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The New Keynesian Phillips Curve in a Swedish context

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Abstract: This paper investigates if inflation dynamics in Sweden can be properly modelled by the New Keynesian Phillips Curve (NKPC). Four versions of the NKPC are tested on quarterly data between 1995 and 2016 using Generalized Method of Moments (GMM) as the estimation method. The following versions are empirically tested: the NKPC with output gap, the NKPC with marginal costs, the hybrid NKPC and the sectoral hybrid NKPC. None of the estimated models yields empirical results that are in accordance with the theoretical predictions, implying weak support of the NKPC as an adequate model for Swedish inflation dynamics.

Keywords: New Keynesian Phillips Curve, inflation, marginal cost, output gap.

I would like to thank my supervisor Milda Norkute for her guidance and valuable comments.

1. Introduction

The driving forces behind inflation in the short run are a widely studied topic, with no unambiguous methods or answers. Empirical research on inflation dynamics and its link to the economic activity has been under the microscope for several decades. Since the classical Phillips Curve in the 1960s, various models have been developed as an attempt to capture inflation dynamics. The Philips Curve suggests a structural trade-off between inflation and unemployment, which has been mainly discarded after many countries experiencing the phenomena of stagflation in the 1970s. Since then, one of the main contributions in the theoretical modelling of short run inflation has been the New Keynesian Phillips Curve (NKPC).

Theoretically, the baseline model relates current inflation to the expectations about future inflation and a measure of the current aggregated real economic activity, e.g. the output gap. The framework of the NKPC is the presence of nominal price inertia in the economy and rational expectations. There is extensive research that empirically tests the validity of the NKPC in explaining inflation with almost as many mixed results. In addition, the model has been extended into several versions. The aim of this paper is to empirically test the performance of the NKPC on the short run inflation dynamics in Sweden.

A broad discussion has evolved in past literature about how to correctly measure the variable in the NKPC that reflects real economic activity. The discussion revolves around whether output gap or marginal costs should be used as the proxy. The underlying theory of New Keynesian models is that a structural relationship between inflation and output is only present when labor markets are perfectly competitive without any rigidity. The NKPC is derived upon the assumption that there exists a degree of inertia in the economy. Widely read studies by Galí and Gertler (GG) (1999), Galí, Gertler, and López-Salido (GGL) (2001a, 2001b) and Sbordone (2002) provide estimates of the NKPC for the Euro area and the United States using marginal costs. They present evidence showing that the NKPC based on the output gap fails to capture inflation dynamics, but when the model is estimated with marginal costs it is empirically successful. The studies find a weak correlation between current inflation and output gap, whereas their data set exhibits strong co-movements between inflation and marginal costs instead. GGL (2001a) argue that labor market frictions are a critical determinant in explaining persistence in inflation, when using marginal costs instead of the output gap. They find these two series being weakly correlated, hence the need for monetary policy models to include labor market frictions.

On the contrary, Neiss and Nelson (2002) estimate the NKPC for the United States, United Kingdom and Austria and finds weak support for the cost-based NKPC. Their results support the use of the output gap-based NKPC rather than with marginal costs, when using theory-based estimates of the output gap instead of detrended output.

This highlights that the issue is not as trivial as solely being about output gap-based versus cost-based versions of the NKPC. Since neither output gaps nor marginal costs are directly observed, they have to be constructed and there are few definitive answers on how it should be done. Neiss and Nelson (2002) argue that the NKPC holds when using output gap series based on theory and that they are closely related to marginal costs, contradicting the results in GGL (2001a). Further, the authors conclude that when using marginal costs instead of the output gap it does not explain inflation better, hence, including labor market frictions is not crucial.

Another source of criticism emerges from the use of aggregated data, which assumes homogeneity in the price setting behavior across sectors. Following the work of Norkute (2015) and Imbs *et al*. (2011), not accounting for heterogeneity might lead to biased estimations of the parameters.

An extension of the NKPC is made by GG (1999), where backwardness (lagged values) in inflation is allowed to enter as an explanatory variable. This model is named the "hybrid NKPC", since it combines features of the backward-looking traditional Phillips Curve and the forward-looking NKPC. The results show that both forward- and backwardness is statistically significant, however expected future inflation has a considerably greater impact on current inflation than the past values. The authors conclude that expectations regarding future inflation and marginal costs are important determinants of short run inflation.

In this paper four versions of the NKPC are estimated with quarterly Swedish data between 1995 and 2016: the NKPC with output gap, the NKPC with marginal costs, the hybrid NKPC and the sectoral version. The employed econometrical estimation method is Generalized Method of Moments (GMM) which accounts for the endogeneity problem between inflation lead used as proxy for expected inflation and the error term.

The paper is structured as follows. Section 2 briefly covers the theoretical framework and the derivation of the NKPC. In section 3, the econometrical methodology is outlined including the estimation method and the data set. Section 4 presents the results when the four versions of the NKPC are empirically estimated using Swedish data. Section 5 concludes.

2. The NKPC – theoretical framework

The NKPC is based on monopolistic competition which implies that firms are, to an extent, able to set their prices. Since the model assumes the existence of nominal price rigidities in the economy, it cannot perform under perfect competition, as prices would then be exogenously given and hence out of the firms' control. The baseline model builds on micro-foundations and is derived from the firm's optimization problem in a framework with nominal rigidities and rational expectations. Firms optimize their profits with respect to the price they choose, whereas they are subject to a constraint. The constraint is their possibility to adjust their prices, not all firms will be able to pick a new price. There are at least two ways to derive the optimizing pricing behavior of the firm that includes the existence of inertia when they set prices: using (1) Calvo pricing or (2) quadratic adjustment costs. Both approaches lead to the same theoretical predictions of the NKPC and in this paper the Calvo-model of sticky prices is used.

Taylor (1979, 1980) is one of the protagonists in the field of investigating the inertia in the adjustment of factor prices. His work emphasizes the existence of rigidities in the wage setting and the ability of wages to adjust when needed, which interacts with the cyclical behavior of economic parameters such as unemployment, output and inflation. Taylor (1980) shows how nominal wage contracts set by forward looking firms and unions, comprising even those that only last one year, have the ability of creating persistence in the level of unemployment. This implies that the effects of a shock on employment will be prolonged due to the disability of wages to adjust immediately, affecting the persistence in inflation, output and other areas of the economy.

Calvo (1983) developed a model of staggered prices in the spirits of Taylors' staggered wages. The model assumes there is a continuum of firms, each of them producing differentiated goods but using identical technology and facing the same demand curve. The aggregate price level and aggregate consumption index are exogenous. In the Calvo model, a price-setter (firm) receives a signal h periods from today. It has a fixed probability of $(1-\theta)$ to be able to react to it and change their price accordingly, and a probability of θ to leaving the price unchanged. The signals are random and the firms who can adjust their prices are only allowed to do so when the signal is received. The probability of setting a new price is constant and independent of both the firms' previous price setting history and the prevailing economic state. [1] This implies that every time a signal is received, only the fraction $(1-\theta)$ of the firms will be able to set a new price. The new price remains fixed all the coming periods until a new signal is received. Since θ is between 0 and 1, it allows for the introduction of different degrees of price stickiness. Thus, the degree of nominal price rigidity in an economy depends on the average fraction of firms that adjusts their prices in each period. The equation for the Calvo pricing model is the following:

$$p_t = \theta p_{t-1} + (1-\theta)p_t^* \qquad (2.10)$$

Equation (2.10) expresses that a proportion of $(1-\theta)$ of the firms are going to adjust their prices upon the signal, choosing their optimal reset price: p_t^*. The remaining fraction, θ, are unable to change their prices, hence keeping the price that prevailed in the past period, p_{t-1} . The new price level after the signal will therefore be a weighted average of the fraction of those firms that resets its price and those that keeps it unchanged. Subsequently, θ measures the degree of price rigidity. The greater the amount of firms holding on to the previous periods' price, the longer is the average time prices are fixed, and vice versa.

In the case of perfect price flexibility the parameter θ is zero, hence the probability of firms adjusting their prices is one. Under such circumstances there would be no amplifying effects of a shock due to nominal price rigidities. On the contrary, under perfect price inflexibility $(\theta \to 1)$, the probability of firms changing their prices goes to zero since they are completely rigid. Yun (1996) shows that models of inflation constructed with sticky prices instead of flexible prices perform better in explaining the links between inflation and output.

[1] Mc Adam and Willman (2007) argue that state independency is an unsatisfactory assumption. Instead, they derive the NKPC in a framework with a state-dependent Calvo signal.

For the firms that do get to change their prices, the new price (optimal reset price, p_t^*) is the one that maximizes their expected discounted profits subject to the Calvo pricing model. The fraction of firms that reset their prices, must consider that it might be fixed for a several periods ahead. This implies they need to account for their expectations about their future marginal costs in order to correctly set a new price. In theory, this is done by firms minimizing the following quadratic loss function:

$$\mathrm{L}(p_t) \;=\; \sum_{k=0}^{\infty} (\theta\beta)^k \, E_t(p_t \;- p_{t+k}^*)^2 \qquad (2.11)$$

$\mathrm{L}(p_t)$ is a loss function of the price, p_t, that the firm chooses. k is the number of future periods, which reflects that the firm takes into account the present and all possible future periods in their decision making, $(t + k)$. θ is the probability of not being able to reset the price and β is the discount factor to get the present value of the future periods: both θ and β lie in the range between 0 and 1, hence their product being less than one.

The term $E_t(p_t \;- p_{t+k}^*)^2$ reflects an important feature: when the firm set a new price based on their current information and beliefs about the future they are not capable of choosing exactly the (unknown) optimal price that will minimize their loss for all future time periods. This will generate a loss, which is the difference between the chosen price for the next periods and the price that would maximize their profits during this time. In the improbable case that the firm successfully targets the optimal price, there is no loss. Firms that choose a price that is further away from the optimal one will suffer greater losses than those being closer to it. The term $E_t(p_t \;- p_{t+k}^*)^2$ is the expected loss due to this uncertainty, where p_{t+k}^* is the unknown, optimal price. The inability to target the optimal price does not only arise from the difficulties in foreseeing the future, another important reason is the existence of rigidities that results in some firms having to be stuck with the price for at least some time even if they realize it is not the optimal one.

The future losses are discounted at rate $(\theta\beta)^k$. $(\theta)^k$ is part of the discount factor since it measures the chance of their price p_t being fixed during $(t + k)$ and not being able to change it, which will generate expected losses. A higher value of θ, means a greater chance of having to keep the price fixed and hence bigger expected future losses.

The solution is the optimal value of p_t that minimizes the firms' loss function. The optimal reset price, p_t^*, is found by differentiating equation (2.11) with respect to p_t:

$$L'(p_t) = 2\sum_{k=0}^{\infty}(\theta\beta)^k E_t(p_t - p_{t+k}^*) = 0 \quad (2.12)$$

Rearranging all the p_t-terms to the left hand side (LHS) yields:

$$[\sum_{k=0}^{\infty}(\theta\beta)^k]p_t = \sum_{k=0}^{\infty}(\theta\beta)^k E_t(p_{t+k}^*) \quad (2.13)$$

Since (θβ) is less than 1 and it is the sum of an infinite series, the geometric sum formula can be applied to the LHS in order to simplify the equation:

$$\sum_{k=0}^{\infty}(\theta\beta)^k = \frac{1}{1-\theta\beta} \quad (2.14)$$

This yields the following expression:

$$\frac{p_t}{1-\theta\beta} = \sum_{k=0}^{\infty}(\theta\beta)^k E_t(p_{t+k}^*) \quad (2.15)$$

The solution is then:

$$p_t = (1-\theta\beta)\sum_{k=0}^{\infty}(\theta\beta)^k E_t(p_{t+k}^*) \quad (2.16)$$

The solution implies that the optimal price for firms that get to reset, equals a weighted average of the optimal prices it would expect to set in the future if there were no rigidities. Since the firm is only allowed to reset their price each time a random signal is given, it tries to choose the price that on average will be the closest or equal to the optimal price.

The optimal price without any rigidities, p_t^*, is based on the firms' optimal pricing strategy which is, following microeconomic theory, a fixed markup over marginal costs:

$$p_{t+k}^* = \mu + mc_{t+k} \quad (2.17)$$

By inserting this expression in (2.16) the following is obtained:

$$p_t^* = (1-\theta\beta)\sum_{k=0}^{\infty}(\theta\beta)^k E_t(\mu + mc_{t+k}) \quad (2.18)$$

Expression (2.18) implies that the optimal price is the discounted sum of all future expected marginal costs. Since equation (2.18) is a first-order difference equation, it can be written as:

$$p_t^* = (\theta\beta)E_t(p_{t+1}) + (1-\theta\beta)(\mu + mc_t) \quad (2.19)$$

In order to derive the NKPC, (2.10) is solved for p_t^*:

$$p_t^* = \frac{p_t}{(1-\theta)} - \frac{\theta p_{t-1}}{(1-\theta)} \tag{2.20}$$

By simplifying (2.20) we obtain:

$$p_t^* = \frac{1}{(1-\theta)}(p_t - \theta p_{t-1}) \tag{2.21}$$

Combining expressions (2.21) and (2.19), the following is obtained:

$$\frac{1}{(1-\theta)}(p_t - \theta p_{t-1}) = (\theta\beta)E_t(p_{t+1}) + (1-\theta\beta)(\mu + mc_t) \tag{2.22}$$

The growth of inflation in period t, π_t, is the difference between the current and past periods' price level, $p_t - p_{t-1}$. Rearranging (2.22) as to get $p_t - p_{t-1}$ on the LHS, current inflation is expressed as the NKPC:

$$\pi_t = \beta E_t(\pi_{t+1}) + \frac{(1-\theta)(1-\theta\beta)}{\theta}(\mu + mc_t - p_t) \tag{2.23}$$

The last part, $(\mu + mc_t) - p_t$, is the deviation of the firm's real marginal cost from the steady state, named $\widehat{mc}_t$:

$$\widehat{mc}_t = (\mu + mc_t - p_t) \tag{2.24}$$

By inserting (2.24) in to (2.25), the NKPC can be written as:

$$\pi_t = \beta E_t(\pi_{t+1}) + \frac{(1-\theta)(1-\theta\beta)}{\theta}\widehat{mc}_t \tag{2.25}$$

The NKPC expresses current inflation as a relationship between the (present value of) expected inflation and the current percent deviation of marginal costs from its steady state. As previously stated, the NKPC incorporates the feature of staggered prices which can be observed by the $(1-\theta)$ term that measures how frequent firms get to reset prices. This part is a fundamental difference from the traditional Phillips curve model that relies on flexible prices. As can be seen, the NKPC directly links current inflation to marginal costs however, they are often proxied by the output gap due to the measurement difficulties. Therefore, the NKPC is frequently expressed as inflation being related to expected future inflation and current output gap, $\hat{y}_t$:

$$\pi_t = \beta E_t(\pi_{t+1}) + \frac{(1-\theta)(1-\theta\beta)}{\theta}\hat{y}_t \tag{2.26}$$

In this paper, the NKPC is analyzed in reduced form, meaning that the estimation of the coefficient $\frac{(1-\theta)(1-\theta\beta)}{\theta}$ is the complete slope of the two structural parameters θ and β together. Therefore, the coefficient is denoted as γ:

$$\gamma = \frac{(1-\theta)(1-\theta\beta)}{\theta} \tag{2.27}$$

Finally, the NKPC with output gap can be written as,

$$\pi_t = \beta E_t(\pi_{t+1}) + \gamma \hat{y}_t \tag{2.28}$$

and with marginal cost in the following way:

$$\pi_t = \beta E_t(\pi_{t+1}) + \gamma \widehat{mc}_t \tag{2.29}$$

The NKPC differs substantially from the traditional Philips Curve. They are similar in the sense that both imply a positive relationship between short run inflation and the current output gap, but thereupon they diverge. Where the traditional Philips Curve states that only past inflation affects the current level, the NKPC incorporates firms forward looking behavior. This is a crucial distinction since the traditional model dismisses beliefs about the future having anything to do with current price setting and thus inflation. What impact has the adding of the expected future economic state? If the empirical results follows the theory to some extent and the true relationship does include forwardness, it has far-reaching policy implications. Expectations about the future inflation affects the monetary policy since it needs to establish credibility in order to maintain price stability in the coming periods. A low credibility increases the current cost of stabilizing inflation.

The NKPC also differs from the traditional model since it incorporates price stickiness. The extent to which prices are rigid is not only relevant in understanding the persistence in e.g. inflation and the output gap; it also affects monetary policy. As the European Inflation Persistence Network (IPN) states, a higher degree of price stickiness will lead inflation to react less on changes in the output gap and the marginal costs. With fewer firms being able to adjust their prices in each period, the inflationary pressure has a slower pace than would be the case in an economy with flexible prices. Consequently, this implies that central banks might need to undertake more aggressive policy changes in order to get the desired effect on the inflation level, making price stabilization more costly with regard to output losses.

3. Econometric model and data set framework

The employed estimation method is Generalized Method of Moments (GMM) with quarterly data between 1993 and 2018. The output gap and marginal costs are expressed as percentage deviations from its steady state using the Hodrick-Prescott (HP) filter, which can lead to biased endpoints. Therefore, the first and last data points are excluded and the sample period is between 1995 and 2016. The GMM method is frequently used when estimating the NKPC since it deals with the endogeneity problems by using instruments (Norkute 2015; Galí and Gertler 1999; Galí *et. al.* 2005). The endogenous variable is the inflation lead, which is expected to be correlated with the error term. Therefore, following Galí and Gertler (1999), the set of instruments consists of four lags of inflation, output gap, commodity price inflation, wage inflation, the long-short interest rate spread and marginal costs. However, the appropriateness of GMM as the estimation method for the NKPC has been criticized by some researchers. Linde (2005) argues that it will likely produce biased estimates and suggest instead using the full information maximum likelihood (FIML) model in order to obtain better results. The GMM might fail if the sample size is small and the instruments are weakly correlated with endogenous variables, thus generating misleading results (Stock *et. al.* 2002). Due to this, the Factor-GMM is implemented by, among others, Norkute (2015) and Kapetanios and Marcellino (2010). Nevertheless, the GMM is still commonly used in estimating the NKPC and is also the estimation method in this paper. Considering the critiques and possible drawbacks, research on alternative estimation procedures of the NKPC with Swedish data is desirable.

The depending variable is the quarterly percentage change in current inflation, measured in two ways to see if the results remain robust: using the GDP-deflator and the Consumer Price Index (CPI).[2] In the sectoral version, the inflation is measured by the sector specific deflator.[3]

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[2] The sources of the data for the GDP-deflator and CPI are the OECD and Statistics Sweden respectively.
[3] The sectoral deflator is constructed by the ratio between nominal and real value added in respective sector, multiplying by 100 and then indexing before calculating the growth rate between each quarter.

The explanatory variables are expected inflation in the next period and current real marginal costs (as deviation from steady state) and the output gap. Next periods' expected inflation rate cannot be observed which constitutes a problem when empirically testing the model. Since the NKPC relies on rational expectations, it assumes firms base their beliefs about next period's inflation upon all current and past information available. Thus, expected inflation can be described as next periods actual inflation, π_{t+1}, plus a random error term, ε_t:

$$E_t[\pi_{t+1}] = \pi_{t+1} + \varepsilon_t \quad (3.10)$$

Since the error term is random and due to rational expectations the current beliefs will occasionally turn out to be higher or lower than the actual outcome in the following period, but on average the error term should be zero. If it did not, that would imply a structural error in the expectations. This implies that the inflation expectations can be included in the equations as the leading value.

Both the output gap and marginal costs are variables with no explicit measurement approach. There are several proxies that might be used, which opens up for a discussion regarding the possible effects of different measurement methods.

Since the output gap is the difference between actual output and its long-term level, which cannot be observed, it needs to be constructed. A relatively uncontroversial way of constructing the output gap is using the H-P filter which also is the approach in this paper. However, different measures of the output gap might affect the ability of the NKPC to approximate inflation which paves the way for further investigation on the subject.

The real marginal costs are proxied by the labor income share as in several earlier papers, which is calculated by the ratio of total nominal labor costs to nominal GDP. In line with the underlying theory, the marginal costs enter the NKPC as the deviation from its trend level. This is constructed in the same manner as the output gap, using the HP-filter. For the sectoral NKPC, the sector-specific real marginal costs enter the equation instead.

The following section provides the results for the equations that have been estimated. The first set of equations that are estimated is the pure forward-looking NKPC with output gap as the measure of real economic activity, using both CPI and the GDP-deflator as depended variables:

$$\pi_t^{cpi} = \beta\pi_{t+1}^{cpi} + \gamma\hat{y}_t \tag{3.11}$$

$$\pi_t^{def} = \beta\pi_{t+1}^{def} + \gamma\hat{y}_t \tag{3.12}$$

The second set of equations replaces the output gap with the marginal costs:

$$\pi_t^{cpi} = \beta\pi_{t+1}^{cpi} + \gamma\widehat{mc}_t \tag{3.13}$$

$$\pi_t^{def} = \beta\pi_{t+1}^{def} + \gamma\widehat{mc}_t \tag{3.14}$$

The third set of equations evaluates the hybrid New Keynesian Phillips Curve with CPI and GDP-deflator as measurements of inflation:

$$\pi_t^{cpi} = \beta\pi_{t+1}^{cpi} + \delta\pi_{t-1}^{cpi} + \gamma\widehat{mc}_t \tag{3.15}$$

$$\pi_t^{def} = \beta\pi_{t+1}^{def} + \delta\pi_{t-1}^{def} + \gamma\widehat{mc}_t \tag{3.16}$$

The fourth, and last, set of equations estimates the sectoral hybrid NKPC. The considered sectors are four: manufacturing, agriculture (including forestry and fishing), construction and services. The sectors are denoted as *j* and for each one the estimated equation is:

$$\pi_{j,t}^{def} = \beta\pi_{j,t+1}^{def} + \delta\pi_{j,t-1}^{def} + \gamma\widehat{mc}_{j,t} \tag{3.17}$$

4. Results

This section examines the empirical validity of four versions of the NKPC. First, it is estimated using output gap as the proxy for real economic activity in Sweden followed by a second estimation where the marginal costs enters instead of the output gap. Further, a hybrid version of the NKPC is considered allowing for backwardness (lagged values) in the inflationary process, in addition to the forward looking component (leading values). The hybrid NKPC is tested following the model of Galí and Gertler (1999). The fourth, and last, model being estimated is the sector-level NKPC, which is a disaggregated version that allows the price setting behavior to differ across sectors, following the work of Norkute (2015) and Imbs et al. (2011). All four versions are estimated in reduced-form and therefore not providing results about the structural parameters.

4.1 NKPC with output gap

According to the underlying theory, the NKPC describes current inflation as being positively related to both the future inflation and the real aggregated economic activity, in this case measured by the output gap. The coefficient of inflation lead, β, should be close to 1 since it corresponds to the discount factor. With the rate on 10-year Swedish government bonds fluctuating around 5 percent, the discount factor should be near 0.9. As mentioned earlier, the construction of the output gap is a disputed issue. In addition to that, even if the underlying theory interprets the output gap as a measure of the business cycle, it does not necessarily need to reflect it. In Dynamic Stochastic General Equilibrium (DSGE) models, the output gap is interpreted as the movements in output that evolves from nominal rigidities in the economy (Neiss and Nelson 2002). Considering these issues, the interpretation of the estimated NKPC is not as trivial as might appear. Table 1 presents the estimates of the NKPC with Swedish data.

Table 1

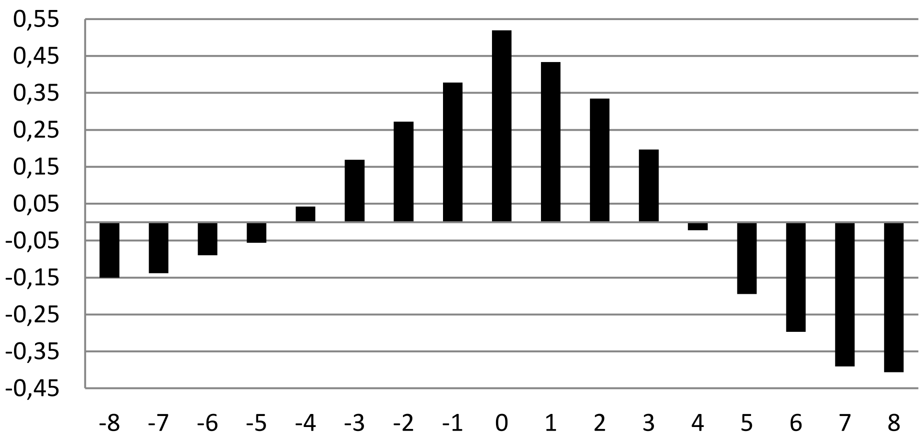
Estimates of the NKPC with output gap

	β	γ
GDP-deflator	-0.167* (0.094)	0.071*** (0.023)
Consumer Price Index	0.323*** (0.089)	0.094*** (0.022)

Notes: This table presents the estimation results of the NKPC following equation (3.11) and (3.12)
* = statistically significant at a 10% significance level
** = statistically significant at a 5% significance level
*** = statistically significant at a 1% significance level

As can be seen from the GMM-estimates, the results are sensible to the choice of inflation measure. Using the quarterly growth of the GDP-deflator, the model clearly does not hold. It is statistically significant at a 10 percent significance level, yet the discount factor is negative which is in direct contrast to the underlying theory. In comparison, using the CPI yields moderately better results. Both explanatory variables are of the right sign and significant at a 1 percent significance level. However, the discount factor is too low in order to be interpreted accordingly and the impact of the current output gap is relatively low. There are no unambiguous interpretations of these estimation results: they could indicate the rejection of the NKPC as an adequate model for capturing Swedish inflation dynamics or it could be the case that the detrended output gap measure creates a misspecification. Nevertheless, the cross-correlations between CPI and the output gap suggest they are strongly contemporaneously correlated in the data set, as figure 1 displays:

Figure 1: Consumer Price Index (t), Output gap (t+k)



Gali and Gertler (1999) reports results using quarterly data for the U.S between 1960 and 1997 that rejects the output gap-based NKPC and speaks in favor of the marginal cost-based version. They present the cross-correlations between inflation (measured as the GDP-deflator) and the output gap in their data set, which shows no contemporaneous correlation between these two. Further, their data set indicates that the output gap and their measure of marginal costs do not co-move, concluding that the output gap fails to proxy the real marginal costs. The authors proxy real marginal costs by the labor income share (i.e. real unit labor costs) and when letting it enter the equation instead of the output gap, their estimation results are in line with the NKPC. They attribute the econometric success of the NKPC to the use of marginal costs. Sbordone (2002) uses a different econometric method, yet reaching very similar conclusions. She argues that the poor performance of the standard NKPC evolves from the failure of the output gap to proxy real marginal costs. Both papers argue that the unit labor costs have a strong contemporaneous correlation with inflation which improve the adequacy of the NKPC. Accordingly, it is not the introduction of forward looking behavior that explains the empirical shortcoming of the standard NKPC. The misstep is assuming proportionality between output gap and marginal costs.

In contrast to these two results, the data set used in this paper displays a co-movement between CPI and output gap. Not only does CPI move in line with the output gap during the same period, it is also positively correlated with the nearest lagging and leading values. This could give some early hints that with Swedish data the NKPC fails in reflecting this positive relationship, preliminarily indicating the model per se might be inadequate. The results when introducing marginal costs being measured as the unit labor costs are presented in the following section.

4.2 NKPC with marginal costs

The results in Table 2 show that the use of the GDP-deflator as measure of inflation yields insignificant results. Thus, henceforth this section only discusses the results with the CPI. As shown in the estimation results, both parameters are significant at a 1 percent significance level, as in the case with the output gap. The parameter for the discount factor is closer to 1 in this case (0.568 compared to 0.323), yet still being considerably lower than what would be consistent with the underlying theory. In addition, the marginal costs enter with the wrong sign suggesting current quarterly inflation growth depends negatively upon the current marginal cost gap.

Table 2

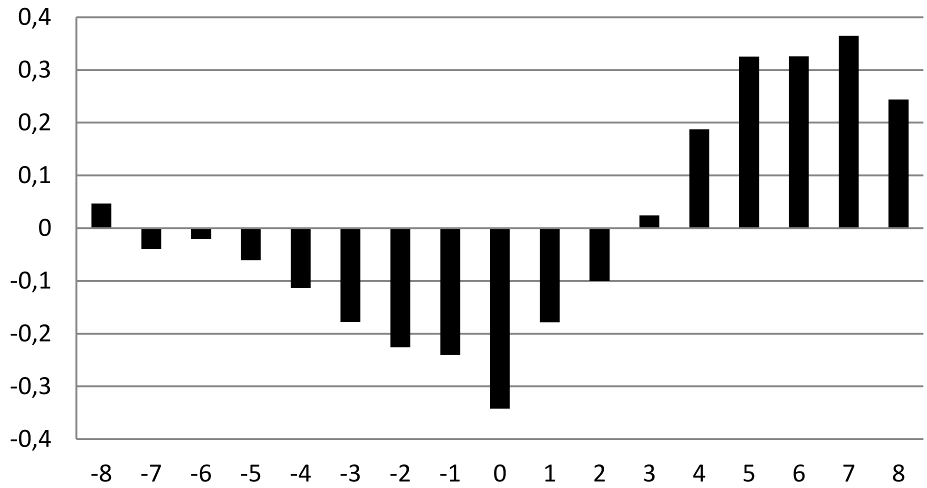
Estimates of the NKPC with marginal cost

	β	γ
GDP-deflator	-0.017	-0.068*
	(0.096)	(0.037)
Consumer Price Index	0.568***	-0.115***
	(0.084)	(0.034)

Notes: This table presents the estimation results of the NKPC following equation (3.13) and (3.14)
* = statistically significant at a 10% significance level
** = statistically significant at a 5% significance level
*** = statistically significant at a 1% significance level

While theory suggests a positive correlation between inflation and marginal costs, the data set shows the opposite as presented in Figure 2 (eight lagged and leading values):

Figure 2: Consumer Price Index (t), Marginal cost (t+k)



In the current period, the correlation between the two variables is strongly negative. It is not until the third lead of marginal costs that CPI reacts positively. This implies that inflation lags marginal costs with three quarters in the data set. There are no definitive conclusions that can be drawn, although it is interesting to consider however a possible explanation could be the price inertia. A negative contemporaneous relationship could indicate that when marginal costs surpass their steady state, a firm cannot directly increase their prices due to a degree of stickiness. This will lead to the prices being relatively lower to the, now higher, marginal costs. It is not until the third to fourth quarter that the general price level in the economy starts to adjust to an increase in the aggregated marginal costs.

The estimations provide little support for the pure forward-looking NKPC properly capturing Swedish inflation dynamics on a quarterly basis. The following section tests the hybrid version, where backwardness is included.

4.3 Hybrid NKPC

The hybrid version of the NKPC allows current inflation to depend upon past values in addition to future expectations and the current aggregated economic activity, as proposed by Galí and Gertler (1999) and Galí *et. al.* (2001)[4]. This paper analyzes the reduced-form version of the hybrid NKPC. The results are presented in Table 3, where δ is the coefficient of the lagged inflation.

Table 3

Estimates of hybrid NKPC

	δ	β	γ
GDP-deflator	-0.164**	0.018	-0.056
	(0.063)	(0.098)	(0.042)
Consumer Price Index	0.283***	0.387***	-0.117***
	(0.059)	(0.092)	(0.030)

Notes: This table presents the estimation results of the NKPC following equation (3.15) and (3.16)
* = statistically significant at a 10% significance level
** = statistically significant at a 5% significance level
*** = statistically significant at a 1% significance level

As in the previous section, when using the GDP-deflator the results are statistically insignificant. Therefore, the focus is solely on the regression with CPI as the inflation measure. Table 3 shows that all three parameters are significant at a 1 percent significance level. In line with the pure forward-looking version, theory suggests that the sum of the coefficients of lagged and leading inflation should be close to 1. The hybrid version generates the closest value to 1, comparing to the results in 4.1 and 4.2. However, at a value of 0.67 it still remains well below what would be predicted by

[4] See Galí and Gertler (1999) for derivation.

theory. Adding the lagged value of inflation does not improve the fit between the empirical and theoretical results regarding the impact of marginal costs. As with the case with only inflation lead, they enter with the wrong sign and the coefficient is essentially the same.

Concluding, extending the NKPC with marginal costs into the hybrid version does not provide any statistical evidence for real marginal costs being positively related to inflation.

4.4 Sectoral hybrid NKPC

One of the critiques against the NKPC is that it relies upon aggregated data, implying all sectors would have the same price-setting behavior. As has been shown, the three previously presented versions of the NKPC rely on aggregated data and have not performed well in describing Swedish inflation dynamics. Therefore, it is relevant to analyze if shifting away from the assumption of homogenous sectors could generate improved results.

In line with Norkute (2015), the examined sectors are agriculture, manufacturing, construction and services. The inflation is the sector-specific deflator and the real marginal costs are proxied by the ratio of labor costs to the nominal value added for each sector. The set of instruments is as before. The analysis shows weak support for the sectoral hybrid NKPC. All the sectors, except manufacturing, exhibit no statistical significance. The estimated parameters are presented in Table 4 (see Appendix). In manufacturing, the estimation results are statistically significant at a 10 percent significance level. With that said, all the coefficients are negative in direct contrast to theory. None of the cases exhibit any positive and statistical significant results, concluding that the sector-specific NKPC is not empirically successful.

5. Conclusions

This paper investigates the ability of the New Keynesian Philips Curve (NKPC) to describe inflation dynamics in Sweden between 1995 and 2016. Previous research has developed several extensions of the model, as a contribution to the baseline model where current inflation is theoretically related to inflation expectations and current economic activity. In this paper, four versions of the NKPC are empirically estimated using Generalized Method of Moments (GMM). The first three models are tested using two measures of inflation for a robust estimation, the CPI and the GDP-deflator.

The first estimated model is the one linking inflation to the inflation lead (used as proxy for expected inflation) and the current output gap. The results show that when using the CPI as inflation measure, the estimated parameters exhibit a stronger statistical significance than in the case with the GDP-deflator. The estimated coefficient of the output gap is positive and significant; however the estimated value of inflation lead is substantially lower than what would be in line with underlying theory. The results indicate that the NKPC with detrended output performs poorly in describing Swedish inflation dynamics. The results resemble various papers that reach similar conclusions although using different data sets.

The second estimated model introduces the marginal costs, proxied by unit labor costs, as the measure for real economic activity. The estimation results show that the NKPC does not provide a better approximation of inflation when using marginal costs instead of output gap. The use of the GDP-deflator yields statistically insignificant parameters, in contrast to the CPI. Although, when using the CPI the coefficients of inflation lead and marginal costs are not in accordance with theory: the first is too low and the second is negative.

The third estimated model examines the hybrid NKPC, where both lagged and leading values of inflation are included as well as the marginal costs. The results follow the same pattern as the estimated results for the pure forward-looking NKPC with marginal costs. The hybrid version does not provide any improved modelling of inflation.

The fourth, and last, estimated model is the sectoral hybrid NKPC. The considered sectors are agriculture, construction, manufacturing and services. In contrast to the previous models, this one uses disaggregated data and hence sector specific measures of inflation and marginal costs. The estimated results show no case where the parameters are both positive and statistically significant. Thus, using disaggregated data still leads to a rejection of the theoretical relationship between marginal costs and inflation.

The main finding of this paper is that no statistical evidence can be provided that supports Swedish inflation dynamics being properly captured by the NKPC. The results are robust to several extensions of the NKPC. A possible reason could be that the construction of output gap and marginal costs is not able to properly capture the aggregated real economic activity. Another explanation might be that the assumptions and micro-foundations behind the NKPC are not suitable for the Swedish case. It could be worth exploring these topics in future research.

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Appendix

Table 4

Estimates of the sectoral hybrid NKPC

	δ	β	γ
Agriculture	-0.065	0.077	0.278*
	(0.077)	(0.101)	(0.151)
Construction	0.148**	-0.082	-0.062***
	(0.070)	(0.062)	(0.023)
Manufacturing	-0.207*	-0.371***	-0.260***
	(0.117)	(0.141)	(0.079)
Services	-0.146*	-0.146	-0.185**
	(0.078)	(0.113)	(0.086)

Notes: This table presents the estimation results of the sectoral hybrid NKPC following equation (3.17)
* = statistically significant at a 10% significance level
** = statistically significant at a 5% significance level
*** = statistically significant at a 1% significance level