Threshold effects of inflation on economic growth: Evidence from dynamic panel threshold regression analysis for 18 developed economies

Jenq Fei Chu[*], Siok Kun Sek[*], Mohd Tahir Ismail[*]

[*]*School of Mathematical Sciences, Universiti Sains Malaysia, Malaysia*

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Corresponding author:
jenqchu@gmail.com

Abstract

Inflation and growth nexus still a main focus in many studies as the existence of trade-off issue in inflation-growth relationship. The objective of this study is to estimate inflation threshold and its impact on inflation-growth relationship. This panel data study involves 18 developed countries over the period 1980–2016 with Consumer price index (CPI) and Gross domestic product (GDP) as variables associated with other determinants such as producer price, exchange rate, trade-openness, interest rate and population growth rate. Dynamic Panel Threshold Regression (DPTR) model that suggested by Kremer et al. (2013) is employed to estimate the threshold of inflation and its effects on economic growth. Our study extended the non-dynamic panel threshold model of Hansen (1999). Our results confirmed that the targeted inflation rate 2% by many central banks is a wise decision if compare to 4% as the impact of inflation on growth in lower inflation regimes is positive and statistically significant at the 5% level. For higher inflation regime, we estimate that inflation rates exceeding 1.44% are associated with lower economic growth, inflation and growth is negatively correlated and statistically significant at 1%. Trade-off relationship only exists at lower regime. By using GMM and Pooled OLS estimation, DPTR model results are proven robust where there is a U-shaped exist.

Keywords: *inflation, growth, developed economies, dynamic threshold regression*

Introduction

Inflation and output growth are the main concern of policymaker as both indicators may reflect the economic condition of an economy. As the main policy targets are to achieve low inflation and high steady growth, the relationship between inflation-growth becomes the attraction of research. Apart from policy implications, the study on inflation-growth is also important as price stability is the main reason or factor that may determine the economic stability. The inflationary pressure and changes in price may transmit into different economic channels and implications.

Although the inflation-growth relationship has long been studied, there are no conclusive findings both theoretically and empirically. The first theory that explained the relationship is the Phillips curve. Historically, Phillips curve with the aid of AD-AS (aggregate demand-aggregate supply) model is able to illustrate the relationship between inflation and output growth in details. AD-AS model explains the positive/negative relationship between inflation and unemployment (output growth). Positive relationship if the unemployment rate rises, so is inflation or vice versa. Conversely, the trade-off is an inverse relationship where a little more unemployment meant a little less inflation or vice versa. On the other hand, stagflation phenomena where, both inflation and unemployment are alarmingly high does not adequate by the Phillips curve (Phillips, 1958).

Due to the failure of the Phillips curve to explain the stagflation condition, there are arguments and disagreements among economists and researchers on the relationship and this topic is still open for debates. Empirical studies also reported contradict results. The results might differ using different estimation approaches and data (different years or countries). As earlier studies applied the linear modelling approaches to estimate the relationship, the linear assumption might not provide a good estimate if the nonlinearity exists. Nonlinearity might due to threshold effect/ structural break. Also, due to country specific characteristics, the relationship might vary using data of different groups of economies. Taking into account of these issues, this study seeks to fill the gap by applying the panel dynamic threshold modelling approach developed by Kremer et al. (2013) to estimate the inflation-growth relationship. Our main objective is to detect the threshold effect of inflation due to changes in the economic structure, and investigate how the threshold effect can affect the inflation-growth relationship. We report the partial results focused in 18 developed countries.

The rest of the paper is organized as follows: Section 2 is the relevant literature reviews. Section 3 highlights the methodology and data used. Section 4 presents the empirical results and discussion. Section 5 provides summary and concluding remarks.

1. Literature Review

According to Akinsola et al. (2017), inflation defined as a general continuous increase in prices of goods and services and fall in the purchasing value of money over time. Preliminary work related to inflation was undertaken by Fisher (1925) where the correlation between the changes in the price level and changes in the volume of employment is studied and strong relationship between the changes is found. In the year of 1954, Phillips estimated the relationship between the unemployment rate and changes in money wage. He has related the changes in income and output to the changes in the price level, namely Phillips curve. The study of Phillips (1958) has discovered the trade-off between inflation and unemployment levels.

However, when Phillips curve does not adequate stagflation phenomena anymore, the studies of relationship between inflation and growth are ultimately grouped into 4 types: (i) Inflation has no consequence on growth (Wai, 1959; Sidrauski, 1967); (ii) Inflation to have a positive effect on long-run growth which caused by money as a substitute for capital (Tobin, 1965; Mundell, 1965); (iii) Inflation has a negative effect on long-run growth due to the character of money, which is an add-on to capital (Stockman, 1981; Feldstein, 1982; Fischer, 1983); and (iv) Inflation has a negative effect on long-run growth, if certain threshold level of inflation rate is achieved (Sarel, 1996; Khan and Senhadji, 2001).

Until today, although inflation and growth relation either theoretically or empirically has been studied broadly, nevertheless it remains inconclusive due to different country background, employment of different proxy variables and methodologies in measuring (Gokal and Hanif, 2004). Some might even deny the existence of the relationship (Paul et al., 1997). Great inflation may affect the economy severely nevertheless there are some economists indicate that moderate inflation also affect economic growth in the long run (Temple, 2000).

As mentioned by Friedman (1977), Fischer and Modigliani (1978) that inflation is harmful to growth when it is too high. Thus, what is the precise inflation rate that suits every economy? At what level of inflation is putting economic growth at risk? According to Altig (2003), there is no right inflation rate. Banks may go through trial and error within the acceptable and suggested range of inflation rate from 2.5 percent to 3.5 percent. Thereafter, with the trial and error and using obtained data and theories, researchers can only conduct the empirical observations and suggest a good reason to support or argue for the targeted inflation rate.

Most of the empirical studies have confirmed the negative non-linear impact of inflation on growth. Moreover, Sarel (1996), Ghosh and Philips (1998), Bruno and Easterly (1998), Khan and Senhadji (2001), Gillman and Kejak (2005) and later confirmed by Kremer (2013)

followed by Vinayagathasan (2013) and Ndoricimpa et.al. (2016) have proven that the negative non-linear impact on growth is mainly happening when it is beyond a certain threshold level. Before Kremer, it is important to note that most of the panel studies in this area use either the non-dynamic (static) panel threshold regression of Hansen (1999) or non-dynamic Panel Smooth Transition Regression (PSTR) of Gonzalez et al. (2005).

Bick (2010) applied non-dynamic (static) panel threshold regression that propounded by Hansen (1999) on a balanced panel data from 40 developing countries. He managed to find a threshold inflation of 19.16% with no regime intercepts and 12.03% by allowing regime intercepts. Their study included the regime intercept which manages to unfold the effects of the threshold. More recent studies by Ibarra and Trupkin (2011), using Panel Smooth Transition Regression (PSTR) that propounded by Gonzalez et al. (2005) obtain a threshold inflation of 4.1% and 19.1% for industrial and non-industrial countries respectively. Same results share by Seleteng et al. (2013), also using PSTR on the Southern African Development Community (SADC) region. Their threshold inflation is at 18.9%. Both Ibarra and Trupkin (2011) and Seleteng et al. (2013) have the impact of inflation is negative on growth in both inflation regimes, but only statistically significant when inflation is above the threshold (high inflation-regime).

Kremer et al. (2013) indicate that the existing studies using panel data on the threshold effects of inflation on growth might have some limitations. Since initial income played as an important variable in growth models, but it is normally being excluded among the control variables. Sometimes, even when initial income is included, the endogeneity problem occurred and eventually causing it is not taken into account as in Khan and Senhadji, (2001), Drukker et al. (2005), Bick (2010) and Seleteng et al. (2013). As a result, it might be misleading in the threshold estimation. Kremer et al. (2013) therefore propose a methodology, namely Dynamic Panel Threshold Regression (DPTR), which improve and overcome some problems building on Hansen (1999), Caner and Hansen (2004).

According to Law and Singh (2014), the economic growth model is a dynamic process in nature. Hence, using a dynamic panel method is more applicable rather than a static threshold specification such as Hansen (1999). Despite the fact that the cross-section threshold analysis techniques proposed by Hansen (2000), Caner and Hansen (2004) are able to deal with the dynamic issue, it is rather suitable to employ panel data threshold analysis. In short, dynamic panel method manages to reveal more information and multicollinearity is able to be reduced. It also manages to control for the cross country heterogeneity.

Kremer's findings reveal a threshold inflation of 2.53% for industrial countries and 17.22% for nonindustrial countries. The relationship is significantly positive below the threshold and significantly negative above the threshold for the industrial countries. As for non-industrial

countries, the relationship is negative in both regimes, but statistically significant only above the threshold. Subsequently, Vinayagathasan (2013) and Ndoricimpa et.al. (2016) study also accords with Kremers' results. Vinayagathasan (2013) has 32 Asian countries from year 1980 to 2009 tested with Kremer's Dynamic Panel threshold model. A threshold of 5.43% was determined. Ndoricimpa et.al. (2016) have selected certain African regional economic communities with different data until the year 2011. Different thresholds are obtained based on different region. Both empirically proven that beneath the threshold rate, no significant effect found on growth while, exceeding the threshold rate causes a negative impact on growth.

Concisely, this study has extended the non-dynamic panel threshold of Hansen (1999), cross-sectional threshold model of Hansen (2000) and Caner and Hansen (2004) by adopting the dynamic panel threshold proposed by Kremer et al. (2013). The impact of inflation on growth is positive before threshold and negatively correlated after threshold. Robustness checked by GMM and Pooled OLS.

2. Methodology and Data

Firstly, data is drawn from Thomson Reuters Datastream Professional, World Development Indicator (WDI) database and International Monetary Fund (IMF) by covering the annual data of year 1980 until 2016 (5-year average) for the 18 developed countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Netherlands, New Zealand, Spain, Sweden, United Kingdom and United State of America. According to previous studies, by using a five-year average of data has given an advantage where business cycle fluctuations can be smoothed out and therefore the medium and long-term relationship between inflation and growth are highlighted (Khan & Senhadji, 2001; Drukker et al., 2005; Ibarra Trupkin, 2011).

Table 1 is the list and definition of variables that being used to test the inflation threshold effect on economic growth.

Table 1. List and definition of variables

lgdp	Five-year average of annual growth rate of log Gross Domestic Product (%) *lgdp=[logGDP(t)-logGDP(t-5)]x100*
π	Five-year average of the annual percentage change in log CPI index (%) π *=[logCPI(t)-logCPI(t-5)]x100*
initial	Five-year average of one period-lagged log Gross Domestic Product (US$) *Initial=lgdp(t-1)*
lppi	Five-year average of log production price (index)
lex	Five-year of log average exchange rate (US$)
lto	Five-year average of log of trade openness (ratio)
ir	Five-year average of central bank interest rate (%)
pop	Five-year average of annual population growth rate (%)

DPTR propounded by Kremer et al. (2013) is implemented in order to estimate the threshold of inflation and its impact on growth within these 18 developed economies. The model is written as follows:

$$y_{it} = \mu_i + \beta_1 q_{it} I(q_{it} \le \gamma) + \delta_1 q_{it} I(q_{it} \le \gamma) + \beta_2 q_{it} I(q_{it} > \gamma) + \phi Z_{it} + \varepsilon_{it} \quad (1)$$

where $i = 1,...,N; t = 1,...,T$; y_{it} is the dependent variable and μ_i the country individual effects. The observations are divided into two regimes. The threshold variable q_{it} is either smaller or larger than the threshold γ that illustrate by slopes β_1 and β_2 . I(·) is the indicator function, which takes the value 1 if the argument in parenthesis is valid, and 0 otherwise. Z_{it} is a vector of the control variables including exogenous variables z_{1it} which are uncorrelated with the error term ε_{it} , and endogenous variables z_{2it}, correlated with the error term ε_{it} . The ε_{it} is assumed to be identically and independently distributed (iid) with mean equal to zero and variance is finite, that is $\varepsilon_{it} \sim (0, \sigma^2)$. According to Arellano and Bover (1995), the

individual effects are eliminated using the forward orthogonal deviations transformation which ensures that the error terms are not autocorrelated. The cross-sectional threshold model of Caner and Hansen (2004) with their instrumental variable (IV) threshold model is applied to this dynamic panel model.

In this study, the dependent variable y is proxied by *lgdp*, the five-year average growth rate of GDP which is obtained *[logGDP(t)-logGDP(t-5)]x100*; the threshold variable q is proxied by π, the five-year average inflation rate which is calculated as *[logCPI(t)-logCPI(t-5)]x100*; the regime-dependent variable is also π; while the control variable (regime-independent variable) Z includes the initial (the lag one of *lgdp*), *lppi*, *lex*, *lto*, *ir* and pop (see Table 1), all also indicated as the five-year average form.

3. Empirical results

Based on the Table 2, the estimated inflation threshold is 1.44% and the 95% confidence interval of [1.38, 3.26] is obtained, which included 2% and but excluded the 4% which are the inflation targeted rates that suggested by Blanchard et al. (2010). Both regimes-dependent coefficients of inflation are statistically significant at 5% and 1% level. These results plausibly indicate that when inflation rate is below the threshold value 1.44%, inflation positively correlates with the economic growth in these 18 developed countries (β_1 = 2.486). By contrast, when inflation is above the threshold value, inflation negatively correlated with growth (β_2 = -1.393). The result implies the inflation-growth relationship is nonlinear with positive relationship below inflation rate 1.44% but negative relationship above the threshold value. The positive relationship means higher inflation is associated with higher growth, in which the policy objective to achieve high GDP growth and low inflation at once is not achievable. Higher growth is achieved with the cost of higher inflation, which implies the existence of trade-off between inflation and growth below the threshold value. For the above threshold value, the negative relationship means lower inflation is associated with higher growth, so that both policy objectives are achievable (no trade-off cost). The result also implies that the threshold value 1.44% inflation rate is the maximum rate that the increment of inflation can stimulate to economic growth. When inflation is higher than this rate, further increment in inflation may harm to growth. Therefore, the 1.44% inflation rate is the optimal rate, with reasonable low in inflation associated with maximum growth. The control variables, all show either weak or limited effect on determining the inflation-growth relationship except the initial *(lgdp(t-1))*.

Table 2. Results of dynamic panel threshold estimation in 18 developed countries

Threshold Estimated		
γ	1.4375	
95% Confidence interval	[1.3830, 3.2627]	
Impact of regime-dependent regressors: inflation, π		
	Estimated coefficients	Standard errors
β_1	2.4863**	1.1967
β_2	-1.3931***	0.4336
Impact of regime-independent regressors		
	Estimated coefficients	Standard errors
$initial_{it}$	-9.0242**	4.4594
$lppi_{it}$	3.8354	5.5412
lex_{it}	11.2536*	6.5937
lto_{it}	-2.7885	5.5496
ir_{it}	-0.3710	0.2995
pop_{it}	3.3738	2.1726
δ_1	-10.0608***	1.5131
Observations	144	
N	18	

Notes: */**/*** indicate significant at the 10/5/1% level respectively.

Two types of robustness checks were carried out to examine the sensitivity of DPTR's result, which is the dynamic system generalized methods of moments (GMM) estimating developed by Arellano and Bover (1995) and Blundell and Bond (1998) and Pooled OLS estimation method. In GMM, we included the square term of inflation in the specification in order to capture the existence of U-shaped. As shown in Table 3, the coefficients on the inflation and inflation square term are statistically positive and negative significantly associated with growth respectively. This indicates that an U-shaped exist between inflation and economic growth, which is matching the DPTR's result in Table 2. Furthermore, Sargan test of over identifying restrictions has proven that the instruments are valid and the model is correctly specified. The results of the diagnostic tests, namely Sargan and the serial correlation tests, suggest that this model is relatively well specified. Both GMM and Pooled OLS with respect to the serial correlation test or AR diagnostic test, AR(1) and AR(2) have rejected the null of the absence of the first and second order serial correlation. Thus, there is no serial correlation

in this model. The calculated optimal rate under GMM, where this rate is without threshold effect is 8.71%. e.g., Optimal rate = 4.6384/ [2(0.2662)]. While with threshold effect, the rate is 1.44%. DPTR seem to be more reasonable compare to GMM and Pooled OLS. By all the comparison between GMM and Pooled OLS, the empirical results of DPTR testing of the non-linear relationship between inflation and growth are robust.

Table 3. Results of dynamic panel GMM and Pooled OLS estimations

	GMM	Pooled OLS
$initial_{it}$	-0.10640	4.1653
	(0.4285)	(9.4147)
$inflation_{it}$	4.6384***	0.8706
	(0.4245)	(1.0087)
$inflation_{it}^2$	-0.2662***	-0.0445
	(0.0503)	(-0.0403)
$lppi_{it}$	-5.8794***	12.0244
	(2.0214)	(-10.7167)
lex_{it}	-1.8239	16.1475*
	(2.5029)	(8.9004)
lto_{it}	5.9310***	9.3577
	(2.1784)	(6.9609)
ir_{it}	0.0987	-0.1347
	(0.1517	(0.1393)
pop_{it}	1.9582	2.5298**
	(2.6795)	(1.0050)
Sargan test of over identifying restrictions	16.7704 (0.9159)	-
Arellano-Bond tests for AR(1)	-1.6802 (0.0929)	-1.81 (0.0697)
Arellano-Bond tests for AR(2)	-1.5675 (0.1170)	-0.35 (0.7277)
Observations	126	126
N	18	8

Notes: */**/*** indicate significant at the 10/5/1% level respectively. The t-statistics are reported in parentheses, except for Sargan, AR(1) and AR(2) tests, which are p-value.

Conclusion and recommendation

By using DPTR, our results our results are in favour with Kremer et al. (2013) where inflation is positively correlated with growth if it is less than the threshold of 1.44% and is negatively correlated with growth when it is above the inflation threshold. We have confirmed the general consensus among the economists, this indicated that with certain level of inflation,

there is a trade-off relationship between inflation and growth as inflation will exert a positive effect on growth. Alternatively, if the inflation exceeds the threshold, there has no trade-off relationship between inflation and growth as the further higher inflation rate will not boost up the economy growth but negatively effect on it. The results are proven robust and valid by the GMM and Pooled OLS method.

Our threshold value is 1.44% which is different from Kremer's industrialized countries threshold value. This may due to the differences of the number of countries that involved as well as the different control variables that taken into account. Our empirical results confirmed inflation has a negative effect on long-run growth, if certain threshold level of inflation rate is achieved as in Sarel (1996) and Khan and Senhadji (2001).

In sum, this study may aid the policy makers in targeting an optimal inflation rate especially for the inflation targeted countries. They can target the inflation rate around an optimal rate in order to achieve the best economy growth based on the recommended value. As in this case of 18 developed countries is recommended around 1.44%. Other variables such as initial and exchange rate are significantly reacted and affect the economy growth. However, in order to reach ideal growth for each and every particular country, some constraints are bind such as the economy background of a particular country might differ from these 18 tested developed countries. Therefore, many more variables that are not tested might take into consideration in future studies.

For further study, with threshold variable, we may capture the existence of threshold relationships between inflation and growth due to the influences of others control variables such as producer price, trade-openness, exchange rate, interest rate and population growth rate rather than just only inflation.

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