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Inflation and Growth: An Estimate of the Threshold Level of Inflation in the U.S.

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Abstract: *The study examines the threshold level of inflation in the US during the period 1960-2011. The model suggests that the threshold level of inflation in the US is between 0 to 1.5 percent quarterly. Above that threshold level, inflation has a significant negative effect on real GDP growth, while below the threshold level, the effect of inflation on real GDP growth is ambiguous.*

I. Introduction

Sustainable economic growth with a stable price level has always been the ultimate goal of any economic policy. Different theories provide different perspectives on the relationship between inflation and growth. While some suggest that this relationship is positive, notably in the short run, others argue that inflation suppresses economic growth. Some other economists rejected both views claiming that inflation does not influence economic growth. Although this debate has not yet been resolved in the literature, many empirical studies have shown that the relationship between inflation and growth is non-linear. That is, low inflation boosts economic growth whereas high inflation suppresses economic growth.

In the aftermath of the Great Depression in the 1930s, central banks all over the world began to monitor the inflation rate carefully. Lately, several countries, such as New Zealand, Australia, Canada, U.K., and the Euro Area started to target the inflation rate at a specific level or range. In the United States, however, although the price stability goal is one of key aspect of monetary policy, there is no consensus on how monetary policy should be conducted to achieve this goal. The Federal Reserve has long been adopting the implicit nominal anchor targeting, which seems to work well in the U.S. because it focuses on domestic considerations. Yet, the lack of transparency and accountability might create a time inconsistency problem that raises inflation.

In a historic shift in January 2012, the Federal Reserve Bank set an inflation target at 2 percent. Later, the Federal Reserve has pushed the short-term nominal interest rates close to zero, which raised concerns about the optimal inflation rate, and whether a very low rate is essential for higher level of investment and growth. This paper, thus, tries to explore and estimate the threshold level of inflation in the U.S. using a conditional least squares technique developed by Khan and Senhadji (2001) for the period from 1960Q1 till 2011Q3.

II. Theory review

The relationship between inflation and economic growth has always been a controversial issue and a subject of debate in the literature. The Classical theory, claiming that there is nothing to prevent the economy from attaining full employment, guarantees –via invisible hand - equilibrium in goods, money and labor markets due to highly flexible price; including wage rates and other input prices. The full employment assumption indicates that the changes in the aggregate demand will not produce any changes in output, and only the price level will respond to these changes. In sum, inflation and output growth are not correlated under the Classical assumption. This can also be realized in the essence of the quantity theory of money. As money supply changes, with both velocity and output stable or constant in the short run, price level changes in the same direction. On the other hand, the Keynesian theory, which is based on stickiness of prices and wages in the short run, allows the aggregate demand components to influence output growth if the economy is running below full employment. However, at the full employment, aggregate demand changes lead to inflation.

In the aggregate expenditure/Phillips curve model, the relationship between inflation and real GDP is clear. The model assumes a negative relationship between the interest rate and output and a positive relationship between output and inflation. The model shows that a rise money supply lowers the interest rates, and low interest rates cause output to increase. Increased output leads to inflation. That is, a rise in the money supply sets off a series of effects that raise inflation. However, this model shows that the causality runs from real GDP to inflation.

Fisher (1993), a first who investigated the non-linear relationship between inflation and growth, used a growth accounting framework to identify the main channels through which inflation reduces growth. He found out that inflation reduces investment, lowers the rate of productivity growth and thus hinders economic growth.

His findings support the conventional view that a stable macroeconomic environment characterized by a reasonably low rate of inflation and a small budget deficit is conducive to sustained economic growth.

Gillman and Kejak (2000) used a micro-foundations framework to show a mechanism about non-linearity in the inflation-growth effect. Their model includes a credit service sector that allows avoidance of the inflation tax. They find an increased in the use of credit as the inflation rate rises, and an increase in the elasticity of substitution between money and credit. This means an increase in inflation rate causes an increase in banking time and leisure use which lowers the net return on human capital, and as a result the lowers balanced growth rate.

III. Empirical literature review

Since there was no consensus from a theoretical standpoint on the relationship between inflation and growth, economists tried to investigate this relationship using empirical models. Empirical literature, however, took two different opposite stands. So while some studies found a positive relationship, others claimed that inflation-output relationship is negative. Lucas (1973) tests the real output-inflation tradeoffs, based on annual time series from eighteen countries over the years 1951-1967. He finds that the positive effect of inflation on real output appears in sixteen out of eighteen countries. However, Barro (1996) examines 100 countries over the period 1960-1990 by using the Instrumental Variables (IV) technique. He finds a negative relationship between inflation and GDP growth. He estimates a 10 percent inflation rate will reduce real GDP per capital by 0.3 to 0.4 percent per year.

When Fisher (1993) suggests a non-linear relationship between inflation and growth, economists began to study the threshold level of inflation. Sarel (1996) tested 87 countries over the period from 1970 to 1990, and he finds that the break point occurs when the inflation rate is 8 percent. Inflation does not have effect on GDP growth below 8 percent or a slightly positive effect on GDP growth. When the inflation rate is above 8 percent, the effect of inflation on GDP growth rate is negative and significant. Burdekin et al. (2000) follow a variant of Sarel's econometric procedure to test whether inflation hinders growth in different economies. They use a panel data set on 21 industrial countries and 51 developing countries over the period 1967-1992. They obtain the threshold level of inflation at 8% for industrial economies but 3% or less for developing countries. Khan and Senhadji (2001) use the ordinary least squares (OLS) method with a new technique, named conditional least squares, to investigate the threshold level of inflation with a panel data set on 140 countries over the period 1960-1998. They find that the threshold level of inflation is at 1 to 3 percent for industrial countries and 11 to 12 percent for developing countries.

After the introduction of the conditional least squares method by Khan and Senhadji (2001), many economists apply that method to examine the threshold level of inflation for individual countries. Ahmed and Mortaza (2005) use the conditional least squares technique to examine the threshold level of inflation in Bangladesh. They find 6% as the threshold level of inflation above which inflation adversely affects economic growth.Mubarik (2005) uses the same method to estimate the threshold level of inflation in Pakistan over the period 1980-2005. He finds that when inflation is above 9 percent, it is inimical to economic growth during the period 1973-2000. Carrera and Risso (2009) find 9 percent to be the threshold level of inflation in Mexico over the period 1970-2007. Sergii (2009) finds that when inflation level is higher 8 percent, economic growth slows down in CIS countries over the period 2001-2008.

Lee and Wong (2005) estimate the threshold levels of inflation for Taiwan and Japan, using a new endogenous threshold autoregressive (TAR) model. They find the threshold level of inflation for Taiwan is 7.3 percent during the period 1965-2002, and two threshold levels of inflation are found for Japan, which are 2.5 percent and 9.7 percent during the period 1970-2001. They suggest that an inflation rate below 9.7 percent is favorable to economic growth in Japan. Munir, Mansur and Furuoka (2009) use the same model to estimate the threshold level of inflation in Malaysia for the period 1970-2005. They suggest 3.89% is the threshold level of inflation in Malaysia.

Several studies have focused attention on output growth-inflation relationship in the United States. Black, Dowd and Keith (2001) examine the relationship between inflation and growth at the states level in the US. They find a positive correlation between inflation and growth during the 1980s, accompanied by a downward trend in inflation, but a negative correlation between inflation and growth during the 1960s and 1970s, accompanied by an upward trend in inflation. Bick and Nautz (2008) use a panel data set of fourteen US cities from January 1998 to August 2005 to examine the inflation thresholds and relative price variability. They suggest that if the goal of monetary policy is to minimize inflation's impact on relative prices, the US inflation rate should be in the range of 1.8 to 2.8 percent.

Billi and Kahn (2008) define the baseline estimate of the optimal inflation rate is constructed to buffer the economy from the consequences of the zero interest rate bound, using the size of shock that have hit the US economy in recent decades. Their analysis follows the New Keynesians model, and they find the optimal inflation rate is 0.7 percent per year, as measured by the personal consumption expenditure (PCE) price index.

They argue that the PCE price index has some measurement errors around 0.5 percent per year, so the range of the optimal inflation rate in the US is between 0.5 to 1.4 percent. Billi (2011) examines the optimal long-run inflation rate (OIR) in the US, using a small New Keynesian model. He finds that if government optimally commits, the OIR is below 1% annually. If government re-optimizes each period, the OIR rises markedly to 17%.

Historical Trends of Inflation and Growth in the U.S

This section provides several figures that show historical trends of inflation and output growth in the United States. Figure (1) presentsthe annual percentage change in Real Gross Domestic Product (GDP) and Consumer Price Index (CPI) in the US from 1961 to 2011. This relationship looks negative during the whole period except for 2008 to 2010. Figure 2 shows the quarterly percentage change in real GDP and CPI, where the largest percentage change in CPI is only 4 percent. Since this is a quarterly percentage change, the fluctuation becomes more frequent, but the range of the fluctuations is less than that found in the annual data. WhileIn figure 1, the inflation rate is around 2.5% since 1990, and Figure 2, inflation rate in the US is around 0 to 1 percent since the 1990s, there is no conflict between figure 1 and 2 because of the variation in quarterly data.
Figure 1.

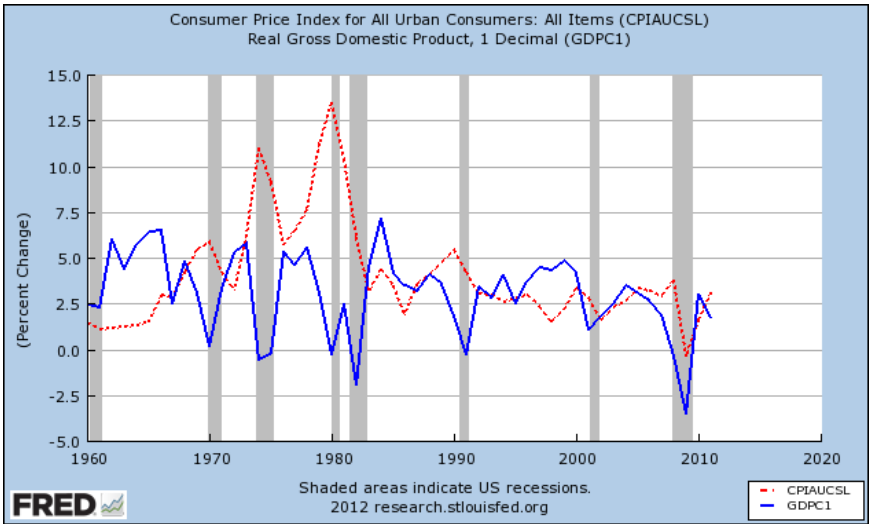
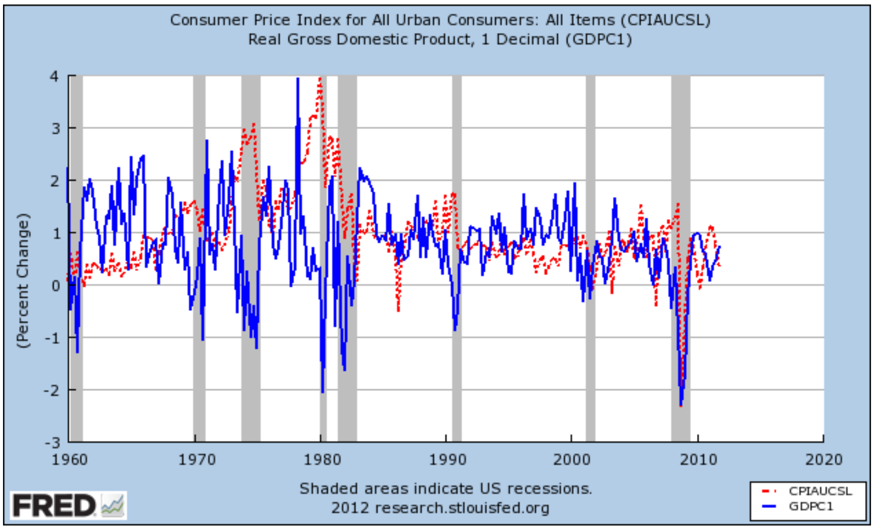


Figure 2



In order to clearly visualize the relationship between output growth and inflation, we need to rule out the effect of the business cycle, and redraw the graph (figure 3 and 4) by taking 5-year averages of the change in the real GDP and CPI. After eliminating the effect of the business cycle, the relationship between GDP growth and inflation becomes clearer. In fact, the inflation rate has not changed a lot in the past 50 years. However, the real GDP growth increased significantly from 1960s to 1970s.

Figures 3 and 4 do not show any non-linear relationship between real GDP growth and inflation as found in the recent literature. Too see the non-linear relationship between these two variables; we need a graph to show only the relation between GDP growth and inflation. Figure 5 and 6 presents the relationship of GDP growth and inflation only.

Figure 3. Five Year Average GDP growth and infaltion rate (annual data)

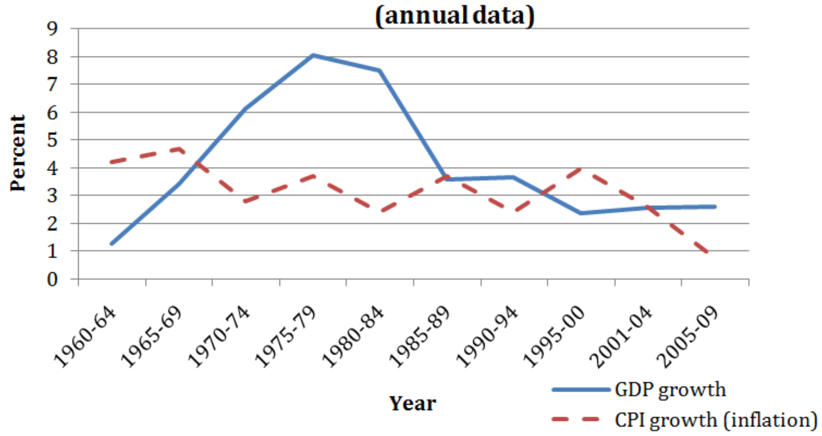
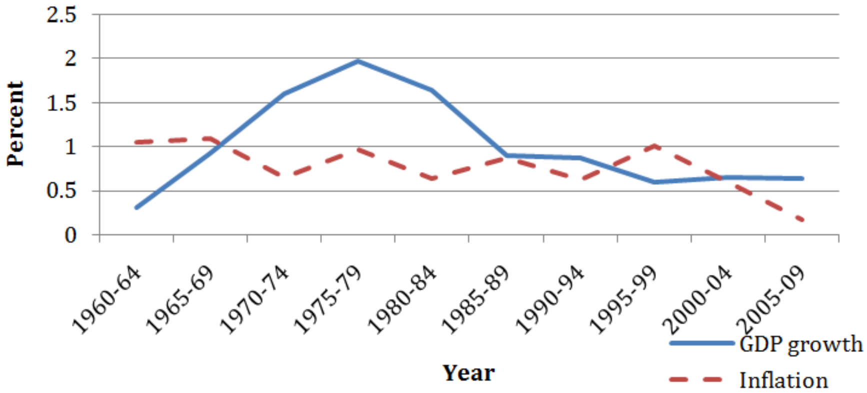
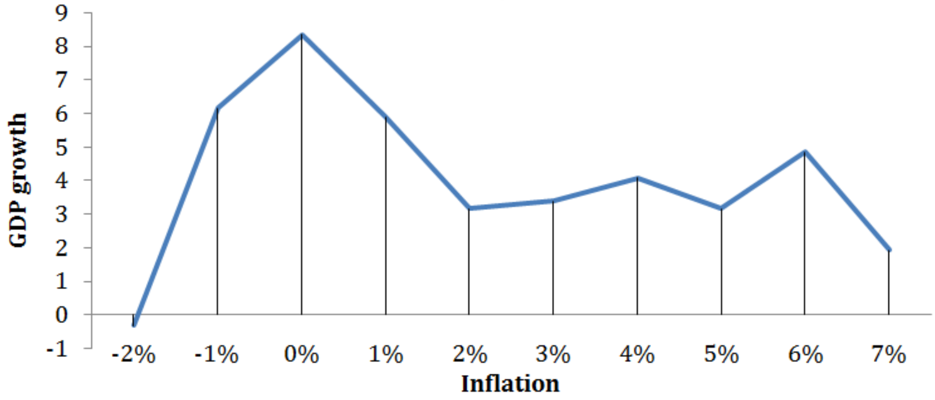


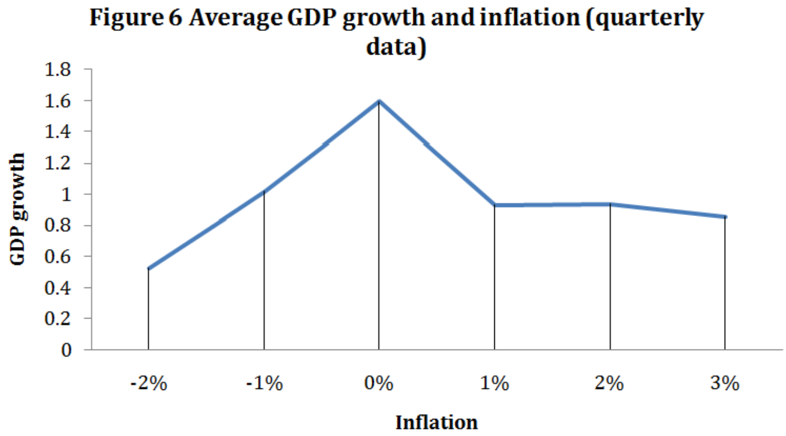
Figure 4. Five Average GDP growth and inflation (quarterly data)



The following Figures (5) and (6) give a good indication that 0% inflation may be the threshold level of inflation in the U.S. The graphs show that zero percent inflation rate is associated with 8% annual real GDP growth and a 1.6 percent quarterly real GDP growth. Based on this visual examination, we can conclude three points. First, a threshold level of inflation may exist in the US economy. Second, a zero percent inflation rate may be the threshold level. Third, our result should not be affected regardless using annual or quarterly data.

Figure 5 Average GDP growth and inflation (annual data)





Threshold Model

This paper utilizes the Threshold model, which is developed by Khan and Senhadji (2001) to analyze the U.S. threshold inflation rate. After reviewing recent studies such asKhan and Senhadji (2001), Mubarik (2005), Carrera and Risso (2009) and Sergii (2009), we select the following independent variables for our threshold level of inflation model.

$$growth_t = \beta_0 + \beta_1 \pi_t + \beta_2 D_t(\pi_t - k) + \beta_3 INV_t + \beta_4 POP_t + \beta_5 OPEN_t + \varepsilon_t$$

Where*growth*isreal GDP growth; π is inflation rate; *K*is the threshold level of inflation; *INV*is the investment growth; *POP*is population acceleration; *OPEN*is the growth of the openness of economy; *t*is the time-series index; εis error term and *D*is a dummy variable which is defined as follows:

$$D_t \begin{cases} 1, if\ \pi_t > k \\ 0, if\ \pi_t \le k \end{cases}$$

This method is based on minimizing the sum of squared residuals with respect to the parameter *k*. The range of k should cover the lowest and highest value of the inflation. Suppose the $S_1(k)$ is a residual sum of squares then:

$$k = \arg\min_k (S_1(k), k = \underline{k}, \ldots, \overline{k})$$

According to this threshold model, the effect of inflation on growth is shown in $\beta_1$when the inflation rate is less than or equal to the value of k and $\beta_1 + \beta_2$when inflation is higher than the value of k.

IV. Data Description

We use quarterly observations starting from 1960Q1 till 2011Q3, and the data come from various sources such as, International Monetary Fund, U.S Department of Commerce: Bureau of Economic Analysis, U.S. Department of Labor: Bureau of Labor statistics, U.S. Department of Commerce: Census Bureau, and Organization for Economic Co-operation and Development.

Growth is measured as quarterly growth rate of real GDP in billions of chained 2005 Dollars with seasonally adjusted;

Inflation is computed as quarterly growth rate of average consumer price index for all urban consumers: all items. (The index is based on 1982-84=100);

Population is measured as quarterly population acceleration rate. Population includes all ages and armed forces oversea in thousands people;

Investment is measured as quarterly growth rate of the gross fixed capital formation in billions of United States Dollars with seasonally adjusted;

Openness of the economy is measured as quarterly growth rate as share of export plus import in GDP. Export is measured as export of goods and services in billions Dollars with seasonally adjusted, and import is measured as import of goods and services in billions Dollars with seasonally adjusted;

Money supply is measured as quarterly growth rate of M2 money supply in Dollars with seasonally adjusted.

The variables in our threshold model are computed as follows:

$$growth_t = 100 * d\log(Y_t) \qquad \pi_t = 100 * d\log(P_t)$$

$$INV_t = 100 * d\log(gfcf_t) \qquad POP_t = 100 * dd\log(Pn_t)$$

$$OPEN_t = 100 * d\log((ex_t + im_t)/Y_t) \qquad MS_t = 100 * d(\log m2)$$

Symbol description:

$growth_t$: real GDP growth

Y_t : real GDP

π_t : inflation

P_t : consumer price index

INV_t : investment growth

$gfcf_t$: gross fixed capital formation

POP_t : population acceleration

Pn_t : number of population

$OPEN_t$: growth of openness of the economy

ex_t : export of goods and services

im_t : import of goods and services

MS_t : money supply growth

$m2_t$: M2 in Dollars

d : first order difference

dd : second order difference

Notice that the growth of money supply is added as an instrument variable for inflation in further analysis. The variables are transformed into logarithm form as it provides a smooth time trend in the dataset. Moreover, the log transformation implications are more plausible than the implications of a linear model.

Table 1. Descriptive statistics

Variables	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
GDP Growth	207	.7496366	.8737801	-2.327633	3.858852
Inflation	207	.987361	.7690264	-2.352667	3.86982
Population	206	-.0007555	.0369065	-.0888824	.0857353
Investment	207	1.511619	2.118955	-8.424282	9.99527
Openness of the economy	207	.1083769	.3729517	-2.136679	1.620727
Money supply	207	1.677845	.8653096	-.2717285	5.314453

Table 1 presents descriptive statistics for the variables. The number of observations on the population variable is 206 because the population variable has to be second differenced to be stationary.

Table 2. Sample correlation

	Inflation	Population	Investment	Openness.	Money supply
Inflation	1				
Population	0.0524	1			
Investment	0.2174	-0.0097	1		
Openness.	0.0878	0.00996	0.2813	1	
Money supply	-0.0068	-0.0465	0.1645	-0.3017	1

Table (2) shows the correlation matrix among the independent variables included in the model. It seems the model does not have serious collinearity problem. Table (3)presents the Augmented Dickey Fuller (ADF) tests results. The ADF test indicates that all the variables need to be first differenced in order to be stationary except for population variable which needs to be second differenced in order to be stationary. Akaike Information criterion (AIC) is also for stationarity as well as lag selection. Table 4 shows the optimal selected lags length based on AIC.

Table 3. Test for Non-Stationarity of variables

		Growth	**Inflation**	**Population**	**Investment**	**Openness.**	**Money S.**
Level	No Trend	-2.084753	-1.322184	-1.208443	-2.007840	1.258461	-1.360980
	With Trend	-2.406418	-1.063298	-1.676265	0.9879	-1.752615	-1.654562
	Result	Non-stationary	Non-stationary	Non-stationary	Non-stationary	Non-stationary	Non-Stationary
1st difference	No Trend	-6.819754	-2.942204	-2.443294	-3.662225	-8.037685	-2.766437
	With Trend	-7.109533	-3.130176	-2.692159	-4.183322	-8.270082	-3.782500
	Result	Stationary	Stationary	Non-Stationary	Stationary	Stationary	Stationary
2nd difference	No Trend	--	--	-4.340158	--	--	--
	With Trend	--	--	-4.322140	--	--	--
	Result	--	--	Stationary	--	--	--

Note: 5 percent critical value is -2.87 for the case of no-trend, and -342 when a trend is included.

Table 4

AIC	Lags
GDP growth	1
Inflation	2
Population	13
Investment	8
Openness of the economy	3
Money supply	9

Figure 7 shows the distribution of the inflation rate after taking log transformation. The distribution is very close that of the normal distribution. Figure 8 shows the distribution of the real GDP growth and the logarithm of inflation rate in our dataset. Most of the observations center around 0 to 2 percent in both growth and logarithm of inflation rate.

Figure 7 Distribution of logarithm of inflation

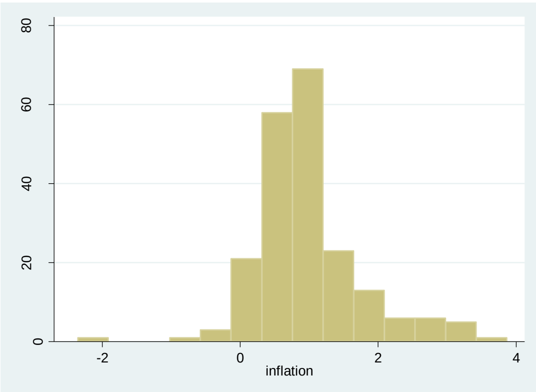
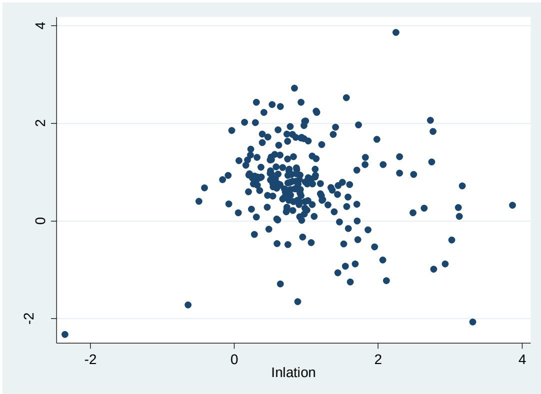


Figure 8 Growth and inflation



Hypothesis

Our hypothesis is that the threshold level of inflation in the US should be at a very low level, maybe close to zero percent inflation. Figure 5 and 6 are the main reason for hypothesis zero percent threshold level of inflation. In addition, Khan and Senhadji (2001) suggest the threshold level of inflation is around 1 to 3 percent for industrial countries. The US is the most advanced country in the world, so a little deviation from that range is reasonable. Furthermore, Feldstein (1997) suggests reducing inflation to zero would cause perpetual welfare gain equal to about 1 percent GDP a year.

Estimation results

The following table (Table 5) shows all the regression results using the original least square method. According to the threshold model, the optimal value of k is the one that can provide a minimum value of the residual sum of squares in the model. The result shows that the lowest RSS appears when k is equal to zero percent.

Table 5. Estimation of the threshold model at k = -2 to 3.5%

(Dependent variable: growth)

k	Variable	Coefficient	Std. Error	t-statistics	Probability	RSS
-2%	Inflation	6.404152	1.787422	3.58	0.000	70.2120019
	Above -2%	-6.747764	1.801886	-3.74	0.000	
	Population	-1.897164	1.123459	-1.69	0.093	
	Investment	.2905687	.0210382	13.81	0.000	
	Openness	-.1099149	.1160231	-0.95	0.345	
	Constant	14.16943	3.6283	3.90	0.000	
-1.5%	Inflation	2.44755	.7321019	3.34	0.001	70.2120019
	Above -1.5%	-2.791162	.7453366	-3.74	0.000	
	Population	-1.897164	1.123459	-1.69	0.093	
	Investment	.2905687	.0210382	13.81	0.000	
	Openness	-.1099149	.1160231	-0.95	0.345	
	Constant	4.860644	1.144	4.25	0.000	
-1%	Inflation	1.415866	.4578601	3.09	0.002	70.2120019
	Above -1%	-1.759479	.4698415	-3.74	0.000	
	Population	-1.897164	1.123459	-1.69	0.093	
	Investment	.2905687	.0210382	13.81	0.000	
	Openness	-.1099149	.1160231	-0.95	0.345	
	Constant	2.433379	.4986283	4.88	0.000	
-0.5%	Inflation	.9693491	.3345194	2.90	0.004	70.0622328

	Above -1.5%	-1.315447	.3456764	-3.80	0.000	
	Population	-1.917394	1.122151	-1.71	0.090	
	Investment	.2889935	.0210695	13.72	0.000	
	Openness	-.1231048	.1162702	-1.06	0.291	
	Constant	1.339065	.2102245	6.37	0.000	
0%	Inflation	.7216263	.2518652	2.86	0.005	69.3100178
	Above 0%	-1.089234	.2656745	-4.10	0.000	
	Population	-1.952097	1.115992	-1.75	0.082	
	Investment	.284497	.0211094	13.48	0.000	
	Openness	-.1503034	.1164951	-1.29	0.199	
	Constant	.7221196	.0771835	9.36	0.000	
0.5%	Inflation	.3193264	.1803472	1.77	0.078	70.7327726
	Above 0.5%	-.722116	.2046711	-3.53	0.001	
	Population	-2.138023	1.128147	-1.89	0.060	
	Investment	.287731	.0212697	13.53	0.000	
	Openness	-.1590784	.1187808	-1.34	0.182	
	Constant	.421806	.0840183	5.02	0.000	
1%	Inflation	-.0540186	.1241496	-0.44	0.663	73.5139957
	Above 1%	-.3633673	.1730206	-2.10	0.037	
	Population	-2.100771	1.150543	-1.82	0.070	
	Investment	.2947609	.0215525	13.68	0.000	
	Openness	-.1218081	.1209775	-1.01	0.315	
	Constant	.4672795	.0907956	5.15	0.000	
1.5%	Inflation	-.2261261	.0976311	-2.32	0.022	74.9197159
	Above 1.5%	-.1435355	.1892526	-0.76	0.449	
	Population	-2.054622	1.163502	-1.76	0.079	
	Investment	.2991648	.021712	13.78	0.000	
	Openness	-.0818742	.1208407	-0.68	0.499	
	Constant	.5494368	.0858402	6.40	0.000	
2%	Inflation	-.2860996	.0837937	-3.41	0.001	75.1351903
	Above 2%	-.0006481	.245401	-0.00	0.998	
	Population	-1.988816	1.165512	-1.71	0.090	
	Investment	.3012842	.0219005	13.76	0.000	
	Openness	-.0671623	.1199691	-0.56	0.576	
	Constant	.5844725	.0811324	7.20	0.000	
2.5%	Inflation	-.2798335	.0737594	-3.79	0.000	75.1280934
	Above 2.5%	-.0524323	.3813924	-0.14	0.891	
	Population	-2.000297	1.164975	-1.72	0.088	
	Investment	.3006686	.0220349	13.65	0.000	
	Openness	-.0678065	.1195336	-0.57	0.571	
	Constant	.5808124	.0773569	7.51	0.000	
3%	Inflation	-.2938282	.0630646	-4.66	0.000	75.105501
	Above 3%	.2008344	.7142329	0.28	0.779	
	Population	-1.959917	1.166138	-1.68	0.095	
	Investment	.302232	.0218128	13.86	0.000	
	Openness	-.0670277	.1194156	-0.56	0.575	
	Constant	.5890433	.0740869	7.95	0.000	
3.5%	Inflation	-.2927618	.0592651	-4.94	0.000	75.0743429
	Above 3.5%	.697292	1.73187	0.40	0.688	
	Population	-1.941548	1.167293	-1.66	0.098	
	Investment	.3017427	.0215807	13.98	0.000	
	Openness	-.0668893	.1193918	-0.56	0.576	
	Constant	.5890728	.0732028	8.05	0.000	

Figure 9. The value of k versus the residual sum of square

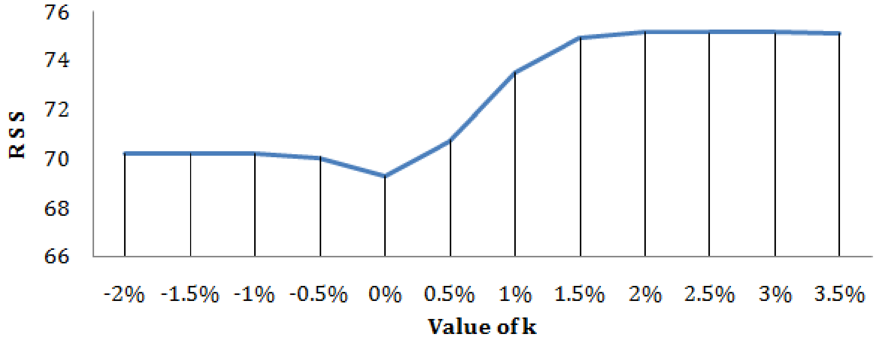


Figure 9 shows the values of RSS with respect to different value of k. k=0% is found to be the lowest RSS value. The result of our threshold model matches with our hypothesis. β_1, which is coefficient of inflation, shows the effect of inflation on the real GDP growth when the inflation rate is lower than or equal to the threshold level. Based on our analysis, when inflation rate is zero percent or below, the growth of real GDP is 0.72 percent. $\beta_1 + \beta_2$ shows the effect of inflation on the real GDP growth when the inflation rate is above the threshold level. The value of $\beta_1 + \beta_2$ is - 0.36 percent (.7216-1.089=-0.36), which emphasizes that inflation rates above the threshold level of zero percent will have an adverse effect on growth.

Although the result matches with our hypothesis, a zero percent threshold level of inflation seems unrealistic. There are only short periods of time when the inflation rate went below zero percent in the US during the period of study, but a positive real GDP growth appears in the US for the most part from 1960 to 2011. For the other variables in the model when k=0%, population and investment growth are significant, but we need to be careful when interpreting the coefficient estimate for population because this variable is in second order difference. If the population growth rate accelerates by 1 percent, the real GDP growth will decrease by 1.95 percent. The coefficient for investment is positive which means the investment growth has positive effect on the real GDP growth. When the growth of investment increases by 1 percent, the growth of real GDP will increase by 0.29 percent. However, the growth of the openness of the economy is insignificant. We are not certain about the reason behind it. Usually, openness may exert a positive or negative effect on growth, but this does not appear to be the case here.

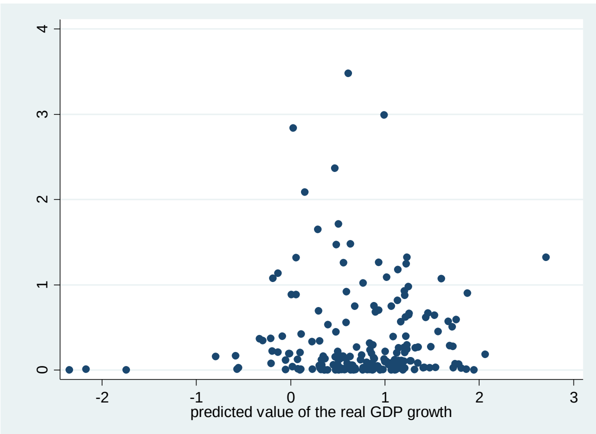
To check the robustness of the results, several test will be run such as the White test. As matter of convenience, we only apply the White test in the model when k=0%.to check for the presence of heteroscedasticity. The test is set as follows

$$\varepsilon_t^2 = \alpha_0 + \alpha_1 \hat{y}_t + \alpha_2 \hat{y}_t^2$$

Where ε_t^2 is the error term in the model when k=0%, $\hat{y}_t$ is the predicted value for the real GDP growth, and $\hat{y}_t^2$ is the square of the predicted value of the real GDP growth.The null hypothesis is rejected if $nR^2 > \chi^2_{2,0.05}$, where $\chi^2_{2,0.05}$ is equal to 5.99.The test statistic in our model, NR^2 is equal to 0.2678, which shows that $\chi^2_{2,0.05} = 5.99$. That is, $nR^2 < \chi^2_{2,0.05}$

Therefore, heteroscedasticity does not exist in the model. Figure 10 show the square of the residuals and the predicted value of real GDP growth

Figure 10



Fischer (1993) argues the causality is more likely to run predominantly from inflation to growth; therefore, the problem of "simultaneity bias" may not be very important. To confirm Fisher argument, we apply the Granger Causality test. Tables 6 and 7 present the Pair Wise Granger Causality test. The results reveal that inflation Granger Causes the real GDP growth, and investment growth also Granger Causes the real GDP growth. That is, the simultaneity bias does not exist in the model. Although the Granger Causality test shows inflation and investment are unidirectional to growth, endogeneity bias problem may still be an issue in the model.

Tables 6. Pair wise Granger Causality

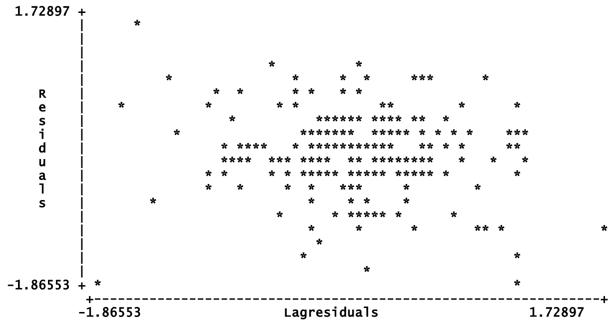
Lags: 1			
Null Hypothesis:	Obs.	F-Statistic	Probability
Inflation does not Granger Cause real GDP Growth	206	8.44096	0.0041
Real GDP Growth does not Granger Cause Inflation		0.98900	0.3212

Tables 7. Pair wise Granger Causality

Lags: 2			
Null Hypothesis:	Obs.	F-Statistic	Probability
Investment does not Granger Cause real GDP Growth	205	4.22815	0.0159
Real GDP Growth does not Granger Cause Investment		1.67423	0.1901

According to economic theory, it is possible for inflation and the real GDP growth to have endogeneity bias. Khan and Senhadji (2001) recommended the use Two-Stage Least Squares (2SLS) to deal with the endogeneity problem. They suggest that inflation and investment should be treated as potentially endogenous to growth. The set of instruments for inflation includes the lag of inflation, the lag of real GDP growth, the lag of the growth rate of money supply, and the growth rate of the terms of trade. The same set of instruments used for investment growth except the lag of inflation is replaced by the lag of investment growth. In our analysis, we substitute the growth rate of terms of trade by the growth of openness of the economy. Most importantly, Khan and Senhadji (2001) point out that the lag of inflation, real GDP growth and investment growth are only valid if the error term in the threshold model is not autocorrelated. As a result, we use the Durbin-Watson(DW) statistic test to test for autocorrelation problem. DW is only applied to test in the model when k=0%. Figure 11 shows distribution of residuals and lag residuals in the model when k=0%, which confirms that autocorrelationdoe not exists.

Figure 11.



Distribution of "residuals and lag residuals" at K=0%

We can now apply 2SLS model. Based on the AIC, we use 1 lag for real GDP growth, 2 lags for inflation, 8 lags for investment, 3 lags for openness of the economy, and 9 lags for money supply.

Following the Khan and Senhadji (2001) procedure, we find that the instrumental variables of inflation and investment are not significant. The results are shown in Table 8 column (1). Therefore, we drop some variables and compare the change in the F-test value and the adjusted R square. The final variables that are used in the instruments are shown in Table 8 column (2).

Table 8.	Dependent variables:			
Independent variables:	Inflation		Investment	
	(1)	(2)	(1)	(2)
Inflation with 2 lags	.5992587*** (.0571231)	.6055851*** (.0525239)	--	--
Investment with 8 lags	--	--	-.0662628 (.0655329)	--
GDP growth with 1 lags	.0876585* (.0491835)	.0933268** (.0445475)	1.068712*** (.159355)	1.134135*** (.1485768)
Openness with 3 lags	.0009287 (.108702)	--	.8531832** (.3624481)	.940251*** (.3552378)
Money supply with 9 lags	.1852061*** (.0514175)	.1944462*** (.0400777)	.2081569 (.1670822)	.3109897*** (.0920707)
Constant	.0307212 (.1083622)	--	.3904948 (.3377998)	--
F-test	40.15	262.85	12.67	58.58
F-test Probability	0.0000	0.0000	0.0000	0.0000
R square	0.4542	0.8017	0.2004	0.4740
Adj. R square	0.4429	0.7987	0.1881	0.4659

***: 1% statistic significance, **:5% statistic significance, *: 10% statistic significance

Table 9. Estimation of the threshold model in 2SLS at k = -1 to 2.5%
(Dependent variable: growth)

k	Variable	Coefficient	Std. Error	t-statistics	Probability	RSS
-1%	Inflation	2.918476	2.827912	1.03	0.303	123.524011
	Above -1%	-3.305158	2.862414	-1.15	0.250	
	Population	-2.108741	1.569361	-1.34	0.181	
	Investment	.2547833	.0588889	4.33	0.000	
	Openness	.066137	.1609624	0.41	0.682	
	Constant	4.062849	2.922635	1.39	0.166	
-0.5%	Inflation	.8623981	1.050888	0.82	0.413	123.524008
	Above -1.5%	-1.24908	1.081757	-1.15	0.250	
	Population	-2.108742	1.569361	-1.34	0.181	
	Investment	.2547832	.0588889	4.33	0.000	
	Openness	.066137	.1609624	0.41	0.682	
	Constant	1.382231	.6144748	2.25	0.026	
0%	Inflation	.3968885	.6397316	0.62	0.536	123.491933
	Above 0%	-.7875577	.6695664	-1.18	0.241	
	Population	-2.101147	1.569129	-1.34	0.182	
	Investment	.2535007	.0590275	4.29	0.000	
	Openness	.0672643	.1607902	0.42	0.676	
	Constant	.7644547	.155642	4.91	0.000	
0.5%	Inflation	.2339989	.4085349	0.57	0.567	122.997916
	Above 0.5%	-.6555239	.4460056	-1.47	0.143	
	Population	-2.056177	1.566231	-1.31	0.191	
	Investment	.2465803	.0594319	4.15	0.000	
	Openness	.0740407	.1597633	0.46	0.644	
	Constant	.4863894	.1999421	2.43	0.016	
1%	Inflation	-.1352013	.2446733	-0.55	0.581	123.79087
	Above 1%	-.3342295	.3491229	-0.96	0.340	
	Population	-1.993456	1.574753	-1.27	0.207	
	Investment	.2516636	.0599198	4.20	0.000	
	Openness	.0875089	.159981	0.55	0.585	
	Constant	.5665747	.1942146	2.92	0.004	
1.5%	Inflation	-.1003271	.1796708	-0.56	0.577	122.508018
	Above 1.5%	-.7894003	.4606508	-1.71	0.088	
	Population	-1.928966	1.56594	-1.23	0.220	
	Investment	.2375552	.0601503	3.95	0.000	
	Openness	.0874843	.1591482	0.55	0.583	
	Constant	.5447822	.1663968	3.27	0.001	
2%	Inflation	-.2657945	.1388398	-1.91	0.057	123.824611
	Above 2%	-.9752377	1.049229	-0.93	0.354	
	Population	-2.097617	1.571237	-1.34	0.183	
	Investment	.2484654	.0609367	4.08	0.000	
	Openness	.0923594	.1600576	0.58	0.565	
	Constant	.6525405	.1494197	4.37	0.000	
2.5%	Inflation	-.3584166	.1131077	-3.17	0.002	124.179016
	Above 2.5%	48.15709	86.00819	0.56	0.576	
	Population	-2.139804	1.575326	-1.36	0.176	
	Investment	.2718802	.0596762	4.56	0.000	
	Openness	.089357	.1602386	0.56	0.578	
	Constant	.6936569	.1434268	4.84	0.000	

Table 9 shows the results of 2SLS. The minimum residual sum of square appears in the model when k=1.5%.Both population and openness of economy are insignificant. The result of 2SLS shows thatinflation rates above 1.5 percent hamperseconomic growth. Since the inflation variable is insignificant when k=1.5%, we cannot interpret the magnitude of the negative effect of inflation on the economic growth. The conclusion using 2SLS is that the inflation rate does not have a significant effect on the real GDP growth when the inflation rate is below 1.5 percent, but inflation has a significant negative effect on the real GDP growth when it goes above 1.5 percent. Combining the results of OLS and 2SLS, we can concludethe threshold level of inflation in the US is 0 to 1.5 percent using quarterly data.

Selecting the inappropriate number of lags may cause some variables to become statistically insignificant. Since the number of lags is selected from the stationary test by AIC, the lag length may not be suitable for both inflation and investment growth endogenous variables. On the other hand, if inflation is not an endogenous variable in the short run, it can be a reason why some variables become insignificant when we go from OLS to 2SLS.

V. Conclusion

This study examines the threshold level of inflation in the US during the period 1960-2011. The model suggests the quarterly threshold level of inflation in the US is between 0 to 1.5 percent. Above that threshold level, inflation has significant negative effect on the real GDP growth, while below that threshold level, the effect of inflation on the real GDP growth is ambiguous.

From a policy point of view, the Federal Reserve tries to stabilize the real GDP at its potential level. When the real GDP is above or below the potential level, inflation, disinflation or deflation may appear. Based on the aggregate expenditure-Phillips model, positive output gaps leads an increase in the inflation, and negative output gaps leads an decrease in the inflation.

During the period of study, the actual GDP and the potential GDP are relatively close except for the financial crisis onward. This explains why the threshold level of inflation is very low in the U.S. However, The Federal Reserve has avoided pushing the inflation rate to zero percent to avoid liquidity trap.

Feldstein (1997) initiates that a zero percent inflation is good for the US economy. He argues that inflation will create a deadweight loss because inflation distorts the consumption over the individual life cycle, the demand for owner-occupied housing, the money supply, etc. Based on his estimation, the overall total effect of reducing inflation from 2 percent to zero can reduce the annual deadweight loss between 0.63 to 1.01 percent of GDP. In addition, inflation uncertainty is another problem that may affect the real GDP growth. Grier et al. (2004) point out that higher inflation uncertainty is significantly negatively correlated with lower output growth and lower average inflation rate, and both inflation and output growth show significant asymmetric response to positive and negative shocks of equal magnitude. In the US case, the inflation uncertainty is not high. The average standard deviation of inflation per every eight quarter is 0.38 percent from 1960 to 2011, and the maximum and minimum standard deviations of inflation are 1.33 and 0.06 percent in the same period of time. Thus, although the Federal Reserve pushes the inflation rate to a very low level, it is unlikely for U.S. to experience deflation.

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