The Costs of Inflation in New Keynesian Models

*Steve Ambler**

- *Academic economists and central banks are increasingly relying on New Keynesian models for forecasting and monetary policy analysis.*
- *Central banks are using these models to refine inflation targets and to develop strategies for reducing inflation variability.*
- *As a result, it is important to understand the new channels in New Keynesian models through which inflation is costly that are absent from traditional analyses.*
- *This article reviews these channels and discusses both their quantitative importance and their significance for monetary policy.*

New Keynesian macroeconomic models have become workhorses for monetary policy analysis by academic economists and central banks.[1] The latest generation of forecasting models being developed by many central banks consists of elaborate New Keynesian models, whose distinguishing feature is the introduction of nominal rigidities via monopolistically competitive firms and/or households that set optimal prices and/or wages at infrequent intervals.[2] The incorporation of nominal rigidities constitutes a link with the old Keynesian models that were prevalent until the 1970s. Because their behavioural equations are based on explicit maximization problems solved by households and firms, they incorporate the main features of the new classical and real business cycle models developed since. New Keynesian models introduce three channels through which inflation is costly and which are absent from the traditional literature on the costs of inflation:

1. Since firms set prices at different times, there is price dispersion across firms. This price dispersion increases at higher rates of trend inflation and entails a loss of efficiency in production.[3]

* Centre Interuniversitaire sur le Risque, les Politiques Économiques et l'Emploi (CIRPÉE), Université du Québec à Montréal. This article was written while the author was Special Adviser at the Bank of Canada (July 2006 to August 2007). I would like to thank Robert Amano, Serge Coulombe, Tiff Macklem, Paul Masson, Stephen Murchison, John Murray, Nooman Rebei, and seminar participants at Industry Canada for helpful discussions and comments. Any remaining errors are my own responsibility. The views expressed in this article are those of the author and not of the Bank of Canada.

1. We briefly outline a standard New Keynesian model on pp. 7–8. Clarida, Galí, and Gertler (1999) contains a good summary of the standard New Keynesian framework.

2. Monopolistic competition refers to a particular way of modelling imperfect competition among sellers in a market. It assumes that sellers face negatively sloped demand curves for their product and take this into account when setting their prices, while taking as given not only the price set by other firms, but also total industry output and the exact price index for industry output. Monopolistic competition is a paradigm that facilitates the modelling of the effects of imperfect competition, since it abstracts completely from strategic interaction among firms. The analytical tractability of the paradigm was demonstrated by Dixit and Stiglitz (1977).

3. The traditional literature on the costs of inflation addresses the issue of price dispersion, but in a context of imperfect information in which consumers expend time and energy to seek out products that are relatively less costly. In New Keynesian models, price dispersion is costly even if there is perfect information about the prices charged by different firms.

2. Since firms set prices under monopolistic competition, their prices are higher than their marginal costs of production. The rate of trend inflation has an effect on the average markup set by firms, and therefore on the size of the distortion that results from monopoly power, which constitutes an additional source of inefficiency.[4]
3. At higher levels of trend inflation, firms' pricing decisions are relatively less sensitive to their marginal costs. Monetary policy acts via its effects on aggregate demand, which in turn is related to firms' real marginal costs. Therefore, monetary policy becomes less effective at higher rates of inflation. This leads to a higher variability of inflation, which is also costly.

With the adoption of explicit inflation targeting by more and more central banks, New Keynesian models are being used to refine inflation targets and to develop strategies for reducing inflation variability. It is therefore crucially important to understand how these new channels operate and their quantitative significance for the costs of inflation. This article reviews the three new channels, explains how they operate, discusses their quantitative importance, and examines their implications for the conduct of monetary policy.

It is crucially important to understand how these new channels operate and their quantitative significance for the costs of inflation.

The article is structured as follows. The next section very briefly reviews the traditional literature on the costs of inflation. The third section briefly presents a simplified version of a standard New Keynesian model. The fourth section explains in detail the workings of the three new channels and discusses their quantitative importance. The fifth section discusses the implications of these new channels for the conduct of monetary policy.

4. The same argument is applicable to nominal wage rigidity. The nominal wage that gives the same average markup over the opportunity cost of leisure will vary directly with trend inflation.

The Traditional Literature on the Costs of Inflation

There is a voluminous literature on the costs of inflation. It would not be fruitful to survey this literature in detail here, but a quick review will highlight the absence from the traditional literature of the channels introduced by New Keynesian models. A comprehensive summary is available in Fischer and Modigliani (1978).[5] They enumerate six types of costs, starting with an economy in which inflation is fully anticipated and where the institutional structure of the economy has fully adapted to inflation. They then gradually relax these assumptions to discuss costs that result from imperfectly anticipated inflation and from the incomplete adaptation of institutional structures to the presence of inflation.

The six costs are:

1. In a fully indexed economy in which all agents have adapted to inflation and all contracts and debt instruments (except for currency) are indexed, inflation is costly because it reduces the use of real balances, which affects "shoe leather costs." In addition, by altering the allocation of real wealth, inflation may affect capital accumulation and growth. Finally, if the unit of account for transactions is nominal, there will be resource costs of changing prices ("menu costs").[6]
2. In an economy in which the tax system is less than fully indexed, inflation creates distortions by affecting relative real after-tax rates of return.
3. In an economy in which private contracts and debt instruments are not fully indexed, inflation again creates distortions by affecting relative real rates of return.
4. In an economy in which inflation is not perfectly anticipated, shocks to inflation will cause ex ante rates of return to diverge from ex post rates of return and will in gen-

5. The more recent survey by Fischer (1994) should suffice to show that little was added to our knowledge of the costs of inflation between the publication of the article by Fischer and Modigliani and the advent of the New Keynesian approach to macroeconomic modelling.

6. Shoe leather costs refers to the costs in time and resources (including wear and tear on shoes) of walking to the bank to make cash withdrawals. Menu costs in its narrow sense refers to the costs of printing new menus with revised prices, and more generally, to the costs of printing new catalogues, posting new prices on store shelves, etc.

eral affect the distribution of income and wealth across individuals.

5. In an economy with uncertain inflation, inflation changes the risk characteristics of assets and affects the allocation of wealth.
6. Finally, attempts by governments to suppress the symptoms of inflation via wage and price controls or controls on nominal interest rates can create additional distortions.

Fischer and Modigliani mention very briefly the costs of inflation through distortions in relative prices when prices are fixed at different times by firms. Their discussion focuses on the effects of *unanticipated* inflation and the role of imperfect information: "such increased variability [in relative prices] leads to misallocation of resources, and to the absorption of resources in search and information gathering activities" (1978, 828). As discussed below, the cost of price dispersion in New Keynesian models arises even with perfect certainty and under perfect information. Fischer and Modigliani do not mention the possibility of a markup distortion. They do discuss the Phillips curve, but not the possibility that its slope may change at different rates of trend inflation.

The New Keynesian Framework

Clarida, Galí, and Gertler (1999) present a compact version of the standard New Keynesian model, which embodies nominal price rigidity only. Wages are flexible, and the labour market clears at all times: Extending the model to include nominal wage rigidity is straightforward, but leads to a more complicated system of equations.

The basic model supposes the existence of a collection of monopolistically competitive firms that produce goods that are imperfect substitutes for the goods produced by their competitors. In most versions of the basic model, the goods are intermediate inputs that are used by a competitive sector that produces a single final good.[7] The firms set their prices optimally for more than one period at a time.[8] In setting their prices, firms take into account their costs of production and the expected future path of prices over the horizon for which they fix their prices.

This basic set-up can be used, given some additional assumptions, to derive the so-called New Keynesian Phillips curve (NKPC), relating current inflation to future expected inflation and to the output gap. In the notation of Clarida, Galí, and Gertler, we have:

$$\pi_t = \lambda x_t + \beta E_t \pi_{t+1} + u_t . \qquad (1)$$

The notation used is as follows: π_t is the deviation of inflation from its long-run level; x_t is the output gap, the proportional divergence between the current level of output and the level that would prevail if prices were perfectly flexible. E_t is the expectations operator conditional on information available at time t. u_t is a disturbance term that is tacked onto the equation (its presence cannot be directly inferred from the optimal price-setting behaviour of firms) and has the interpretation of a cost-push shock (something that generates fluctuations in inflation independently of fluctuations in the output gap). β is a parameter that measures individuals' subjective discount rates (which also measures the weight they give as shareholders to firms' future profits versus current profits). λ is a positive parameter that depends on the characteristics of firms' production functions, the degree of substitutability across different types of goods, the frequency at which firms change their prices, and on β.

The additional assumptions needed to derive an NKPC of this form include the following:

- Firms have a constant probability of being able to revise their prices in any given period. Therefore, when a firm sets its price, it does not know with certainty for how long the price will remain fixed. This assumption, first used by Calvo (1983), facilitates aggregation across firms and leads to the simple functional form of the NKPC.[9]
- Either the long-run trend rate of inflation is equal to zero, or (following Yun 1996), in periods when firms do not reoptimize their prices, they can nevertheless adjust their prices at a rate determined by trend inflation. Once again, this assumption is respon-

7. Another version of the basic model makes the assumption that the goods are imperfect substitutes from the point of view of consumers who have a taste for diversity. The two different versions of the model are algebraically equivalent.

8. In the standard New Keynesian model, the reason why firms set prices for more than one period is not made explicit. This assumption is justified by appealing to menu costs of changing prices or costs of gathering the information necessary to make an informed decision concerning the firm's output price, but these costs are most often not an explicit part of the model. The state-dependent pricing models discussed below are exceptions to this rule. In these models, the menu costs of changing prices are modelled explicitly.

9. Another widely used pricing scheme is that of Taylor (1980). Under Taylor pricing, firms keep their prices constant for a fixed number of periods. It is usually assumed that different cohorts of firms change their prices in staggered fashion.

sible for the simple functional form of the Phillips curve.

- The NKPC is derived by aggregating the optimal price-setting decisions across firms and then taking a first-order approximation of the resulting equation around the trend rate of inflation, which must be zero unless the Yun (1996) assumption is used.
- The aggregate capital stock is fixed in the short run, but capital can be reallocated instantaneously and costlessly across different firms.

Much of the discussion of the costs of inflation and of the implications of New Keynesian macroeconomics for monetary policy has taken this simple form of the NKPC for granted. This can be quite misleading, as we will argue below.

The New Keynesian model is completed by a dynamic IS curve:[10]

$$x_t = -\varphi(i_t - E_t\pi_{t+1}) + E_t x_{t+1} + g_t, \qquad (2)$$

where i_t is a short-term nominal interest rate (measured as the deviation from its long-run level), and g_t is an aggregate demand disturbance. This equation can be derived from the consumption Euler equation of the representative private agent after imposing the condition that consumption equals output minus government spending.[11]

An interest rate reaction function for the central bank can be added, assuming that the monetary policy instrument is the short-term interest rate, in which case we have a three-equation system for the three endogenous variables i_t, x_t, and π_t. Alternatively, it is possible to derive the optimal monetary policy by defining a loss function that depends on inflation and the output gap and by minimizing the loss function subject to the NKPC.[12]

10. The IS curve is the relationship, in standard Keynesian models, between the interest rate and output that yields equilibrium in the goods market.

11. The Euler equation comes from the household's first-order condition for asset holdings, which yields an equation relating current consumption and expected future consumption. The basic model abstracts from investment and assumes a closed economy.

12. Woodford (2003) shows how to derive such a loss function as an approximation of the utility function of the representative agent. In solving the problem, the central bank is assumed to be able to choose the inflation rate and the output gap subject to the NKPC. The interest rate that will allow these targets to be achieved can then be backed out using equation (2).

The Costs of Inflation in New Keynesian Models

Inflation and relative wage and price dispersion

By considering the pricing behaviour of firms in long-run equilibrium, it is possible to show that there is a *negative* trade-off between average (trend) inflation and output in New Keynesian macroeconomic models.[13] (Note that this argument concerns the properties of the long-run equilibrium itself rather than the properties of linearizations around it.) The first author to demonstrate this result was Ascari (2004).[14]

The reasoning that leads to this negative trade-off is as follows. If firms fix their prices for several periods, their relative prices will decline over time if trend inflation is positive. Firms will front-end load their prices so that they are initially higher than the overall price level and are on average lower than the overall price level when firms are allowed to reoptimize their prices. Firms will produce less of their good than is socially optimal when they first set their prices, and as inflation erodes their relative prices, will wind up producing too much of their goods. If a social planner could allocate resources, he or she would equalize the marginal productivity of each type of good produced by the monopolistically competitive firms. Because of price rigidity, this type of equalization does not happen. The marginal social product of firms with relatively high prices is too high. The marginal social product of firms with relatively low prices is too low.

This price dispersion occurs under positive trend inflation even in the absence of aggregate uncertainty:

13. Equation (1) shows that, for a given value of expected future inflation, there is a positive trade-off in the short run. By dropping time subscripts and solving for the relationship between inflation and output, the long-run trade-off also appears to be positive, and authors such as Devereux and Yetman (2002) and Blanchard and Galí (2005) have made this claim. Since the equation is based on a linear approximation, however, and variables are measured as deviations from their long-run values, the latter are, by construction, equal to zero in the long run. The equation should not be used to infer anything about the long-run trade-off in isolation from the rest of the model.

14. Buiter (2006, 2007) argues that any model in which there is a long-run trade-off between inflation and output, either positive or negative, is not well specified. He argues that the Lucas (1976) critique implies that an inflationary environment would lead firms to index their prices using rules similar to the one proposed by Yun (1996). This flies in the face of casual evidence that firms in inflationary environments do in fact fix their prices for long periods of time without indexing them to trend inflation. It also ignores the resource costs to firms of implementing the price changes implied by their indexation rules. State-dependent pricing models such as that of Dotsey, King, and Wolman (1999), in which the costs of changing prices are modelled explicitly and the average length of price rigidity is endogenous, are immune to the Lucas critique, but do not prejudge the issue of whether price dispersion varies with trend inflation in the steady state.

firms that have set their prices more recently have higher relative prices (and lower output) than firms that have not had a chance to reoptimize their prices for a longer period. Furthermore, the degree of front-end loading of prices is an increasing function of the trend rate of inflation. The steady-state spread between the firm with the highest relative price and the firm with the lowest relative price increases with the rate of trend inflation. Price dispersion is therefore an increasing function of trend inflation, and real gross domestic product (GDP) is a decreasing function of steady-state inflation. These results hold qualitatively, not only for Calvo pricing, but for any pricing scheme that has the property that average contract length is independent of the trend rate of inflation. The size of the effect of trend inflation on output is highly sensitive to the type of pricing scheme that is assumed. We take up this issue in the next subsection.

Price dispersion is an increasing function of trend inflation and causes real GDP to be a decreasing function of steady-state inflation.

The quantitative importance of price dispersion

The quantitative importance of this cost depends critically on assumptions concerning the type of wage- and price-setting. Ascari (2004) calibrates a standard new Keynesian model with realistic numerical values for its structural parameters. He shows that, under Calvo pricing, even moderate inflation has very strong effects on the steady-state level of output because of the assumption that all firms have a probability of being able to revise their price no matter how long it has been in effect. This means that there will be a small number of firms that have not revised their price for a very long time. Their relative prices are so low that they capture a large fraction of the total market. Ascari shows that with moderately high trend inflation (on the order of 15 per cent to 20 per cent inflation at annual rates, depending on the elasticity of substitution across different types of goods), steady-state output falls to zero, and there is no well-defined equilibrium. The relative price of the small number of firms that have not changed their price in a long time is so low that they capture all of aggregate demand, leaving nothing for the other firms in the economy.

Under Taylor pricing, the quantitative effects of price dispersion are smaller by an order of magnitude than under Calvo pricing. Taylor pricing holds that firms keep their prices constant for a fixed, rather than a random, number of periods. With positive trend inflation, the firms with the lowest relative prices have not changed their prices for the number of periods equal to one less than the average length of the price contract (which is the same for all firms). Under Calvo pricing, the firms with the lowest relative prices have kept their prices constant for an indefinitely long period of time, even if the *average* number of periods between price changes is relatively low.

Amano, Ambler, and Rebei (2006) extend Ascari's result to look at the effects of trend inflation outside the steady state. Since stochastic shocks can affect the dispersion of prices outside the deterministic steady state, it is necessary to use higher-order approximations of the model's equilibrium conditions in order to capture these effects: Schmitt-Grohé and Uribe (2005) show that a linearized model such as the basic New Keynesian model will, by construction, be unable to capture the effect of shocks on wage and price dispersion. Amano, Ambler, and Rebei find that Ascari's results (2004) are amplified outside of the deterministic steady state. Under Calvo pricing, stochastic shocks have quantitatively very large effects on price dispersion, and these effects increase with the rate of trend inflation. Under Taylor pricing, the effects are quantitatively very small.

The quantitative difference for price dispersion between Calvo pricing and Taylor pricing has important consequences for the welfare costs of trend inflation. Under both pricing schemes, trend inflation reduces economic welfare because of the loss of output, but the costs of trend inflation are extremely high under Calvo pricing and very mild with Taylor pricing. The quantitative impact of trend inflation under Calvo pricing is so high that Ascari (2004) and Amano, Ambler, and Rebei (2006) question the usefulness of this pricing scheme. New Keynesian models with Taylor pricing and Calvo pricing may bracket the true cost of inflation resulting from price dispersion,[15] indicating a need for empirical work to better assess the true cost of price dispersion. Researchers will first have to identify plausible empirical equivalents for the rather abstract

15. Furthermore, if the average duration of price rigidity actually decreases at higher levels of inflation, the costs of inflation resulting from price dispersion could be even lower. In models where the degree of price rigidity depends on the average rate of inflation, it would also be necessary to take account of the resource costs of changing prices to get a complete measure of the welfare costs of inflation.

intermediate goods that are used in the models.

While the effects of price dispersion under Taylor pricing are quantitatively very small, Amano et al. (2007) show that even with Taylor contracts, nominal wage rigidity can have quantitatively important effects on economic welfare. This result is compatible with Huang and Liu (2002), who show that rigid nominal wages lead to a higher degree of persistence in New Keynesian models than rigid nominal prices, and with Ambler (2006), who shows that it is easier to justify nominal wage rigidities as an equilibrium outcome in the face of small adjustment costs than it is to justify nominal price rigidities.

Finally, state-dependent pricing models such as those analyzed by Dotsey, King, and Wolman (1999) and Golosov and Lucas (2003) have the property that the average length of price rigidity reacts endogenously to changes in trend inflation.[16] The dynamics of price dispersion have not yet been analyzed in this type of model, but this is a potentially fruitful avenue for future research.[17]

Effects of trend inflation on markups

The monopolistically competitive firms in New Keynesian models face downward-sloping demand curves for their products. The most common assumption is that their demand curves have a constant elasticity of demand. If they were able to reset their prices in each period, profit maximization would entail a proportionally constant markup over their marginal costs. Since they fix their prices for several periods, their markup will vary from period to period during the price contract. With positive trend inflation, the markup will be eroded over time.

With flexible prices, monetary policy has no leverage over the markup. If nominal prices are rigid, the average markup will depend on trend inflation. The reasons for this are not obvious. Wolman (2001) distinguishes between two effects of inflation on the average markup. First, higher inflation leads firms that do adjust their prices to set a higher markup in order to protect themselves against the erosion of their relative prices from future inflation. Second, higher inflation accelerates the rate of erosion of the markup of firms whose prices remain fixed. Wolman refers to this latter effect as the erosion effect. He shows that, in a simple model with two-period price rigidity, the erosion effect dominates at very low levels of inflation, so that rising inflation decreases the average markup. At higher levels of inflation, the former effect dominates. Wolman also shows that a low, positive inflation rate minimizes the average markup in the steady state.

The average markup is directly related to trend inflation.

Another way of looking at this problem is as follows. Costs are typically convex in output. At higher rates of trend inflation, an individual firm's relative price varies more over the life of the contract. When it resets its price, the firm front-end loads the price. The firm's relative price is high initially, and therefore its output (which is determined by the demand for its product) is low. Over time, inflation erodes the relative price, which is typically below average just before the price is reset. The firm's output increases over the life of the price contract, and its marginal cost increases more than proportionally. In order to achieve the same average markup above marginal cost over the life of its price contract, the firm must initially set a higher relative price. Aside from a region for very low positive values of trend inflation where the erosion effect dominates, the average markup is directly related to trend inflation.

The quantitative importance of variable markups

The inflation rate at which the average markup is minimized depends on all of the structural parameters of the model, including the elasticity of substitution across different types of goods and the average length of the nominal price rigidity. In general, the markup-minimizing inflation rate is low, and the minimum average markup is not much lower than with a zero rate of trend inflation. With low to moderate rates of trend inflation, the average markup does not vary by much. Economic welfare is therefore not too sensitive to the rate of trend inflation over this range when looking only at the markup channel.

Inflation and the slope of the Phillips curve

As discussed above, the standard NKPC is derived under the restrictive assumption that either trend inflation is zero or firms adjust their prices at a rate equal to trend inflation even during periods when they are not allowed to reoptimize their prices. If the prices of all firms increase at the rate of trend inflation,

16. Bakhshi, Khan, and Rudolf (2004) show how to derive a Phillips curve based on a model of state-dependent pricing.

17. Golosov and Lucas (2003) show that steady-state price dispersion is affected, but not strongly, by trend inflation (see their Figure 3).

the slope of the Phillips curve is independent of trend inflation.

The assumption can be relaxed by assuming that firms are not allowed to adjust their prices during periods when they are not allowed to optimize their prices, and by dropping the assumption that trend inflation is zero. Under Calvo pricing, it is still possible to derive a fairly simple Phillips curve by aggregating across firms and linearizing around a given (non-zero) rate of trend inflation. This extended New Keynesian Phillips curve (ENKPC)[18] has the following form:

$$\tilde{\pi}_t = \beta\Pi E_t\tilde{\pi}_{t+1} + \gamma x_t + u_t + v_t, \qquad (3)$$

where

$$\gamma = \left(\frac{1-\alpha\beta\Pi^{(\theta-1)}}{\alpha\Pi^{(\theta-1)}}\right)(1-\alpha\beta\Pi^{\theta}). \qquad (4)$$

Here, $\tilde{\pi}_t$ is defined as the deviation of inflation from trend inflation, which is given by γ. The slope of the Phillips curve, which is given by $\Pi - 1$, now depends on the rate of trend inflation. The structural parameters on which γ depends include α, which gives the constant probability that an individual firm will not be allowed to revise its price during a given period, and θ, which gives the elasticity of substitution across the different goods produced by the monopolistically competitive firms.

Several points are worth noting about the ENKPC. First, we can recover the standard NKPC by setting $\Pi = 1$ (i.e., by assuming zero trend inflation). Second, the level of the inflation target alters the relationship between inflation and output, thereby altering the dynamics of inflation. Specifically, the output gap parameter is decreasing in Π, so a decline in the central bank's inflation objective strengthens the link between inflation and the output gap. In other words, with a lower (higher) inflation objective the current output gap has to vary less (more) to achieve a given change in inflation, all else being equal.[19] In this sense, monetary policy is more effective at lower levels of trend inflation. Not only is there an inverse relationship between trend inflation and the output gap parameter, there is also a direct relationship between trend inflation and the impact of expected inflation on current inflation.

The intuition for this last result is straightforward. The ENKPC indicates that when firms set their prices, they pay attention to expected future inflation and to real marginal cost. With low trend inflation, the most important determinant of profits is the expected evolution of real marginal cost, captured by the term for the output gap in equation (3). At higher rates of trend inflation, the evolution of inflation has a relatively more important impact on profits, and expected future inflation gets relatively more weight in firms' optimal pricing rule. Inflation becomes less sensitive to marginal cost. The ENKPC merely says that the relative weight on real marginal costs versus expected future inflation declines as trend inflation increases. Insofar as real marginal cost is directly related to the output gap, the Phillips curve becomes flatter. This means that monetary policy (which acts by affecting aggregate demand) becomes *less* effective at higher rates of inflation.

This result may seem counterintuitive, especially in light of the conjecture by Taylor (1999) that the degree of pass-through from fluctuations in marginal cost to output prices would decline with trend inflation. His result can be understood in the context of fixed menu costs for changing prices. It is as if we were to endogenize the frequency of price changes in the basic New Keynesian model, making it a direct function of the rate of trend inflation.

Monetary policy becomes less *effective at higher rates of inflation.*

The reduced effectiveness of monetary policy is a cost of inflation. Ascari and Ropele (2006) show that, under discretionary monetary policy, it is optimal for the central bank to respond less strongly to variations in inflation resulting from cost-push shocks. This can explain the empirical regularity of a direct relation between the level and the variability of inflation. Amano, Ambler, and Rebei (2005) show that this positive relationship between the average level of inflation and inflation variability holds when the central bank can precommit to the optimal monetary policy. Because of the reduced effectiveness of monetary policy at higher rates of trend inflation, this constitutes an additional cost of trend inflation in terms of economic welfare.

18. Detailed derivations of the ENKPC can be found in Ascari and Ropele (2006) and Bakhshi et al. (2003).

19. It is important to note that these results hold only for moderate rates of trend inflation such as those experienced in many industrialized countries over the past three decades. As shown by Ascari (2004), at higher levels of inflation, their output literally falls to zero with Calvo pricing.

Implications for Monetary Policy

The three channels through which inflation is costly have implications both for monetary policy in the long run (the choice of the steady-state level of inflation), and for the conduct of short-run stabilization policy (the optimal degree of price-level stability).

Optimal trend inflation in New Keynesian models

Price dispersion is minimized in the steady state when trend inflation is equal to zero. The costs resulting from the markup distortion are minimized at a low, positive rate of inflation. When choosing an optimal rate of trend inflation, the costs of these two distortions would have to be balanced at the margin. In a simple model with two-period price rigidity, Wolman (2001) shows that the price-dispersion distortion is quantitatively much more important, so that the optimal rate of trend inflation is very close to zero.

With nominal wage rigidities, a trend rate of *wage inflation* of zero would minimize welfare costs owing to wage dispersion, while a slightly positive rate of wage inflation would minimize the average markup of nominal wages over the opportunity cost of forgone leisure. With both nominal wage and nominal price rigidities, the costs of all four distortions in the steady state (price dispersion, wage dispersion, the average markup of prices over marginal costs, and the average markup of wages over the opportunity cost of leisure) would have to be balanced at the margin. If the trend rate of wage inflation equals the trend rate of price inflation, which must be the case in the absence of technological progress, this would once again give an optimal trend inflation rate very close to zero.

If the trend rate of technological progress is positive, the trend rates of wage and price inflation would have to differ so that real wages could grow along the economy's balanced growth path. The work of Amano et al. (2007) and of Ambler and Entekhabi (2006) suggests that the most costly distortion is the one resulting from wage dispersion. Balancing the costs of the two dispersion distortions and the two markup distortions at the margin would lead to an optimal trend rate of wage inflation very close to zero. Consequently, the optimal rate of price inflation would be *negative*. Amano et al. (2007) show that because of the nonlinearities inherent in the New Keynesian model, the introduction of technical progress increases the benefits of lowering the trend rate of price inflation towards zero.

The flattening of the Phillips curve at higher rates of trend inflation would also favour a trend inflation rate of zero in order to maximize the efficacy of monetary policy. Obviously, when the three channels introduced by New Keynesian models are combined with traditional channels, the optimal trend inflation rate will balance all of the costs and benefits at the margin. For example, the inability to pay interest on outside money balances will push the optimal trend inflation rate towards that implied by the Friedman rule.[20]

Optimal stabilization policy

Stochastic shocks have the effect of causing fluctuations in price and wage dispersion and in average markup. A central question in the context of New Keynesian models concerns the optimal degree of price-level variability. Earlier papers addressed this question using relatively simple versions of the New Keynesian model and concluded that price-level stability is the optimal monetary policy. This is the conclusion of Goodfriend and King (1997).[21] In their model, the trend inflation rate is taken as given and is not necessarily equal to zero. Their model actually implies that strict inflation targeting is optimal, so that past inflation surprises are accommodated by the central bank.

Goodfriend and King's model assumes only nominal price rigidity, and they characterize monetary policy as optimal if it allows the economy to attain the same equilibrium that it would under flexible prices (even though the flexible price equilibrium is suboptimal, owing to imperfectly competitive firms that set prices above their marginal costs of production). In richer settings, price stability may no longer be optimal. Erceg, Henderson, and Levin (2000) set up a model with both nominal wage and price rigidities,[22] in which the markup distortions are corrected through the use of fiscal policy. Only two distortions remain, stemming from the two types of nominal rigidity, but the central bank cannot achieve a Pareto-efficient allocation if it has only one instrument. They show that the utility of the representative private agent can be approximated with a loss function that depends on variability in price and wage inflation and the output

20. The Friedman rule stipulates that, for efficiency reasons, cash balances should carry the same real rate of return as interest-bearing assets. This holds when the inflation rate is sufficiently negative to reduce the nominal interest rate on bonds to zero.

21. Goodfriend (2002) includes a relatively non-technical summary of the main arguments of Goodfriend and King (1997).

22. Both wages and prices are set using Calvo contracts in their model.

gap. They also show that the optimal monetary policy involves some real wage adjustment and that between prices and nominal wages, it is the most flexible variable (the one with the shortest average contract length) that optimally does the most adjusting.

Schmitt-Grohé and Uribe (2005) study optimal fiscal and monetary policy in a more elaborate New Keynesian model that includes both nominal price and nominal wage rigidities (once again wages and prices are set using Calvo contracts) and other sources of distortion such as distortionary taxation. Some of the features of their model would seem to favour variable inflation as the optimal monetary policy: for example, the existence of non-indexed nominal government bonds creates an incentive to use inflation to erode the real value of government debt. Nevertheless, they find that the optimal monetary policy involves a very low volatility of prices.[23] Since wages and prices are set using Calvo contracts, this is likely to accentuate the costs of price dispersion both in the steady state and in response to stochastic shocks: Their results may not be robust to the introduction of alternative pricing schemes. In addition, they include aggregate technology shocks in their model, but technology is stationary, so that there is no wedge in the long run between price inflation and wage inflation. This feature of their model is also likely to favour price stability as the optimal monetary policy.

23. They calculate the optimal monetary and fiscal policies by assuming that the government can precommit to its announced policies and by solving for the government's optimal strategies subject to the first-order conditions of private agents.

Conclusions

New Keynesian models have immensely enriched our qualitative understanding of the costs of inflation. They will be used by central banks for the foreseeable future as forecasting tools and for analyzing the optimal conduct of monetary policy. This article argues that the quantitative importance of the impact of inflation on economic welfare depends on how nominal price and wage rigidities are modelled, which varies widely across different types of New Keynesian models. Clearly, further fine-tuning of inflation targets and of strategies to keep inflation on target in both the short and the medium term will depend on developing a better understanding of the new channels and of how important they are for quantifying the costs of inflation.

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