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Phillips Curve: Forward or Backward Looking?

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Abstract: We estimate both a forward looking and a hybrid New Keynesian Phillips Curve using Generalized Method of Moments (GMM). The findings suggest that inflation is persistent phenomenon in Pakistan and past inflation is having significant explanatory power. Contrary to conventional wisdom, the output gap is not statistically significant in explaining inflation in Pakistan. We also analyze the change in inflation dynamics across time. Results are robust when different proxies are used for output gap. It can be concluded that inflation is both backward looking and forward looking in Pakistan.

Key words: New Neoclassical synthesis · New Keynesian Phillips Curve · Hybrid New Keynesian Phillips Curve · Output gap · GMM estimation

INTRODUCTION

Managing inflation is one of the prime objectives for any central bank of the world. For understanding how monetary policy affects inflation, it is imperative to understand the dynamics of inflation. Moreover, inflation dynamics may differ from country to country due to differences in economic structure, degree of openness and the extent of imperfect competition etc. The importance of optimal monetary policy to curb inflation can be evidenced from an enormous amount of literature that is developed in economics during last two decades [1]. It is the prime responsibility of monetary authority to forecast and control inflation. Fortunately, a rich body of literature now exists on this important topic.

In New Keynesian macroeconomics framework (also called New Neoclassical Synthesis) the dynamics of inflation are analyzed in a very distinct way using the so-called New Keynesian Phillips curve (NKPC). This NKPC is based on Calvo's [2] staggered price model where certain fractions of firm change their prices while rest keep prices fixed. New Keynesian Phillips curve expresses current inflation in terms of expected future inflation and output gap. Later on, Fuhrer and Moore [3] criticized that with backward looking inflation, model is not good at explaining the inflation dynamics. Keeping in view above criticism, Gali and Gertler [4] extended its theoretical frame work by including backward looking inflation as well and calling it Hybrid NKPC. The Hybrid NKPC is part of Comprehensive macroeconomic models based on New Keynesian economics called Dynamic Stochastic General Equilibrium (DSGE) models. For brief explanation of such models, interested reader can see [5] and references therein. The scope of this paper is limited to specification and estimation of NKPC.

There has been only limited research of NKPC in Pakistan. To the best of our knowledge, there is only one study about NKPC in Pakistan where the use of annual data made the series restricted to only thirty observations [6]. It is well recognized in the literature that estimates based on GMM may be biased in small samples [7].

This paper has two objectives. First it estimates forward-looking NKPC and a hybrid NKPC for Pakistan with a view to determine whether inflation dynamics in Pakistan are forward looking, backward looking or hybrid. Second, the paper investigates the stability and structural changes in inflation dynamics across time by considering two sub-periods.

New Keynesian Phillips Curve has received significant theoretical acceptability and its empirical findings are also plausible. Empirical work generally discusses the relevance of variable used for real activity and whether NKPC is more forward looking or backward looking [8, 9]. There has been considerable debate on

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variable to be used as proxy for real activity. Theory suggests that real marginal cost is the main factor that explains the ultimate force which pushes the dynamics of inflation in the economy [4]. Output gap is another variable that can be used in NKPC for real activity instead of real marginal cost [4]. Theoretically, output gap cannot be observed therefore it is constructed using various methodologies.

This paper is organized as follows. In next section, the standard versions of the NKPC and modeling strategy are presented. Section 3 describes the data. Estimations are discussed in section 4 and the last section summarizes the major findings and presents conclusions.

Model for Estimation: As mentioned earlier, the New Keynesian framework provides a broad framework for analysis of monetary policy. NKPC explains one aspect of such framework. Our methodology is based [4]. Gali and Gertler NK Phillips curve is based on Calvo's [2] price mechanism that is spread out over a period of time (Staggered Prices) where each firm may reset its price in every period with a probability of 1-è. Rest of the firms will adjust their prices in later periods. This price re-setting is independent of time elapsed since last adjustment. è is an Index of Price Stickiness. Under Calvo's staggered price mechanism, price dynamics will be as follows;

$$\pi_t = \theta + (1-\theta)\left[\frac{p_t^*}{P_{t-1}}\right]$$

whereas π_t is the inflation rate between time t and t-1 and p_t^* is the new price at time t. p_t^* is expected to be such price at which monopolistic firms will maximize the market value of profit generated. After incorporating price and wage rigidities into the monopolistic environments and combining them into real business cycle models, Gali and Gertler [4] specify the Phillips curve is as follows;

$$\pi_t = \beta \underset{t}{E}\{\pi_{t+1}\} + \lambda\, rmc_t \qquad (1)$$

Where $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$

$\underset{t}{E}\{\pi_{t+1}\}$ is the rational expected value of inflation in period t+1 and rmc_t is the real marginal cost at time t. The coefficient β is the discount factor and it can be further seen that λ depends on both the degree of price stickiness and the discount factor.

Another variant of the above NKPC is where real marginal cost is replaced with output gap as another measure of aggregate economic activity, as follows.

$$\pi_t = \beta \underset{t}{E}\{\pi_{t+1}\} + k\, \tilde{y}_t \qquad (2)$$

Where $\tilde{y}_t$ is the output gap that can be computed by taking log deviation of actual output from potential output i.e. $\tilde{y}_t = y_t - y_t^n$. Also log deviation of real marginal cost from steady state is proportional to the output gap.

Some argue that according to New Keynesian framework, inflation should lead to output gap [3]. In other words, due to increase (decrease) in inflation, subsequent increase (decrease) in output gap is expected, whereas empirical evidence suggests otherwise. They argue that empirically current output gap and expected future inflation move in same direction whereas current output gap and past inflation move in opposite directions. Considering this criticism, Gali and Gertler [4] extend the basis of Calvo staggered pricing mechanism and derived hybrid NKPC. As mentioned earlier, under Calvo staggered pricing mechanism, a certain fraction, è, of firms keep their prices unchanged while other revise them. So that P_t, the price index in period t, is given by

$$P_t = \theta P_{t-1} + (1-\theta)P_t^*$$

where P_t^* represents revised prices.

Gali and Gertler [4] assume that price revisions by firms can be based either on forward or backward looking behavior. Specifically a fraction ω of the firms set prices at P_t^F based on forward looking forecast while the rest set prices to P_t^B based on backward looking criterion. So that,

$$P_t^* = \omega P_t^F + (1-\omega)P_t^B$$

Using the above formulation, the Hybrid NKPC is as follows;

$$\pi_t = \beta^B \pi_{t-1} + \beta^F \underset{t}{E}\{\pi_{t+1}\} + \lambda\, rmc_t \qquad (3)$$

Or if output gap is used as a measure of economic activity;

$$\pi_t = \beta^B \pi_{t-1} + \beta^F \underset{t}{E}\{\pi_{t+1}\} + k\, \tilde{y}_t \qquad (4)$$

In the last, to investigate whether forward looking component of NKPC is getting more explanatory power, we augment the above equation, the details of which will be discussed later in this paper, as follows;

$$\pi_t = \beta^B \pi_{t-1} + \beta^F \underset{t}{E}\{\pi_{t+1}\} + \Omega\,(D * \underset{t}{E}\{\pi_{t+1}\}) + k\,\tilde{y}_t$$

where D is the dummy variable having value 1 if time period is from 1991 to 2010 and 0 otherwise.

Data Description: Various sources are used for gathering data for estimation of NKPC. Basic variables for NKPC are Real Gross Domestic Product (GDP) and Inflation rates. Real GDP is de-seasonalised and then de-trended resulting in construction of Output gap. Four lags, each of output gap and of inflation have been used as Instrumental variables. J-statistic confirms that four lags[1] are sufficient to counter any endogeneity in the model.

Quarterly frequency is used and sample period consist of forty one years that is from 1970 to 2010. Source of Quarterly GDP is Arby [10]. Data series for Quarterly GDP from 2004 onwards is generated, on the same lines, by the authors. Inflation is constructed from Consumer Price Index that is collected from IMF IFS-2011. It is also important to mention here that quarterly GDP is not officially available and Arby [10] has transformed annual data into quarterly data. This series is fairly close to the annual official series and provides reasonable confidence for using it for analysis. Several other researchers have also used the same series [11-13].

Estimation Result: First of all, we estimate equation (2) which is a conventional forward looking NKPC without any backward looking terms. The estimation results for equation (2) have been reported in table 1. For this estimation our sample covers the time period from 1970Q1 to 2010Q4. Our baseline variables are inflation and Output gap (a variable representing real economic activity). Inflation rates have been computed from Consumer Price index whereas for output gap, further three proxies have been employed. These proxies are detrended GDP, quadratic de-trended GDP and Hodrick Prescott (HP filtered) GDP.

Table 1 can be divided into four horizontal parts. Each part is presenting the estimation results of same equation (2) under alternative different scenario, with each scenario employing different proxy for output gap. Fourth part of the table is an exception where equation (2) has been estimated subject to the restriction that β=1.00, as will be explained later.

It is evident, from table 1, that coefficient of real activity is insignificant while coefficient of forward looking inflation is not only highly significant but its value is very near to 1.00. Theoretically, the steady state value for inflation is assumed at 4.00 annually, that is equivalent to 0.99 (or 1.00 approx) when quarterly data is used. The value of 0.99 is frequently used in the literature.

Table 1: Estimation of New Keynesian Phillips Curve, 1970 to 2010

Output gap Measures		β	*k*	*Adjusted* R^2
Detrended GDP	J-Stat= 0.0751	1.0054	0.3836	83.34%
	Obs= 155	p=0.0000	p=0.9040	
	Inst=9			
Quadratic Detrended GDP	J-Stat= 0.0822	1.0037	-2.8468	83.46%
	Obs= 155	p=0.0000	p=0.5388	
	Inst=9			
HP filtered GDP	J-Stat= 0.0738	1.0011	-5.5259	83.26%
	Obs= 155	p=0.0000	p=0.4722	
	Inst=9			
Detrended GDP	J-Stat= 0.0868	1.0000	-6.6359	82.57%
Restricted Beta=1.00	Obs= 155		p=0.1084	
	Inst=9			

Notes: This table provides the estimation results of Eq. (2) using Generalized Method of Moment (GMM) methodology. Estimations have been conducted, on quarterly data, covering the sample period of 1970:Q1 to 2010Q4. Instrumental variable used for GMM estimation include four lags of inflation and four lags of output gap including a constant by default. In Bandwidth selection, 4 have been used due to quarterly data. In second Column, J-statistics along with no. of observation and number instruments have been given to test Overidentifying restriction. P-values for significance level are shown in brackets.

[1] We also estimate Eq (2) with eight and twelve lags and find no significant difference. Results have not been reported to save space but available upon request. We are thankful to an anonymous referee for suggesting this robustness check.

Table 2:Estimation of Hybrid New Keynesian Phillips Curve, 1970 to 2010

Output gap Measures		β^F	β^F(-1)	β^F(-2)	Ψ	κ
Detrended GDP	J-Stat= 0.0479	0.4137	0.9000	-0.4335	0.1162	0.3634
	Obs= 155	(p=0.0020)	(p=0.0006)	(p=0.0792)	(p>0.0500)	(p=0.6108)
Adjusted R^2=94.99%	Inst=9					
Quadratic Detrended GDP	J-Stat= 0.0481	0.4311	0.8679	-0.4085	0.1059	-0.3132
	Obs= 155	(p=0.0021)	(p=0.0013)	(p=0.0999)	(p>0.0500)	(p=0.8038)
Adjusted R^2=95.02%	Inst=9					
HP filtered GDP	J-Stat= 0.0299	0.5677	0.5826	-0.1744	0.0202	-5.1991
	Obs= 155	(p=0.0001)	(p=0.0354)	(p=0.5311)	(p>0.0500)	(p=0.4153)
Adjusted R^2=94.44%	Inst=9					
Detrended GDP	J-Stat=0.0294	0.5000	0.7096	-0.2632	0.0505	-4.8722
Restricted Beta=0.500	Obs= 155		(p=0.0000)	(p=0.2180)	(p>0.0500)	(p=0.4678)
Adjusted R^2=94.83%	Inst=9					

Notes: This table provides the estimation results of Eq. (4) using Generalized Method of Moment (GMM) methodology. Estimations have been conducted, on quarterly data, covering the sample period of 1970:Q1 to 2010Q4. Instrumental variable used for GMM estimation include four lags of inflation and four lags of output gap including a constant by default. In Bandwidth selection, 4 have been used due to quarterly data. In second Column, J-statistics along with no. of observation and number instruments have been given to test Overidentifying restriction. P-values for significance level are shown in brackets. 'Ψ' reports the sum of third and fourth lag of inflation.

Due to this reason, we re-estimate equation (2) while keeping value of β restricted at 1.00 in order to examine any significant change in coefficient of output gap. We can see the results are presented in the bottom of panel of table 1, the coefficient of output gap remains statistically insignificant.

One important econometrics issue is to analyze the appropriateness of instruments used, both, in terms of their relevance and also in terms of their numbers. Hansen's J□test can be employed to analyze this issue. This test is also known as test for over□identifying restrictions. Under the null hypothesis that 'Model is Valid', the J□statistic follows a Chi□square distribution with degree of freedom (No. of Instruments less No. of parameters). The value of J□Statistic given by E□view 5.0 is multiplied by number of observation and compared to critical value of Chi□square distribution. For example, J□Statistic * No of Observations = 0.0815* 144 = 11.74. The critical value is $\chi^2_{(0.05,\,11)} = 19.68$ So Null Hypothesis cannot be rejected and our model is valid. In both estimations, four lags of the instruments have been used. Table 1 also reports J□statistics for all estimated models. Test for over□identifying restrictions (J□test) cannot reject the validity of the instruments.

Although the estimated coefficient for equation (2) and its degree of fit are reasonable but empirical criticism on restrictive nature of NKPC is not yet addressed in our analysis. Various researchers [8, 14] and reference therein) has conducted research to analyze whether inflation is more forward looking or more backward looking in various economies. For example, inflation in Australia is mainly backward looking [9]. Hendry's Specific to General methodology also motivates us to examine if other variables can be included in NKPC to make its fit better.

Due to these reasons, we augment NKPC with backward looking component in equation 4, known as Hybrid NKPC. Table 2 reports the estimation results. We included four lags of inflation in equation 4 to examine the persistence in inflation. However to simplify the results, we have reported only results for first and second lag and the sum of lag 3 and 4 has been collectively shown in Ψ. For this estimation too, we use the three proxies for output gap mentioned above.

Estimation results show that major source of inflation lies in its first lag. The output gap, still, does not seem to explain inflation dynamics in Pakistan. Another interesting result that is evident from table 2 is the relatively larger impact of backward looking inflation and lesser impact of forward looking impact of inflation in Pakistan across whole sample period of almost four decades. This result is very robust for all three proxies of output gap.

One thing is very evident from estimation results of both general NKPC and hybrid NKPC that coefficient of output gap is insignificant in all of these cases. In other words, contrary to theory, empirically inflation does not seem to be explained through output gap. The same conclusion can be seen in [4, 15-17]. The failure in obtaining a statistically significant short term explanatory relation of real activity in explaining inflation is, it is argued [4], obviously unsettling for general economic theory.

Estimation result for full sample period depict that in Pakistan inflation seems to be relatively more backward looking. But it is important to consider that the whole sample period consists of various phases during which economic policies, ways to conduct policies and even the economy dynamics have changed. We are interested in analyzing whether phenomenon of Hybrid inflation has been consistent across sample for Pakistan or not. That is why; we are ignoring various lags here and restricting ourselves to one lag only. Our methodology is also justified from Table2 where only first lag of inflation is significant at 5% confidence level.

Keeping in view this rationale, we divide whole sample period into two sub-samples that is 1970Q1-1990Q4 and 1991Q1-2010Q4. Privatization of economy as a national policy was adopted in 1990-91. From this time onwards, the role of private sector started increasing in the economy. This is the sole reason for selecting 1991 as breaking point for full sample period. Comparison of these sub-samples will help us in analyzing whether inflation dynamics in Pakistan have changed or not. Consistent to our methodology, we estimate the model for sub-sample period for all three proxies of output gap. The results can be seen in Table 3, Table 4 and Table 5.

Across both sub periods, the hybrid nature of inflation dynamics seems consistent. Another interesting variation can be seen in coefficients of inflation across the sample period. The difference in magnitude of forward-looking inflation and backward-looking inflation across both sub samples can be the indication of change in intensity of forward looking inflation dynamics. We can see that the coefficient of β^F has increased from 0.4776 to 0.4952 in table 3, from 0.4780 to 0.4804 in table 4 and from 0.4823 to 0.4964 in table 4. Although the increase is very small but it may be taken as ray of change. To examine whether the change is statistically significant or not, we re-estimated the model after introducing a dummy variable for later sub period with the interaction of forward looking

Table 3: Estimation of Hybrid New Keynesian Phillips Curve - Using Detrended GDP

Period		β^F	β^B	κ
Full Sample: 1970-2010	J-Stat= 0.0642	0.4964	0.5000	0.4861
Adjusted R^2=94.89%	Obs= 155	(p=0.0000)	(p=0.0000)	(p=0.5251)
	Inst=9			
Sub-period I: 1970-1990	J-Stat= 0.0745	0.4776	0.5168	0.3947
Adjusted R^2=93.93%	Obs= 76	(p=0.0000)	(p=0.0000)	(p=0.7336)
	Inst=9			
Sub-period II:1991-2010	J-Stat= 0.1226	0.4952	0.5087	0.4083
Adjusted R^2=96.43%	Obs= 79	(p=0.0000)	(p=0.0000)	(p=0.6095)
	Inst=9			

Notes: This table provides the estimation results of Eq. (4) using Generalized Method of Moment (GMM) methodology covering the sample period of 1970:Q1 to 2010Q4 and two subsample periods. Detrended GDP is used as proxy for output gap. Instrumental variable used for GMM estimation include four lags of inflation and four lags of output gap including a constant by default. In Bandwidth selection, 4 have been used due to quarterly data. In second Column, J-statistics along with no. of observation and number instruments have been given to test Overidentifying restriction. P-values for significance level are shown in brackets.

Table 4:Estimation of Hybrid New Keynesian Phillips Curve - Using Q-Detrended GDP

Period		β^F	β^B	κ
Full Sample: 1970-2010	J-Stat= 0.0629	0.4921	0.5041	-0.5861
Adjusted R^2=94.89%	Obs= 155	(p=0.0000)	(p=0.0000)	(p=0.6292)
	Inst=9			
Sub-period I:1970-1990	J-Stat= 0.0821	0.4780	0.5152	-1.5765
Adjusted R^2=93.90%	Obs= 76	(p=0.0000)	(p=0.0000)	(p=0.5382)
	Inst=9			
Sub-period II:1991-2010	J-Stat= 0.1259	0.4804	0.5248	0.1328
Adjusted R^2=96.41%	Obs= 79	(p=0.0000)	(p=0.0000)	(p=0.9101)
	Inst=9			

Notes: This table provides the estimation results of Eq. (4) using Generalized Method of Moment (GMM) methodology covering the sample period of 1970:Q1 to 2010Q4 and two subsample periods. Quadratic Detrended GDP is used as proxy for output gap. Instrumental variable used for GMM estimation include four lags of inflation and four lags of output gap including a constant by default. In Bandwidth selection, 4 have been used due to quarterly data. In second Column, J-statistics along with no. of observation and number instruments have been given to test Overidentifying restriction. P-values for significance level are shown in brackets.

Table 5: Estimation of Hybrid New Keynesian Phillips Curve - Using HP Filtered GDP

Period		β^F	β^B	κ
Full Sample:1970-2010	J-Stat= 0.0707	0.4965	0.4996	2.0234
Adjusted R^2=94.91%	Obs= 155	(p=0.0000)	(p=0.0000)	(p=0.7833)
	Inst=9			
Sub-period I: 1970-1990	J-Stat= 0.0889	0.4823	0.5094	-3.5440
Adjusted R^2=93.87%	Obs= 76	(p=0.0000)	(p=0.0000)	(p=0.7708)
	Inst=9			
Sub-period II: 1991-2010	J-Stat= 0.1256	0.4963	0.5076	0.3476
Adjusted R^2=96.44%	Obs= 79	(p=0.0000)	(p=0.0000)	(p=0.9376)
	Inst=9			

Notes: This table provides the estimation results of Eq. (4) using Generalized Method of Moment (GMM) methodology covering the sample period of 1970:Q1 to 2010Q4 and two subsample periods. HP filtered GDP is used as proxy for output gap. Instrumental variable used for GMM estimation include four lags of inflation and four lags of output gap including a constant by default. In Bandwidth selection, 4 have been used due to quarterly data. In second Column, J-statistics along with no. of observation and number instruments have been given to test Overidentifying restriction. P-values for significance level are shown in brackets.

Table 6: Estimation of Hybrid New Keynesian Phillips Curve $\pi_t = \beta^B \pi_{t-1} + \beta^F \underset{t}{E}\{\pi_{t+1}\} + \Omega\,(D * \underset{t}{E}\{\pi_{t+1}\}) + k\,\tilde{y}_t$ (with Interactive Dummy), 1970 to 2010

Output gap Measures		β^F	β^B	κ	Ω
Detrended GDP	J-Stat= 0.06173	0.5132	0.5033	0.8010	-0.0357
	Obs= 155	(p=0.0000)	(p=0.0000)	(p=0.4958)	(p=0.4624)
Adjusted R^2=94.78%	Inst=9				
Quadratic Detrended GDP	J-Stat= 0.0678	0.7142	0.4382	5.2259	-0.2968
	Obs= 155	(p=0.0000)	(p=0.0000)	(p=0.1421)	(p=0.0715)
Adjusted R^2=85.15%	Inst=9				
HP filtered GDP	J-Stat= 0.06625	0.5769	0.48777	4.0677	-0.1273
	Obs= 155	(p=0.0000)	(p=0.0000)	(p=0.6308)	(p=0.1405)
Adjusted R^2=93.19%	Inst=9				

Notes: This table provides the estimation results of augmenting Eq. (4) with interactive dummy variable using Generalized Method of Moment (GMM) methodology. Estimations have been conducted, on quarterly data, covering the sample period of 1970:Q1 to 2010Q4. Dummy variable is 1 when time period is from 1991 to 2010 and 0 otherwise. Instrumental variable used for GMM estimation include four lags of inflation and four lags of output gap including a constant by default. In Bandwidth selection, 4 have been used due to quarterly data. In second Column, J-statistics along with no. of observation and number instruments have been given to test Overidentifying restriction. P-values for significance level are shown in brackets. 'Ω' reports the coefficients for interactive dummy variable.

inflationary component. Dummy variable is 1 when time period is from 1991 to 2010 and 0 otherwise. Results have been reported in Table 6. The coefficient of interactive dummy variable is insignificant @ 5% in all three cases. New Keynesian economics stresses that for effective monetary policy, central banks now need to manage the expectations of economic agent as well. Greenspan's, while giving his testimony in Humphrey-Hawkins issue in 1994, states as: "The challenge of monetary policy is to interpret current data on the economy and financial markets with an eye to anticipating future inflationary forces and to countering them by taking action in advance."

The estimation results of this paper don't confirm the relatively increased importance of forward looking aspect across time in Pakistan. Still, it can be argued that, as [4] do, "while the benchmark pure forward looking model is rejected on statistical grounds, it still appears to be a reasonable first approximation of reality."

CONCLUSION

This paper examines inflation dynamics in Pakistan in the context of closed economy. We consider whether inflation in Pakistan is forward looking, backward looking or a hybrid phenomenon. Our analysis consists of three steps. Firstly, we estimated a simple forward looking close economy version of the New Keynesian Phillips Curve. Secondly, we augmented it with lags for inflation to examine whether backward looking coefficients are significant. And thirdly, we divide the whole sample into two sub-samples and re-estimate model to analyze the subsample stability.

Generalized Method of Moments (GMM) is used for all specification of model because it is considered as one of standard methodology for handling forward looking variables. Major source of inflation lies in its first lag whereas, contrary to conventional wisdom, the output gap becomes insignificant in explaining inflation in Pakistan. Our results regarding insignificance of Output gap are robust not only across various proxies of output gap but also across all the specifications of NKPC used in this paper. Also empirically inflation seems to be a Hybrid phenomenon i.e. both forward looking and backward looking in Pakistan.

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