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The new Keynesian Phillips curve: An update on recent empirical advances☆

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ABSTRACT

This paper presents a comprehensive review of the newly emerging literature on the New Keynesian Phillips Curve (NKPC). The theoretical predictions, econometric estimation techniques as well as the corresponding empirical evidence are discussed focusing on both the closed economy and the open economy versions of the NKPC. A number of important findings are reported about the ability of NKPC to explain the process of inflation dynamics. First, there is weak support for the open economy version of the NKPC to be able to track inflation dynamics if imported inputs are used in the production process. Second, the NKPC describes inflation dynamics across sectors if microeconomic and sectoral level data are used. Further, the survey data employed as a proxy for inflation measure in the newer studies provide enhanced support to the closed economy NKPC with the sign, size and statistical significance of coefficients in line with the theoretical predictions. We provide fresh empirical evidence to check the first finding from the review. The deep structural parameters for four different versions of the NKPC, the pure forward looking NKPC, the Gali and Monacelli's (2005) NKPC, the open economy NKPC and the open economy hybrid NKPC, are estimated for Australia, Canada, New Zealand and the United Kingdom. These estimated coefficients show some support that the specifications of open economy NKPC, which incorporate prices of imported goods as opposed to the terms of trade and real exchange rate, seems to be a better, however, weak indicator of the inflation dynamics. These findings may have important policy implications.

1. Introduction

This paper presents an extensive review of the recent empirical advances in estimating the New Keynesian Phillips Curve (NKPC). The NKPC, which relates inflation process to the expected future inflation and a measure of the real economic activity like the output gap, has been widely debated in the literature due to its mixed performance in explaining the inflation dynamics across a number of advanced countries. The deliberations over the usefulness of NKPC incorporate, among other issues, the use of closed economy versus the open economy versions of the NKPC, the forward looking versus hybrid versions of the NKPC, the empirical proxies employed to measure the output gap and inflation as well as potential endogeneity problems in estimating the NKPC.

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A corpus of new studies, especially in the last decade, is bringing in some fresh perspectives into the working and influence of NKPC in the academic and policy domain. A number of these papers focus on the open economy versions of the NKPC and try to disentangle the effect of imported products on domestic inflation. Some other studies use micro-level disaggregated and sector level data as well as survey based inflation measures to re-estimate the empirical performance of the NKPC as proposed in the theory. Quite a few papers explore the globalization angle and investigate if there is any relationship between globalization and inflation within the ambit of the NKPC. However, till date, there is no systematic review of these newer studies on the NKPC. The key aim of this paper is to fill this gap. We carefully evaluate the emerging stock of knowledge and discuss the lessons to be learnt from this new wave of research. Further, we provide empirical estimates for different versions of the NKPC for four advanced economies and show that there is some weak support for the open economy NKPC in line with the recent evidence.

Keynes and his ideas dominated the macroeconomic thought process from the 1929's Great Depression until the early 1970s. Rising unemployment in the 1970s became a major policy problem and the Keynesians were baffled to explain the simultaneous rise in inflation and unemployment (stagflation) within their framework. Their argument was mainly based on the assumptions that changes in aggregated demand yield changes in output with sluggish adjustment of prices and wages in the product and factor markets. The money wage was treated as exogenous while it was believed that whenever the aggregate demand exceeded the aggregate supply, it would generate inflation in the economy. The idea of nominal rigidities in the product and factor markets was not based on microeconomic foundations, and the classical economists questioned these nominal frictions, which further reduced the popularity of Keynesian macroeconomics in policy circles.

For Keynesians, the main intellectual challenge was to provide the microeconomic foundations to these nominal rigidities in the presence of rational expectations. In this context, many important contributions were made in the form of asymmetric information, staggered contracts, efficiency wage hypothesis and the new Keynesian Phillips Curve in the late 1970s and the late 1980s.

The NKPC is one of those contributions, which lay down the microeconomic foundations to Keynesian macroeconomics. It assumes expectations of inflation are rational and prices are sticky where the role of future price expectations in setting prices cannot be ignored. It is based on the theoretical contributions of Taylor (1980); Rotemberg (1982) and Calvo (1983), which retain the assumptions of nominal rigidities to explain inflation. These theoretical models, as Roberts (1995) points out present a common relationship, called the New Keynesian Phillips Curve, which relates inflation process to the expected future inflation and a measure of the real economic activity like the output gap.

The NKPC is different from the earlier Phillips Curve, as originally proposed by Phillips (1958)[1] which posited a trade-off between money wage changes and unemployment over the time period 1861–1957 for the United Kingdom. Samuelson and Solow (1960) then tested the Phillips curve for the United States and found that the money wage growth and unemployment relationship for the US was similar to that of the Phillips's results for the UK.

The NKPC assumes that the expectations of inflation are rational instead of adaptive. As a result, it is different from the expectations-augmented Phillips Curve, developed by Friedman (1968) and Phelps (1968). Further, the NKPC also differs from the renowned 1970s Lucas supply curve and the Phillips Curve, as developed in Lucas and Rapping (1969). The Lucas and Rapping (1969) version of the Phillips Curve under rational expectations suggests only unanticipated inflation (changes in money supply) can affect the output while the neutrality of money (i.e., money does not affect real fundamentals like output and employment) holds.[2] It also restricts inflation expectations to the current time period.

The NKPC, on the other hand, suggests that it is the future expectations of inflation that determine current inflation. In particular, the features of nominal rigidities distinguish the NKPC from its counterparts, proposed by the classical economists. In this context, the absence of nominal rigidities in NKPC would yield the same new classical Phillips Curves, which assume instantaneous adjustment of wages and prices in the factor and product markets.

Given the popularity and significance of NKPC in theory and practise, it remains an active area of research both in academic and policy arenas. The theoretical microeconomic foundations and the inherent role of future price expectations render the NKPC a pivotal role in monetary policy making. These nominal rigidities in factor and product markets reflect monetary non-neutrality and make the NKPC useful in conducting monetary policy. As a result, it has been empirically tested and widely debated in the literature over the last two decades. Rudebusch and Svensson (2001) and Fuhrer (1995) are among the prominent studies discussing the empirical evidence of the Phillips Curve. Recently, Gordon (2011) provides an overview of the history of the Phillips curve.

In spite of the NKPC's strong theoretical underpinnings, the empirical validity of NKPC in explaining the process of inflation dynamics is widely criticized. For instance, the theoretical predictions of NKPC, which suggest a boost in the level of output in response to anticipated disinflation, contradict the anecdotal and historical evidence. The response of inflation to monetary policy is observed to be gradual at best and researchers, on the other extreme, find disinflations causing economic recessions (e.g.Ball, 1994; Mankiw, 2001; Mankiw & Reis, 2002).

Contrary to the theoretical predictions of NKPC, the data also reveal that the current output gap, the main driving force variable, co-moves positively with the future inflation rate. The coefficient on current output gap turns out to be incorrectly signed (negative) and statistically insignificant (Gali & Gertler, 1999). The NKPC should also contain lagged inflation in its theoretical structure, which suggests a lack of inflation inertia (Fuhrer & Moore, 1995).

[1] See Sleeman (2011) for details and an autobiography of Phillips.
[2] See Bull & Frydman (1983) for discussion of the Lucas Phillips Curve.

These empirical reservations are not only confined to the closed economy versions of NKPC. The open economy extensions of NKPC which model the role of foreign shocks using the real exchange rate and the terms of trade, as derived in Gali and Monacelli (2005), are also rejected by the data. In the Gali and Monacelli (2005) NKPC (henceforth, GMNKPC), the openness parameter, which should be positive and statistically significant for an open economy, is either incorrectly signed (negative) or statistically insignificant in estimations (e.g.Allsopp, Kara, & Nelson, 2006; Guay, Luger, & Zhu, 2003).

Over the last decade, the empirical performance of NKPC has also been tested using different measures of the output gap, survey expectations of inflation and rational expectations of inflation. In addition to introducing features of an open economy, the recent studies also tested the NKPC using micro-level disaggregated and sectoral level data.

A number of studies argue that the output gap is not a suitable proxy for the driving force variable in estimating NKPC. Instead the role of the real marginal cost is introduced to explain inflation dynamics (e.g.Gali & Gertler, 1999; Sbordone, 2002; Woodford, 2001). Compared to the aggregate data, the NKPC performs well in the sectoral data. This is due to the heterogeneity in price adjustment, which affects the estimates of NKPC (e.g.Leith & Malley, 2007; Petrella & Santoro, 2012). The evidence also suggests that the open economy NKPC, which introduces the prices of intermediate imported inputs or real imports and foreign competition, outperforms the closed economy NKPC. The later extensions are found to be useful in explaining inflation dynamics for the open economies (e.g.Batini, Jackson, & Nickell, 2005; Rumler, 2007).

The process of globalization has increased over the last two decades. The trade integration among different countries as a result of globalization may also affect the process of inflation dynamics. The availability of cheaper imported inputs not only decreases the marginal cost of firms but also increases the competition among domestic firms. In particular, globalization can mute the sensitivity of inflation to the domestic economic activity (domestic resource capacity) and may bring to the forefront the issue of foreign resource dimensions in determining domestic inflation. The emerging literature is focusing on these lines of research where inflation dynamics are primarily driven by the foreign factors as opposed to the domestic factors which yield important monetary policy implications. For instance, the role of foreign resource capacity in determining domestic inflation may reduce the ability of the central bank to stabilize inflation and output gap.

The empirical evidence of the impact of globalization on inflation dynamics is mixed across the US, the European countries and the OECD countries. For example, Gamber and Hung (2001); Borio and Filardo (2007); Pehnelt (2007) and Guerrieri, G ust, and López-Salido (2010) find support for the role of globalization in influencing inflation dynamics whereas Ball (2006); Ihrig, Kamin, Lindner, and Marquez (2010) and Milani (2012) provide evidence that the global resource capacity does not explain inflation dynamics. Sbordone (2007) and Woodford (2007) also extend the New Keynesian framework to introduce the role of globalization to explain inflation dynamics where the degree of openness affects the marginal cost and the mark-ups of the firms, and hence the elasticity of inflation to marginal cost, as depicted by the slope of the NKPC.

The theory and derivations of NKPC have been discussed in a number of influential papers by Mankiw (2001); Woodford (2003) and Tsoukis, Kapetanios, and Pearlman (2011). Recently, Ólafsson (2006) and Mavroeidis, Plagborg-Møller, and Stock (2014) review the empirical evidence of NKPC.

The reviews, though exhaustive, are plagued with a number of shortcomings. To begin with, the surveys focus exclusively on the closed economy version of the NKPC and within that the papers mainly highlight only a particular, albeit important, econometric issue pertaining to the identification problem in the estimation process.[3] Second, the existing reviews do not discuss the newly emerging empirical evidence of estimating the open economy version of NKPC. Third, the extant surveys do not discuss the findings from the closed economy version of NKPC estimated with the disaggregated sectoral level data. Finally, the reviews do not delve into the role of global resource capacity or the effect of globalization in determining domestic inflation and associated important policy implications.

The present paper focuses on these gaps and assesses the NKPC literature in several important dimensions. First and foremost, the paper evaluates the newly emerging literature of the empirical estimation of the open economy versions of NKPC. Second, instead of focusing on one particular econometric problem (identification), this paper discusses the theoretical predictions of NKPC under different empirical specifications and in the process uncovers additional econometric issues regarding the estimation of NKPC. In so doing, the study also highlights the pros and cons of using disaggregated data at the micro and sectoral level to explain inflation dynamics using the NKPC. Third, unlike the previous reviews, the current survey incorporates the studies on globalization and inflation using the NKPC.[4] The process of globalization is becoming more pervasive and this may enhance the response of inflation to foreign resource capacity (foreign output gap). The recent theoretical developments and empirical evidence on the extent to which globalization has affected inflation dynamics are discussed using NKPC. Fourth, we provide the updated and recent estimates using four different versions of the NKPC, the pure forward looking NKPC, the GMNKPC, the open economy NKPC and the open economy hybrid NKPC, for Australia, Canada, New Zealand and the United Kingdom. This is done to validate the first finding from our ensuing assessment of the recent stock of knowledge. For each country, the deep structural parameters like the discount factor, the price stickiness (and hence the duration of price adjustments), the fraction of backward looking price setters and the degree of openness are estimated using two different measures of inflation, consumer price inflation and domestic goods price inflation. The robustness of results is also checked using different sample periods and incorporating various important policy and event related changes (like the 1970's oil price shock and the adoption of inflation targeting policy). Finally, some important policy implications of all results are presented.

[3] In particular, see the recent comprehensive review by Mavroeidis et al. (2014).

[4] We thank an anonymous referee for the suggestion to incorporate globalization and inflation dynamics in the review.

The comprehensive review and the new empirical evidence presented in the paper point to a number of important findings. First, the open economy NKPC specifications which incorporate real imports or prices of intermediate imports as production inputs, appear to be an important (however weak) determinant of the inflation process. Second, the survey data provide enhanced support to the NKPC with the sign, size and statistical significance of the coefficients being closer to the theoretically predicted parameters of NKPC. Third, in comparison to the aggregate data, the NKPC performs better when the disaggregated sectoral level data is used, and hence the NKPC can explain inflation dynamics across different sectors. Finally, the results from four different versions of the NKPC, the pure forward looking NKPC, the GMNKPC, the open economy NKPC and the open economy hybrid NKPC, suggest that the specifications of open economy NKPC, which incorporate prices of imported goods as opposed to the terms of trade and real exchange rate, better (albeit weakly) explain the process of inflation dynamics for Australia, Canada, New Zealand and the United Kingdom. The estimation results, therefore, are in line with the first verdict of the review. These findings may have important policy implications, especially in regards to the conduct of monetary policy.

The first finding reveals that the intermediate input costs play a significant role in the production process and have a direct bearing on the marginal cost of firms, which in turn affects inflation. On the contrary, the GMNKPC is not a good candidate in explaining inflation dynamics. One of the important reasons for GMNKPC's failure to describe inflation dynamics is related to the assumption that all imports are final consumption goods consumed by the households rather than the (intermediate) production inputs used by the producers. The second and third findings discussed above bring forth the microeconomic foundations of NKPC to the forefront of empirical estimation. In particular, the third conclusion that the NKPC explains the dynamics of inflation and marginal cost at the sectoral level also has important policy implications. Since the process of inflation dynamics is different across different sectors of a particular economy, this finding suggests that the monetary policy would affect price level and marginal cost of these different sectors to a varying degree. The heterogeneity in duration of price stickiness can make the response of monetary policy gradual in some sectors. The aggregate data, however, would not be able to capture this heterogeneity. Therefore, the estimation of NKPC with disaggregated data helps in the understanding of the varying nature of price stickiness across different sectors. This also provides useful insights about stabilizing overall inflation, output growth and output volatility. Further, the mark-up over marginal cost varies across different sectors, and as Lawless and Whelan (2011) emphasize, this heterogeneity may determine the potential impact of monetary policy across different sectors.

In terms of the above outcomes, this evaluation suggests that the extensions of the closed economy NKPC to the open economy NKPC better explain the process of inflation dynamics. The open economy NKPC specifications provide additional source of information (i.e., extra variables of imported inputs or exchange rate and terms of trade) to determine inflation process of a particular economy. Since the disaggregated data capture the varying nature of price stickiness across different sectors, the estimation of open economy NKPC specifications where the sectoral inflationary pressures may respond to the foreign shocks (like exchange rate or terms of trade) would be an interesting area of future research.[5] These sectoral estimations may provide important insights for monetary policy to stabilize inflation and output gap.

The rest of this paper is organized as follows. In Section 2, we describe the settings and empirical specifications of the closed economy and open economy versions of NKPC. In Section 3, we discuss the results arising from different empirical specifications of the closed economy version of NKPC using aggregate data across different countries. This section also covers various econometric problems researchers have to address including the omnipresent weak identification issue. Section 4 contains the empirical evidence of NKPC emerging out of the use of disaggregated data and the survey forecasts of expected inflation. In this section, the focus is on the empirical estimation of the closed economy version of NKPC using the sectoral data and the survey data. The review of the extant results and estimation issues pertaining to the open economy version of NKPC is presented in Section 5. We put forward an up-to-date appraisal of the new empirical studies concentrating on the open economy versions of NKPC and summarize their main results so far. Section 6 presents the evidence of the links between globalization and inflation using the NKPC. The theoretical developments, empirical evidence and the particular channels through which globalization may affect the elasticity of inflation to marginal cost (depicted by the slope of the NKPC) are presented in this section. Finally, in Section 7, we present the updated and recent estimates of four different versions of the NKPC for four advanced countries to check if the open economy version of the NKPC is able to explain inflation dynamics as outlined in the first finding from the survey. Here we find some weak support for the open economy NKPC since the open economy NKPC version incorporating prices of imported goods as opposed to the open economy NKPC involving terms of trade and real exchange rate, seems to track down the process of inflation dynamics in these four countries. Section 8 concludes the review with a brief discussion on lessons learnt and outlining some possible directions for future research.

2. The closed and open economy NKPC

2.1. The closed economy NKPC

The NKPC has been derived in a monopolistic, competitive environment where identical firms produce differentiated products and face similar kinds of restrictions in optimizing prices in the market. The price elasticity of demand for a product is assumed to

[5] Note that Gali and Monacelli's (2005) theoretical open economy NKPC is not a sectoral model as it relates overall CPI inflation (not sectoral inflationary pressures) to the driving force variable (i.e., output gap) and terms of trade or exchange rate specifications. Also the openness parameter is based on household consumption basket and not on the foreign input production as mentioned before.

be constant across firms. The theoretical formulation of NKPC under the Calvo (1983) version assumes that each firm optimizes prices in each period with probability $(1-\theta)$while other firms keep prices unchanged with probability (θ). Firms choose the optimal price level, which maximizes the discounted sum of current and expected profits over time.

The reduced form of NKPC, which relates current inflation to expected future inflation and output gap or marginal cost, is defined as follows (for the derivation of NKPC, see Gali & Gertler, 1999; Mankiw, 2001; Woodford, 2003).

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \lambda \hat{x}_t \tag{1}$$

Where $\hat{x}_t = x_t - \bar{x}_t$ and $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$. E_t is the expectation operator. The NKPC, Eq. (1), is also known as the baseline pure forward-looking NKPC, which relates the current domestic goods inflation to the expected future inflation and the proxy for real economic activity. x is the real marginal cost which is calculated as the deviation from the steady state level. The elasticity of inflation to marginal cost, the reduced form slope coefficient λ, is a function of the deep structural parameters, the frequency of price adjustment θ and the subjective discount factor β.

In the baseline pure forward looking NKPC, there is no theoretical role for the lagged inflation while the empirical evidence points to the highly persistent nature of inflation. Fuhrer and Moore (1995) report that the baseline pure forward looking NKPC does not generate inflation persistence and leads to the poor empirical fit of the NKPC. Consequently, the expected inflation and lagged inflation were simultaneously incorporated as determinants of current inflation in the baseline pure forward looking NKPC. This modification is known as the hybrid NKPC where a fraction $(1-\omega)$ of the firms is assumed to be forward-looking that set prices taking into account future marginal cost using all available information at time t. The remaining firms ω are backward-looking and set prices based on recent past level of aggregate prices. This leads to the following reduced form of the hybrid NKPC (Gali & Gertler, 1999).

$$\pi_{H,t} = \alpha_f E_t \pi_{H,t+1} + \alpha_b \pi_{H,t-1} + \lambda \hat{x}_t \tag{2}$$

Where $\lambda = (1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1}$ and the reduced form parameters are defined as follows.

$$\begin{bmatrix} \alpha_f = \beta\theta\phi^{-1} \\ \alpha_b = \omega\phi^{-1} \\ \phi = \theta + \omega[1-\theta(1-\beta)] \end{bmatrix} \tag{2a}$$

α_f and α_b are the weights attached to expected future inflation and lagged inflation, respectively. If all firms are forward-looking in price-settings, the fraction of the backward-looking firms would be zero and the hybrid NKPC is converged to the baseline NKPC, Eq. (1).[6]

2.2. The open economy NKPC

The baseline pure forward looking NKPC (Eq. 1) and the hybrid NKPC (Eq. 2) do not consider the role of foreign factors like trade openness and exchange rate dynamics. Gali and Monacelli (2005) have extended the New Keynesian Dynamic Stochastic General Equilibrium (DSGE) model to the small open economy, which includes an open economy forward-looking New Keynesian Phillips Curve. The Gali and Monacelli (2005) small open economy New Keynesian Phillips Curve (GMNKPC) provides an explanation of nominal price rigidities and captures the interaction of a small open economy to the rest of the world.

The reduced form of GMNKPC similar to the baseline pure forward looking NKPC, Eq. (1), relates current inflation to expected future inflation and marginal cost, as defined below.

$$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \lambda \hat{mc}_t \tag{3a}$$

The foreign shocks of the terms of trade and exchange rate enter via the Consumer Price Index (CPI) and play an important role in the process of inflation dynamics. The difference between the open economy GMNKPC and the baseline pure forward looking NKPC is due to the difference between the domestic goods inflation $\pi_{H,t}$ and the CPI inflation π_t. The difference between $\pi_{H,t}$ and π_t is proportional to the percentage change in the terms of trade Δs_t as defined below.[7]

$$\pi_t = \pi_{H,t} + \alpha \Delta s_t \tag{3b}$$

[6] Some studies attempt to provide microeconomic foundations for adding lagged inflation to the pure forward NKPC. In this context, Christiano, Eichenbaum, & Evans (1997) propose the indexation mechanism, while Gali & Gertler (1999) introduce rule-of-thumb price-setting, which provide theoretical grounds for the role of lagged inflation in the pure forward looking NKPC. Cogley & Sbordone (2008) report that variations in trend inflation as related to the shift in monetary policy explain inflation persistence without lagged inflation in the baseline pure forward looking NKPC.

[7] The terms of trade is defined as the price of foreign goods in terms of home goods. It suggests that a decline in the change in the terms of trade implies a fall in the prices of foreign goods.

By using Eq. (3a) and (3b), we can derive an open economy NKPC of Gali and Monacelli (2005), which explicitly shows the impacts of foreign shocks (i.e., terms of trade) on inflation. The GMNKPC specification based on the terms of the trade is given by.

$$\pi_t = \beta E_t \pi_{t+1} + \lambda \hat{mc}_t + \alpha[\Delta s_t - \beta E_t \Delta s_{t+1}] \tag{3c}$$

The terms of trade s_t and real exchange rate q_t are related to each other under the assumption of the complete exchange rate pass-through $q_t = (1-\alpha)s_t$. This can be used to derive the following real exchange rate specification of the GMNKPC.

$$\pi_t = \beta E_t \pi_{t+1} + \lambda \hat{mc}_t + \frac{\alpha}{1-\alpha}[\Delta q_t - \beta E_t \Delta q_{t+1}] \tag{3d}$$

The domestic marginal cost and output gap are not proportional in the open economy GMNKPC, $\hat{mc}_t = (\sigma_\alpha + \phi)\hat{x}_t$. By substituting this relationship, the open economy GMNKPC can also be derived in terms of the output gap for both the terms of trade and the real exchange rate specifications.

$$\pi_t = \beta E_t \pi_{t+1} + \kappa_\alpha \hat{x}_t + \alpha[\Delta s_t - \beta E_t \Delta s_{t+1}] \tag{3e}$$

$$\pi_t = \beta E_t \pi_{t+1} + \kappa_\alpha \hat{x}_t + \frac{\alpha}{1-\alpha}[\Delta q_t - \beta E_t \Delta q_{t+1}] \tag{3f}$$

where the slope parameter $\kappa_\alpha = \lambda(\sigma_\alpha + \varphi)$ is a function of the following structural parameters.

$$\begin{bmatrix} \lambda = \dfrac{(1\text{-}\theta)(1\text{-}\beta\theta)}{\theta} \\ \sigma_\alpha = \dfrac{\sigma}{(1\text{-}\alpha) + \alpha\omega} \\ \omega = \sigma\gamma + (1\text{-}\alpha)(\sigma\eta\text{-}1) \end{bmatrix} \tag{3g}$$

where σ is the inter-temporal elasticity of substitution in consumption. φ measures the inter-temporal labour-leisure choice. θ is the measure of price stickiness. γ is the measure of substitution between goods produced in other countries. η is a measure of the substitution between domestic and foreign goods. $\alpha$is the share of imported goods in home consumption and, hence, is an index of openness. β is the time discount factor.

The parameter α is an estimate of the degree of openness, which affects inflation through its impact on the slope of GMNKPC. If $\alpha = 0$, the open economy NKPC converges to the closed-economy baseline pure forward looking NKPC as outlined in Eq. (1). The similar result holds if $\sigma = \eta = \gamma = 1$ *or* $\omega = 1$. The important feature of the GMNKPC is that they relate the process of inflation dynamics for an open economy. The composite term, the difference between the current change in terms of trade and the expected change in terms of trade in Eq. (3c) and (3e), and the difference between the current change in exchange rate and expected change in exchange rate in Eq. (3d) and (3f) define the inflation process for an open economy. The GMNKPC based on the terms of trade assumes that the movements in the terms of trade and inflation are related over time. Similarly, the real exchange rate specification suggests that the relationship between the movements in real exchange rate and inflation holds over time. Since the model assumes that the exchange rate pass-through is complete, Eq. (3c) to (3f) should yield identical results.

One of the important assumptions of the GMNKPC is that all imported goods are consumer goods. However, this assumption does not hold as imported goods are also used as intermediate inputs. The price of these imported goods affect the marginal cost of firms Kuttner & Robinson, 2010, and may affect the desired price level and the inflation rate. The GMNKPC also assumes that the exchange rate pass-through is complete. Instead the empirical evidence show that the exchange rate pass-through is incomplete in the OECD countries (Campa & Goldberg, 2005). Compared to the GMNKPC, the following specification of the open economy NKPC considers the prices of imported goods, which affect the marginal cost of firms defined by the weighted average of both domestically produced and imported goods (Balakrishnan & Lopez-Salido, 2002).

$$\pi_t = \beta E_t \pi_{t+1} + \lambda[(1-\alpha)\hat{mc}_t + \alpha(p_t^m - p_t)] \tag{4a}$$

The consumer price inflation π_t is determined by the marginal cost and price of imported goods p_t^m relative to the domestic prices p_t. The parameter λ is a function of deep structural parameters of the frequency of price adjustment θ and the subjective discount factor β, as defined before in Eq. (1). The parameter α is an index of openness and captures the effect of real import prices on inflation. The slope of the open economy NKPC, the elasticity of inflation to the marginal cost $\lambda(1-\alpha)$, is also determined by the share of imported prices, which is not the case in the baseline forward looking NKPC and the GMNKPC. The

restriction that $\alpha=0$ converges to the pure forward looking NKPC and implies that imports are final consumer goods, which do not affect marginal cost of the firms. The hybrid version of the open economy NKPC can also be derived as follows.

$$\pi_{H,t} = \alpha_f E_t \pi_{H,t+1} + \alpha_b \pi_{H,t-1} + \lambda\left[(1-\alpha)\hat{mc}_t + \alpha(p_t^m - p_t)\right] \tag{4b}$$

The reduced form parameters α_f and α_b -the weights attached to the expected future inflation and the lagged inflation- are function of the deep structural parameters of ω (the degree of price indexation such as fraction of backward looking price setters), θ (the price stickiness parameter) and β (the time discount factor). The elasticity of inflation to the marginal cost $\lambda(1-\alpha)$ is again determined by the share of the prices of imported goods. The higher is the openness parameter the lower is the elasticity of inflation to the marginal cost. Eq. (4b) also nests three versions of the NKPC. The restriction $\alpha=0$ yields the hybrid NKPC, Eq. (2) and implies that imports are final consumer goods and exchange rate pass-through is complete. The restriction $\omega=0$, assuming that all the firms are forward looking, converges to the pure forward looking open economy NKPC with $\alpha_b=0$ and $\alpha_f=\beta$ as shown in Eq. (4a). The restriction that $\alpha\neq0;\omega\neq0$ yields the open economy hybrid NKPC, depicted in Eq. (4b).

We estimate all four different versions of the NKPC, pure forward looking NKPC, GMNKPC, open economy NKPC, as well as the open economy Hybrid NKPC for Australia, Canada, New Zealand and the United Kingdom. The structural parameters β, θ, ω and $\alpha$are estimated and the duration of price stickiness is retrieved using the price stickiness parameter with the transformation $1/(1-\theta)$. The results of these four variants of NKPC are reported and discussed in section 7.

3. Empirical evidence on the estimation of closed economy NKPC

The baseline NKPC and the hybrid NKPC have been tested primarily for the United States and the Euro-area countries. In this section, we discuss the empirical performance of the closed economy version of NKPC (both the baseline NKPC and the hybrid NKPC). Our major focus is on the results as well as statistical and econometric issues for a broader set of developed countries within the OECD group.

3.1. The forward and backward looking inflation dynamics

The empirical performance of NKPC crucially depends on the proxy for the real activity. The output gap, generally measured by taking the difference of the (log) real GDP from the fitted linear or quadratic time trend, is commonly used for estimation of the NKPC. However, the estimated coefficient on output gap turns out to be incorrectly signed (negative) and statistically insignificant. Gali and Gertler (1999) emphasize that the output gap obtained from the de-trended GDP is not a good proxy and the potential level of output contains considerable variations. Gali and Gertler (1999) along with additional studies such as Woodford (2001) and Sbordone (2002) proposed marginal cost to be a better proxy of the output gap.[8]

Gali and Gertler (1999) tested the baseline NKPC and the hybrid NKPC for the United States. They employed the generalized method of moment (GMM) estimator and used the labour income share as a proxy for the marginal cost. For the baseline NKPC, they find that the coefficient on labour income share is positive and statistically significant. However, if the output gap is used as a proxy for the economic activity, the coefficient turns out to be statistically insignificant and incorrectly signed (negative). Similar findings are reported for the hybrid NKPC with the labour income share. In particular, the coefficient on expected inflation that ranges from 0.59 to 0.87 is statistically significant and dominates the coefficient on lagged inflation, which ranges from 0.085 to 0.383.

This suggests that inflation dynamics are forward looking in the United States. The structural parameters of the frequency of price stickiness, the discount factor and the fraction of backward-looking price setters are all correctly signed (positive) as well as statistically significant. These results provide empirical support for the NKPC and also suggest that the NKPC can explain inflation dynamics in the US.

In another paper, Gali, Gertler, and Lopez-Salido (2001) demonstrated that similar to the findings for the United States, the NKPC with the labour income share instead of the output gap also explained inflation dynamics for the Euro-area data. The coefficient on labour income share remained positive and statistically significant in both the baseline NKPC and the hybrid NKPC. The coefficient on expected inflation was again quantitatively larger than the coefficient on lagged inflation. This suggests that inflation dynamics are also forward-looking, a finding consistent with the theoretical predictions of NKPC.

However, the use of labour income share as a proxy for marginal cost as well as the GMM methodology used in Gali and Gertler (1999); Gali et al. (2001) and Sbordone (2002) have been questioned and criticized. In particular, Rudd and Whelan (2005, 2006) emphasized that the coefficient on lagged (forward) inflation is biased downwards (upwards) as influence of the lagged inflation has already been captured by the expected inflation in the first-stage regression. Rudd and Whelan (2005, 2006) focussed on the estimation of the closed-form of NKPC that linked current inflation to the expected discounted sum of future values of the driving force, such as the labour income share or the output gap. They found that the NKPC displayed a poor

[8] The relationship between the marginal cost and the output is approximately proportional and, as a result, the marginal cost is a suitable proxy for the output gap in the estimation of NKPC.

empirical fit for the United States data. The labour income share was not a valid proxy for the real economic activity while the data also did not support the dominant role of future inflation against lagged inflation. These findings are contrary to Gali and Gertler (1999) and Gali et al. (2001).

Rudd and Whelan (2007) provided additional empirical evidence to show that the labour income share exhibits counter-cyclical movements in economic recessions while the output gap is pro-cyclical with recessions. Therefore, the output gap seems to decline in economic recessions and, as a result, it is a better proxy than the labour income share for real economic activity. Lindé (2005) also argues that the estimation of NKPC with GMM produces biased results in Gali and Gertler (1999) and Gali et al. (2001) while an alternative estimation methodology, the Full Information Maximum Likelihood, shows that the NKPC is rejected by the data.

Gali, Gertler, and Lopez-Salido (2005) responded to Rudd and Whelan (2005, 2006) and Lindé (2005) and clarified that the earlier empirical findings of Gali and Gertler (1999) and Gali et al. (2001) remained valid under different empirical specifications, estimation methods as well as different sets of instruments. They also criticized the empirical approach adopted in Rudd and Whelan (2005, 2006) and Lindé (2005). Gali et al. (2005) emphasized that the reduced form coefficients are functions of the deep structural parameters in NKPC. However, the reduced form coefficients, as estimated in Rudd and Whelan (2005, 2006) and Lindé (2005), do not provide any structural interpretation of the NKPC. Gali et al. (2005) also tested the closed-form of NKPC and emphasize that the results confirm that the problem is with the use of output gap as a proxy for the real economic activity rather than any structural weaknesses in the NKPC model.

Supporting the above findings, Neiss and Nelson (2005) reaffirmed that the output gap as a forcing variable is positive and statistically significant if the output gap is estimated using the theory-based estimates; i.e., incorporating productivity and technology shocks. They used data over the sample period from 1961q4 to 2000q4 and showed that the output gap based NKPC where the gap was measured by the proposed theory-based estimates, explained inflation dynamics for the USA, the UK and also Australia.

3.2. The NKPC under different empirical specifications

The important findings from Gali and Gertler (1999) and Gali et al. (2001) revealed that the estimated coefficient on expected inflation is statistically significant and also larger than the coefficient on lagged inflation. The output gap as a proxy for the real economic activity is incorrectly signed (negative) and statistically insignificant. However, the labour income share is a valid proxy for estimation in both the baseline NKPC and the hybrid NKPC. These findings have been re-evaluated under different empirical extensions, which are discussed in this sub-section.

Bårdsen, Jansen, and Nymoen (2004) revisited the empirical success of NKPC for the aggregate Euro area data in Gali et al. (2001) and also for the United Kingdom as in Batini et al. (2005). Bårdsen et al. (2004) emphasized that there is a long run co-integrating relationship between levels of wages, prices and productivity, especially for the United Kingdom. This co-integrating relationship should be incorporated in the empirical estimation of NKPC. Bårdsen et al. (2004) used the error correction component as an explanatory variable in the NKPC. In addition, they allowed additional lags of inflation and the output gap as regressors instead of instruments. Bårdsen et al. (2004) reported the 'fragile' statistical significance of the labour income share and also pointed that the dominance of expected inflation against lagged inflation was not statistically robust in the hybrid NKPC. The size of coefficient on expected inflation decreased under different empirical specifications. This indicated that the estimated coefficients of NKPC are not robust across alternative empirical specifications.

Mehra (2004) argued that the supply shocks have direct impacts on inflation and the effect of these supply shocks should be included in the estimation of NKPC. Mehra (2004) employed relative import prices as a proxy for supply shocks and estimated the reduced form of NKPC for the United States over the updated sample period (1961q1-2003q2) as well as over the Gali and Gertler (1999) sample period (1964q1-1997q4). The results revealed that the dominance of expected inflation against lagged inflation is not robust in the hybrid NKPC.

In general, the hybrid NKPC specification, Eq. (2), contained one lead and one lag of inflation. Jondeau and Le Bihan (2005) tested the NKPC allowing for different lags and leads of inflation for the Euro-area, Germany, France, Italy, the UK and the USA over the sample period (1970q1-1999q4). The results indicated that three lags and leads yield statistically significant coefficient on the labour income share and the output gap. However, neither the output gap nor the labour income share as a forcing variable affected the dominance of coefficient on expected inflation. On the contrary, the coefficient on lagged inflation remained statistically significant, and also quantitatively important for the European countries. These findings are in contrast to the US based on the findings of Gali and Gertler (1999), which showed that the backward-looking coefficient is less important compared to the forward-looking coefficient of inflation. In general, Jondeau and Le Bihan (2005) findings do not support the main theoretical predictions of NKPC for the European countries.

Zhang, Osborn, and Kim (2008) emphasized that there are significant shifts in the United States monetary policy especially in the era of Paul Volker and Alan Greenspan, which may affect the reduced form parameters of NKPC. These structural breaks may have an important impact on the reduced form parameters of NKPC. Zhang et al. (2008) employed Andrews (1993) and Andrews and Ploberger (1994) unknown structural breakpoint tests to detect the structural breaks in the NKPC. The results revealed that the role of expected inflation is not significant in the 1970s when inflation was high and volatile, but inflation dynamics are forward-looking after the 1980s. On the other hand, the coefficient on lagged inflation had also decreased after the 1980s. These results support the main theoretical predictions of the baseline NKPC consistent with Gali and Gertler (1999) and Gali et al. (2001).

The impact of potential structural breaks on the reduced form parameters of NKPC have also been discussed in Castle, Doornik, Hendry, and Nymoen (2010) who identify nine structural breaks (i.e., location-shift dummies) in the United States inflation over the sample period (1960q1-1997q4). They added these shift dummies to the reduced form of the hybrid NKPC and found that all the shift dummies are statistically significant. The coefficient on labour income share remains statistically insignificant and the coefficient on expected inflation, which drops from 0.62 to 0.25, is also statistically insignificant. Castle et al. (2010) conclude that once structural breaks are introduced in the hybrid NKPC, the coefficient on expected inflation does not dominate the coefficient on lagged inflation and the statistical significance of labour income share is also not statistically robust in the hybrid NKPC. These results are contrary to the findings in Gali and Gertler (1999).

The slope coefficient of NKPC turned out to be quantitatively small and also statistically insignificant for most countries, in particular for the US. This showed that inflation did not respond to the marginal cost. Kuttner and Robinson (2010) and other references in their paper discussed the possibilities that the increasing process of globalization had reduced the inflation rate significantly over the last two decades.[9] The marginal cost of firms had decreased due to different reasons (like cheap imported inputs), which decreased the price level and also changes in the price level (inflation). Kuttner and Robinson (2010) found that for the United States and Australia, the slope coefficient of NKPC had decreased, which showed that the Phillips curve has become flatter after 1984. However, the coefficient on expected inflation still dominated the lagged inflation. This also showed that inflation dynamics are forward looking consistent with the main theoretical predictions of NKPC.

Abbas and Sgro (2011) tested the validity of the baseline NKPC and the hybrid NKPC for Australia. They used different measures of marginal cost and output gap to proxy the driving force variable with different sets of instruments. The results showed that inflation dynamics were forward looking in Australia while the lagged inflation is statistically significant only after the 1980s. They also observed a major structural break in inflation process in 1983, which was related to the move towards the flexible exchange rate regime in Australia. In particular, the output gap (and also marginal cost) does not drive inflation in Australia. This is contrary to the main theoretical prediction of the NKPC.

The NKPC suggests that inflation is determined by the output gap. The positive output gap shows that the actual GDP is greater than the potential GDP, and this excess demand generates inflationary pressures. On the other hand, the large and persistent negative output gap causes recessions. The central bank uses the short term policy rate to stabilize the output gap (and also inflation). For example, the expansionary monetary policy is used to offset the effects of negative output gap and boost the real economic activity.

Given the important theoretical relationship between output gap and inflation, many studies have also tested the impact of output gap on inflation. Recently, Valadkhani (2014) tests the impact of output gap on inflation for three countries; Canada, the UK and the US. He uses the Markov switching model and finds that "the output gap has more influence on inflation when inflation exhibits large and erratic variations". In this context, we can understand that inflation variability also plays an important role in defining the relationship between output gap and inflation.

In the NKPC framework, inflation variability is not considered in estimation of the relationship between output gap (also marginal cost) and inflation. This may be one of the potential reasons for rejection of the NKPC on empirical grounds.

3.3. The NKPC and weak identification problem

The influential empirical findings of Gali and Gertler (1999) regarding forward looking inflation dynamics in the United States were also subject to the weak identification problem. This problem was related to the econometric estimation of NKPC. In this context, the set of instruments used for estimating NKPC is weekly correlated with expected inflation, the endogenous regressor. The week instruments can affect the estimates of NKPC. A number of empirical studies like Ma (2002); Dufour, Khalaf, and Kichian (2006) and Nason and Smith (2008) discussed this weak identification problem, and re-evaluated the results of NKPC based on Gali and Gertler (1999) and Gali et al. (2001). These findings are briefly discussed in this sub-section. Mavroeidis et al. (2014) provide an excellent overview of the weak identification problem plaguing the closed economy NKPC estimation using data for the USA.

Nason and Smith (2008) used the weak-identification robust tests based on Anderson and Rubin (1949) for testing NKPC for the US, the UK and Canada. They emphasized that the future predictability of driving force variable (the labour income share or the output gap) beyond the current and the lagged values (more than one lag) of inflation and labour income share can resolve the weak identification problem. The NKPC, as they point out that, even with a complete New Keynesian system (i.e., investment saving equation and the monetary policy rule) is not identifiable and does not have extra variables to be used as additional instruments for identification of the NKPC.

Nason and Smith (2008) also employed the recently developed Guggenberger and Smith (2008) weak identification robust test and found that, in addition to the weak identification problem, the parameters of NKPC were also not stable across different sets of instruments. Their findings do not support Gali and Gertler (1999) and Gali et al. (2001). Similarly, like the United States, the results also do not show that inflation dynamics are forward-looking in the United Kingdom as well as in Canada.

In a recent study, Kleibergen and Mavroeidis (2009) also discussed the problem of weak instruments in the estimations of NKPC with GMM. They emphasized that the weak instrument problem arises due to the limited dynamics of labour income share, which is used as a proxy for the real marginal cost. The coefficient on labour income share was very small (closer to

[9] Section 6 discusses in details the effect of the increasing process of globalization on inflation dynamics.

zero) suggesting that the labour income share does not drive inflation. They also argued that the commonly used Stock and Yogo (2005) test, which is used for testing the strength (weakness) of instruments in estimating NKPC, was not powerful enough compared to other tests, in particular, the Anderson and Rubin (1949) test.

For testing the empirical validity of NKPC, Kleibergen and Mavroeidis (2009) proposed the extension of conditional likelihood ratio statistic based on Moreira (2003) and Kleibergen (2005) tests to the GMM estimator. These tests remained powerful even in the case of weak identification problems. Applying these tests, they showed that inflation dynamics are forward-looking in the US and lagged inflation also does play an important role in explaining inflation. This lends support to Gali and Gertler (1999). Additionally, the results revealed that the slope of NKPC is smaller after 1984 which indicates that the NKPC has become flatter in the US.

In general, the results based on this section show that inflation dynamics are forward looking. Consistent with the theoretical predictions of NKPC, the coefficient on expected inflation dominates the lagged inflation. This suggests that inflation expectations are forward looking. In particular, firms are forward looking in their price setting decisions, as compared to the fraction of non-rational expectation firms, such as backward looking price-setters.

4. Empirical estimation of NKPC using survey forecasts of expected inflation and disaggregated data

4.1. Evidence from survey forecasts

The data on actual/realized future inflation have been widely used as a proxy for expected inflation in the estimation of NKPC. The alternative measure of expected future inflation is the survey data, which may reflect the real world behaviour of economic agents in response to the available set of information in a particular economy. A number of studies like Adam and Padula (2011); Henzel and Wollmershäuser (2008); Nunes (2010); Paloviita (2006); Roberts (1995) and Zhang et al. (2008) resorted to survey data on inflation expectations to test the closed economy baseline pure forward looking NKPC and the hybrid NKPC. These main findings and also some policy implications from these studies are discussed in this sub-section. In Table 1 (Appendix A), the highly cited papers and summary of their results of the NKPC estimated with the survey expectations are shown.

In an important study before Gali and Gertler (1999) and Gali et al. (2001); Roberts (1995) tested the NKPC using Michigan Survey and Livingston Survey as proxies for inflation expectations. The unemployment rate and output gap were used as proxies for the real economic activity. Both these proxies were correctly signed (positive) and statistically significant with these survey based measures of inflation expectations. However, these estimates were statistically insignificant when actual future inflation is used as a proxy for inflation expectations.

Roberts (1995) also found that the estimation of NKPC with the survey inflation expectations provided similar results over the high inflationary periods of 1973. This shows that economic agents adjust their expectations about inflation accordingly. However, the actual realized inflation data cannot capture agents' future inflation expectations leading to the empirical failure of NKPC.

For the US and also Canada, Dufour et al. (2006) tested the NKPC using both the survey measures of inflation expectations and the realized actual inflation. They used survey expectations from the Survey of Professional Forecasters for the US over the sample period from 1970q1 to 1997q4, which correspond to the Gali and Gertler (1999) sample period. For Canada, the inflation expectations were taken from Conference Board of Canada survey over the sample period (1970q1–2000q4). They used both the output gap and marginal cost as proxies for the real economic activity and employed identification-robust IV-estimators. The results showed that the hybrid NKPC explained inflation dynamics for the US. However, for Canada, the results did not provide empirical support for the hybrid NKPC.

Paloviita (2006) tested the baseline forward-looking NKPC and the hybrid NKPC for 12 –European Monetary Union countries.[10] The OECD inflation forecasts were used to proxy for inflation expectations. The baseline NKPC explained inflation process in the Euro area data. Both the output gap and labour income share served as good proxies for the driving force variable. The process of inflation dynamics was found to be the forward looking. She concluded that although the baseline NKPC explains inflation dynamics, the hybrid NKPC was also important to capture inflation persistence in these European countries.

Most of the studies for the US only used inflation expectations from the Survey of Professional Forecasters. On the other hand, Zhang, Osborn, and Kim (2009) employed broader and different measures of survey expectations. They tested the NKPC using Survey of Professional Forecasters, Green Book quarterly forecasts of GDP inflation and also one year ahead general public inflation forecasts from the Michigan Survey. They evaluated the empirical validity of NKPC both with the survey inflation expectations and the rational inflation expectations (actual future inflation).

Zhang et al. (2009) used the output gap as a proxy for the real economic activity and the data on potential GDP were obtained from the Congressional Budget Office. They also suggested that the use of one period lagged inflation as a regressor in the hybrid NKPC was not sufficient and ignoring other lags of inflation (i.e., more than one lag), produced the serial correlation problem. In turn, this affected the validity of instruments in the GMM estimation of NKPC. They also found that the coefficient on output gap was positive and statistically significant. The coefficient on lagged inflation dominated the coefficient on expected inflation. This

[10] These countries include Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal and Spain.

suggested that inflation dynamics were backward looking rather than forward looking. This was contrary to the earlier findings of Gali and Gertler (1999) and Gali et al. (2001).

The NKPC when estimated with survey inflation expectations yielded better results. This suggested that the survey inflation expectations and the rational inflation expectations (i.e., actual future inflation) have different implications for the estimation of NKPC. Nunes (2010) emphasized that the estimation of NKPC with survey expectations without considering rational expectations may yield misleading results about the estimates of expected inflation and lagged inflation. He used survey expectations from the survey of professional forecasters, and integrated both the rational expectations and the survey expectations approaches to test the NKPC.

Nunes (2010) also tested if inflation dynamics remain forward looking for the US when survey expectations are introduced to test the NKPC. It is found that the estimate on expected inflation is larger than the lagged inflation. This suggests that inflation dynamics are forward looking and also dominates the backward looking expectations. This finding is consistent with Gali and Gertler (1999). However, the fraction of backward looking price setters is higher with survey expectations, as compared to what was originally estimated by Gali and Gertler (1999).

In a recent study, Adam and Padula (2011) estimated the baseline NKPC and the hybrid NKPC for the United States using the Survey of Professional Forecasters over the sample period (1968q4-2003q1).The results are consistent with the predictions of NKPC across both the measures of marginal cost and output gap. They also estimated the structural parameters of NKPC, which were found to be positive and statistically significant with the survey based inflation expectations. The estimate on frequency of price stickiness showed that prices are fixed for around five quarters. These results provided empirical support to the NKPC and suggest that the NKPC explains process of inflation dynamics in the US.

The results based on survey data in general showed that the particular reason for the failure of NKPC to explain inflation dynamics is associated with the use of the proxy for expected inflation. The realized future inflation which was used to proxy for expected inflation do not reflect agents' inflation expectations compared to the direct measures of survey inflation expectations. As a result, the sign, size and statistical significance of the coefficients of NKPC are closely in line with the theoretical predictions of NKPC when the survey measures of inflation expectations are used for estimating NKPC.

These findings suggest some practical implications. Though the survey measures of inflation expectations reflect the agents' actual behaviour about inflation expectations (and also show empirical validity of the NKPC), it is well-known that the survey based measures are subject to other criticism. One of the important implications in addition to the measurement problem is itself the validity of these survey measures. These survey responses may show limited interest and also sometimes irresponsible response of the agents. In this context, the empirical success of NKPC with survey measures, as discussed above, is also questionable and may be unreliable for monetary policy considerations.

4.2. The NKPC at the disaggregated level data

The variation in prices across different sectors affects the aggregate inflation rate, and also affects the estimation results of NKPC. Recently, the NKPC has been tested for the sectoral and the disaggregated data (Byrne, Kontonikas, & Montagnoli, 2013; Imbs, Jondeau, & Pelgrin, 2011; Leith & Malley, 2007; Petrella & Santoro, 2012).

The main advantage of using sectoral data is that it captures heterogeneity of price stickiness that varies across different sectors. The aggregate data do not capture these sectoral differences rather price stickiness is assumed to be common across firms. On the other hand, the mark-up over marginal cost is also taken as constant over average duration of prices. However, Lawless and Whelan (2011) emphasized that the mark-up over marginal cost varies across different sectors. The varying mark-up affects the slope parameter of NKPC (i.e., output gap or marginal cost). As a result, the estimation of NKPC with the disaggregated data captures both the heterogeneity in mark-up over marginal cost and the heterogeneity in price stickiness across different sectors.

The results based on different studies show that compared to the aggregate data, the disaggregate data fit the NKPC well. We discuss the main findings and also some policy implications from these strands of studies in this sub-section. In Table 2 (Appendix A), we list the highly cited papers and summarize their results of NKPC, as estimated at the sectoral and disaggregate level data.

Recently, Byrne et al. (2013) used a disaggregated international panel database of 14 OECD countries[11] 15 economic sectors[12] prices to estimate the reduced-form hybrid NKPC. The marginal cost as a proxy for real economic activity drives inflation process with disaggregated data, and inflation dynamics are also forward looking, as implied by the NKPC model. Regarding country-specific findings, the NKPC also provided reasonable approximation of the data with relatively low inflation persistence and statistically significant marginal cost effects for larger countries like the USA, the UK and France. However, the results from smaller countries like Ireland and Belgium do not lend support to the hybrid NKPC.

Petrella and Santoro (2012) tested the NKPC for 458 United States manufacturing industries over the sample period (1958–1996). They emphasized that inflation at the sectoral level can account for heterogeneity in prices, which may produce biased estimates of NKPC at the aggregate level data. They also argued that the labour income share based on the intermediate goods was an effective measure of the driving force variable to test the NKPC.

[11] The countries are: Austria, Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, the UK and the USA.

[12] The sectors include agriculture, hunting, and forestry; fishing; mining and quarrying; total manufacturing; electricity, gas and water; construction; wholesale and retail trade; hotels and restaurants; transport, storage and communication; financial intermediation; real estate, renting, and business activity; public administration, defence, and compulsory social security; education; health and social work; and other community, social, and personal services.

Following Rudd and Whelan (2006); Petrella and Santoro (2012) used the closed form of both the baseline NKPC and the hybrid NKPC. The output gap and the labour income share of intermediate goods are employed as proxies for the real activity. The current and expected future values of the labour income share of intermediate goods are found to be statistically significant in a number of sectors. The authors concluded that inflation dynamics are forward-looking for the US and these results are also consistent with the theoretical predictions of the baseline NKPC.

Leith and Malley (2007) estimated sectoral Phillips curves for 18 US manufacturing industries over the sample period from 1958q2 to 1996q3. They use industries intermediate-goods cost as a proxy for the marginal cost. This is a broader measure of marginal cost compared to the commonly used measure like the labour-income share. The labour cost (wages) is heterogeneous across different sectors, and an aggregate measure of labour income share may yield inconsistent estimates of the forward and backward looking inflation expectations.

Leith and Malley (2007) also found that the NKPC explains inflation dynamics in these sectors. The estimates of sectoral Phillips curves for these manufacturing industries show that the two-third of firms are forward looking in price setting decisions. This suggests that the forward-looking price setting behaviour is dominant across firms. However, the degree of backward looking behaviour and price stickiness vary across industries. In particular, price stickiness is higher in durable-goods industries than the non-durable-goods industries. The average duration of price adjustment ranges from eight months to two years in the United States.[13] The results, in general, provide empirical support to the NKPC at the US sectoral level data.

The labour-income share as a proxy for the marginal cost has been widely used after Gali and Gertler (1999). The theoretical predictions of NKPC suggest that the labour-income share should be pro-cyclical (i.e. decreasing in recessions). However, some empirical studies (Rudd and Whelan (2007) and Mazumder (2010) find that the labour-income share is counter-cyclical in the US.

Mazumder (2010) argued that even if the labour income share becomes pro-cyclical after adjusting over time hours, which vary frequently and wage rate is not fixed but depends on the number of hours, the NKPC does not fit the US manufacturing data. He used sectoral level marginal cost of the US manufacturing industries to test the baseline NKPC and the hybrid NKPC over the sample period from 1960q1 to 2007q3. The results based on disaggregate sectoral data do not provide empirical support to both the baseline NKPC and the hybrid NKPC. The estimates on labour income share are incorrectly signed (negative) contrary to the theoretical predictions of NKPC.

Besides the United States, the NKPC has also been tested for some European countries at the sectoral level data. The results from those studies suggest that the NKPC explains inflation dynamics in these countries.

For example, Imbs et al. (2011) estimated sectoral NKPC in France for 16 sectors, comprising of agriculture, manufacturing and services related activities. They observe that compared to aggregate prices the sectoral prices respond more quickly to exogenous shocks in the marginal cost. This affects the estimates of forward and backward looking inflation expectations and also the estimates of nominal price rigidities across different sectors.

Imbs et al. (2011) found that the backward looking behaviour of price setting firms is not common and varies across sectors. The process of inflation dynamics is forward looking and the marginal cost explains inflation in most sectors. The coefficient on marginal cost is quantitatively large and statistically significant over the sample period from 1978q1 to 2005q3. The results yield support for the NKPC. They also find that the frequency of price change depends on the nature of goods. The prices of non-durable goods change more frequently than the prices of durable-goods. The duration of price rigidities, which is assumed to be common across firms in aggregate data, varies between two quarters and almost two years from sector to sector. Conversely, the aggregate data suggest the duration of price adjustment is less than one year in French data.

Lawless and Whelan (2011) tested the NKPC for 630 sectors of 15 EU countries and 459 US manufacturing sectors.[14] The sample period runs from 1970 to 2005 for European-countries and from 1959 to 1996 for the US. In addition, they also provide evidence for the US with the aggregate data over the sample period from 1970q1 to 2008q4. The labour- income share and output gap of those sectors are used as proxies for the driving force variable.

Lawless and Whelan (2011) found that the NKPC fails to fit the sectoral data for these European countries. The estimated coefficients on labour income share are incorrectly signed (negative) for majority of these sectors.

In general, the overall results based on sectoral data from the above studies show that the intermediate-goods cost rather than the labour-income share is a better proxy for the real economic activity. Compared to the aggregate data, the NKPC fits the disaggregated data well across different sectors and explains the process of inflation dynamics. These results yield important policy implications, in particular, for the monetary policy. In this context, the monetary policy should be able to influence the price level and marginal cost of different sectors with a varying degree. The heterogeneity with long duration of price stickiness would also make the response of monetary policy gradual in some sectors.

The sectoral heterogeneity arises due to different reasons and one of the reasons is related to the demand-side variations across different sectors (Erceg & Levin, 2006). The monetary policy affects individual demand and marginal cost of different sectors, and this variation in responses of marginal cost to monetary policy across sectors is not captured at the aggregate level data. The estimation of NKPC with disaggregated data helps in understandings of dynamics of inflation and marginal cost. This also provides useful insights about stabilizing overall inflation and sectoral output of an individual economy.

[13] The heterogeneity in price adjustment has also been found in the micro-level data (e.g., see, Bils and Klenow (2004) and Nakamura and Steinsson (2008).

[14] These countries include Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and the United Kingdom.

5. Empirical advances in estimating the open economy NKPC

Inflation dynamics are generally different in open economies and accordingly the role of intermediate imported inputs or real imports has been introduced to the closed economy NKPC in some studies (e.g. Batini et al., 2005; Rumler, 2007). A recent emerging literature has also tested the role of external factors such as the terms of trade and real exchange rate based on the theoretical extensions of Gali and Monacelli (2005) open economy NKPC (GMNKPC), as discussed in Section 2 (see, inter alia, Allsopp et al., 2006; Mihailov, Rumler, & Scharler, 2011; Abbas, Bhattacharya, Mallick, & Sgro, 2015). In this section, we discuss the empirical evidence and also some policy implications of the open economy NKPC. In Table 3 (Appendix A), we list the highly cited papers and summarize their results of the empirical estimation of the open economy NKPC.

Batini et al. (2005) extended Gali and Gertler (1999) closed economy NKPC to the open economy NKPC for the United Kingdom. They emphasized that the employment adjustment costs affect the marginal cost of firms. The labour income share as a proxy for real marginal cost also does not take into account these employment adjustment costs, which affect inflation process.

Batini et al. (2005) introduced the employment adjustment costs, the relative prices of imported inputs and the foreign competition pressures in the marginal cost function to estimate the open economy NKPC. The coefficients on expected inflation, labour income share, employment terms and real import prices are correctly signed and statistically significant over the sample period from 1972q3 to 1999q2. However, the output gap and the proxy for foreign competition are not statistically significant. They conclude that the labour income share as a measure of real marginal cost should be adjusted with the relative prices of imported inputs, the employment adjustment costs and the foreign competition to estimate NKPC for an open economy, like the United Kingdom.

In another study, Rumler (2007) estimated the open economy NKPC specification incorporating imported intermediate goods as production inputs for aggregate Euro-area data as well as individual nine Euro-area countries[15] over the sample period from 1980q1 to 2003q4. The labour income share and imported intermediate inputs describe inflation dynamics. The empirical fit of the open economy NKPC is improved after using both imported and domestic intermediate inputs. The estimated frequency of price rigidity varies across the Euro-area countries and remains lower in the open economy NKPC than the closed economy NKPC. Rumler (2007) concluded that the single monetary policy implemented by the Euro-system has different inflationary implications for individual countries in the Euro-area.

Allsopp et al. (2006) tested the GMNKPC for the United Kingdom and find that the coefficient on labour income share as a proxy for real economic activity is positive (0.167) but statistically insignificant over the sample period (1964q2–2002q3). The coefficient on discount factor is positive, statistically significant and ranges from 0.92 to 1.002. The openness parameter, the main parameter of interest, is positive (0.034) but statistically insignificant and also turns out to be incorrectly signed (−0.061) in the sub-sample period (1980q1–2002q3). For Australia, the openness parameter is also incorrectly signed for the sample period (1971q1–2001q3). These results suggest that the GMNKPC is not supported by both the United Kingdom and Australian data.

In another study for the United Kingdom, Kara and Nelson (2003) also estimated the GMNKPC and reported that the openness parameter remained incorrectly signed with both the output gap and the labour income share as proxies for the real economic activity. These results are also robust across different reduced form specifications of GMNKPC.

One of the common empirical observations based on different studies is that the openness parameter of GMNKPC is either incorrectly signed (negative) or statistically insignificant. This empirical problem is not only confined to the United Kingdom and Australia. Guay et al. (2003) found that the openness parameter is also statistically insignificant over the sample period (1970q1–2000q4) for Canada as well. In addition, the coefficient on labour-income share is also statistically insignificant. The estimate on frequency of price stickiness remains positive and statistically significant. Guay et al. (2003) also report that the duration of price adjustments is around seventeen quarters in Canada. All these findings, in general, show that the GMNKPC cannot explain inflation dynamics for Canada.

The GMNKPC has also been tested for a broader set of the OECD countries. Mihailov et al. (2011) tested the GMNKPC for ten OECD countries[16] over the sample period (1970q1–2007q4). They find that the openness parameter is incorrectly signed (negative) for Austria, France and Spain while it is positive and statistically significant for other countries. The results show moderate support to the GMNKPC in explaining inflation dynamics for these OECD countries.

Recently, Abbas et al. (2015) tested the GMNKPC for Australia. They estimated five different versions of the GMNKPC including an extension to the hybrid GMNKPC using both the terms of trade and the real exchange rate as explanatory variables of foreign shocks. The marginal cost and output gap are employed as proxies for the real economic activity. Their empirical framework is also extensive and employs five different sets of instruments to estimate GMNKPC in addition to controlling for different policy and event related structural changes (i.e., changes in the exchange rate regime and adoption of explicit inflation targeting).

Abbas et al. (2015) also rejected the GMNKPC for Australia over the sample period (1959q3–2009q4). The openness parameter is incorrectly signed (negative) in both the terms of trade and real exchange rate specifications of GMNKPC. The slope coefficient

[15] These countries include Austria, Belgium, Finland, France, Germany, Greece, Netherlands, Spain, and Italy.
[16] The countries are: Austria, Canada, France, Germany, Italy, The Netherlands, Spain, Sweden, Switzerland and the United Kingdom.

is incorrectly signed (negative) irrespective of the proxy for real activity (the output gap or the non-farm labour income share). Similarly, the coefficient on frequency of price stickiness is statistically insignificant in most cases. The terms of trade and exchange rate specifications do not tend to drive inflation process, as predicted by the GMNKPC.

There are also numerous studies which specifically test the impact of trade openness and exchange rate regimes on inflation. The empirical evidence is contradictory about the impact of trade openness on inflation. Ghosh (2014) provides a compact review of those studies, and his own findings show that there is no 'clear evidence' which can suggest that the trade openness yields low inflation. These findings also suggest that the relationship between inflation and trade openness is largely rejected by the data.

The results based on open economy NKPC, in general, suggest that the intermediate input costs play an important role in the production process and affect directly the marginal cost of firms, which in turn drives inflation. However, the dynamics of terms of trade and exchange rate as proposed by the GMNKPC do not drive inflation. These results are interesting for the open economies where inflation process should be related to these foreign shocks. However, the GMNKPC is commonly rejected by the data for majority of the open economies, as discussed before.

One of the important reasons for rejecting GMNKPC is due to the absence of a stable long-run relationship between the real exchange rate and the terms of trade. The GMNKPC assumes that the real exchange rate is proportional to the terms of trade. This implies full and instantaneous exchange rate pass-through and the changes in exchange rate and consumer price inflation should be strongly related over time. However, it is well-established that there is a weak and low pass-through from exchange rate to consumer price inflation. This incomplete exchange rate pass-through increases the inflation rate and breaks down the proportional relationship between exchange rate and term of trade (see, Monacelli, 2005 for discussions). As a result, this incomplete pass-through also affects the structural parameters of GMNKPC.

Another reason which may lead to the empirical failure of GMNKPC is due to the assumption that all imports are final consumption goods consumed by the households, which implies that they do not enter into the production process. However, as Allsopp et al. (2006) point out that imports are also intermediate goods and it is not appropriate to model all imports as final consumption goods, which is contrary to the theoretical predictions of the Gali and Monacelli (2005) open economy NKPC.

6. Globalization and Phillips curve

In this section, we discuss the recent theoretical developments and empirical evidence of globalization and inflation dynamics within the NKPC literature. The particular channels through which globalization can affect inflation and its wide-ranging policy implications related to the implementation of monetary policy are also discussed in this section.

The process of globalization increases trade integration between countries in the world. Globalization, therefore, has the potential in opening up access to larger markets and opportunities for all stakeholders in the economy including the policy makers. From the perspective of firms, the increased competition as a result of trade integration and the degree of openness will have implications for their marginal cost and the profit mark-ups. The elasticity of inflation to marginal cost (depicted by the slope of the NKPC) directly responds to trade integration. In a similar vein, the globalization process can affect the inflation process and the driving force variables like the domestic output gap and marginal cost within the context of the New Keynesian Phillips Curve.

It has been observed that inflation has significantly fallen in the industrial countries during the last couple of decades (see, Helbling, Jaumotte, and Sommer (2006) for a comprehensive discussion). This decline in the rate of inflation may be attributed to increased globalization across countries. This line of research has gained attention in both academic and policy circles in recent years. We selectively mention the studies of Gamber and Hung (2001); Rogoff (2003, 2006); Cecchetti and Debelle (2006); Helbling et al. (2006); Borio and Filardo (2007); Yellen (2006); Bernanke (2007); Sbordone (2007); Mishkin (2009) and Woodford (2007) among the leading ones focusing on the role of globalization and its consequence on the inflation process.

The empirical evidence of the impact of globalization on inflation dynamics is mixed across the US, the European countries and the OECD countries. For example, some studies like Gamber and Hung (2001); Borio and Filardo (2007); Pain, Koske, and Sollie (2006); Guerrieri et al. (2010) and Auer, Degen, and Fischer (2010) support the role of globalization in reducing the inflation rate. On the other hand, Tootell (1998); Ball (2006); Ihrig et al. (2010); Milani (2012) and López-Villavicencio and Saglio (2014) argue that globalization has no bearing on the process of inflation dynamics.

The inflation process can be influenced by globalization in various ways given its broad impacts traversing through different sectors of the economy like the factor product and financial markets. Globalization has the direct bearing on inflation through changes in the prices of imported goods. The cheaper import prices of manufacturing inputs (as well as consumer goods) lower the marginal cost of firms, which reduces the inflation rate. In addition, globalization indirectly affects inflation through increasing competition in the economy. In this case, the domestic producers face an elastic demand curve and due to increased availability (and also substitutability) of foreign goods of similar quality in the domestic market, the domestic producers would not be able to increase their prices since this may lead to reduction in the demand for their goods. The increased competition also reduces the overall price level (and hence inflation rate) while increasing the quantity of the product.

Further, the process of globalization mutes the sensitivity of inflation to the domestic economic activity like the domestic resource capacity/output gap or marginal cost. In turn, the domestic inflation depends more on the foreign real activity like the foreign resource capacity/output gap as opposed to the domestic output gap. A number of studies introduce the foreign output to explain the inflation process, and also find that the foreign output gap as opposed to domestic output gap is a key driving

force variable of inflation for the US and other OECD countries. This suggests that the dynamics of inflation and output gap have changed.

Gamber and Hung (2001) provide empirical support for the role of globalization in lowering the US inflation rate. They augment Gordon (1982) Phillips curve specification, which uses controls for the supply shocks, by including the foreign resources capacity to explain the US inflation dynamics. The foreign resource capacity variable is constructed using the trade-weighted average capacity of the major thirty five trading partners. Gamber and Hung (2001) report that the estimate of foreign resource capacity is positively significant thus emphasizing the role of globalization in driving inflation over the sample period from 1971 to 1999. The authors conclude that the foreign excess capacity reduces inflationary pressures, because the firms can import cheaper inputs from the foreign markets. The increased competition from the foreign produced goods may also restrict the price rise of domestic products.

In a later influential study, Borio and Filardo (2007) test the impact of global resource capacity (foreign output gap) on domestic inflation for a broader set of sample countries that include sixteen advanced countries and the euro area.[17] They find the elasticity of inflation to output gap (the slope of the Phillips curve) has decreased for many countries in recent periods. This is also known as the flattening of the Phillips curve which suggests that the response of inflation to variations in domestic output is very low. At the same time, the foreign resource capacity has become an important driving force of inflation. The authors conclude that inflation is largely determined by the foreign output gap over the sample period 1985–2005. Consequently, the role of the domestic output gap in driving inflation has decreased significantly for industrialized countries.

Pain et al. (2006) also argue that the import prices are an important determinant of consumer price inflation in the OECD countries. They apply a different estimation methodology, the error correction model, in comparison to the often used ordinary least squares technique, to test the impact of globalization on inflation for twenty one OECD countries.[18] Pain et al. (2006) find that globalization has reduced the sensitivity of inflation to domestic real activity. However, the foreign output gap does not drive inflation, and the sensitivity of inflation to the import prices has increased in these countries over the 1980–2005 period.

Helbling et al. (2006) report that the role of globalization through the import prices has only small effects on inflation. Instead, globalization increases foreign competition, which decreases the relative prices and the inflation rate. The increasing process of globalization has decreased the sensitivity of inflation to the domestic output gap in eight advanced economies[19] over the sample period 1960–2004.

Pehnelt (2007) tests the effects of globalization on inflation dynamics in twenty two OECD countries[20] over the sample period 1980–2005. The fixed effects panel estimates show that using unemployment as a proxy for the domestic output gap tends to explain inflation before the early 1990s. The estimate on foreign output gap is quantitatively larger than the estimate of domestic output gap and is also positively significant after the 1990s. These findings support the role of globalization in explaining inflation dynamics in the OECD countries.

In comparison to the above, a number of papers provide evidence against the impact of globalization on the inflation process. For example, Ball (2006) tests the role of globalization in explaining the US inflation dynamics and finds that the estimate on the interaction of output with trade is quantitatively insignificant. This rules out the sensitivity of inflation to foreign factors like the foreign output gap. Ihrig et al. (2010) argue that the results reported by Borio and Filardo (2007) in favour of globalization are not statistically robust. The alternative empirical specifications, such as the interactions of import prices and ratio of imports to GDP, do not yield statistically significant coefficients, and, therefore, they reject the impact of globalization on inflation process for eleven OECD countries.[21] Ihrig et al. (2010) also test the impact of the foreign output gap on inflation dynamics. The estimate on foreign output gap is incorrectly signed (negative) and statistically insignificant for most of the industrial countries. The response of domestic inflation to the import prices also does not increase over time and lends credence to the argument that inflation dynamics are mainly determined by the domestic output gap. Calza (2009) also provides evidence that the global resource capacity does not explain inflation dynamics for the European countries over the 1979–2003 period.[22]

One of the common features of the above studies is that they use the backward looking Phillips curve specifications to test the impact of globalization on inflation dynamics. Recently, Sbordone (2007) and Woodford (2007) extend the New Keynesian framework to introduce the role of globalization to explain inflation dynamics. These theoretical specifications are based on microeconomic foundations. In these models, the relationship between the change in price level and marginal cost of the firms is affected by globalization. The current inflation is defined as a function of the expected future inflation, the current domestic output gap and also the foreign output gap. The foreign output gap is an additional variable, which

[17] The countries include Australia, Austria, Belgium, Canada, France, Germany, Italy, Japan, Netherlands, New Zealand, Norway, Spain, Sweden, Switzerland, the UK, the USA and Euro area.

[18] The sample countries included Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Korea, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States.

[19] These countries include Australia, Canada, Germany, France, Italy, Japan, the United Kingdom, and the United States.

[20] The sample countries are Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, the United Kingdom and the United States.

[21] The countries include Australia, Belgium, Canada, France, Italy, Japan, Netherlands, Sweden, Switzerland, the United Kingdom and the United States.

[22] The empirical analysis is based on the data of 26 advanced and developing economies (the euro area plus 25 individual countries) that include Argentina, Australia, Brazil, Canada, Chile, China, India, Indonesia, Japan, Malaysia, Mexico, New Zealand, Norway, Peru, Philippines, Saudi Arabia, Singapore, South Africa, South Korea, Sweden, Switzerland, Thailand, Turkey, the United Kingdom and the United States.

captures the impact of globalization on the domestic inflation. In the open economy NKPC and GMNKPC, as discussed in Section 2.2, the foreign resource capacity does not directly affect inflation. The foreign shocks, such as the terms of trade and real exchange rate, affect inflation via the openness parameter, which is defined as the share of foreign produced goods in the home consumption basket.

The empirical evidence based on the New Keynesian model provides partial support to the impact of globalization on inflation dynamics. Milani (2012) finds that in the US, the elasticity of inflation to the domestic output gap (slope of New Keynesian Phillips curve) has slightly decreased while the elasticity of inflation to the foreign output gap is quantitatively zero over the 1960–2007 period. This shows the insignificant role of globalization in driving the US inflation dynamics. Similarly, the effect of globalization on the IS (Investment-Saving) curve and the monetary policy rule is also negligible. As a result, globalization does not affect the key macroeconomic relationship, as summarized in the NKPC and IS equations. In an earlier study, Milani (2009), however, reports that the estimate on foreign output gap turns out to be positive after 1985 which provides some support for the role of global resource capacity in explaining the US inflation dynamics.

Guerrieri et al. (2010) adopt a direct approach to test the role of globalization in the NKPC framework. Under the Calvo (1983) price setting framework as embedded in the NKPC, they derive an open economy NKPC specification where the domestic inflation is determined by the marginal cost and the price of imported goods. The authors use the domestic tradable prices to test the role of foreign competition on the US inflation. The producer prices are employed given their ability to capture direct effects of the external competition on inflation. The results suggest that foreign competition is an important determinant of tradeable inflation. This effect is then transmitted to the overall inflation rate, which fell by two percent in the 1990s. They conclude that the foreign competition plays an important role in explaining the US inflation via the desired mark-ups of the firms over the sample period 1983–2006.

Recently, López-Villavicencio and Saglio (2014) test if the process of globalization has either decreased the trade-off between inflation and output gap, as defined by the slope of Phillips curve, or caused a possible shift in the preference of conducting monetary policy. They test the monetary policy function defined by the Taylor rule, and used the Phillips curve to test the relationship between inflation and output gap for the three sample countries, France, the UK and the USA. The results show that the Phillips curve has become flattened and the policy makers' response to stabilize inflation and output gap has changed over time. However, globalization has neither decreased the slope of Phillips curve nor caused the change in the preferences of monetary authorities during the 1970–2012 period.

Based on the above discussion, it can be argued that the effect of globalization via import prices or foreign output gap affects inflation dynamics. However, the extent to which inflation responds to globalization differs across countries, sample periods and the empirical specifications of the Phillips curve used. It is important to note that if globalization affects the inflation process either contemporaneously or in the near future, then the price dynamics would be primarily driven by the foreign factors as opposed to the domestic factors. This particular finding has important policy implications for conducting monetary policy (see, inter alia, Mishkin (2007, 2009). On the other hand, if globalization produces deflationary pressure and helps stabilize the inflation rate, then it would provide incentives for the central banks to expand the output growth. In this context, Razin and Loungani (2005) and Razin and Binyamini (2007) suggest that globalization through trade openness can reduce variations in households consumption, which in turn, decreases the fluctuations in the output gap. The above process provides an incentive for the monetary policy makers as they can focus on stabilizing the inflation rate given the seemingly marginal variations in the output gap.

7. Estimation results and discussion

In this section, we provide recent evidence on the ability of NKPC to explain inflation dynamics for four open economies-Australia, Canada, New Zealand and the United Kingdom. For each country, the structural parameters of four different models of the NKPC -the pure forward looking NKPC, GMNKPC, open economy NKPC and open economy hybrid NKPC are estimated. The estimation results are reported in Tables (1)-(7).

As discussed before in Section 3, the Generalized Method of Moment (GMM) estimation method is widely used to test the NKPC to control the potential endogeneity problem. This problem arises due to both reverse causality and simultaneous determination of inflation and expected change in real exchange rate by other macroeconomic fundamentals (for example policy interest rate). We also apply GMM to estimate four structural parameters of β (time discount factor), θ (the price stickiness parameter related to the duration of price adjustment as $1/(1-\theta)$), α (degree of openness) and ω (degree of price indexation to past inflation). Further, the slope parameter which is a composite function of these structural parameters is also estimated. The theoretical predictions suggest that all these parameters should be positively significant and less than one in magnitude to support the theoretical predictions of NKPC.

For each country, the estimation results are reported over two sample periods. The first sample period is the full sample period, which starts from the availability of data for each country.[23] The second sample period is based on the introduction of

[23] The main source of data is the *OECD Main Economic Indicators* (*MEI*) *database* (http://stats.oecd.org/OECDStat_Metadata/ShowMetadata.ashx?Dataset=MEI&Lang=en).

Table 1
GMM estimates of the pure forward looking NKPC.
$\pi_{H,t} = \beta E_t \pi_{H,t+1} + \lambda \hat{x}_t$
Where $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	AUS		CAN		NZ	UK	
	1959q3–2011q1	1993q2–2011q1	1961q1–2011q1	1991q1–2011q1	1990q1–2011q1	1963q1–2011q1	1992q4–2011q1
Constant	−0001	0002	−0000	0005***	0006***	0000	0004***
	(0.00055)	(0.0022)	(0.00066)	(0.00084)	(0.00055)	(0.00054)	(0.00063)
β	1036***	0723**	1038***	0037	−0219*	0988***	0426***
	(0.042)	(0.25)	(0.063)	(0.14)	(0.087)	(0.042)	(0.092)
θ	0968***	0888***	0982	0962***	0969***	1006	1002***
	(0.29)	(0.044)	(5244.2)	(0.0073)	(0.013)	(8714.8)	(0.0091)
λ	−0000	0045	−0000	0038***	0039*	−0000	−0001
	(0.0098)	(0.044)	(0.0093)	(0.010)	(0.018)	(0.0086)	(0.0052)
N	200	71	194	80	83	190	73
p-Value of the Hansen's J statistic	0678	0928	0546	0886	0764	0828	0792

Note: The dependent variable is domestic goods inflation. Instruments used include five lags of inflation and two lags each for the output gap and interest rate spread. The start of the full sample period depends on the availability of data. The sub-sample period starts with the implementation of inflation targeting policy in each country. For New Zealand, the estimates after implementation of inflation targeting policy are only reported given the limitations of data. The specification of weighting matrix is HAC, Kernal Bartlett and lags chosen by Newey-West method. The HAC-robust standard errors are reported in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

inflation targeting policy for each country. For robustness check, the results are also reported incorporating various important macroeconomic changes that occurred in these countries over the sample period (1959q3-2011q1). These policy and event based structural changes include the 1970's oil price shock, introduction of the flexible exchange rate regime in the 1980s and the introduction of inflation targeting in the earlier 1990s. If these potential structural breaks are not controlled by the shift dummies in regressions, then the estimates of NKPC may lack statistical robustness, as debated in Zhang et al. (2008) and Castle et al. (2010).

Table 1 reports the results of the pure forward looking NKPC, as depicted in Eq. (1) in Section 2. Although the coefficient on the time discount factor β is positively significant for all countries except New Zealand, it is imprecisely estimated (i.e., greater than one) for Australia and Canada over the full sample period. The price stickiness parameter θ is positively significant and decreases in the sub-sample period. For Australia, θ decreases from 0.97 to 0.88 and suggest that prices are adjusted about nine quarters. The duration of price adjustment also decreases in Canada as θ is 0.96 and shows that prices are adjusted about twenty six quarters. This is comparatively higher than Australia but lower than New Zealand where the price adjustment is estimated around thirty one quarters. For the UK, θ is imprecisely estimated. In the pure forward looking NKPC, the slope parameter λ is a composite function of two structural parameters β and θ. λ is positively significant for Canada and New Zealand over the second sample period and the full-sample period, respectively. In general, the structural parameters of the NKPC are imprecisely estimated (either positively insignificant or greater than one) in most cases. This suggests that the pure forward looking NKPC is rejected by the data in the case of all four countries over both the sample periods.

The pure forward looking NKPC is a closed-economy specification, and this may be the potential reason for its failure to describe inflation dynamics for these small open economies. In the GMNKPC (see, Eq. (3c)and (3f)), the parameter α that governs the degree of openness captures the impact of foreign shocks (terms of trade and real exchange rate) on the inflation process, and hence is of particular interest in the context of these four sample countries. However, the results show that the GMNKPC is rejected by the data. In Table 2, the parameter $\alpha$is positively significant only for Australia and turns out to be incorrectly signed (negative) for other countries. Similarly, the structural parameters $\beta$and θ and the slope parameter are also imprecisely estimated. The results remain robust when different structural breaks are added in Table 3. Therefore, the GMNKPC fails to explain inflation dynamics in all four countries.

One of the major theoretical assumptions of the GMNKPC that imported goods are only consumption goods is not a valid assumption as imports also contain intermediate inputs and the prices of imported goods affect the marginal cost of firms. The specification of the open economy NKPC, outlined in Eq. (4a), adjusts the marginal cost. These results are reported with and without structural breaks in Tables 4 and 5, respectively. In this open economy NKPC model, the parameter α, i.e., the weight attached to the relative import prices, is correctly signed (positive) for Canada, New Zealand and the UK. It is also statistically significant for New Zealand and the UK.

For the second sample period which focuses on inflation targeting, the quantitative size of α increases about two fold from 0.35 to 0.75 for the UK. For Canada, α is positive but statistically insignificant and drops from 0.53 to 0.28. Compared

Table 2
GMM estimates of the open economy GMNKPC.
$\pi_t = \beta E_t \pi_{t+1} + \lambda \hat{mc}_t + \frac{\alpha}{1-\alpha}[\Delta q_t - \beta E_t \Delta q_{t+1}]$
Where $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	AUS		CAN		NZ	UK	
	1974q3–2010q4	1993q2–2010q4	1970q1–2011q1	1991q1–2011q1	1990q1–2011q1	1972q1–2011q1	1992q4–2011q1
Constant	−0001*	−0003**	−0000	0005***	0002	0003**	0009***
	(0.00062)	(0.00090)	(0.00025)	(0.00047)	(0.0014)	(0.00092)	(0.00062)
β	1043***	1100***	1036***	0069	0582*	0824***	−0668***
	(0.012)	(0.041)	(0.025)	(0.079)	(0.23)	(0.050)	(0.055)
θ	0979	0954	0926***	1002***	1104***	0862***	0986***
	(19,784.9)	(22,500.2)	(0.058)	(0.0095)	(0.15)	(0.048)	(0.020)
α	0074***	0058***	−0160***	−0099***	−0023	−0652***	−0006
	(0.019)	(0.013)	(0.036)	(0.020)	(0.022)	(0.20)	(0.028)
λ	−0.000	−0002	0003	−0002	−0034	0046	0023
	(0.020)	(0.022)	(0.0083)	(0.0088)	(0.026)	(0.027)	(0.034)
N	143	70	161	80	84	153	73
p-Value of the Hansen's J statistic	0684	0877	0663	0881	0614	0622	0704

Note: The dependent variable is consumer price inflation. Instruments used include five lags for inflation and two lags each for the output gap, marginal cost and change in real exchange rate. The sub-sample period starts with the implementation of inflation targeting policy for each country. For New Zealand, the estimates after implementation of inflation targeting policy are reported given the limitations of data. The specification of weighting matrix is HAC, Kernal Bartlett and lags are chosen by Newey-West method. The HAC-robust standard errors are reported in parentheses.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 3
GMM Estimates of the open economy GMNKPC
$\pi_t = \beta E_t \pi_{t+1} + \lambda \hat{mc}_t + \frac{\alpha}{1-\alpha}[\Delta q_t - \beta E_t \Delta q_{t+1}]$
Where $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$.

	(1)	(2)	(3)
	AUS	CAN	UK
	1974q3–2010q4	1970q1–2011q1	1972q1–2011q1
Constant	0003	0017***	0002
	(0.0049)	(0.0050)	(0.0053)
β	0969***	−0060	−0823***
	(0.042)	(0.16)	(0.20)
θ	1016	0963***	0861***
	(27,138.1)	(0.019)	(0.048)
α	0074***	−0032	−0447**
	(0.021)	(0.033)	(0.14)
λ	−0000	0040	0276*
	(0.026)	(0.022)	(0.12)
Dum1984	−0.003		
	(0.004)		
Dum1993	0004		
	(0.0022)		
Dum1982		−0013**	
		(0.0040)	
Dum1991		0008	
		(0.0051)	
Dum1992			0041***
			(0.0058)
Dum1973		0009	0140*
		(0.015)	(0.070)
N	143	161	153
p-Value of the Hansen's J statistic	0449	0427	0754

Note: For Australia, the dummies for 1984 and 1993 are used to capture the important events of the beginning of flexible exchange rate and inflation targeting. For Canada, the dummy 1982 and the dummy 1991 are used for the abandonment of monetary targeting and beginning of the inflation targeting. The dummy 1992 is used for inflation targeting in the UK. In addition, the dummy for 1973 is also used for the oil price shock. See Table 2 for other details.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 4
GMM Estimates of the open economy NKPC.
$\pi_t = \beta E_t \pi_{t+1} + \lambda[(1-\alpha)m\hat{c}_t + \alpha(p_t^m - p_t)]$
Where $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	AUS		CAN		NZ	UK	
	1974q3–2010q4	1993q2–2010q4	1971q1–2011q1	1991q1–2011q1	1990q1–2011q1	1972q1–2011q1	1992q4–2011q1
Constant	−0001**	−0001	0000	0004***	0003	0007***	0009***
	(0.00049)	(0.00072)	(0.00024)	(0.00038)	(0.0015)	(0.0015)	(0.00026)
β	1043***	1021***	0987***	0231***	0502*	0467***	−0643***
	(0.0084)	(0.027)	(0.020)	(0.064)	(0.25)	(0.093)	(0.038)
θ	0956**	0948***	0915***	1018***	1411	0815***	0972***
	(0.30)	(0.21)	(0.028)	(0.010)	(4204.7)	(0.014)	(0.0033)
α	−79,345	13,557	0534	0276	0093*	0347***	0717***
	(9159.7)	(143.1)	(0.34)	(0.21)	(0.039)	(0.046)	(0.088)
$\lambda(1-\alpha)$	0011	−0022	0004	−0010*	−0077**	0092***	0013*
	(0.014)	(0.021)	(0.0056)	(0.0050)	(0.027)	(0.017)	(0.0056)
N	144	71	160	80	84	153	73
p-Value of the Hansen's J statistic	0799	0950	0804	0944	0551	0690	0940

Note: The dependent variable is the consumer price inflation. Instruments used include five lags for inflation and two lags each for the output gap, marginal cost, real import prices and change in real exchange rate. The sub-sample period starts with the implementation of inflation targeting policy for each country. For New Zealand, the estimates after implementation of inflation targeting policy are reported given the limitations of data. The specification of weighting matrix is HAC, Kernal Bartlett and lags are chosen by Newey-West method. The HAC-robust standard errors are reported in parentheses.* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

to Canada and the UK, the quantitative size of α is small (0.09) though positively significant for New Zealand. This is perhaps due to the small size of the New Zealand economy. However, the other structural parameters are estimated imprecisely in few cases. The discount factor β is imprecisely estimated, such as it is greater than one for Australia in both the

Table 5
GMM Estimates of the open economy NKPC.
$\pi_t = \beta E_t \pi_{t+1} + \lambda[(1-\alpha)m\hat{c}_t + \alpha(p_t^m - p_t)]$
Where $\lambda = \frac{(1-\theta)(1-\beta\theta)}{\theta}$.

	(1)	(2)	(3)
	AUS	CAN	UK
	1974q3–2010q4	1971q1–2011q1	1972q1–2011q1
Constant	0007	0008*	0005**
	(0.0066)	(0.0038)	(0.0018)
β	0935***	0425*	−0182*
	(0.037)	(0.17)	(0.085)
θ	1034	0973***	0849***
	(31,948.3)	(0.025)	(0.034)
α	0730	0765	0297***
	(18.8)	(0.79)	(0.080)
$\lambda(1-\alpha)$	−0000	0004	0144**
	(0.050)	(0.016)	(0.050)
Dum1984	−0.006		
	(0.005)		
Dum1993	0005		
	(0.0028)		
Dum1982		−0006	
		(0.0033)	
Dum1991		0006*	
		(0.0025)	
Dum1992			0021***
			(0.0024)
Dum1973		−0009	0047*
		(0.014)	(0.021)
N	144	160	153
p-Value of the Hansen's J statistic	0272	0534	0605

Note: For Australia, the dummies for 1984 and 1993 are used to capture the important events of the beginning of flexible exchange rate and inflation targeting. For Canada, the dummy 1982 and the dummy 1991 are used for the abandonment of monetary targeting and beginning of the inflation targeting. The dummy 1992 is used for inflation targeting in the UK. In addition, the dummy for 1973 is also used for the oil price shock. See Table 4 for other details.
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 6
GMM estimates of the open economy Hybrid NKPC
$\pi_{H,t} = \alpha_f E_t\pi_{H,t+1} + \alpha_b\pi_{H,t-1} + \lambda[(1-\alpha)mc_t + \alpha(p_t^m - p_t)]$
Where $\alpha_f = \frac{\beta\theta}{\theta+\omega[1-\theta(1-\beta)]}$; $\alpha_b = \frac{\omega}{\theta+\omega[1-\theta(1-\beta)]}$; $\lambda = \frac{(1-\omega)(1-\theta)(1-\beta\theta)}{\theta+\omega[1-\theta(1-\beta)]}$.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	AUS		CAN		NZ	UK	
	1974q3–2010q4	1993q2–2010q4	1971q1–2011q1	1991q1–2011q1	1990q1–2011q1	1972q1–2011q1	1992q2–2011q1
Constant	0001*	0000	0000	−0000	0004***	0001	0002
	(0.00047)	(0.00065)	(0.00025)	(0.00039)	(0.0010)	(0.00078)	(0.0022)
β	0903***	0906***	0934***	1503**	0426***	0934***	0583*
	(0.052)	(0.18)	(0.078)	(0.46)	(0.11)	(0.066)	(0.29)
θ	1033***	0934***	1102***	0600***	0974***	0829***	0947***
	(0.29)	(0.20)	(0.21)	(0.16)	(0.078)	(0.026)	(0.032)
ω	0115	0367***	0545***	0602***	−0267*	0067	0065
	(0.064)	(0.063)	(0.14)	(0.067)	(0.12)	(0.045)	(0.10)
α	0269	−0706	−0496	−0093	0373	0135	0207
	(2.30)	(3.07)	(3.91)	(0.37)	(1.08)	(0.17)	(0.17)
$\lambda(1-\alpha)$	−0001	0009	0001	0012	0014	0035**	0018
	(0.0088)	(0.014)	(0.0050)	(0.0088)	(0.069)	(0.013)	(0.014)
N	144	71	160	80	83	153	75
p-Value of the Hansen's J statistic	0816	0908	0844	0925	0803	0822	0909

Note: The dependent variable is the domestic goods inflation. Instruments used include five lags for inflation and two lags each for the output gap, marginal cost, real import prices and change in real exchange rate. The sub-sample period are based on the implementation of inflation targeting policy for each country. For New Zealand, the estimates after implementation of inflation targeting policy are reported given the limitations of data. The specification of weighting matrix is HAC, Kernal Bartlett and lags are chosen by Newey-West method. The HAC-robust standard errors are reported in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Table 7
GMM estimates of the open economy Hybrid NKPC
$\pi_{H,t} = \alpha_f E_t\pi_{H,t+1} + \alpha_b\pi_{H,t-1} + \lambda[(1-\alpha)mc_t + \alpha(p_t^m - p_t)]$
Where $\alpha_f = \frac{\beta\theta}{\theta+\omega[1-\theta(1-\beta)]}$; $\alpha_b = \frac{\omega}{\theta+\omega[1-\theta(1-\beta)]}$; $\lambda = \frac{(1-\omega)(1-\theta)(1-\beta\theta)}{\theta+\omega[1-\theta(1-\beta)]}$.

	(1)	(2)	(3)
	AUS	CAN	UK
	1974q3–2010q4	1971q1–2011q1	1972q1–2011q1
Constant	0006	0003	0000
	(0.0060)	(0.0030)	(0.00067)
β	0827***	0588***	0853***
	(0.11)	(0.13)	(0.093)
θ	1036***	1185***	0865***
	(0.15)	(0.27)	(0.037)
ω	0024	0421**	0019
	(0.13)	(0.14)	(0.080)
α	0033	0156	0033
	(0.94)	(0.095)	(0.22)
$\lambda(1-\alpha)$	−0005	−0020*	0038*
	(0.013)	(0.0097)	(0.017)
Dum1984	−0004		
	(0.0049)		
Dum1993	−0001		
	(0.0015)		
Dum1982		−0003	
		(0.0026)	
Dum1991		0002	
		(0.0018)	
Dum1992			0004*
			(0.0015)
Dum1973		−0015	0027***
		(0.011)	(0.0080)
N	144	160	153
p-Value of the Hansen's J statistic	0665	0628	0676

Note: For Australia, the dummies for 1984 and 1993 are used to capture the important events of the beginning of flexible exchange rate and inflation targeting. For Canada, the dummy 1982 and the dummy 1991 are used for the abandonment of monetary targeting and beginning of the inflation targeting. The dummy 1992 is used for inflation targeting in the UK. In addition, the dummy for 1973 is also used for the oil price shock. See Table 6 for other details.

sample periods and incorrectly signed (negative) for the UK in the second sample period. The parameter θ is also imprecisely estimated (greater than one) for Canada and New Zealand. For the UK, the duration of price stickiness is significantly increased to around thirty five quarters after adopting inflation targeting policy. The parameterα also affects inflation dynamics via the slope parameter, which is a composite function of three structural parameters β,θ and α. The slope parameter is only positively significant for the UK and provides evidence related to the flattening of Phillips Curve.[24] Compared to the open economy GMNKPC, this specification of the open economy NKPC better explains the inflation process at least for the UK.

The results of the hybrid open economy NKPC including both the expected future inflation and the lagged inflation are reported with and without structural breaks in Tables 6 and 7, respectively. The parameter ω determines the degree of backward looking price setters. The results show that ω is positively significant for Australia and Canada only. For Australia, ω is statistically significant over the second sample period and increases two-fold to 0.37 suggesting that more than a quarter of the firms are backward looking in Australia. For Canada, ω slightly increases to 0.60 in the second sample period and suggests that more than half of price setters are backward looking in setting prices. On the other hand, ω is small (0.07), statistically insignificant and same before and after inflation targeting for the UK. The other structural parameters are imprecisely estimated in most cases. The parameter$\alpha$is either incorrectly signed (negative) or statistically insignificant in all cases. The slope parameter, which is a composite function of four structural parameters β, θ, α and ω in the open economy hybrid NKPC, is positively significant only for the UK. The open economy hybrid NKPC fails to explain inflation dynamics for all these countries, and these results are also robust when structural breaks are introduced in Table 7.

In general, the results based on four different versions of the NKPC, the pure forward looking NKPC, the GMNKPC, the open economy NKPC and the open economy hybrid NKPC, suggest that the NKPC model fails to explain the inflation dynamics for all four open economies; Australia, Canada, New Zealand and the United Kingdom. However, among all these four different versions, the data provide weak support to the open economy NKPC that incorporates the effects of real import prices on the inflation process.

8. Conclusion

The New Keynesian models of inflation provide microeconomic foundations for price stickiness and are found to be robust to the 'Lucas Critique'. The New Keynesian Phillips Curve (NKPC), based on rational expectations, introduces the role of future price expectations and the expected real marginal cost in the price-setting mechanism. These features increase the importance of NKPC in making informed choices regarding the monetary policy. In spite of its' strong theoretical underpinnings, the empirical evidence of NKPC is widely debated, especially in terms of understanding the associated inflation dynamics.

In this paper, we survey the recent empirical advancements on estimating the closed economy and open economy versions of NKPC covering a large number of developed countries, and discuss different empirical approaches including the use of disaggregated survey level and microeconomic data. We also test the ability of the NKPC model for four open economies, Australia, Canada, New Zealand and the United Kingdom. For each country, the estimates are provided based on four different versions of the NKPC, the pure forward looking NKPC, the GMNKPC, the open economy NKPC and the open economy hybrid NKPC using different measures of inflation (consumer goods price inflation and domestic goods price inflation) and incorporating multiple policy related structural changes.

Based on the discussion from the newly emerging empirical literature, we highlight three important findings. First, the open economy version of NKPC incorporating intermediate imports prices as production inputs has better explanatory power for the inflation process compared to the terms of trade and the real exchange rate specifications of the open economy NKPC. Second, in comparison to the evidence using aggregate/macroeconomic data, the performance of the closed economy version of NKPC was improved once disaggregated microeconomic and sectoral level data was used. In these cases, the NKPC also explains inflation dynamics across different sectors. Third, the results of the existing studies based on survey data, in general, provided enhanced support to the closed economy NKPC with the signs, size and the statistical significance of the coefficients closer towards the theoretical predictions of NKPC. Our results suggest that compared to the GMNKPC, the open economy NKPC that incorporates the prices of imported goods in the marginal cost function better explains the inflation process at least for the UK.

The above outcomes can be interpreted in the following way. The open economy version of NKPC seems to be more appealing in the globalized world where at times monetary policy decisions are either coordinated across countries or closely replicated by countries in the developed world. It is also an undeniable fact that intermediate inputs play an increasingly important role in the production processes across developed countries. Therefore, the open economy version of NKPC appears to be more important in understanding the process of inflation dynamics across developed countries. The second and third findings emphasize the importance of microeconomic foundations of NKPC for empirical estimation. Researchers can now employ disaggregated data with more

[24] Section 6 discusses in details about the *flattening* of the Phillips curve.

ease given the advancement in microeconomic data collection techniques as well as their improving dissemination across countries.

The latest advancements notwithstanding, a number of cautionary measures need to be followed especially regarding the estimation of NKPC in regards to the weak identification problem. We suggest that extensions of the closed economy NKPC to the open economy NKPC can provide additional sources of information for the identification of NKPC. Another useful addition would be the estimation of open economy NKPC using disaggregated data which may not only address the heterogeneity in prices across sectors but also provide an additional set of variables for estimation of the NKPC.

Appendix A

Table 1
Overview of the main findings of the NKPC estimated with survey forecasts.

Studies	Countries	Sample Period	Estimation Method	Survey-based measure of inflation expectations	Slope Parameter	Main Findings
Roberts (1995)	United States	1949–1990	IV-estimator	I. Michigan Survey II. Livingston Survey of the Federal Reserve Bank of Philadelphia	The unemployment rate and output gap are used to proxy for the real activity. Both these proxies are correctly signed (positive) and statistically significant.	The NKPC does not explain inflation process when actual future inflation is used to proxy for inflation expectations. Contrarily, the NKPC fits the data well with the survey measures of inflation expectations.
Adam and Padula (2011)	United States	1968Q4–2003Q1	OLS IV-estimator	Survey of professional Forecasters	Both the marginal cost and output gap are used as proxies for the real activity. The estimates of the output gap and marginal cost are positive and statistically significant.	The NKPC explains inflation dynamics when survey-based inflation expectations are used to proxy for the expected inflation.
Dufour et al. (2006)	United States, Canada,	US:1970Q1–1997Q4 Canada:1970Q1–2000Q4	Identification-robust IV-based inference	I. Survey of Professional Forecasters II. Conference Board of Canada	Both the output gap and marginal cost are used. The estimates provide support only for the US.	The hybrid NKPC provides supports for the US data. However, the hybrid NKPC does not explain inflation dynamics for Canada.
Paloviita (2006)	12-EMU countries. Austria, Belgium, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal and Spain	1977–2003	OLS, GMM	OECD inflation forecasts	Both the output gap and marginal cost turn out to be suitable proxies for the real activity.	The baseline forward-looking NKPC and the hybrid NKPC are tested for the Euro-area data. The process of inflation dynamics is found to be forward-looking. The baseline NKPC better explains inflation dynamics.
Zhang et al. (2009)	United States	1960–2005 Survey of Professional Forecasters – 1968Q4–2005Q4 and 1970Q1–2005Q4; 1 quarter and 1 year ahead forecast, respectively. Michigan Survey – 1968Q3–2005Q2 Greenbook – 1968Q3–1999Q4	OLS, GMM	I. Survey of Professional Forecasters II. Michigan Survey III. Green book Forecasts	The output gap is based on the potential GDP, as obtained from Congressional Budget Office. The estimate of the output gap is smaller after 1981 compared to pre-1981.	They test the NKPC using survey measures of inflation expectations, and also incorporate multiple structural breaks. The results show three structural breaks in 1975, 1981 and 2000. The NKPC receives empirical support and inflation dynamics are forward looking over the recent period after 1981.

Note: The main findings of the NKPC estimated with the survey forecasts as a proxy for expected inflation are reported. These are well-cited papers and have been ranked according to the number of Google Scholar citations as of April 2014.

Table 2
Overview of the main findings of the NKPC estimated with the disaggregated data.

Studies	Countries	Sample Period	Estimation Method	The measure of disaggregated/ sectoral data	Slope Parameter/measure of driving force	Main Findings
Leith and Malley (2007)	United States	1958Q2–1996Q3	GMM	Eighteen manufacturing industries at SIC two-digit level.	They use intermediate-goods cost of the industries to proxy for the marginal cost. Compared to the labour-income share, this is a broader measure of marginal cost to proxy for the real economic activity.	The estimates of sectoral Phillips curves for eighteen manufacturing industries show that two-thirds of firms are forward looking in price-setting. The degree of backward-looking and price stickiness have significant variations across industries. Price stickiness is higher in durable-goods industries than the non-durable-goods industries. The results lend support for the NKPC.
Lawless and Whelan (2011)	United States 15 EU-countries Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and United Kingdom	US:1959–1996 EU countries: 1970–2005	GMM	459 US manufacturing sectors 630 sectors for 15 EU countries.	They use both labour income share (also combined materials cost) and output gap of these sectors as proxies for the real activity. The estimated coefficients of labour income share are incorrectly signed (negative) for majority of these sector.	They conclude that the NKPC using both the aggregate and sectoral level data fails to explain dynamics of inflation and labour income share, as suggested by the NKPC.
Mazumder (2010)	United States	1960Q1–2007Q3	GMM	US manufacturing sector	He uses sectoral level labour income share of the manufacturing industries. The new measure of labour income share is constructed, which is pro-cyclical consistent with the NKPC.	He tests both the baseline NKPC and the hybrid NKPC specifications using the disaggregated data. The estimates on the new manufacturing labour income share, which is pro-cyclical, are incorrectly signed (negative). The results show that the disaggregated NKPC cannot explain inflation dynamics.
Imbs et al. (2011)	France	1978Q1–2005Q3	GMM, ML	16 sectors based on agriculture, manufacturing and services.	The sectoral labour income share is used as a proxy for the marginal cost. The coefficient on the labour income share is quantitatively larger and statistically significant in most sectors.	The duration of price rigidities is not common and varies across different sectors. Inflation dynamics are forward-looking and prices respond to the marginal cost across these sectors. The results yield support to the NKPC.

Note: The main findings of the NKPC estimated at the disaggregated or sectoral level data are reported. The studies included in this table are well-cited and have been ranked according to the number of Google Scholar citations as of April 2014.

Table 3
Overview of the main findings of the open economy version of NKPC.

Studies	Countries	Sample Period	Estimation Method	Slope Parameter	Main Findings
Neiss and Nelson (2005)	United Kingdom, Australia and United States	UK: 1961 Q4–2000 Q4 Australia: 1962 Q3–2000 Q4 USA: 1961 Q1–2000 Q4	IV-estimator	The output gap as forcing variable is positive and statistically significant.	The output gap based NKPC can explain inflation dynamics for all the three countries if the output gap is estimated using theory-based estimates (e.g. incorporating productivity and technology shocks).
Batini et al. (2005)	United Kingdom	1972Q3–1999Q2	GMM	Compared to the output gap, the labour income share is statistically significant. The openness parameter based on the relative imports prices explains inflation dynamics.	The NKPC explains inflation dynamics. The real imports prices in addition to the employment costs affect inflation process.
Bårdsen et al. (2004)	Euro area and United Kingdom	Euro area: 1971Q3–1998Q1 UK:1972Q3–1999Q1	GMM,2SLS	The labour income share and output gap are not statistically significant.	The data rejects the NKPC. The estimated coefficients of the NKPC are not robust across different empirical specifications.

Table 3 *(continued)*

Studies	Countries	Sample Period	Estimation Method	Slope Parameter	Main Findings
Rumler (2007)	Austria, Belgium, Denmark, Spain, Finland, France, Greece, Italy, and Netherlands as well as the Euro-area aggregate	1980Q1–2003Q4	GMM	The size, sign and statistical significance of the labour income share varies across countries and for the euro area aggregate data, the labour income share is correctly signed (i.e. positive) but not statistically significant in most cases.	The open-economy NKPC outperforms the closed-economy NKPC. The labour income share adjusted with the imported and domestic intermediate inputs better explains inflation dynamics for the euro area data as well as individual nine euro area countries.
Jondeau and Le Bihan (2005)	Euro-area, Germany, France, Italy, the UK and the USA	1970Q1–1999Q4	GMM, Maximum-Likelihood	The choice of the output gap and labour income share does not affect the forward-looking parameter of NKPC. Three lags and leads yield statistically significant coefficient of the labour income share and the output gap.	The empirical success of NKPC depends on the lead and lag structure, which affects the coefficients of the forward looking parameter.

Note: The main findings of open economy NKPC for open economies based on the well-cited papers are presented for different countries. These papers have been ranked according to the number of Google Scholar citations as of April 2014. This is in line with Table 1 of Mavroeidis et al. (2014) who reported for the closed-economy version of the NKPC [see page 59].

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