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Forecasting inflation for India with the Phillips Curve: Evidence from internet search data

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Abstract

This paper forecasts inflation based on the New Keynesian Phillips curve for India using internet search-based inflation expectations. We find that compared to inflation forecasts based on traditional time-series estimation method like AR(1) or household-survey based inflation expectations, our model that employs inflation expectations of agents based on real time inflation-related internet search, has better inflation forecasting performance. From a policy standpoint, this underscores the importance of analysing big data for the purpose of forecasting inflation.

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1. Introduction

In this paper, we forecast inflation for India by employing the hybrid New Keynesian Phillips curve (HNKPC) developed by Gali and Gertler (1999) in conjunction with real time internet-based search data. The HNKPC, that is derived from the optimal price setting behavior of the monopolistically competitive firms in a Calvo (1983)-type framework, consists of a weighted average of the past and future expected values of inflation. While the past values of inflation are observable, the expected values of inflation (termed as inflation expectations) are non-observable, thereby posing a challenge in estimating the parameters of HNKPC (Jean-Baptiste 2012). Thus far, the inflation expectations term in estimating the NKPC for India have been captured by time series forecasts like AR, ARIMA etc. The novelty of our study is that we employ inflation expectations derived from the internet search data (captured by Google Trends) to first estimate the HNKPC for India and then forecast inflation.[1]

For the past few years, following the seminal work of Choi and Varian (2012), internet-based data, such as Google Trends, have been widely used to forecast various economic indicators. However, studies focusing on forecasting inflation based on Google Trends data is limited to Guzman (2011), where the inflation expectations derived from Google Trends is compared with the survey-based measures of inflation expectations for the US and it is found that the inflation expectations derived from Google Trends outperform the other measures of inflation expectations.

We go one step ahead in employing the Google Trends-based inflation expectations in the HNKPC and forecast subsequent inflation for India. In doing so, the first step is to estimate the HNKPC for India. However, the equation of HNKPC (elaborated in following Section 2) includes the expected inflation term that is an unobservable variable. Household survey-based inflation expectations is used widely in the literature as a measure of inflation expectations and we too employ this to estimate the HNKPC. Additionally, we also use internet search-based (given by Google Trends) inflation expectations to estimate the HNKPC, a method that has not been used in the Indian context thus far. Next, using the output obtained from the above estimated HNKPC, we forecast inflation for India. We compare the forecast performance of our model against household survey-based HNKPC and traditional time-series AR(1) forecasts. Our results indicate that the HNKPC based on Google Trends data improves the forecasting performance of inflation compared to traditional estimation methods, thereby highlighting the role of analyzing big data from a monetary policy perspective.

The rest of the paper is organized as follows. Section 2 briefly outlines the HNKPC. Section 3 describes the data and estimation results. Section 4 presents the results of forecasting evaluation, and Section 5 concludes.

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[1] The NKPC has been estimated in the Indian context primarily to understand the inflation dynamics (Paul (2009), Dua and Gaur (2010), Mazumder (2011), Singh et al. (2011), Patra and Kapur (2012), Sahu (2013) and Behera et al. (2018)). As far as the question for forecasting inflation in India based on the NKPC goes, we could locate the studies of Kapur (2013) and Paul et al. (2017). Kapur (2013) forecasts wholesale price index (WPI) and non-food manufactured product inflation using backward-looking Phillips curve and finds the forecasts to be strong, while Paul et al. (2017) compare the Phillips curve forecast with their P-star model forecast and find the latter to perform better.

2. The Hybrid New Keynesian Phillips Curve

Gali and Gertler (1999) derived the NKPC based on the Calvo (1983) price-setting behavior of the monopolistic firms. The inflation rate thus derived by solving for the firm's optimization problem, is given by Equation (1).

$$\pi_t = \frac{(1-\theta)(1-\theta\beta)}{\theta - \theta\eta\mu} z_t + \gamma_f E_t \pi_{t+1} \tag{1}$$

where z is the excess demand, θ is the probability that the firms will not change their price, μ is the firm's demand elasticity and η is the elasticity of marginal cost with respect to the output. In view of capturing the inflation inertia, Gali and Gertler (1999) incorporate ω proportion of firms who do not update their inflation expectations and continue with past inflation. The addition of ω in the above equation generates the hybrid NKPC (HNKPC) which is denoted by Equation (2).

$$\pi_t = \lambda \left(\frac{1}{(1-\eta\mu)} \right) z_t + \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} \tag{2}$$

where,

$$\lambda = \left(\frac{(1-\omega)(1-\theta)(1-\theta\beta)}{\theta} \right) \varphi^{-1}$$

$$\gamma_f = \beta\theta\varphi^{-1}$$

$$\gamma_b = \omega\varphi^{-1}$$

$$\varphi = \theta + \omega[1 - \theta(1-\beta)]$$

The reduced form of Equation (2) is represented by Equation (3).

$$\pi_t = \lambda y_t + \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \varepsilon_t \tag{3}$$

where π_t is the inflation rate at time period *t*, y_t is the seasonally adjusted output gap at time period *t*, $E_t\pi_{t+1}$ is expectation about inflation for time period *t+1* during period *t*, and π_{t-1} is the past inflation. Equation (3) represents the hybrid NKPC since it incorporates both expected inflation and lag of actual inflation.

3. Estimation

3.1 Data description

3.1.1 Google Trends derived Inflation Expectations

The internet search data has been collated from Google Trends (https://trends.google.co.in/trends/) for the search keyword "Inflation" in India between 2006: Q3 and 2018: Q3 at a quarterly frequency.

Equation (4) represents the inflation expectations derived from the Google Trends data, $(GT\_InfExp)_t$, based on the methodology of Bicchal and Durai (2019) who had generated the series for the Indian economy and demonstrated the existence of desired time-series properties.

$$(GT\_InfExp)_t = \frac{GT_t}{GT_{initial}} * \pi_{initial}^{WPI} \tag{4}$$

GT_t is the Google Trends index in time period t and a proxy for internet search data, $GT_{initial}$ is the Google Trends index for the initial or starting year and $\pi_{initial}^{WPI}$ is the realized WPI inflation rate for the initial year.

3.1.2. Inflation Expectations Survey of Households (IESH)

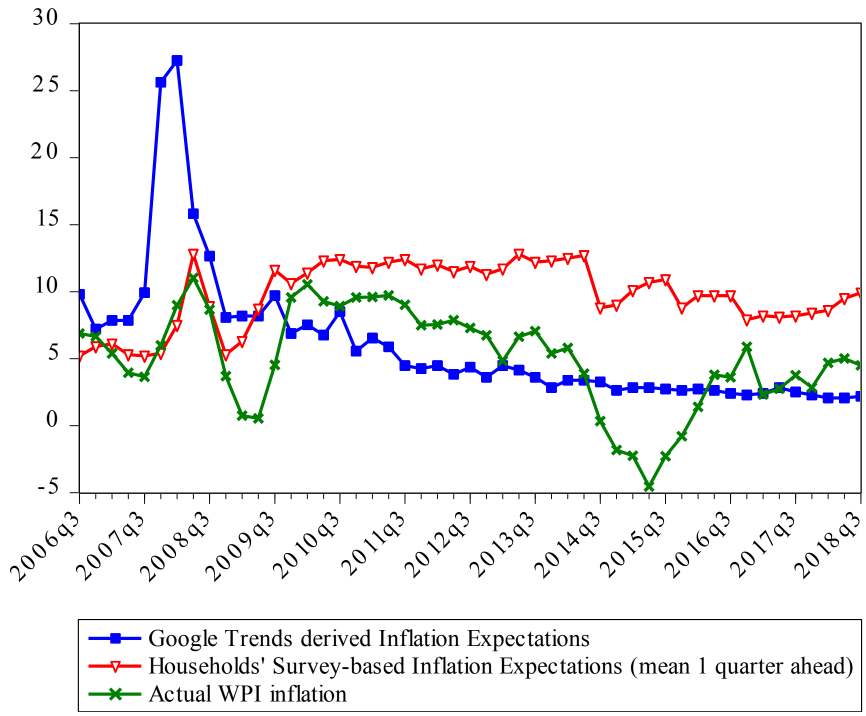
The IESH is conducted quarterly by the Reserve Bank of India (RBI) since 2005. At present, the survey covers around 6000 households across 18 major cities of India and records the mean of current, 1 quarter-ahead, and 4 quarters-ahead quantitative inflation expectations.

3.1.3 Wholesale Price Index (WPI) Inflation

WPI inflation was the official inflation rate for India until 2014. Given that our sample spans from 2006 to 2018, this inflation rate is considered and the data is collected from the RBI, Database of Indian Economy.

A comparison of the Google search-based inflation expectations and survey-based inflation expectations, against realized WPI inflation is presented in Figure 1.

Figure 1: Comparison of inflation expectations and realized inflation



It is observed that for most part of the sample period considered in this study, the households' survey-based inflation expectations have remained well above the realized WPI inflation. This is a common tendency observed across economies since households generally tend to over-estimate inflation (Dräger and Nghiem 2020, Duca et al. 2020, Ehrmann and Tzamourani 2012, Malmendier and Nagel 2016, and Das et al. 2016). On the other hand, the Google Trends derived inflation expectations series, starting 2009: Q3, remains below the realized WPI inflation, except for a small period between 2014: Q3 and 2016: Q1.

3.1.4 Output Gap

The output gap is generated by taking the difference between the seasonally adjusted real GDP and the trend derived from HP filter. The series is seasonally adjusted by using X-13 ARIMA developed by the U.S. Census Bureau.

3.2 Estimation results

Table 1 presents the GMM estimation results of the restricted $(\gamma_f + \gamma_b = 1)$, and unrestricted versions of benchmark HNKPC for India (Equation (3)) where the inflation expectations term is represented by the internet search-based (Google Trends) inflation expectations (columns 1 and 3), and by the survey-based inflation expectations of the general public (columns 2 and 4).

Table 1: Estimation of the HNKPC

Equation:

$$\pi_t = \lambda y_t + \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \varepsilon_t$$

	Restricted Regression		Unrestricted Regression	
	1	2	3	4
Output Gap	0.56 (0.38)	1.21*** (0.43)	0.98** (0.38)	1.43*** (0.25)
Google Trends derived Inflation Expectations	0.14*** (0.04)	--	0.09* (0.05)	--
Households' Inflation Expectations (mean 1 quarter ahead)	--	0.01 (0.04)	--	0.07 (0.05)
Past Inflation	0.86*** (0.04)	0.99*** (0.04)	0.86*** (0.04)	0.81*** (0.08)
$\bar{R}^2$	0.78	0.75	0.78	0.77
D-W Statistics	1.32	1.49	1.45	1.47
S.E.E.	1.75	1.84	1.73	1.78
Hansen J test	5.61 (0.69)	8.12 (0.42)	3.80 (0.80)	5.36 (0.62)

***, ** and * stand for 1, 5 and 10 percent levels of significance respectively. All estimations are done using the generalized method of moment (GMM) using instruments following Gali and Gertler (1999). Figures in parenthesis represent heteroskedasticity adjusted standard errors. The J-test and its significance level is a test of over identifying restrictions. SEE is a standard error of the estimate. The sample period is 2006Q3 - 2018Q3.

Columns 1 and 3 indicate that the benchmark HNKPC for India when internet search-based inflation expectations is considered, exists for the unrestricted version only (column 3) since the coefficients of output gap, past inflation and expected inflation, are all positive and significant. Past inflation is dominant in determining current inflation as it has a higher weightage (0.86 in column 3) compared to that of the forward looking component (0.09 in column 3).

However, for the HNKPC estimated using survey-based inflation expectations (columns 2 and 4), the forward-looking component is not significant, thereby implying the absence of the HNKPC and presence of backward-looking NKPC.

The results suggest that the unrestricted version of HNKPC exists for India when the internet search-based inflation expectations is considered, while backward-looking NKPC exists for survey-based inflation expectations.

4. Forecast Accuracy Comparison

In this section we test the forecast performance of the internet search-based HNKPC model estimated above when compared with the benchmark time series AR(1) forecasts. This type of forecast comparison is inspired by the empirical works of Ang et al. (2007) and Jean-Baptiste (2012). Ang et al. (2007) use forecasting models based on macro variables, asset markets variables and inflation survey data for the United States and compare the inflation forecast with standard time-series forecasting model like ARIMA. They conclude that as far as inflation forecasts are concerned, the forecasting model with survey data outperforms the other models. Jean-Baptiste (2012), who estimates the New Keynesian Phillips Curve for the United Kingdom using survey-based inflation expectations, finds that compared to the traditional forecast tool like AR(1), inflation forecasts based on survey-based inflation expectations perform better.

In our case, since restricted version of internet-search based inflation expectations and survey-based inflation expectations did not establish the existence of HNKPC, only Google Trends based inflation expectations of the unrestricted version of HNKPC is considered for the purpose of inflation forecasting.

Following the convention in the literature, we next compare the this forecast with the benchmark time-series AR(1) forecast of inflation. The standard specification of the AR(1) model is given by Equation (5):

$$\pi_t = \alpha + \gamma\pi_{t-1} + \mu_t \tag{5}$$

where μ_t is the error term and α is the constant.

Table 2: Out-of-sample inflation forecasting performance

	1 Step Ahead Forecast	2 Steps Ahead Forecast	3 Steps Ahead Forecast	4 Steps Ahead Forecast
Unrestricted HNKPC (Google Trends based inflation expectations)				
MAE	1.33	1.47	1.77	2.11
MAPE	0.47	0.58	0.54	0.52
RMSE	1.55	1.75	2.12	2.51
Autoregressive (1) Model				
MAE	1.49	2.00	2.47	2.53
MAPE	0.66	1.05	0.91	0.65
RMSE	1.77	2.30	2.99	3.49

MAE -Mean Absolute Error; MAPE- Mean Absolute Percentage Error, RMSE -Root Mean Square Error

Table 2 reports the various forecast performance indicators for out-of-sample inflation forecast based on the unrestricted HNKPC employing Google Trends based inflation expectations, as well as the AR(1) forecasts. For all the forecast horizons, the unrestricted HNKPC outperforms the autoregressive model. Compared to the AR(1) model the mean absolute error (MAE), mean absolute percentage error (MAPE), and root mean square error (RMSE) of the unrestricted HNKPC model are the lowest across all forecast horizons.

This result indicates that inflation forecasting based on the internet search data (Google Trends) in conjunction with the HNKPC outperforms the standard time series model.

5. Conclusion

In India, the forecast for inflation has been traditionally done using standard time series models. In this paper, we depart from this standard practice and instead forecast inflation based on the New Keynesian Phillips curve for India using internet search-based inflation expectations. We find that compared to inflation forecasts based on traditional estimation methods like AR(1) or household-survey based inflation expectations, our model that employs inflation expectations of agents based on internet search for the keyword "Inflation", has better forecasting performance. This signifies the importance of garnering economic policy-related information based on the real-time internet search pattern of agents, compared to traditional sources like surveys etc.

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