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The Growth-Inflation Nexus for the US over 1801-2013: A Semiparametric Approach

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Abstract

We try and detect whether there exists a threshold level of inflation for the US economy over 1801-2013, beyond which it has a negative effect on economic growth. We use a combination of nonparametric (NP) and instrumental variable semiparametric (SNP-IV) methods to obtain inflation thresholds for the United States. The results suggest that the relationship between growth and inflation is hump shaped—that higher levels of inflation reduce growth more. Our results consistently show that inflation above two per cent negatively affects growth.

Keywords: Inflation, growth, nonparametric, semiparametric

JEL classifications: E31, O49, C14

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1 Introduction

What rate of inflation is unfavorable for economic growth? This paper shows that inflation above two per cent reduces GDP growth. We analyse the inflation-growth trade-off in a semiparametric model using 213 years of United States GDP and inflation data. This paper contributes to the existing literature with a specific focus on the United States and avoids assumptions regarding explicit functional relationships.

The inflation-growth trade-off is interesting for various reasons. Its policy relevance relates to making decisions regarding interest rates and understanding the endogenous response of output growth to inflation. With interest rates being at the zero lower bound (ZLB) it is natural to ask what rates of inflation is optimal. This is equally important when the Fed considers the rate of inflation that reduces the probability of hitting the ZLB. However, raising inflation expectations have economic costs - a decrease in GDP growth. The literature on the inflation-growth nexus show mixed results on the level of inflation that subtracts from economic growth. If certain rates of inflation increase growth, Mundel-Tobin effect,[1] then one might make the argument of raising the inflation target.

The so-called point at which inflation has a negative effect on economic growth has policy consequences. Consequently many studies attempt to pinpoint the exact inflation threshold. The empirical methods used are diverse and cover nonlinear functional forms (to test possible hump-shaped relationships) to linear regressions estimated over certain break points to dynamic models that are estimated over certain periods (i.e. rolling window regressions) and panel models that take account of cross-sectional heterogeneity.

The large body of research that analyses inflation thresholds impose a functional form (see Barro, 1995; Fisher, 1993 and Rousseau and Wachtel, 2000 as an example) - a practice that might be wrong. Our paper comes perhaps closest to Vaono and Shiavo (2007) who use nonparametric methods in a panel framework to study possible inflation thresholds. We depart from their work only by focusing on obtaining results for the U.S.. We use instrumental variable (IV) methods to control for possible endogeneity between growth and inflation in a semiparametric model. This gives us an unbiased model free from assuming a functional form that imposes a nonlinear relationship or one that assumes inherent structural breaks, i.e. we let the data speak for itself.

2 Literature review

It is generally accepted that inflation reduces overall welfare. The welfare costs of inflation have been extensively studied for the U.S. The general consensus is that inflation reduces overall welfare irrespective of discretionary or committed monetary policy. As an example, Miller et al. (2014) estimate the time-varying welfare costs of inflation in a money demand model using a time-varying cointegrated model. Their estimate of the welfare cost of 10 per cent inflation in terms of GDP range between 0.025 and 0.75 per cent, with an average of 0.27 per cent. This is well in line with other studies (see Fisher, 1981; Serletis and Yavari, 2004 and Ireland, 2009).

[1] This effect occurs when inflationary monetary policy makes investors substitute investment for growth improving capital investment.

From a theoretical perspective, Billi (2010) studies the optimal long-run rate of inflation in a New-Keynesian model that counteracts the negative economic effects of hitting the ZLB. Billi (2010) obtains estimates of the long-run inflation rate under three regimes: discretionary, commitment and a Taylor rule and implicitly accounts for misspecification in all cases. Under commitment policy, the optimal inflation rate is 0.2% (under no misspecification) and 0.9% (extreme misspecification) whereby the government hits the zero-lower-bound only occasionally. The government can stimulate the economy by creating inflation expectations and commitment implies a lowering of real interest rates. The consumption (welfare) loss is lower in the model with commitment compared to the model with discretion. The optimal long run inflation rate is very high if a government re-optimises (discretion) and extremely high accounting for misspecification. This causes high inflation expectations that could lead to high real interest rates that harm the economy. The optimal inflation rate can be as high as 13.4% and 16.7% (under extreme misspecification). Finally, under a standard Taylor rule the optimal long run inflation rate is between 8% and 9.8% (this rule does not account for inertial interest rates). Consumption loss is lowest in the model with an inertial Taylor rule (as opposed to a standard Taylor rule, commitment and re-optimizing government) - this allows for slightly higher optimal long run inflation target. Billi (2010) shows that discretionary policy makers are so averse to deflation, that they are willing to tolerate massive inflation bias. This model, however, assumes that the monetary policy rate is the only policy measure available.

Reifschneider and Williams (2000) find a 2% inflation goal to be a sufficient level to counter the adverse economic effects of the ZLB. The frequency of mild recessions, due to the ZLB on the output gap, are reduced for a two per cent inflation target compared to a zero per cent inflation target. However, the frequencies of severe recessions are higher in a model of two per cent inflation target relative to a zero inflation target.

Krugman (1998) interestingly states that committed inflation policy is a reason that economies remain at the ZLB: Agents perceive expansionary monetary policy as temporary and believes the central bank's commitment to low inflation. A higher inflation commitment or alternative government policies might help an economy escape from the ZLB.

Unfortunately the cost of higher inflation is ignored in the Krugman study and the welfare costs of inflation are low when escaping the ZLB in Billi (2010).

Khan and Senhadji (2001) estimate the inflation threshold of about 11% of developing countries and 1% for industrialized countries.

Burdekin et al. (2004) show that inflation (as low as single digit inflation) has a negative impact on economic growth. They estimate a spline equation that allows for structural breaks in inflation. This allows them to study the impact of inflation on growth at various thresholds. The growth cost of inflation becomes more pronounced at inflation levels in excess of 50%. Furthermore, they show that the inflation impact on growth is biased downwards when not accounting for nonlinearities.

Barro (1997) shows that a ten per cent increase in inflation reduces growth in real GDP per capita by about 0.2-0.3 percentage points per year—a significant reduction of GDP over a long period, which highlights the importance of price stability from a GDP perspective. This is in line with a plethora of panel studies that obtain similar results (see Roubini and Sala-i-Martin, 1992; Fisher, 1993 and Chari et al., 1995)

Bruno and Eastery (1998) show, however, that the negative association between inflation and economic growth is difficult to establish for low to moderate levels of inflation in a panel of 31 countries—they emphasise that pooled cross-country datasets are not informative about what happens to growth at low levels of inflation; something that this paper tries to remedy.

Vaona and Schiavo (2007) show that the relationship between inflation and growth is nonlinear. They use nonparametric and semi-parametric IV methods to estimate thresholds. A 12 per cent threshold is obtained for developed countries while no clear indication of a threshold is found for developing countries.

Vaona (2012) obtains a different result compared to Vaona and Schiavo (2007) using a similar methodology on a different dataset of 85 countries. This time he shows that inflation has a negative linear impact on growth: Inflation is simply growth reducing.

3 Methodology

We use annual real GDP growth and inflation data from 1801 to 2013 are calculated as percentage change of the real GDP (at constant 2009 prices) and the consumer price index (with a base period of 1982-1984). While the real GDP data comes from the Global Financial Database, the CPI data is obtained from the website of Professor Robert Sahr.[2] Our start and endpoints of the sample is purely driven by data availability; though the CPI data goes as far back as 1774, real GDP data is only available from 1800. Since we use growth rates of the two variables, we loose the observations corresponding to 1800. We control for different lags of inflation and GDP. This gives us 213 observations over different regimes and possible structural breaks. Inflation over the period averaged 1.37 per cent while GDP growth averaged 3.65 per cent (see Table 1).

Table 1: Descriptive statistics

	Inflation	Growth rate
N	213	213
Mean	1.3713	3.6559
S.D.	5.4928	5.3335
Min	-17.1358	-13.9291
Max	22.1161	16.9925
Skewness	0.5057	-0.3137
Kurtosis	2.4409	0.6985
JB	64.3380***	8.3180**
$Q(1)$	59.5541***	7.6934***
$Q(4)$	80.8971***	9.4057*
ARCH(1)	45.9068***	13.5161***
ARCH(4)	62.6250***	20.7283***

Notes: In addition to the mean, the standard deviation (S.D.), minimum (min), maximum (max), skewness, and kurtosis statistics, the table reports the Jarque-Bera normality test (JB), the Ljung-Box first [$Q(1)$] and the fourth [$Q(5$] autocorrelation tests, and the first [ARCH(1)] and the fourth [ARCH(5)] order Lagrange multiplier (LM) tests for the autoregressive conditional heteroskedasticity (ARCH). The asterisks ***, ** and * represent significance at the 1%, 5%, and 10% levels, respectively.

[2] http://oregonstate.edu/cla/polisci/sahr/sahr.

We use a semiparametric model. In the case of the inflation-growth relationship, conditional expectation restrictions might not be satisfied—especially if there are strong feedback loops between inflation and GDP growth. We use an IV approach to control for endogeneity. The semiparametric model allows the data uncover a more realistic functional form. Our relatively large sample size reduces the possibility of misspecification bias.

The selected IV models are based on the Wu-Hausman and the Sargan *J*-test. The *J* statistic tests the null hypothesis that all instruments are exogenous. Hausman-Wu tests the null that the regressors are not correlated with the disturbance term.

In the first stage we determine which instruments are relevant. A first-stage F-test is used to determine whether or not the instruments should enter the first stage regression. Weak instruments imply a small first-stage F-test. The auxiliary instrumental variables regressions take the following form:

$$\pi_t = \mu + \theta z_t + \varepsilon_t \tag{1}$$

where π_t=inflation rate, $z_t = [\pi_{t-1}, \pi_{t-2}, \dots, \pi_{t-p}, g_{t-1}, g_{t-2}, \dots, g_{t-q}]$ (instrumental variables), g_t=real GDP growth rate and $\varepsilon_t \sim iid(0, \sigma^2)$ is the error term.

Then we estimate the OLS and IV regression models of the following form:

$$g_t = \alpha + \beta\pi_t + \varepsilon_t \tag{2}$$

and OLS-lagged estimates the model:

$$g_t = \alpha + \beta\pi_{t-1} + \varepsilon_t \text{ with OLS.} \tag{3}$$

Finally, the semiparametric specification can be expressed as follows:

$$g_t = \phi x_t + f(\pi_t) + \varepsilon_t \tag{4}$$

$f(\pi_t)$ is a nonlinear function and x_t is a set of exogenous variables. We account for the possibility that $E[\varepsilon_t | \pi_t] \neq 0$ by estimating (4) using those models for which instrument validity is not rejected by the Sargan *J*-test. Following Vaona and Schiavo (2007), we estimate the model in equation (4) using the semiparametric IV estimation approach of Park (2203). The degree of complexity, or optimal data driven method of bandwidth selection, is determined using the least-square cross validation method of Li et al. (2013). A Gaussian kernel is used for all nonparametric and semiparametric models.

4 Results

Our instruments and exogenous variables only include lagged inflation and lagged GDP. Unfortunately we do not have enough observations going back until 1802 to control for other variables such as investment or terms of trade. Table 2 and 3, however, report that our instruments are reliable. We estimate nine specifications with different instruments. The specifications in Table 2 indicate that all instruments are adequate (F-test is rejected).

Table 2: Estimates of the IV Auxiliary Regressions

	Instruments	R^2	Adj. R^2	$\hat{\sigma}$	F	$Q(20)$
Model 1	π_{t-1}	0.3197	0.3164	4.4506	97.2871***	25.1592
Model 2	π_{t-1}, π_{t-2}	0.3214	0.3149	4.4558	48.7916***	25.5407
Model 3	$\pi_{t-1}, \dots, \pi_{t-3}$	0.3241	0.3142	4.4577	32.7724***	26.9195
Model 4	$\pi_{t-1}, \dots, \pi_{t-4}$	0.3350	0.3220	4.4325	25.6969***	24.1412
Model 5	π_{t-1}, g_{t-1}	0.3219	0.3153	4.4542	48.9004***	24.3469
Model 6	$\pi_{t-1}, \pi_{t-2}, g_{t-1}$	0.3232	0.3133	4.4608	32.6359***	24.8406
Model 7	π_{t-1}, π_{t-2} g_{t-1}, g_{t-2}	0.3253	0.3121	4.4647	24.5929***	25.6369
Model 8	$\pi_{t-1}, \dots, \pi_{t-3}$, $g_{t-1}, \dots, g_{t-3}$	0.3281	0.3082	4.4774	16.4424***	26.8569
Model 9	$\pi_{t-1}, \dots, \pi_{t-4}$, $g_{t-1}, \dots, g_{t-4}$	0.3395	0.3131	4.4614	12.8523***	23.3202

Notes: R^2 is the coefficient of determination; Adj. R^2 is the adjusted coefficient of determination; $\hat{\sigma}$ is the standard error of the regression; F is the regression F statistic; $Q(20)$ is the Ljung-Box portmanteau tests of autocorrelation for order up to 20. *, **, and *** denote significance at 10%, 5%, and 1%, respectively

The Sargan J-statistic from Table 3 show that only models 1, 2, 3, 4, 8 and 9 should be used in the semiparametric model. The coefficient of inflation and lagged inflation on GDP growth are all negative: Inflation reduces economic growth in a linear model. The non-instrumental regressions seem to underestimate the effects of inflation on GDP growth, while the estimates of the IV regressions are all very similar between [-0.274, -0.323].

Table 3: OLS and IV Estimates of the Linear Growth and Inflation Relationship

	Instruments	Intercept [α]	Inflation [β]	Wu-Hausman F-test	Sargan J-Test
OLS		3.8468***	-0.1451**		
		(0.3810)	(0.0686)		
OLS lagged		3.8983***	-0.1796***		
		(0.3790)	(0.0681)		
IV Model 1	π_{t-1}	4.0940***	-0.3180***	3.0120*	
		(0.4130)	(0.1230)		
IV Model 2	π_{t-1}, π_{t-2}	4.0930***	-0.3180***	3.0290*	0.001
		(0.4130)	(0.1230)		
IV Model 3	$\pi_{t-1}, \dots, \pi_{t-3}$	4.1020***	-0.3230***	3.2840*	0.281
		(0.4130)	(0.1220)		
IV Model 4	$\pi_{t-1}, \dots, \pi_{t-4}$	4.0670***	-0.2990**	2.573	1.495
		(0.4100)	(0.1200)		
IV Model 5	π_{t-1}, g_{t-1}	4.0560***	-0.2920**	2.179	6.7700***
		(0.4110)	(0.1220)		
IV Model 6	$\pi_{t-1}, \pi_{t-2}, g_{t-1}$	4.0590***	-0.2940**	2.264	6.8570**
		(0.4110)	(0.1220)		
IV Model 7	π_{t-1}, π_{t-2}	4.0520***	-0.2880**	2.119	7.1830*
	g_{t-1}, g_{t-2}	(0.4110)	(0.1210)		
IV Model 8	$\pi_{t-1}, \dots, \pi_{t-3}$,	4.0690***	-0.3010**	2.529	8.953
	$g_{t-1}, \dots, g_{t-3}$	(0.4110)	(0.1210)		
IV Model 9	$\pi_{t-1}, \dots, \pi_{t-4}$,	4.0310***	-0.2740**	1.832	10.481
	$g_{t-1}, \dots, g_{t-4}$	(0.4080)	(0.1190)		

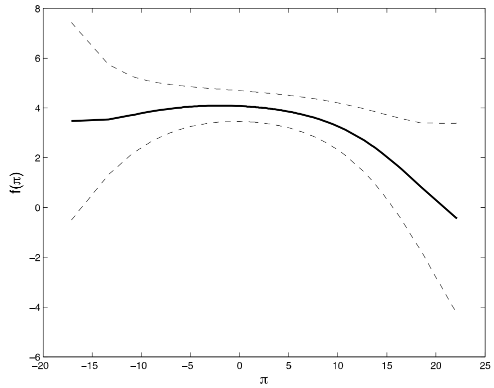
Notes: OLS model is the estimate of $g_t = \alpha + \beta\pi_t + \varepsilon_t$, while OLS-lagged estimates $g_t = \alpha + \beta\pi_{t-1} + \varepsilon_t$ using non-instrumental OLS estimation. IV models are estimated by two stage least squres using the corresponding instruments given in the second column. Wu-Hausman F statistic tests for the endogeneity of the inflation in Equation (2) given the instruments. Sargan J statistic tests for the overidentfying restrictions. *, **, and *** denote significance at 10%, 5%, and 1%, respectively.

Figure 1 plots the relationship between inflation and economic growth. This relationship is nonlinear for all the specifications. Deflation seems to increase growth while inflation consistently reduces GDP growth across various specifications. The inflation threshold is close to zero and as high as per cent. Anything higher than two per cent reduces GDP growth. The nonlinear nature shows that high inflation decreases growth proportionally more compared to low inflation. The slope of Figure 1 is fairly flat for deflation.

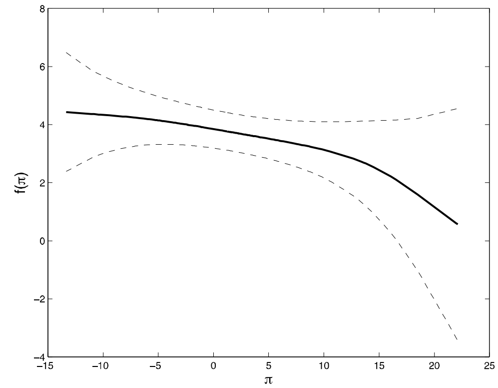
The effects of deflation on growth should be analysed with caution. The adverse economic effects of the ZLB, such as the inability of monetary policy to stimulate aggregate demand in recessions (see Krugman, 1988), might outweigh the growth benefits of deflation. It would seem prudent for the FED to keep inflation expectations anchored at a very low level, given the consequences of the ZLB and balancing it with the economic effects of higher inflation; or in the model specification of Bille (2010)—commitment seems to be the appropriate policy response. An analysis of the economic benefits and adverse effects of deflation is beyond the scope of this paper, but offers an interesting avenue for further study.

Figure 1: NP and SNP-IV Estimates

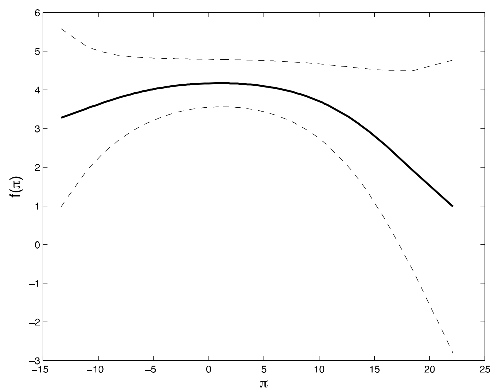
(a) NP estimate of $g_t = f(\pi_t) + \varepsilon_t$



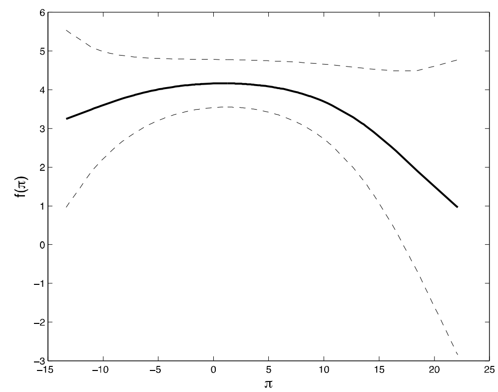
(b) NP estimate of $g_t = f(\pi_{t-1}) + \varepsilon_t$



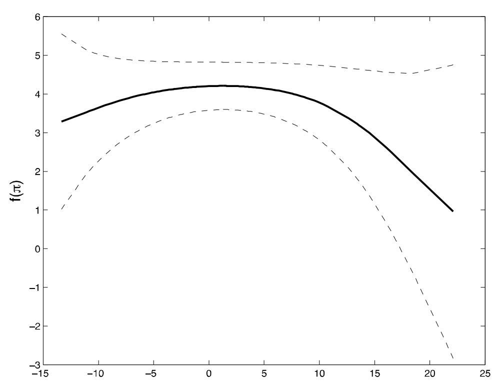
(c) SNP-IV estimate of IV Model 1



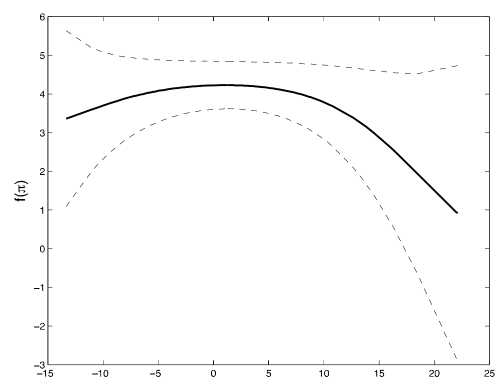
(c) SNP-IV estimate of IV Model 2



(c) SNP-IV estimate of IV Model 3

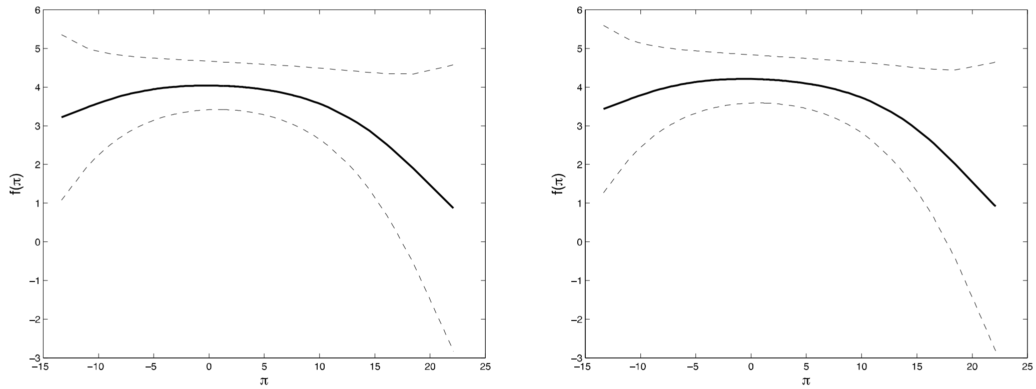


(c) SNP-IV estimate of IV Model 4



(c) SNP-IV estimate of IV Model 8

(c) SNP-IV estimate of IV Model 9



5 Conclusion

We analyse the effects of inflation on economic growth for the United States. Contrary to some research results, we show that low inflation also reduces growth. We use semiparametric instrumental variables method to control for endogeneity. The results consistently suggest that the inflation-growth relationship is nonlinear, with a threshold of about two percent. The hump shaped relationship implies that high inflation reduces economic growth proportionally more relative to low inflation. An interesting finding of this paper shows that deflation increases growth. This paper does not suggest that the Fed should follow a deflation policy—the obvious consequence being that monetary policy becomes ineffective at the zero lower bound. This result does however warrant further investigation of a comparison of the economic benefits of deflation and the adverse effects of the zero lower bound on growth.

References

Billi, R.M. (2010). Optimal inflation for the U.S. economy. The Federal Reserve Bank of Kansas City. RWP 07-03.

Barro, R.J. (1995). Inflation and economic growth. National Bureau of Economic Research. NBER WP NO. 5326

Bruno, M. and Easterly, W. (1998). Inflation crises and long-run growth. *Journal of Monetary Economics,* 41(1998):3-26.

Budekin, R.C.K., Denzau, A.T., Keil, M.W., Sitthiyot, T. and Willett, T.D. (2004). When does inflation hurt economic growth? Different nonlinearities for different economies. *Journal of Macroeconomics,* 26(2004): 519-532.

Chari, V.V., Jones, L.E. and Manuelli, R.E. (1995). The growth effects of monetary policy. Federal Reserve Bank of Minneapolis WP.

Fischer, S. (1981). Towards an understanding of the costs of inflation: II. *Carnegie-Rochester Conference Series on Public Policy,* 15:5-41.

Fischer, S. (1993). The role of macroeconomic factors in growth. National Bureau of Economic Research. NBER WP NO. 4565.

Ireland, P. N. (2009). On the welfare cost of inflation and the recent behavior of money demand. *American Economic Review,* 99: 1040-1052.

Khan, S. and Senhadji, A. (2001). Threshold effects in the relationship between inflation and growth. IMF Staff Papers 48 (1), 1–21.

Krugman, P.R. (1998). It's baaack: Japan's slump and the return of the liquidity trap. *Brookings Papers on Economic Activity,* 29(1998):137-206.

Li, Q. and J. Lin and J.S. Racine (2013). Optimal Bandwidth Selection for Nonparametric Conditional Distribution and Quantile Functions. *Journal of Business and Economic Statistics*, 31:57-65.

Miller, S.M., Martins, L.F. and Gupta, R. (2014). A time-varying approach of the U.S. welfare cost of inflation. *Department of Economics, University of Connecticut, Working Paper No. 2014-11.*

Park, S. (2003). Semiparametric instrumental variable estimation. *Journal of Econometrics*, 112, 381–399.

Reifschneider, D. and Williams, J.C. (2000). Three lessons for monetary policy in a low-inflation era. *Journal of Monery, Credit and Banking,* 32(4):936-966.

Roubini, N. and Sala-i-Martin, X. (1992). A growth model of inflation, tax evasion, and financial repression. National Bureau of Economic Research. NBER WP NO.4062.

Rousseau, P. and Wachtel, P. (2001). Inflation, financial development and growth. *Economic Theory, Dynamics and Markets: Essays in honor of Ryuzo Sato, T. Negishi,R. Ramachandran, K. Mino, eds., Kluwer, 2001.* Available at SSRN:http://ssrn.com/abstract=252929.

Serletis, A. and Yavari, K. (2004). The welfare cost of inflation in Canada and the United States. *Economics Letters,* 84: 199-204.

Vaona, A. and Schiavo, S. (2007). Nonparametric and semiparametric evidence on the long-run effects of inflation on growth. *Economics Letters,* 94(2007): 452-458.

Vaona, A. (2012). Inflation and growth in the long run: A new Keynesian theory and further semiparametric evidence. *Macroeconomic Dynamics,* 16(2012): 94-132.