 merit discussion, and are addressed as follows:

First, as indicated in Figures 2(a), we found that both positive and negative shocks in real GDP per capita in the short run are transmitted with negative impacts on total fertility rate. However, the negative shock in real GDP per capita in the short run is transmitted with a higher intensity than the positive one. Also, the aggregate long-run effect of a decrease in real GDP per capita on total fertility rate, described by the asymmetry line, is significantly larger than that of an increase, and the equilibrium adjustment is achieved over ten years. These results reveal that the total fertility rate, in general, is pro-cyclical with respect to business cycles, and are in line with previous studies showing that fertility is pro-cyclical with respect to business cycles (Bellido and Marcén, 2016; Cazzola *et al*., 2016; Jones and Schoonbroodt, 2016; Cherry and Wang, 2015; Comolli and Bernardi, 2015; Schneider, 2015; Currie and Schwandt, 2014; Percheski and Kimbro, 2014; Cherlin *et al*., 2013; Goldstein *et al*., 2013; Lanzieri, 2013; Neels *et al*., 2013; Sobotka *et al*., 2011; Őrsal and Goldstien, 2010). Nevertheless, the asymmetrically negative response of total fertility rate to a positive change of real GDP per capita in the short-run is also consistent with the counter-cyclical pattern in total fertility rate found in several previous studies (Aksoy, 2016; Ermisch, 1988; Butz and Ward, 1979). The counter-cyclical pattern in total fertility rate during economic boom periods (in terms of a positive shock in real GDP per capita) and the pro-cyclical pattern in total fertility rate during economic recession periods (in terms of a negative shock in real GDP per capita) reconcile a mixed or changing cyclical pattern in female fertility rate (Lagerborg, 2015; Hashimoto, and Kondo, 2012; Adsera and Menendez, 2011; Engelhard *et al*., 2004; Ahn and Mira, 2002; Mocan, 1990).

Second, Chen (2013) investigated the asymmetric relationship between fertility and its determinants. The ADL threshold cointegration model used in his research fails to distinguish the asymmetrical responses of fertility rate to positive changes of determinants from those to positive changes of determinants. In addition, Chen's study did not provide any information concerning the dynamic adjustment towards a new long-run equilibrium after an unexpected shock. The results obtained from the NARDL used in this study make a contribution beyond those of previous studies regarding the relationship between business cycles and fertility rates. Third, as shown in Figure 2(b), we find that the positive shock of crude marriage rate in the short run leads to a higher total fertility rate, but the negative shock of crude marriage rate in the short run results in a lower total fertility rate. The aggregate long-run effect of crude marriage rate on total fertility rate depicted by the asymmetry line suggests that a change in crude marriage rate will increase total fertility rate, and the adjustment towards the equilibrium fertility rate, in terms of significance of aggregate effect, is achieved within two years. Fourth, Figure 2(c) demonstrates that a positive shock of crude death rate in the short run increases total fertility rate, but a negative shock of crude death rate in the short run decreases total fertility rate. The aggregate long-run effect of crude death rate on total fertility rate indicated by the asymmetry line demonstrates that a change in crude death rate will increase total fertility rate, and the adjustment towards the equilibrium fertility rate is achieved over ten years. Finally, a change of prevalence of education in the short-run did not generate any significant results in the plot of the dynamic multiplier. This result partially reflects the failure to identify an asymmetric response of total fertility rate to prevalence of education in Table 4.

4. Conclusion

Due to the recent global economic crises, the investigation of the relationship between fertility rate and business cycles has become an active field in demographic economics. This study enriches the literature on the relationship between fertility rate and business cycles by detecting the asymmetric response of total fertility rate to business cycles in Taiwan over the period from 1950 to 2015, using the novel NARDL model developed by Shin *et al.* (2014) for the first time. Taiwan was selected as the target of this study because Taiwan is one of the lowest-low fertility countries (National Development Council, 2014), and its low fertility has not only decreased the future supply of manpower but has also accelerated population aging. It follows that those who are in the labor market will bear a heavier burden of social security in the future, a condition generating a deterioration effect on Taiwan's economy.

The evidence from our NARDL model suggests that there are asymmetric effects of business cycles on total fertility rate. Both economic boom (in terms of an increase in real GDP per capita) and recession (in terms of a decrease in real GDP per capita) will decrease the fertility rate, but the effect of economic recession dominates that of economic boom. Our results are consistent with the prediction from the New Home Economic theory of fertility behavior developed by Becker (1991) and its extensions. The asymmetrically negative response of total fertility rate to the positive change of real GDP per capita reflects the fact that the substitution effect (namely, role conflict between mother and employee) dominates the income effect of childbearing (the nature of normal goods consumption for childbearing). Contrarily, the asymmetrically negative response of total fertility rate to the negative change of real GDP per capita reflects the fact that the substitution effect is dominated by the income effect of childbearing during the recession. Therefore, policy implications generated from our results include the ideas that intervention designed to increase female fertility should put more emphasis on the reduction of the substitution effect of childbearing (such as the provision of care for children) during economic boom periods, while subsidies for childbearing and care for children that could significantly reduce the income effect of childbearing should be provided during economic recession periods. We are aware that, in order to prevent the ecological fallacy of research, the inference of this study cannot be generalized to predict individual fertility behavior. Such a limitation of this study is inherent in is its ecological (time series) type of analysis. We must rely on future longitudinal panel type analyses using individual behavior data to overcome the limitation of this study.

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