Estimates of the New Keynesian Phillips Curve for Pakistan

This paper presents estimates of the New Keynesian Phillips Curve (NKPC) for the agriculture, manufacturing and services sectors of Pakistan's economy. The real marginal cost—derived from dynamic translog cost function—labour share of income and output gap are the indicators of economic activity along with past and expected inflation to determine inflation dynamics in each sector. The estimates of the structural parameters of the NKPC are consistent with economic theory in most of the models. Within sample forecast performance and other diagnostic tests indicate that the derived measure of real marginal cost performs better relative to the specifications with labour share of income or output gap. Further, the NKPC based on restrictive Cobb-Douglas production technology with labour input only does not perform better than the models that considers more inputs and intermediate cost. Our results show that the manufacturing is forward-looking sector followed by services and agriculture sectors.

Inflation, Phillips Curve, Real Marginal Cost, Pakistan.
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1. Introduction

Empirical investigation of the New Keynesian Phillips Curve (NKPC) has garnered research attention of many researchers (Gali et al. 2005; Christiano et al. 2005; Neiss and Nelson 2005; Batini et al. 2005) especially after the estimation of the structural model of inflation by Gali and Gertler (1999) and Sbordone (2002). The important aspect of Gali and Gertler (1999) is to establish the empirical link between short run inflation dynamics and real economic activity with strong theoretical underpinnings. They replace the ad hoc measure of economic activity (i.e. output gap) by the labour share of income considering it as a proxy of real marginal cost. Mazumder (2010), however, criticizes usage of the labour share of income due to its counter cyclical behaviour. Consequently, Dupuis (2004) and Batini et al. (2005) consider a variety of variables that represent the better dimension of real marginal cost. In continuation of this literature, we derive a new measure of real marginal cost from the dynamic translog cost function.

Regarding the estimation of NKPC on countries' aggregate data, Byrne et al. (2013) and Norkute (2015) highlight an important point that if price-setting behaviour differs across sectors then there is a possibility of getting biased parameter estimates in NKPC models that are applied to aggregated data. In such situation, the importance of real marginal cost will be underestimated and inflation persistence will be overestimated (Imbs et al. 2007). This point essentially leads towards the idea of estimating separate NKPC for heterogeneous sectors. Against this background, this paper provides estimates for structural models of inflation for the agriculture, manufacturing and services sectors of Pakistan's economy.

Most studies estimate the NKPC on data of industrialized economies and there exist relatively few studies for developing countries like Pakistan. Saeed and Riaz (2012) estimate purely forward-looking and hybrid form of the NKPC with output gap. They find that inflation is largely a backward-looking phenomenon in Pakistan, and they demonstrate that the output gap is mostly negative and insignificant, which confirms the point raised by Gali and Gertler (1999) that output gap is not an appropriate determinant of inflation. Satti et al. (2007), however, find that inflation is a forward-looking phenomenon in the case of Pakistan.

They use labour share of income along with lead and lag of inflation. Their estimates of NKPC with output gap yield a negative coefficient, but the coefficient of the labour share of income possesses the theoretically correct sign. However, their estimate of the discount factor is quite low and is not fully justified in the paper. Therefore, the inconclusive findings and limited literature motivates a new estimation of Phillips Curve for Pakistan's economy.

This paper presents estimates of NKPC models for three sectors with three distinct indictors of economic activity— real marginal cost, labour share of income, and output gap. Differentiating the estimated dynamic translog cost function with respect to output yields marginal cost. Further, to take care of sector wise heterogeneity, we estimate NKPC for agriculture, manufacturing and services sectors of Pakistan's economy. We consider the Generalized Method of Moments (GMM) to handle the endogeneity that might arise due to the correlation of error terms with expected inflation and indicators of economic activity. The real marginal cost, derived from translog cost function, considers multi-input structure of the production technology. However, the labour share of income assumes an underlying production function of labour input only. Therefore, there is need to consider a specification of hybrid NKPC that includes other input costs as well. Malikane (2014), Petrella and Santoro (2012) and Batini et al. (2005) consider broader determinants (intermediate costs and more than just labour input) of inflation in NKPC that are comparable with the specification with real marginal cost. The results indicate that the NKPC that considers output gap and labour share of income as forcing variable do not perform well. It indicates that the restrictive assumption of using Cobb-Douglas technology with only labour input cannot capture the inflation dynamics in different sectors of Pakistan's economy.

The structure of the paper is as follows. After the introduction in the first section, Section 2 presents the estimation method and data issues. Section 3 discusses the empirical results and section 4 concludes.

2. Methodology

Derivation of marginal cost from translog cost function and estimation of Phillips curves are two important steps of methodology. This section starts with the description of static and dynamic translog cost functions. It discusses the theoretical properties of an appropriate long run and static cost function. Short run dynamic cost functions are derived from their counterpart long run static functions. Differentiating the dynamic functions with respect to output provides the nominal marginal costs. We use sector specific deflators to convert the nominal marginal costs into real. Finally, we estimate the hybrid NKPC by using these real marginal costs.

2.1 Derivation of Real Marginal Cost

2.1.1 Cost Functions

We specify the static translog cost function without adjustment costs and equilibrium in long run (Lau 1971; Christensen et al. 1973; Diewert 1974; Lau 1974). We denote factor prices by W_i, respective quantities by X_i and level of output by Y. Total cost (TC) equals $\sum W_i X_i$:

$$\boldsymbol{Ln(TC) = \alpha_0 + \sum_i \alpha_i\big(Ln(W_i)\big) + \frac{1}{2}\sum_i\sum_j \gamma_{ij}\big(Ln(W_i)\big)\Big(Ln\big(W_j\big)\Big) + \beta_y\big(Ln(Y)\big) + \frac{1}{2}\beta_{yy}\big(Ln(Y)\big)^2 + \sum_i \rho_{iy}\big(Ln(W_i)\big)\big(Ln(Y)\big) + \alpha_x(t) + \alpha_{xx}(t)^2 + \sum_i \rho_{ix}\big(Ln(W_i)\big)(t) + \beta_{yx}\big(Ln(Y)\big)(t) + \varepsilon_t,} \tag{1}$$

where *i* and *j* denote inputs.

To derive the share equation of each input of this static function, we use Shephard's lemma.

$$S_i = \alpha_i + \sum_j \gamma_{ij}\Big(Ln\big(W_j\big)\Big) + \rho_{iy}\big(Ln(Y)\big) + \rho_{ix}(t). \tag{2}$$

We jointly estimate the total cost function (Eq. 1) and cost share equations (Eq. 2) with Full Information Maximum Likelihood (FIML) after imposing symmetry and linear homogeneity restrictions. FIML provides the efficient estimators for models with nonlinear parameters (Urga and Walters 2003). This flexible cost function is unable to guarantee the satisfaction of condition for monotonicity and concavity in factor prices. Therefore, we consider imposing these conditions in the case of violation (such as unexpected sign of cost share of inputs, elasticity of total cost with respect to output and principal minors of Hessian matrix).

Here, the monotonicity in inputs implies that the estimated cost share of each inputs is positive. The monotonicity in output holds if $\frac{\partial(Ln(TC))}{\partial(Ln(Y))} > 0$.

2.1.2 Dynamic Cost Function

We follow Hall and Nixon (1999, 2000) in deriving the dynamic system. Anderson and Blundell (1982) introduce the error correction mechanism. We consider this mechanism for the derivation of dynamic translog cost function and share equations. It ensures consistency and integration of cost function with input share equations,

$$Ln(TC_t) = m\left(Ln(TC_t^*)\right) + (1-m)\left(Ln(TC_{t-1})\right) + (1-m)\left(\sum_i S_{i,t-1}\left(Ln\left(P_{i,t}\right)\right)\right) - (1-m)\left(\sum_i S_{i,t-1}^*\left(Ln\left(P_{i,t-1}\right)\right)\right) + \sum_i \sum_j \beta_{ij}\left(S_{j,t-1}^* - S_{j,t-1}\right)\left(Ln\left(P_{i,t}\right)\right), \quad (3)$$

$$\Delta S_{it} = m(\Delta S_{it}^*) + \sum_j k_{ij}\left(S_{j,t-1}^* - S_{j,t-1}\right). \quad (4)$$

We jointly estimate the dynamic cost functions (Eq. 3) and cost share equations (Eq. 4) by using the iterative Maximum Likelihood procedure. Iterative Maximum Likelihood is equivalent to 3SLS and provides efficient and consistent estimates of the multivariate system (Allen and Urga 1999). Eakin et al. (1990) maintain that the statistics (such as marginal cost, elasticities of substitution and economies of scale) derived from the translog cost function are nonlinear combination of estimated parameters. Accordingly, they conclude that a non-linear function derived from normally distributed estimated coefficients will not follow the same distribution. This nonlinearity raises questions on the reliability of confidence intervals. Further, there are many parameters to be estimated in the flexible functional forms and these forms require reasonable number of observations. The issue of the unknown distribution of the statistics and sample size can be resolved by bootstrapping. This method constructs standard error estimates and confidence intervals. Therefore, with the objective to strengthen the statistical inference procedure, we use the bootstrap method. In the case of unknown distribution of the errors, we draw the errors randomly with replacement from the residuals of the estimated models. Singh (1981) and Politis (2003) say that even a weak dependence between observations of a time series leads towards inconsistent estimates. Bootstrap method applied to total data results in loss of dependence information.

Consequently, bootstrap fails to provide valid estimates of standard errors. This raises the issue of inconsistency. Following Politis (2003) suggestion of using block-sampling method for such issues, we perform resampling with replacement from the blocks for creating pseudo data. We do 1,000 replications to find out the distribution of the underlying core and computed parameter estimates. From these distributions, normal confidence intervals are constructed. We report the significance of the parameters by using the bootstrap normal confidence intervals.

We derive the nominal marginal cost as follows,

$$MC = \frac{\partial TC}{\partial Y} = \frac{\partial(Ln(TC))}{\partial(Ln(Y))}\frac{Y}{TC} = \frac{Y}{TC}\left(\beta_y + \beta_{yy}\big(Ln(Y)\big) + \sum_i \rho_{iy}\big(Ln(W_i)\big) + \beta_{yx}(t)\right), \qquad (5)$$

this linearized to;

$$\widetilde{MC}_t = \widetilde{Y}_t - \widetilde{TC}_t + \frac{1}{h}\left[\beta_{YY}\widetilde{Y}_t + \frac{1}{r}\left[\sum \rho_{iY}\widetilde{W}_{\iota t}\right]\right], \qquad (6)$$

Where $r = \overline{\sum \rho_{\iota Y} Ln(W_{\iota t})}$ and $h = \overline{[\beta_Y + \beta_{YY} Ln(Y_t) + \sum_\iota \rho_{\iota Y} Ln(W_{\iota t}) + \beta_{Yx}(t)]}$.

This derived real marginal cost is the core determinant of inflation in the structural model of NKPC. Gali and Gertler (1999) consider labour share of income as an indicator of economic activity in the NKPC.

2.2 The Specification of the NKPC

We use the real marginal cost, derived from the dynamic translog cost function, as a forcing variable in the NKPC. The underlying production technology of this flexible cost function considers multiple inputs. Therefore, this real marginal cost possesses a natural advantage over labour share and output gap, which are based on production function with labour input only. Therefore, we can only compare the specification of NKPC with derived real marginal cost to the specification that also considers measure based on broader production function. Malikane (2014), Batini et al. (2005) and Petrella and Santoro (2012) consider broader specification of NKPC, which is comparable with the specification of real marginal cost. Batini et al. (2005) start with Cobb-Douglas production function with labour input only and assume that firms also use imported inputs. Therefore, costs depend on share of labour and price of imported material. Further, overall demand conditions of the economy determine equilibrium markup. Therefore, this broad specification includes real exchange rate and output gap as additional determinants of inflation. Real exchange rate and output gap capture the competitiveness and cyclical effects respectively.

Based on this discussion, we suggest four specifications of hybrid Phillips curve by changing the measures of real economic activity as:

$$\pi_t = \gamma + \gamma^f(\pi_{t+1}) + \gamma^b(\pi_{t-1}) + \theta(RMC_t) + \varepsilon_t, \tag{7}$$

$$\pi_t = \gamma + \gamma^f(\pi_{t+1}) + \gamma^b(\pi_{t-1}) + \theta(SL_t) + \varepsilon_t, \tag{8}$$

$$\pi_t = \gamma + \gamma^f(\pi_{t+1}) + \gamma^b(\pi_{t-1}) + \theta(Gap_t) + \varepsilon_t, \tag{9}$$

$$\pi_t = \gamma + \gamma^f(\pi_{t+1}) + \gamma^b(\pi_{t-1}) + \theta_g(Gap_t) + \theta_s(SL_t) + \theta_w(re_t) + \theta_m(p_t^m - p_t) + \theta_o(oil_t) + \theta_n n_t + \varepsilon_t, \tag{10}$$

where π_t is inflation, RMC_t is real marginal, SL_t is labour share of income and Gap_t is output gap. re_t, p_t^m, oil_t and n_t are the real exchange rate , import prices, international crude oil prices and employed labour force respectively.

Gali and Gertler (1999), Gali et al. (2001), Leith and Malley (2007) among many others use the GMM technique for the estimation of the NKPC as the correlation of the error terms with the indicators of economic activity leads to an endogeneity problem. Another source of endogeneity is the implied correlation between the forward-looking component in NKPC and the error term, which occurs when the lead of actual inflation replaces the expected inflation. With the assumption of rational expectations and complete information, the expectation of the forward term of inflation can be replaced by actual inflation because economic agents do not make systematic mistakes in predicting future inflation. Roberts (1995), however, argues that it may provide an inconsistent estimate if any part of the model is not properly specified, and therefore, suggests McCallum (1976) approach in which the information set can be restricted by using instrumental variables for the expected inflation. Further, Roberts (1995) concludes that inflationary expectations derived from the consumer surveys (Livingston and Michigan) are more appropriate and better indicator of future inflation. Due to unavailability of inflation expectation surveys in Pakistan, we consider McCallum (1976) approach.

Roodman (2009) maintains that the inclusion of many instruments may raise the issue of bias and weak instruments. Therefore, the choice of optimal number of instruments becomes a critical issue. Hence, we adopt the strategy of Malikane (2014) in the selection of the appropriate numbers of instruments. The procedure begins with considering the maximum lags of the instruments that are used by Gali and Gertler (1999) in the estimation of first stage regressions of the GMM estimation. In addition, we include international crude oil prices due to the importance of energy (Bernanke 2007; Malikane 2014). Therefore, lag of real marginal cost, labour share of income, output gap, interest rate spread along with the international oil prices, inflation in food items, and growth in imported goods prices are the instrumental variables. Moreover, we adopt a parsimonious approach in the selection of the lags of instrumental variables.

2.3 Data Sources and Variable Construction

Annual data from 1973 to 2013 is collected from various issues of Pakistan Economic Survey (2013), Pakistan Energy Yearbook (2013), and Census of Manufacturing Industries of Pakistan (2006). Owing to different data issues, particularly due to structural break of data in 1971, the sample period starts from 1973. Measure of inflation is the annual growth rate of respective deflator. Labour share, $SL_t = \frac{W_t N_t}{P_t Y_t}$ where $P_t Y_t$ is nominal GDP of the respective sector and $W_t N_t$ is the compensation to employees in that specific sector. Hodrick-Prescott (HP) filter technique provide the measure of output gap.

Marginal cost, derived from the estimated dynamic translog cost function, is a proper variable according to theoretical derivations of NKPC. This measure is derived from a flexible functional form whereas labour share of income is computed by assuming a restricted Cobb-Douglas technology. Further, dynamic correlations of real marginal cost with lag, level, and lead of inflation are consistently positive in all sectors (Table 1). However, dynamic correlations in the case of labour share of income and output gap are not indicating any positive picture. Table 1 reports the dynamic correlation of inflation with two periods lead and one period lag of the real marginal cost, output gap and labour share of income.

Table 1: Dynamic Correlation of Current Inflation with Indicators of Economic Activity

Correlation of π_t with	Agriculture	Manufacturing	Services
RMC_{t-1}	0.20	0.30	0.40
RMC_t	0.26	0.29	0.46
RMC_{t+1}	0.10	0.34	0.46
RMC_{t+2}	0.07	0.02	0.03
Gap_{t-1}	0.11	0.00	0.33
Gap_t	-0.05	0.22	0.43
Gap_{t+1}	0.25	0.35	0.36
Gap_{t+2}	-0.05	-0.42	0.20
SL_{t-1}	-0.10	0.19	0.10
SL_t	0.04	0.15	0.05
SL_{t+1}	-0.02	0.11	0.03
SL_{t+2}	0.03	0.06	-0.02

2.4 Diagnostic Procedure

Reliability of the results depends on appropriate and detailed diagnostic procedures. On the basis of theory and empirical research (Roberts 1995; Gali and Gertler 1999; Gordon 2011; Malikane and Mokoka 2014), it is well established that there is need to search for better instrumental variables for indicators of economic activity (real marginal cost, labour share of income and output gap) and lead of inflation. Instrumental variables should explain the endogenous variables and should be orthogonal to the errors. The presence of weak instrument may lead to weak identification and non-normal distribution, which creates doubts on the inferential procedure. Therefore, we examine the relevance and validity of instruments. The LM test investigate the relevance of excluded instruments with a null hypothesis of model is under identified. The LM statistics is χ^2 distributed with degrees of freedom equal to one plus number of excluded instrument minus number of endogenous variables. Further, partial R^2 due to Shea (1997) and F statistics are also reported to investigate the relevance of instruments. In GMM estimations, we test over identifying restrictions by using Hansen J test that is χ^2 distributed with degree of freedom equal to number of over identifying restrictions. These tests are useful in investigating the relevance and validity of instruments.

3. Results

3.1 Real Marginal Cost

We estimate the static translog cost function for agriculture, manufacturing and services sectors of Pakistan's economy by imposing linear homogeneity and symmetry conditions. Positive cost shares of inputs and elasticity of total cost with respect to output confirms the monotonicity in inputs and outputs. Homotheticity implies that cost function is not homogeneous and we test this by using the likelihood ratio test. The translog cost function does not satisfy the global curvature condition because of unexpected signs of principal minors of Hessian matrix. Therefore, we evaluate the local concavity at each data point and find satisfactory results at all data points. The data set satisfies the condition of monotonicity in prices. Table 3 reports the factor shares at the mean values. We adjust these factor shares in a way so that these sum up to unity. In order to test for cointegration, Augmented Dickey Fuller (ADF) tests are applied to the residuals of static translog cost function and ADF test statistics is compared with the critical value given in MacKinnon (1991). Table 4 presents the results, which reject the null hypothesis of no cointegration. The results of static long run systems satisfy the theoretical conditions and confirm the cointegration in the static system.

In the second stage, we estimate the dynamic translog cost function (Eq. 3) along with the share equations (Eq. 4). We use the iterative full information Maximum Likelihood procedure to ensure the efficiency of the estimates. Table 2 reports the estimates of static and dynamic systems. Most estimated parameters are significant at conventional levels. The dynamic systems improve the value of log likelihood from static models by 13%, 12% and 10% for the manufacturing, agriculture and services sectors respectively. In order to get the expression for the marginal cost mentioned in Eq. 5, we differentiate the dynamic cost functions with respect to output quantity. It provides the nominal marginal cost. We convert these nominal marginal costs into real by using sector specific deflators.

Table 2: Estimates of Cost Functions

	Manufacturing Sector		Agriculture Sector		Services Sector	
	Dynamic	Static	Dynamic	Static	Dynamic	Static
Constant	-32.290**	-66.000*	-260***	-277.7***	8.225	-3.545
α_1	1.561*	1.410*	-1.73**	0.9	-0.561	0.3
α_2	3.143*	1.820*	0.19	2.31*	0.284*	0.097
α_3	0.095	0.920*	-	-	-	-
α_4	-3.799*	-3.140*	2.54*	-2.21**	1.276*	0.613***
β_y	5.113**	11.020*	39.33***	39.2***	0.305	1.596
α_x	-0.195	-0.680*	-0.12	-0.49	-0.103	0.037
γ_{11}	0.070*	0.050*	0.05*	0.06**	0.103*	0.140*
γ_{22}	0.028	0.090*	0.013***	0.04*	0.00	0.012*
γ_{33}	0.006	0.010*	-	-	-	-
γ_{44}	0.044*	-0.110*	0.003	-0.01	-0.084*	-0.102*
β_{yy}	-0.245	-0.770*	-2.89***	-2.7***	-0.033	-0.06
α_{xx}	0.002**	0.000*	0.000	0.00	0.001*	0.001
α_{12}	-0.016***	0.01	-0.032*	-0.04*	-0.01	-0.025*
α_{13}	-0.026*	-0.020*	-	-	-	-
α_{14}	-0.027*	-0.040*	-0.02***	-0.02	-0.093*	-0.115*
ρ_{1y}	-0.149*	-0.120*	0.16*	-0.02	0.024	-0.08
ρ_{1x}	0.000	0.000**	0.002	0.000	-0.015*	-0.011*
γ_{23}	-0.032*	-0.01	-	-	-	-
γ_{24}	0.02	-0.090*	0.02***	0.01	0.009	0.013
ρ_{2y}	-0.209*	-0.140*	-0.01	-0.16*	-0.014	0.011
ρ_{2x}	-0.002	0.000*	0.009*	0.01*	0.002*	0.001
γ_{34}	0.052*	0.020*	-	-	-	-
ρ_{3y}	0.008	-0.080*	-	-	-	-
ρ_{3x}	0.003	0.000*	-	-	-	-
ρ_{4y}	0.349*	0.330*	-0.15*	0.19**	-0.01	0.067
ρ_{4x}	-0.001	-0.010*	-0.01**	-0.01*	0.013*	0.01
β_{yx}	0.013	0.060*	0.01	0.03	0.023	0.010*
m	0.869*	-	0.95*	-	0.725*	-
β_{11}	0.445*	-	-0.06	-	0.312*	-
β_{12}	-0.147*	-	-0.42	-	-0.173*	-
β_{13}	-0.171*	-	-	-	-	-
β_{14}	-0.127**	-	-0.36**	-	-0.139*	-
β_{22}	0.070*	-	0.48**	-	0.356*	-
β_{23}	0.017	-	-	-	-	-
β_{24}	0.060*	-	0.35**	-	-0.183*	-
β_{33}	0.126*	-	-	-	-	-
β_{34}	0.028	-	-	-	-	-
β_{44}	-0.040*	-	23.25	-	-0.322*	-
Log-L	535.8	474.9	319.8	284.9	332.1	302.5

*, ** and *** indicate significance at 1%, 5% and 10% levels respectively. Labour, other inputs, energy and capital are 1,2,3 and 4 inputs respectively. Y is output. Dynamic functions are estimated by iterative FIML

Table 3: Input Shares and Homotheticity Tests

Inputs	Manufacturing	Agriculture	Services
labour	13.0*%	72.9*%	40.5*%
Other Inputs	39.0*%	10.6*%	-
Capital	38.0*%	16.5*%	55.5*%
Energy	8.0*%	-	4.0*%
Homotheticity Tests (χ^2)	11.782	95.16	20.01

* and ** indicate significance at 5% and 10% levels respectively

Table 4: Cointegration Tests of Static Systems

Equations of	Manufacturing	Agriculture	Services
Total Cost	-3.970*	-3.205**	-4.546*
Share of Labour	-4.221*	-3.047	-3.443*
Share of Other Inputs	-3.093	-4.435*	-3.900*
Share of Energy	-4.384*	-	-

* and ** indicate significance at 5% and 10% levels respectively.

3.2 NKPC

We estimate the three conventional specifications of hybrid NKPC (Gali and Gertler 1999) by considering real marginal cost, labour share of income and output gap. With the objective to consider enriched specification, we estimate the specification of Batini et al. (2005) as well. In their specification, the labour share of income, output gap, international oil prices, import prices and real exchange rate determines inflation. Therefore, we estimate four hybrid NKPC for each sector. Significance of lagged inflation term in the models leads towards the selection of Hybrid form. The predictability of real marginal cost, labour share of income and output gap is judged by within sample forecast performance indicators, diagnostic procedure and statistical significance of parameters. Table 5 reports the estimated structural parameters and indicators of within sample forecast performance. Table 6 presents the diagnostic tests.

Estimated slope coefficients of real marginal cost are positive and statistically significant in all the models. The results of Models 2 and 3 indicate that the slope coefficients of labour share of income and output gap suffer from statistical insignificance. Output gap is an important determinant of inflation in the manufacturing sector. In the case of Gali and Gertler (1999) specifications, real marginal costs based models are better than the models with labour share of income and output gap. Model 4 incorporates the broader specification of Batini et al. (2005) in which we consider intermediate costs and more inputs. Therefore, Models 1 and 4 are comparable due to broader specification. As far as significance of parameters is concerned, Model 1 with real marginal cost performs better than Model 4 in the agriculture sector of Pakistan. The slope coefficient of labour share of income is insignificant in all the specifications of all the sectors. All point estimates conform with economic theory but there are issues of statistical significance in models estimated with labour share of income and output gap. However, within sample forecast evaluation indicators support the performance of Model 4, which has the lowest errors.

The relevance and validity of instrumental variables is quite crucial in estimation with endogenous regressors. With the objective to investigate the issue of under and over identification of models, we adopt appropriate diagnostic procedure. Table 6 presents the results. Shea partial R^2, LM and F statistics indicate that there is no issue of under-identification in most of the models. Further, Hansen's J statistics support the estimation in the case of over identification issue.

Hybrid specification of NKPC estimated with the real marginal cost is the best model. Further, dominance of forward-looking behaviour in hybrid specification is clear because the coefficient of inflation-lead tends to be higher than the parameter associated with lag of inflation. The manufacturing sector is forward-looking as the coefficient of lead-inflation is 85% whereas the corresponding coefficient estimates for agriculture and services sectors are 62% and 61% respectively (Table 5). Coefficients of lead and lag of inflation are statistically significant in specifications of real marginal cost and labour share of income. Overall results indicate that the price-setting behaviour of firms in services and agriculture sectors are somehow similar whereas firms in manufacturing sector are behaving differently.

Table 5: Estimates of New Keynesian Hybrid Phillips Curve

	Agriculture Sector				Manufacturing Sector				Services Sector			
	Model-1	Model-2	Model-3	Model-4	Model-1	Model-2	Model-3	Model-4	Model-1	Model-2	Model-3	Model-4
Constant	-0.011	0.003	-0.102	-0.08	-0.014**	0.003	-0.026	-0.053**	-0.004	0.002	-0.040	-0.037
RMC_t	0.021*	-	-	-	0.005*	-	-	-	0.011*	-	-	-
Gap_t	-	0.320	-	0.290	-	0.046	-	0.775*	-	0.417	-	0.929*
SL_t	-	-	0.159	0.090	-	-	0.223**	0.090	-	-	0.100	0.040
π_{t-1}	0.371*	0.249	0.247*	0.325*	0.125*	0.164	0.189**	0.272	0.388*	0.307*	0.271*	0.150*
π_{t+1}	0.621**	0.735*	0.592*	0.658*	0.853*	0.808*	0.810**	0.755*	0.609*	0.688*	0.710*	0.843*
rp^w	-	-	-	0.025	-	-	-	0.225*	-	-	-	0.500*
rp^m	-	-	-	0.039*	-	-	-	0.404*	-	-	-	0.072**
oil	-	-	-	-0.042*	-	-	-	-0.066*	-	-	-	-0.033*
n_t	-	-	-	0.68*	-	-	-	0.414*	-	-	-	0.471*
RMSE	0.066	0.071	0.065	0.057	0.052	0.052	0.052	0.042	0.034	0.035	0.036	0.029
MAE	0.049	0.055	0.050	0.045	0.039	0.040	0.039	0.033	0.027	0.028	0.027	0.023
MAPE	1.213	1.390	1.269	0.903	0.497	0.528	0.511	0.482	0.320	0.324	0.312	0.296
Theil	0.285	0.305	0.286	0.244	0.245	0.248	0.244	0.188	0.154	0.161	0.168	0.132

* and ** indicate significance at 5% and 10% levels respectively.

Table 6: Diagnostic Test of Hybrid Models

	Model-1	Model-2	Model-3	Model-4
Agriculture				
K-P rank LM Stat	20.38 (0.0)	16.96 (0.0)	23.14 (0.0)	11.88 (0.54)
J Stat	1.29 (0.5)	3.94 (0.1)	2.33 (0.3)	10.02 (0.59)
Manufacturing				
K-P rank LM Stat	18.26 (0.0)	19.12 (0.0)	13.59 (0.0)	6.79 (0.82)
J Stat	0.96 (0.6)	1.18 (0.6)	2.02 (0.4)	5.90 (0.03)
Services				
K-P rank LM Stat	22.32 (0.0)	19.77 (0.0)	10.35 (0.0)	3.916 (0.78)
J Stat	3.35 (0.2)	2.40 (0.3)	4.06 (0.1)	3.153 (0.79)

	π_{t+1}	RMC_t	π_{t+1}	Gap_t	π_{t+1}	SL_t	π_{t+1}	SL_t	Gap_t
Agriculture									
Shea Partial R^2	0.58	0.96	0.45	0.38	0.67	0.86	0.53	0.54	0.27
F Stat	2.31 (0.1)	13.15 (0.0)	15.29 (0.0)	171.26 (0.0)	4.29 (0.0)	154.44 (0.0)	7.53 (0.0)	1.10 (0.42)	16.3 (0.0)
Manufacturing									
Shea Partial R^2	0.56	0.99	0.51	0.72	0.50	0.88	0.28	0.88	0.25
F Stat	15.90 (0.0)	28.14 (0.0)	15.90 (0.0)	101.35 (0.0)	35.39 (0.0)	211.88 (0.0)	17.30 (0.0)	271 (0.0)	16.01 (0.0)
Services									
Shea Partial R^2	0.73	0.97	0.73	0.56	0.67	0.96	0.14	0.79	0.33
F Stat	232.20 (0.0)	122.59 (0.0)	232.20 (0.0)	40.67 (0.0)	19.08 (0.0)	597.70 (0.0)	3.14 (0.0)	295 (0.0)	8.85 (0.0)

Note: P-values are given in parenthesis

4. Conclusion

This study contributes to the literature on empirical estimation of structural model of the NKPC by replacing the labour share of income and output gap with real marginal cost. Further, in order to tackle the issue of sector wise heterogeneity, we estimate the hybrid specifications of NKPC for agriculture, manufacturing and services sectors of Pakistan. Estimates of structural parameters of Phillips Curve are consistent with economic theory. The forward-looking behaviour is quite dominant in all estimated models. However, firms are forward-looking in manufacturing sector relative to the agriculture and services sectors. The output gap and labour share of income do not perform well and estimated models with these variables suffer from the issues of statistical insignificance of parameters. The diagnostics procedures and statistical significance of parameters indicate that the real marginal cost derived from dynamic cost functions is a better determinant of inflation in Phillips Curve than the competing specifications with labour share of income or output gap.

Compliance with Ethical Standards:

We have not received any funding or grant for this study and there is no conflict of interest.
Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

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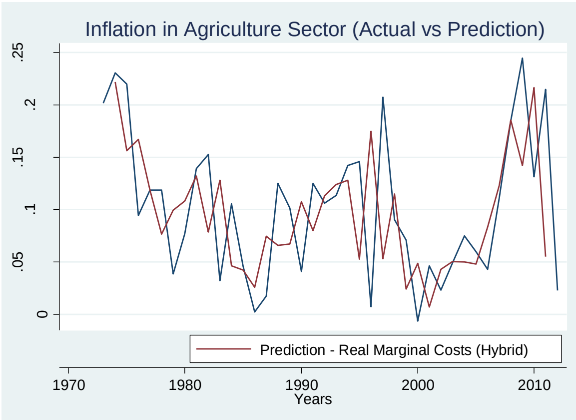
Appendix



Inflation in Agriculture Sector (Actual vs Prediction)
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Prediction - Real Marginal Costs (Hybrid)
1970
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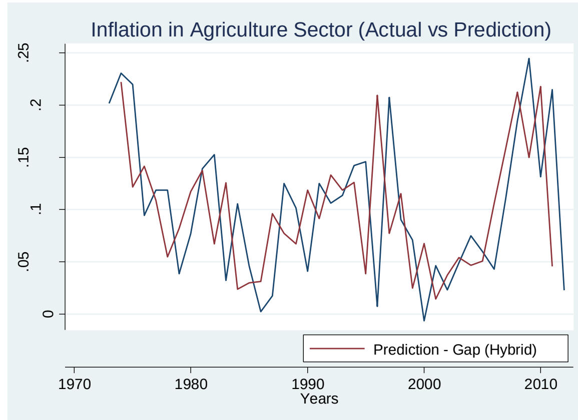
Years



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Prediction - Gap (Hybrid)
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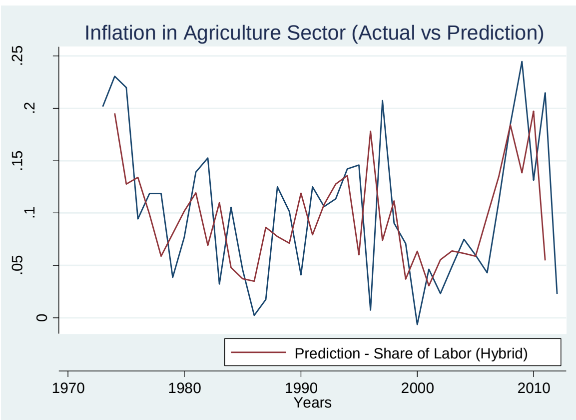

Inflation in Agriculture Sector (Actual vs Prediction)
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Prediction - Share of Labor (Hybrid)
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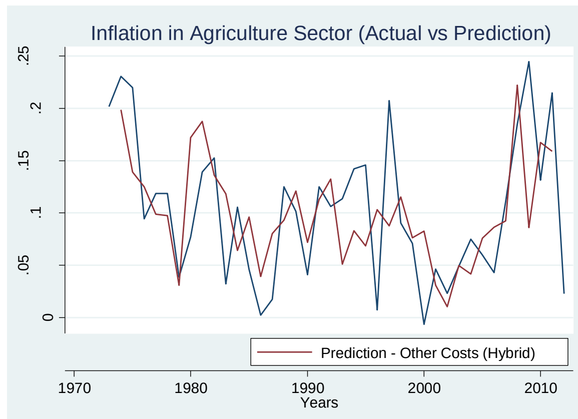

Inflation in Agriculture Sector (Actual vs Prediction)
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Prediction - Other Costs (Hybrid)
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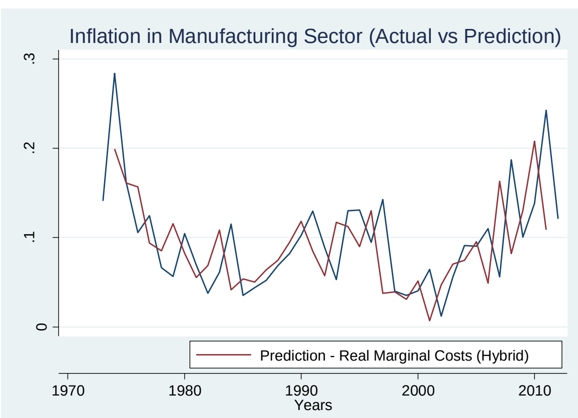

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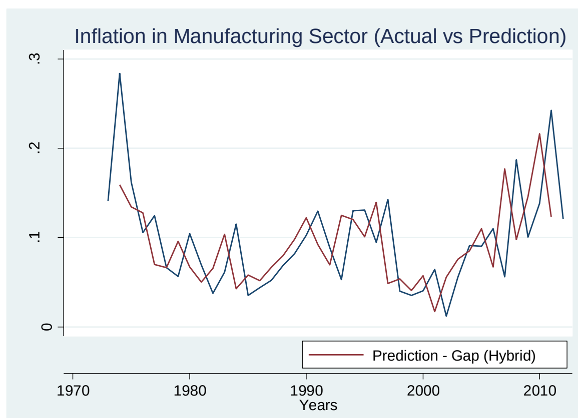

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Prediction - Gap (Hybrid)
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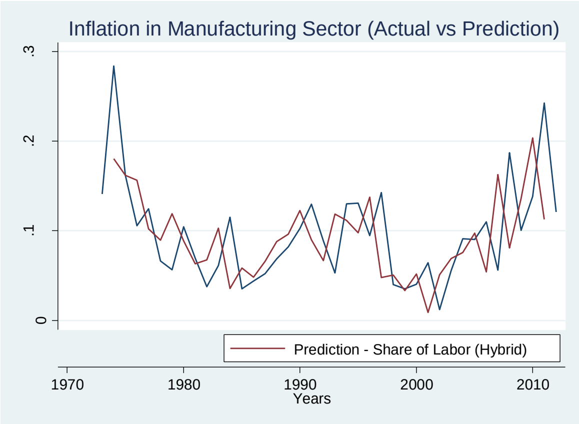
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Prediction - Share of Labor (Hybrid)
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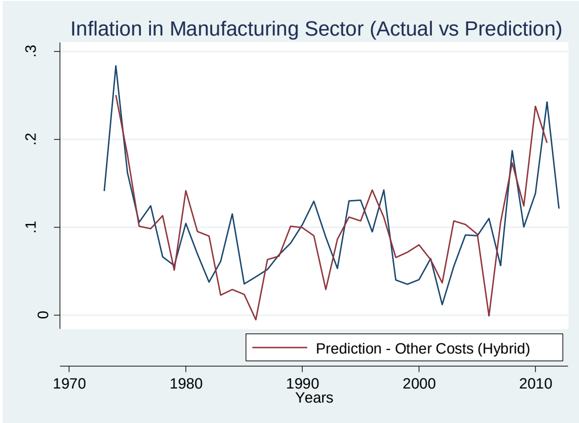
Inflation in Manufacturing Sector (Actual vs Prediction)
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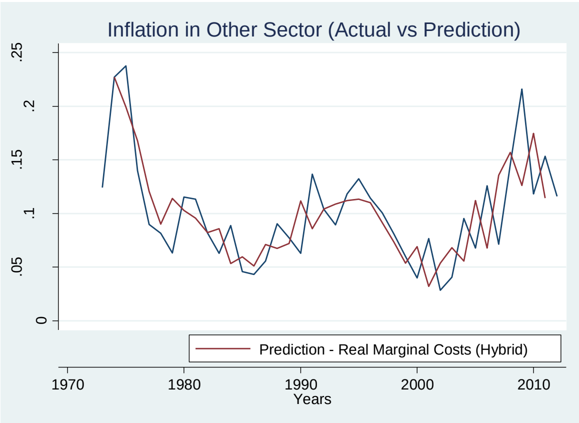
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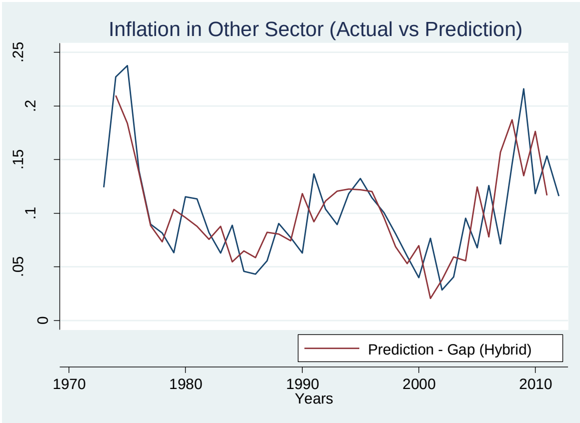
Inflation in Other Sector (Actual vs Prediction)
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Prediction - Gap (Hybrid)
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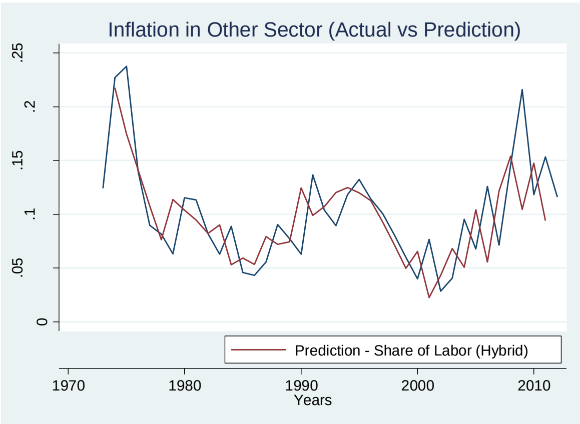
Inflation in Other Sector (Actual vs Prediction)
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Prediction - Share of Labor (Hybrid)
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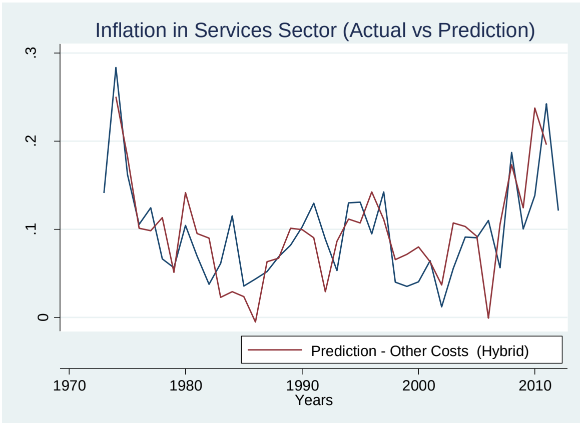
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Prediction - Other Costs (Hybrid)
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