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by

Thorvardur Tjörvi Ólafsson

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Economics Department

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Thorvardur Tjörvi Ólafsson*

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Abstract

This paper provides a survey on the recent literature on the new Keynesian Phillips curve: the controversies surrounding its microfoundation and estimation, the approaches that have been tried to improve its empirical fit and the challenges it faces adapting to the open-economy framework. The new Keynesian Phillips curve has been severely criticized for poor empirical dynamics. Suggested improvements involve making some adjustments to the standard sticky price framework, e.g. introducing backwardness and real rigidities, or abandoning the sticky price model and relying on models of inattentiveness, learning or state-dependant pricing. The introduction of open-economy factors into the new Keynesian Phillips curve complicate matters further as it must capture the nexus between price setting, inflation and the exchange rate. This is nevertheless a crucial feature for any model to be used for inflation forecasting in a small open economy like Iceland.

Keywords: New Keynesian Phillips curve, price setting, inflation, DSGE models, open economy, exchange rate pass-through, inattention.

JEL Classification: E30, E31, F41.

* Economist, Research and Forecasting Division, Economics Department, Central Bank of Iceland, Kalkofnsvegi 1, 150 Reykjavík. Email: thorvardur.olafsson@sedlabanki.is. The views expressed in this paper do not necessarily reflect those of the Central Bank of Iceland.

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1. Introduction

The use of dynamic stochastic general equilibrium (DSGE) models with a solid microeconomic foundation and market imperfections has become increasingly popular in academic macroeconomics. The precise modelling approach to imperfections in the goods, factor and financial markets in DSGE models cover the waterfront in today's macroeconomics. This development has not gone unnoticed by policy-making institutions. The gap between academic macroeconomic models and applied policy models has decreased in recent years. This is a reflection of a wider convergence between monetary theory and policy making in practice. As Walsh (2006) notes: "Today … [c]entral banks employ DSGE models for policy analysis. Policy makers think in terms of rules. They recognize the value of credibility and commitment. They try to reduce uncertainty in markets by providing information about the likely future path of interest rates. All these characteristics of the modern practice of policy have been grounded in recent developments in monetary theory. And academic economists are focusing their analysis on issues that are of interest to and of practical relevance for policy makers", (Walsh, 2006: 23).

This union of academic and applied policy models is evident in the trend in macroeconomic model building at policy-making institutions. There has been a clear tendency away from the large-scale disaggregated models of the 1970s towards tractable small- and medium-sized models, well suitable for medium-term policy analysis, which is the basis for efficient monetary policy making in an uncertain environment. The older large-scale models were criticized on a number of fronts, e.g. for lacking microeconomic foundation, their treatment of expectations formation, their forecasting abilities in comparison to simple vector autoregression (VAR) models, their underlying econometric methodology (identification, and dealing with non-stationarity) and their modelling of the cost of disinflation in terms of output losses.[1] In the words of Pesaran and Smith (1995): "the models did not represent the data … did not represent the theory … were ineffective for practical purposes of forecasting and policy", (Pesaran and Smith, 1995: 65-66).

[1] Diebold (1998) surveys the main literature and provides the classic references, Bårdsen et al. (2005) supply a recent update on the methodological issues, Fukac and Pagan (2006) categorize macroeconomic models into four generations, where fourth generation models are DSGE models or at least models that incorporate DSGE features, Brayton et al. (1997) describe the evolution of macro models used at the U.S. Federal Reserve Board, Coletti et al. (1996) review the history of macroeconomic modelling at the Bank of Canada and Spencer and Karagedikli (2006) reflect on the New Zealand experience. Pagan (2003) discusses the trade-off between theoretical and empirical coherency and how models used at central banks try to resolve this trade-off.

DSGE models represent an ambitious attempt to combine progress in macroeconomic theory, structural forecasting and practical monetary policy making. They build on a foundation of rigorous stochastic dynamic optimization and are thus not as exposed to Lucas' (1976) critique as their earlier counterparts. Disagreement remains on the precise structure of these models and how well they manage to combine theoretical consistency and empirical coherency.

The adaptation of DSGE models to practical use in policy making is a red-hot research area in some of the main policy institutions in the world, including; U.S. Federal Reserve, European Central Bank, Bank of England, Bank of Canada, Reserve Bank of New Zealand, Central Bank of Chile, Sveriges Riksbank, Norges Bank, Bank of Finland and the IMF.[2] Many issues remain unsolved. First, the precise modelling of the microeconomic foundation of DSGE models with regard to imperfections in various markets, price setting and expectations is still controversial. Second, various estimation approaches to DSGE models have been tried, e.g. maximum likelihood, general method of moments and Bayesian approach, while others favour calibrating methods. Third, forecast performance of these models has to be tested more thoroughly and how vulnerable they are to misspecifications. Fourth, the ability of these models to communicate clear stories to policy makers and the public needs to be analysed. Finally, another burning research issue is extending DSGE models to an open-economy framework.[3]

The Central Bank of Iceland is interested in DSGE models and is looking into building such a model if they prove to be a helpful and supportive tool for inflation targeting. But model building is a time-consuming effort and a stone by stone approach can often be well advised, especially when the bank currently has a new reasonably well-functioning core model. The first stone is to survey the landscape and collect the most up-to-date knowledge of these models.

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[2] See Edge et al. (2005a,b,c), Juillard et al. (2005a,b), Smets and Wouters (2004) and Erceg et al. (2006) for DSGE models of the US economy, Smets and Wouters (2003), Adolfsson et al. (2005c), and Jondeau and Sahuc (2006) for the euro zone, Harrison et al. (2005) for Britain, Binette et al. (2004), Moran and Dolar (2002), and Murchison et al. (2004) for Canada, Liu (2005) for New Zealand, Medina and Soto (2005) for Chile, Adolfsson et al. (2005a,b) and Curdia and Finocchiaro (2005) for Sweden, Qvigstad (2005) for the development within Norges Bank, Kilponen et al. (2004) for Finland, and Laxton and Pesenti (2003) for IMF's new GEM model.

[3] For discussion on some of these issues, see Fukac and Pagan (2006), Alvarez-Lois et al. (2006), Del Negro, Schorfheide, Smets, and Wouters (2006), Del Negro and Schorfheide (2003, 2005), Sims (2002), An and Schorfheide (2005), and Adolfsson, Andersson, Lindé, Villandi and Vredin (2005).

This paper focuses on the ongoing theoretical development of the structure of the supply-side of small-scale DSGE models, which is most often represented by a version of the new Keynesian Phillips curve. It provides a bird's eye view of the recent literature on the new Keynesian Phillips curve: the controversies surrounding its microeconomic foundation and estimation, the approaches that have been tried to improve its empirical fit and the challenges it faces adapting to the open-economy framework where it must capture the nexus between price setting, inflation and the exchange rate. This is a crucial feature for any model to be used for inflation forecasting in a small open economy like Iceland.

The paper is structured in the following way. Section 2 discusses the development of new Keynesian economics, which is the main framework used in modern monetary analysis. Section 3 examines the microfoundation of the new Keynesian Phillips curve, with special emphasis on its measure of excess demand and how different price setting structures lead to different specifications of the new Keynesian Phillips curve. Section 4 takes a look at the stylized facts of inflation dynamics and how the new Keynesian Phillips curve has problems with fitting the data. Section 5 provides an overview of the three groups of approaches, which have been tried, to improve the empirical fit of the new Keynesian Phillips curve. Section 6 looks at the first approach, which involves staying within the traditional sticky price framework but making some adjustments to improve the empirical fit of the curve. The section surveys the growing literature on the hybrid Phillips curve, the need for the introduction of real rigidities into new Keynesian models and the so-called hazard function approach to price setting modelling. Section 7 examines the second line of approach to improve the fit of the new Keynesian Phillips curve, which relies on various factors from behavioural economics and the limited information approach. Section 8 portrays some new empirical evidence on price setting and inflation dynamics resulting from vast empirical research in recent years and discusses what these new findings reveal about the different modelling approaches to improving the empirical fit of the new Keynesian Phillips discussed in the previous sections.

Section 9 looks at the adaptation of the new Keynesian Phillips curve to an open-economy framework. Of course, all the issues discussed regarding the closed economy Phillips curve in the previous sections are still central in the open-economy approach. The addition of open-economy factors amplifies the complexity as new channels arise, especially the introduction of exchange rate dynamics and shocks from abroad. The section is divided

into two subsections. First, a few controversial issues in the specification of the microfoundation of the open economy new Keynesian Phillips curve are discussed, e.g. price setting and exchange rate pass-through, and how it has evolved in open-economy DSGE models. The second subsection looks at various estimations of different forms of open economy new Keynesian Phillips curves.

Section 10 concludes with a brief summary of the main findings and a discussion on what approach seems most promising of being able to solve the problems that the new Keynesian Phillips curve has in fitting the empirical facts and ensuring a successful adaptation to the open economy.

2. New Keynesian Economics

Short-run inflation dynamics is a pivotal issue in macroeconomics, model design and monetary policy making. Various improvements have been made in model design with regard to inflation dynamics. In the old IS-LM framework prices or wages were fixed and there was no room for price adjustment structure. Like many of the models used in monetary policy analysis in the 1970s and 1980s, the IS-LM model "started from curves", its equilibrium conditions are not the results of optimization of private agents in the economy (see McCallum and Nelson, 1999 for a discussion on the weakness of the IS-LM paradigm). The Phillips curve entered the economic field as a simple empirical relationship between wage inflation and unemployment. The two last decades of the 20th century were turbulent yet fruitful times where the Phillips curve re-entered macroeconomic models as a structural relationship derived from first principles. The new Keynesian Phillips curve is now the dominant approach to wage and price modelling in macroeconomics and a key relationship in modern macroeconomic models.

Two key improvements to inflation dynamic modelling were behind the development of the new Keynesian Phillips curve. First, explicit modelling of expectations and the emphasis on forward-looking behaviour in the inflation process marked a great advancement. This is of course due to the works of Friedman (1968), Phelps (1967), Sargent (1971) and Lucas (1972, 1976). This has important consequences for monetary policy making as pointed out by Walsh (2006). If private agents' expectations about future inflation are important determinants of inflation it underlines the importance of monetary policy making to be systematic, credible and transparent. This expectational channel of monetary

policy introduces a new instrument for monetary authorities, i.e. the possibility to influence inflation by influencing forward-looking expectations. This has led to an ongoing discussion on the advantages of commitment versus discretion, different from the debate of the 1980s resulting from the time-inconsistency literature (see Persson and Tabellini, 1990, for a survey on the time-inconsistency literature). The current debate centres on the benefits from committing to price stability even in the absence of an inflationary bias, e.g. by introducing an official inflation target, and being transparent in formulation, communication and implementation of monetary policy in order to anchor future inflation expectations and improve the trade-off between stabilizing inflation and output gap volatility. Walsh (2006) draws attention to the strong contrasts between this new transparency literature and the policy advice of models from the 1970s through the 1990s in which policy was only effective if policy makers succeeded in surprising private agents in the economy.

The second improvement in inflation dynamic modelling is the introduction of implicit price and wage optimization problems within a monopolistic environment, most often of the Dixit and Stiglitz's (1977) type, leading to staggered price and wage setting in the tradition of Fischer (1977), Taylor (1980) and Calvo (1983).[4] Kimball (1995) and Yun (1996) were the first to introduce Calvo price setting into stochastic, optimizing-agent models. Earlier combinations of monopolistic competition and staggered price setting, e.g Svensson (1986), Blanchard and Kiyotaki (1987), Blanchard and Fischer (1989), Akerlof and Yellen (1991), were either static, not based on explicit optimization problems of all agents in the economy or partial equilibrium models.

These two improvements are vital ingredients in new Keynesian economics, which is the main workhorse framework used in modern monetary policy analysis in a closed economy framework.[5] New Keynesian models represent a convergence between (i) simple (static) policy-oriented models, such as the IS-LM model, (ii) Keynesian emphasis on the role of monopolistic competition, markups, and costly price adjustments (e.g. Mankiw and Romer, 1991), and (iii) dynamic general equilibrium models with their roots in the real business cycle literature (see e.g. Kydland and Prescott, 1982, Long and Plosser, 1983,

[4] In monopolistic competition, there is a large number of firms, each producing differentiated products that buyers view as close, though not perfect, substitutes for one another. Each firm therefore has enough pricing power in the market for its particular product variant, that it can charge a price at a mark-up over its marginal cost of production.

[5] Goodfriend (2004) prefers the term "New Neoclassical Synthesis", which refers to Paul Samuelson's original attempt to bridge the gap between classical and Keynesian economics in the 1950s.

Prescott, 1986). The on-going debate on the appropriate specification of new Keynesian models, which is reflected in part in this paper, does not suggest that this convergence is yet complete. Diverse modelling approaches are still confronted and they give rise to different policy-implications. Krugman (2000) and Mankiw (2006) both refer to this convergence as a truce rather than a synthesis.

New Keynesian models range from small-scale canonical models without a solid microfoundation, which yet provide a stylized representation of the key aggregates in the economy whilst capturing the essence of the transmission mechanisms of monetary policy, to full-blown DSGE models where equilibrium levels are derived from optimization problems faced by consumers, workers, producers, investors, and even monetary authorities in an environment characterized by various forms of rigidities.[6]

New Keynesian models provide a tractable framework for analysis of optimal monetary policy design for a closed economy. The combination of dynamic optimizing agents, nominal rigidities and other market imperfections provides better understanding of transmissions of various types of shocks and allows for the derivation of optimal policy based on welfare analysis.

A small-scale new Keynesian model for a closed economy basically consists of three components. The demand block is represented by an *expectational IS curve*, which is a linear approximization to the representative household's intertemporal Euler equation. This relates the level of real activity to expected (and sometimes past) real activity and the real interest rate.[7] The supply block is represented by a price setting equation - *the new Keynesian Phillips curve* - which can be derived from various price setting behaviour, as will be discussed later. It relates inflation to expected (and sometimes past) inflation and a measure of excess demand. The model is closed by a *monetary policy rule*, which can either be directly specified or derived from the minimization of a central bank's loss function, which again can be derived from the maximization of the representative household's utility function as shown by Woodford

[6] DSGE macroeconomic models used for quarterly economic forecasting in practice at central banks, e.g. BEQM at the Bank of England and JEM at the Bank of Japan, are more complex in structure as they seek to have a well defined steady state and a careful accounting of stock-flow relations. These models are sometimes built in two distinctive parts: (i) a theoretical core part, which is a structural DSGE model, and (ii) an ad hoc non-core part, which includes additional variables and short-run dynamics not captured by the structural model in the core part, (see Harrison et al., 2005). Other larger DSGE models use an integrated approach and rely on Bayesian estimation methods, e.g. Smets and Wouters (2003), Adolfsson et al. (2005b).

[7] In the new Keynesian framework, each variable is most often expressed in terms of its deviation from equilibrium, i.e. in "gap" terms.

(2001). The policy interest rate setting is thus commonly a reaction function where the monetary authorities respond to the output gap and (expected) inflation.[8] These small-scale models are simple, coherent and plausible models of the monetary transmission mechanisms and are consistent with the view that the fundamental role of monetary policy is to provide an anchor for inflation and inflation expectations. An extensive literature has dealt with optimal monetary policy design in such a framework in recent years, e.g. Taylor (1999), Svensson (1999), Clarida, Galí and Gertler (1999), Woodford (2003a) and Walsh (2003).

This paper centres on the Phillips curve, which is one of the most important and controversial relation in macroeconomics. The Phillips curve has developed immensely since it was first introduced as a simple statistical relationship between money wage growth and unemployment by Phillips (1958). Few economic relations have caused as much a stir amongst economists and policy makers around the world as the Phillips curve. It has been blamed for the Great Inflation of the 1970s as it convinced many economists and policy makers at the time that there was a reliable and exploitable trade-off between the level of unemployment and the inflation level, even in the long run. The Phillips curve has undergone recurrent revisions as macroeconomics has evolved with the introduction of rational expectations, intertemporal optimization and various rigidities. It has developed from being a pure statistical relationship found in the data in the 1950s and 1960s, to being nearly declared dead in the 1970s and 1980s, and resurrected in the 1990s.[9]

The major issues regarding the Phillips curve have been (i) the choice of variables to include in the relationship, (ii) the modelling of its microfoundation, especially regarding price setting, expectations and various rigidities in the goods, labour and capital markets, and (iii) the optimal estimation approach. The ongoing debate on the Phillips curve, which has lasted for almost a half a century now, is the result of disagreement on these issues.

The introduction of open-economy factors complicate matters further as they influence all the issues mentioned above: new variables have to be included, the microfoundation is altered and estimation is made more difficult. Exchange rate economics is filled with puzzles and exchange rate forecasting is one of the most difficult tasks for economists. But although open-economy elements complicate modelling and estimation

[8] Berg et al. (2006a,b) provide an overview of the new Keynesian model approach to monetary analysis and a practical how-to guide for building such models and using them for forecasting.
[9] See Mankiw (2006) and Woodford (1999) for good overviews of the development of macroeconomics.

efforts it is crucial for policy-makers to have efficient tools for policy analysis. Introducing open-economy factors into DSGE models is thus at the top of the agenda at many policy institutions around the world.

3. The Microfoundation of the New Keynesian Phillips Curve

In the forward-looking new Keynesian Phillips curve, inflation π_t is a function of expected future inflation $E_t\pi_{t+1}$ and some measure of (log) real disequilibrium $\hat{s}_t$:

$$\pi_t = \beta E_t \pi_{t+1} + \xi \hat{s}_t \tag{1}$$

where β is a traditional utility discount factor and the coefficient ξ is a function of underlying model parameters, amongst them the degree of price stickiness, as discussed later. The new Keynesian Phillips curve, expressed in equation (1), can be derived from a model of optimizing price setting firms assumed operating within a monopolistic competition facing constant demand elasticities and subject to barriers to price adjustments. This section looks at how different price setting modelling approaches lead to different Phillips curves and the question of the appropriate measure of the real disequilibrium factor.

3.1 Price Setting

An important issue in the specification of the new Keynesian Phillips curve is the form of its price setting structure. As discussed earlier, the combination of monopolistic competition and the staggered price setting approach within a general equilibrium framework marked a great improvement in inflation dynamic modelling. Arrow (1959) was the first to note that the assumption of some degree of market power is crucial for any discussion on firm's pricing decision. In a Walrasian economy, every firm is a price-taker and the market clears in equilibrium where price equals marginal cost (P=MC). In contrast, a firm operating in an imperfect competitive environment takes into consideration the downward-sloping demand curve for its product and sets price at a mark-up over marginal costs to maximize profits (this mark-up is given by (P-MC)/P or simply P/MC, which is a monotonic transformation of the former and the inverse of real marginal cost).[10] The relation between prices, marginal

[10] Dixit and Stiglitz's (1977) monopolistic competition model is the standard form of imperfect competition in new Keynesian economics. It is characterized by the constant elasticity of demand, which excludes all dynamic

costs and the mark-up, and how they affect aggregate demand, are crucial in new Keynesian models, as discussed later.

Dynamic price adjustment has traditionally been modelled as either *state-dependant* or *time-dependant*. The former represent price changes in a cost-benefit analysis framework where firms readjust their prices if the profit from doing so exceeds the cost of adjustment. The duration of price stickiness in state-dependant models is thus endogenous and a function of the state of the economy. These models are hard to solve and will not be discussed in much detail in this paper. The latter assumes that firms change their prices on an exogenous schedule that is unaffected by the state of the economy. The staggered price-setting approach belongs to the time-dependant group. It emphasizes the nature of the price decision itself and the environment that this decision is taken in. It was originated to explain the empirical findings on price setting that prices change infrequently.

The new Keynesian Phillips curve can be derived from various versions of time-dependant price setting in a closed economy framework as shown by Roberts (1995) and discussed in Taylor (1999). These versions include Taylor's (1980) fixed duration staggered wage-price contract setting, Calvo's (1983) random time-dependant price setting and Rotemberg's (1982) adjustment cost price setting, which is not strictly time dependant but its implications are similar to time-dependant models as shown by Roberts (1995).

Let us take a closer look at Calvo's (1983) random time-dependant pricing as it is so commonly used in DSGE models. In his framework, each firm resets its price with probability (1-θ) each period, as each adjustment opportunity occur randomly and independently of the time that has passed since its last price adjustment. The number of firms is assumed large and they are further assumed identical, apart from their differentiated products and the timing of their price adjustments.[11] Hence, (1-θ) represents the fraction of firms adjusting their prices in each period and θ denotes the portion of firms keeping their prices unchanged. The aggregate price level, p_t, is then a combination of the lagged price level, p_{t-1}, and the optimal price, p_t^*, chosen by the set of firms that adjust their prices in

elements into the response of demand to prices, and makes the profit-maximizing mark-up over marginal costs constant regardless of changes in demand or in the cost of production. Mark-ups nevertheless vary in traditional sticky-price models as firms cannot all charge the desired mark-up without cost.

[11] If these assumptions are coupled with monopolistic competition, which is the traditional way of introducing market power in new Keynesian models, firms are also assumed to use the same production technology and face demand curves with constant and equal demand elasticities.

that period: $p_t = \theta p_{t-1} + (1-\theta) p_t^*$ (each variable expressed in terms of percent deviation from a zero inflation steady state). The average time over which a price is fixed is given by $(1-\theta)\sum_{k=0}^{\infty} k\theta^{k-1} = (1-\theta)^{-1}$. Hence, if $\theta = 0{,}75$ in a quarterly model, prices are fixed on average for a year. This price frequency interpretation is only valid if either there are common factor markets or capital is fixed such that it is independent of the pricing decision made by the individual firm, as discussed later.

The optimal price, set at time *t* by the set of firms adjusting their prices in that period, is the price that maximizes expected discounted profits subject to the process for determining when the firm will next be able to adjust. This can be expressed as

$$p_t^* = (1-\beta\theta)\sum_{k=0}^{\infty} (\beta\theta)^k E_t\left\{mc_{t+k}^n\right\} \tag{2}$$

Thus, firms consider the expected future path of marginal cost in light of the probability that their prices may remain fixed for a number of periods. Combining this with the expression for the aggregate price level and denoting the inflation rate as $\pi_t \equiv p_t - p_{t-1}$, makes it possible to derive a typical forward-looking new Keynesian Phillips curve:

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \lambda mc_t \tag{3}$$

where β is a discount factor, $\lambda_t \equiv \frac{(1-\theta)(1-\beta\theta)}{\theta}$ is a function of the frequency of price adjustment, θ, and mc_t is the percent deviation of the firm's real marginal costs from its steady state level. The new Keynesian Phillips curve in equation (3) is often expressed in terms of an output gap instead of marginal cost, as will be discussed shortly.

Recently, a *limited information approach* to price setting has been introduced. In the so-called inattentive version of this approach, price adjustment is recursively time-contingent, as rational agents choose only to sporadically update their information sets and plans, as information is costly to acquire, absorb and process. This type of price setting gives rise to a

different kind of Phillips curve than is normally referred to as new Keynesian, although it is very Keynesian in spirit.

Mankiw and Reis (2002) introduced sticky information price setting in the limited information tradition. Sticky information represents a different kind of barrier to price adjustment than the popular Calvo framework. Their sticky-information model is based on the assumption that information spreads slowly throughout the economy. In contrast to the Calvo type staggered price models, every firm sets its price every period, but firms gather information and work out optimal prices slowly over time. In their sticky-information model, λ represents the fraction of firms that obtains new information concerning the state of the economy and calculates a new trail of optimal prices.

The inattentive approach is evolving into a fully-fledged macroeconomic model and will be discussed in detail in section 7.1.

3.2. The Measure of Real Disequilibrium

A second important issue in the specification of the new Keynesian Phillips curve in equation (1), in addition to its price setting structure, is its measure of the real disequilibrium. Unemployment, relative to the natural rate, or the output gap, defined as the gap between actual and potential output, were the measures of real disequilibrium used in the traditional version of the Phillips curve. According to the new Keynesian version, real marginal cost (MC/P) is the correct measure of the real disequilibrium that drives inflation, see equation (3). This stems from the fact that marginal cost of production is a crucial factor determining how a monopolistic firm sets its price, as discussed earlier. The aggregate price level, and hence inflation, is an accumulation of these pricing decisions. This relationship between the behaviour of an individual firm's marginal cost, its mark-up and the dynamics of inflation is vital in new Keynesian models.

Until recently it was common to relate real marginal costs to an output gap measure and thus use an output-gap based version of the new Keynesian Phillips curve instead of a marginal-cost based Phillips curve. This simplification of a proportionate relation between real marginal costs and the output gap relies on strict assumptions regarding technology, preferences and labour market structure, e.g. that all firms use a Cobb-Douglas production technology and face a common wage, and hence marginal cost is the same for all firms and independent of the production level of each firm. This simplification has been criticized and

lately the labour share has increasingly been used as a proxy for marginal cost instead. In a simple Cobb-Douglas technology setting, the labour share is proportional to real marginal costs. But this approach has also been challenged, as will be discussed shortly.

A third important issue regarding the new Keynesian Phillips curve is how it fits the data. This is the subject of the next section.

4. Inflation Dynamics and the New Keynesian Phillips Curve

The new Keynesian Phillips curve is far from being unanimously agreed upon and as Galí and Gertler note "[r]econciling the new [Keynesian] Phillips curve with the data, has not proved to be a simple task", (Galí and Gertler, 1999: 201). Empirical research into the nature of inflation dynamics is a classic task for economists and a continuing undertaking by monetary authorities and various other institutions.

4.1 The "Stylized Facts" on Inflation Dynamics

The "stylized facts" on inflation dynamics are the following (see Fuhrer and Moore, 1995, Rogoff, 2003, Favero, 2001, and Melick and Galati, 2006):

- near universal fall in inflation in recent years;
- inflation persistence, i.e. there is a large amount of inflation inertia, although it seems to be declining in recent years in connection with decreasing mean inflation;
- there is a short-run trade-off between inflation and real activity; [12]
- inflation initially responds little to changes in monetary policy and they have their full impact with lags of up to two years;
- disinflationary policies have contractionary effects on output;
- maximum effects of changes in monetary policy have their impact on output before inflation.

The global disinflation has been attributed to improved monetary and fiscal policy making and better policy institutions, increased competition due to globalization of markets and productivity trends. This feature is often modelled by introducing a regime change, increased credibility or by a time-varying inflation target in new Keynesian models.

[12] Mankiw (2001) discusses the "inexorable and mysterious" trade-off between inflation and unemployment, as he calls it.

Cecchetti and Debelle (2006) provide a recent survey of the existing evidence on inflation persistence. First, they cite a number of studies that have found that the autocorrelation (AR) coefficient is often close to one in many countries when estimated on data over the past twenty years. Second, they refer to some more recent papers that have looked at whether persistence has changed over time. Studies using rolling regressions have found that the AR coefficient has declined significantly over the past decade in many of the main industrialized countries. Other studies, which allow for a structural break in the mean of inflation, also find considerably declined persistence. Research into price setting behaviour and inflation persistence has amplified lately and the use of disaggregated data and surveys has increased. The results will be discussed in more detail in section 8.

The degree of inflation persistence is important for monetary policy making for a number of reasons. First, stabilizing inflation following adverse shocks is more expensive in terms of output losses when the degree of inflation persistence is higher, i.e. the sacrifice ratio is higher. Second, persistence can undermine the anchoring of inflation expectations, which is a fundamental role of monetary policy. Finally, the effects of monetary policy are delayed by higher persistence, as will be discussed shortly.

4.2. Empirical Fit of the New Keynesian Phillips Curve

Mankiw (2001) discusses three failures of the new Keynesian Phillips curve. First, Mankiw cites Ball (1994a, b), which shows that a fully credible disinflation can cause an economic boom in a new Keynesian model with rational expectations contrary to empirical facts. Mankiw reaches the same result using impulse response function analysis where he shows that a contractionary monetary shock, which causes a decline in inflation, is found to cause falling unemployment contrary to empirical facts.

Monetary authorities around the world recognize that there is a short-run trade-off between stabilizing inflation and output. There is also a widespread agreement that policymakers should try to stabilize both inflation and output. This trade-off is illustrated by a stylized *Taylor curve* (sometimes called the efficient monetary policy frontier), which represents the set of variance-minimizing combinations of inflation and output that are technically feasible. This trade-off is in variances, not levels, contrary to what was a popular interpretation of the original Phillips curve version. Svensson (1999) notes: "there is considerable agreement among academics and central bankers that the appropriate loss

function both involves stabilizing inflation around an inflation target and stabilizing the real economy, represented by the output gap …. Inflation targeting central banks are not what King (1997) referred to as 'inflation nutters' … Thus, it seems non-controversial that real-world inflation targeting is actually flexible-inflation targeting", (Svensson, 1999: 200-202). New Keynesian models have had problems producing such a trade-off endogenously and have commonly added an ad hoc cost push shock to equation (1). But of course, "this is a fix, not an acceptable solution" as coined by Blanchard and Galí (2005: 17).

A number of approaches have been tried to derive a microfoundation for such cost push shocks. Steinsson (2003) models two potential sources: time varying income taxes and time varying monopoly power of producers. He finds that for reasonable calibrations of the model, the former approach results in very small shocks while the latter is capable of creating large disturbances to the Phillips curve. Ravenna and Walsh (2006) show that an endogenous cost-push shock arises, and thus an endogenous trade-off between stabilizing the variability of inflation and the output gap, when a cost channel for monetary policy is introduced into a new Keynesian model. A cost channel is present when a firm's marginal cost depends directly on the nominal interest rate. Interest rates also appear in a firm's marginal cost in the model in Christiano, Eichenbaum and Evans (2005). They note that a drop in interest rates after an expansionary monetary policy shock pushes marginal costs down and that this effect is strong enough to bring about a temporary fall in inflation. Blanchard and Galí (2005) also get an endogenous trade-off between the stabilization of the variances of inflation and the output gap when labour market imperfections are introduced into a DSGE model, as will be discussed later. An endogenous trade-off also arises in Monacelli's (2005) model when exchange rate pass-through is incomplete.

Second, Mankiw (2001) cites Fuhrer and Moore (1995) who show that a staggered Taylor model has trouble generating the degree of inflation persistence found in the data. In Taylor's setup, prices are set as a mark-up over marginal cost in a sequence of overlapping wage contracts, lasting for a fixed number of periods. Shocks affect prices via wages and price-level persistence increases with the length of the wage contracts. But although prices display inertia, inflation does not need to exhibit persistence. This *persistence problem* applies to the forward-looking new Keynesian Phillips curve, whether it is derived from Taylor (1980) or Calvo (1983) pricing. In Calvo's setup, price setters are forward-looking and inflation can jump immediately to its new level in response to a shock. The only inertia in inflation is

inherited from the inertia in its driving variable, i.e. real marginal costs. Kiley (2002) has nevertheless shown that Taylor's setup displays less price-level persistence than Calvo's, as some prices remain fixed for many periods in Calvo's settings but price-level persistence in Taylor's framework depends on wage stickiness and no wages remain fixed longer than the duration of the longest contract.

Price-level persistence and inflation persistence have different implications for monetary policy making. Disinflations are costly, in terms of output losses, in case of the latter but not in the former unless monetary policy lacks credibility.

Rudd and Whelan (2006) emphasize that the persistence problem faced by the new Keynesian Phillips curve is not that it cannot match the autocorrelation of inflation found in the data, as discussed by e.g. Fuhrer and Moore (1995), but that it fails to account for the empirical importance of lagged inflation in reduced-form inflation equations, even after having conditioned on driving variables for the inflation process. They note that when the new Keynesian Phillips curve specification is combined with the assumption of rational expectations, it makes a very precise prediction about inflation dynamics. This can be seen by applying repeated substitutions to equation (1), which yields:

$$\pi_t = \xi \sum_{k=0}^{\infty} \beta^k E_t \hat{s}_{t+k} \tag{4}$$

This implies that inflation depends solely on current and expected future values of the real disequilibrium (expressed by the output gap or the labour share). But this does not mean that the new Keynesian Phillips curve cannot predict a highly autocorrelated inflation rate. In fact it does so as long as the measure of real disequilibrium is highly autocorrelated, which applies to de-trended output and the labour share according to Rudd and Whelan (2006). Kiley (2005) also provides evidence of inertia in the labour share.

The third failure of the new Keynesian Phillips curve, according to Mankiw (2001), is that it is incapable of producing empirically plausible impulse response functions to monetary policy shocks. According to empirics, monetary shocks should have a delayed and gradual effect on inflation. In contrast, according to the new Keynesian Phillips curve the purely forward-looking inflation can adjust immediately to changes in monetary policy. This also contrasts the empirical fact that nominal shocks appear to have their greatest effect on

inflation only after they have their maximum effect on real activity. Mankiw (2001) thus concludes: "Although the new Keynesian Phillips curve has many virtues, it also has one striking vice: It is completely at odds with the facts. In particular, it cannot come even close to explaining the dynamic effects of monetary policy on inflation and unemployment," (Mankiw, 2001: C52).

Chari et al. (2000) discuss another persistence problem that sticky price models have, closely related to Mankiw's discussion on the third failure of the new Keynesian Phillips curve: "The central challenge to a theory of monetary business cycles is to find a solution to the persistency problem. Monetary economists have long searched for a mechanism that has a multiplier effect in the sense that small frictions lead to long periods of endogenous price rigidity and, hence, persistent output movements. Here we find that the staggered price-setting mechanism is not the long-sought solution", (Chari et al, 2000: 1177). Dotsey and King (2000) point to the irony of this *real output persistence problem*: "Though built with increasingly precise microfoundations, modern optimizing sticky price models have displayed a chronic inability to generate large and persistent real responses to monetary shocks …. This is an ironic finding, since Taylor (1980) and other researchers were motivated to study sticky price models in part by the objective of generating large and persistent business fluctuations", (Dotsey and King, 2000: 1).

5. In Search of Improvements

Various approaches have been tried to improve the empirical fit of the new Keynesian Phillips curve. They can broadly be categorized into three groups.

The first approach involves staying within the traditional sticky price framework, which commonly uses Calvo's (1983) random time-dependant price setting, but making some adjustments. These adjustments come in four forms. The first adjustment involves abandoning the assumption of rational expectations and allowing for some *backwardness* by a share of agents in expectation formation and price setting in order to produce inflation inertia. This has been done by assuming a rule of thumb price behaviour by some firms (Galí and Gertler, 1999) or some form of price indexation (Christiano, Eichenbaum and Evans, 2005, and Smets and Wouters, 2003).

The second adjustment to the traditional sticky price framework emphasizes the importance of using a *measure of real marginal cost* instead of the output gap as the driving

variable in the Phillips curve, as the relative relationship between marginal cost and the output gap is very unstable. Galí and Gertler (1999) combine these two approaches, as discussed in the next section.

The third adjustment to the traditional sticky price framework involves introducing various forms of *real rigidities*, e.g. sticky wages and firm-specific capital, to solve the persistence problem. Christiano, Eichenbaum and Evans (2005), Erceg, Henderson and Levin (2000) and Blanchard and Galí (2005) follow this approach.

The fourth adjustment to the traditional sticky price framework entails allowing the probability of price adjustment to increase with the duration of price stickiness such that firms are more likely to change their prices as time passes from their last adjustment. This is in line with results from various studies on price setting behaviour, as discussed later. This *hazard function model of price adjustments* is analysed by e.g. Sheedy (2005) and Álvarez, Burriel, and Hernando (2005).

In addition to the above, most traditional sticky price models include an ad hoc cost push shock in order to get a trade-off between stabilizing inflation and output, as discussed earlier.

The second approach to improve the new Keynesian Phillips curve follows a different path. It abandons the traditional sticky price framework and incorporates various factors from Phelps' (1970) limited information approach and behavioural economics. This approach comes mainly in two forms. First, there is *the inattentive model of limited information* emphasized by e.g. Mankiw and Reis (2002), Ball, Mankiw and Reis (2005), Reis (2006) and Reis (forthcoming). Second, there is *the learning model* studied by e.g. Milani (2005a, b).

The third approach to improve the new Keynesian Phillips curve relies on state-dependant price setting. Dotsey, King and Wolman (1999) introduced state-dependant price setting into a DSGE model. Dotsey and King (2005) provide a recent update. Gertler and Leahy (2006) derive an analytically tractable Phillips curve based on state-dependant pricing, which they claim is able to match the micro evidence on price setting although they have problems accounting for the persistence of inflation. Danziger (1999) and Golosov and Lucas (2003) emphasize that state-contingent models reduce the real impact of monetary policy shocks. These results seem to indicate that state-dependant price setting is not a likely solution to the real output persistence problem. Furthermore, models that rely on state-

dependant pricing are much harder to solve than standard sticky price models. This approach will not be dealt with in this paper.

The following discussion will discuss the first two approaches to improving the new Keynesian Phillips curve.

6. Improvements to the Sticky Price New Keynesian Phillips Curve

The first approach to improve the empirical fit of the new Keynesian Phillips curve involves making some adjustments to the standard sticky price version. These adjustments entail allowing for some backwardness in expectation formation and price setting, using the labour share rather than the output gap as a driving variable, introducing some forms of real rigidities or applying the so-called hazard function approach to pricing. This section will discuss each in turn.

6.1 Hybrid, Marginal Cost-based Phillips Curve

Galí and Gertler (1999) propose a hybrid marginal cost based Phillips curve, where they assume that a subset of firms set prices according to a backward-looking rule of thumb. Hence, lagged inflation enters the Phillips curve as an independent variable:

$$\pi_t = \lambda mc_t + \gamma_f E_t\{\pi_{t+1}\} + \gamma_b \pi_{t-1} \tag{5}$$

where $\lambda \equiv (1-\omega)(1-\theta)(1-\beta\theta)/\phi$, $\gamma_f \equiv \beta\theta/\phi$, $\gamma_b \equiv \omega/\phi$, and $\phi \equiv \theta + \omega[1-\theta(1-\beta)]$. They emphasize that the hybrid Phillips curve in (5) differs in two important ways from other hybrid versions used in earlier empirical work, e.g. by Fuhrer and Moore (1995). First, the coefficients in the hybrid Phillips curve are all explicit functions of three model structural parameters: the degree of price stickiness, θ, the degree of "backwardness", ω, and the discount factor, β. Woodford (2005) discusses how this interpretation is limited to the case of common factor markets, as discussed later.

Second, real marginal costs are used as a measure of demand pressure as opposed to an output gap. Much discussion has centred around whether and under what circumstances real marginal cost can be related to an output gap measure. A desirable feature of changing to a marginal cost-based Phillips curve, according to Galí and Gertler, is that it directly

accounts for productivity gains and wage pressures on inflation, which are often missed by using the output gap. In addition, traditional output gap estimation methods are fraught with large uncertainties which can affect the empirical fit of an output-gap based Phillips curve.

Real marginal costs are of course unobservable. Galí and Gertler (1999) propose using average unit labour costs to measure nominal marginal cost, which means using the labour share of income as a proxy for real marginal cost. This proposal relies on a Cobb-Douglas technology setting where output, Y_t, is given by $Y_t = A_t K_t^{\alpha_k} N_t^{\alpha_n}$, ($A_t$ denotes technology, K_t capital, and N_t labour). In this setting, real marginal costs are given by the ratio between real wages and the marginal product of labour, i.e. $MC_t = (W_t / P_t)/(\partial Y_t / \partial N_t) = \frac{S_t}{\alpha_n}$, where $S \equiv W_t N_t / P_t Y_t$ is the labour income share. Expressed in terms of deviations from the steady state, this becomes: $mc_t = s_t$.

Galí and Gertler's (1999) main results are the following: First, that the labour share is a statistically significant driving variable of the inflation process. Second, that forward-looking behaviour dominates price setting, although backwardness is statistically significant it is of limited quantitative importance. Thus, although the forward-looking new Keynesian Phillips curve is rejected by the data, it is a reasonable approximation to the inflation process. They stress further research into the cyclical behaviour of marginal costs, as discussed later.

Angeloni et al. (2005) note that there are four sources of inflation persistence in a hybrid model such as in Galí and Gertler (1999), corresponding to each of the right-hand-side terms (a cost-push shock is added to the hybrid model in equation (5)): (i) Mark-up gap persistence, which they call "extrinsic persistence", (ii) backwardness in the price-setting mechanism ("intrinsic persistence"), (iii) persistence due to inflation expectation formations ("expectations-based persistence"), and (iv) persistence in the stochastic error term ("error-term persistence"). Cecchetti and Debelle (2006) argue that "the price setting process itself is unlikely to be a source of positive persistence – indeed the opposite may be true. With forward-looking behaviour, persistence will be zero. … The inflation expectations process is therefore the likely source of inflation persistence.", (Cecchetti and Debelle, 2006: 318).

Blanchard and Galí (2005) refer to this appending of a lagged inflation term in equation (5) as "a fix, not an acceptable solution" (Blanchard and Galí, 2005: 24). Christiano, Eichenbaum and Evans (2005) introduce a variant of Calvo's (1983) price mechanism where

firms that cannot re-optimize their prices use dynamic price indexation. Smets and Wouters (2003) use a similar approach in their DSGE model for the euro area, although they allow for partial indexation. Blanchard and Galí (2005) refer to this kind of indexation as an "unconvincing fix, with little basis in fact", (Blanchard and Galí, 2005: 24).

Vast efforts have been put into empirical work on new Keynesian models of price-setting, inspired by the acclaimed success of hybrid marginal cost-based new Keynesian Phillips curves by Galí and Gertler (1999) and Sbordone (2002). Several authors have criticized their approach and questioned their results. The disagreement has mainly focused on five issues: First, what do the empirical results reveal about the importance of forward-looking versus backward-looking variables in the relationship? Second, which estimation approach to the new Keynesian Phillips curve should be used? Third, should real marginal costs be represented by the labour share or an output gap in the Phillips curve? Fourth, is further research into the dynamics of real marginal costs needed, e.g. with regard to modelling labour market rigidities. Fifth, how many lags of inflation should be included in the hybrid specification. Finally, some have claimed, e.g. Rudd and Whelan (2006), that the whole approach to price setting modelling has to be revised as the new Keynesian Phillips curve fails to fit the empirical results on inflation dynamics.

6.1.1 Backward- or Forward Looking?

The values of γ_f and γ_b in equation (5) are very critical for the relationship between monetary policy, inflation and real activity. If inflation expectations are entirely forward-looking $(\gamma_b = 0)$ equation (5) becomes equal to the fully forward-looking Phillips curve in equation (1), which can be solved forward to show that inflation is simply equal to the sum of all future expected gaps (disequilibria). Berg et al. (2006a) refer to this as the "speedboat" economy, as a small (if perceived to be persistent) hike in policy interest rates will have a large and simultaneous effect on current inflation. If γ_f is zero, the Phillips curve is backward-looking and current inflation becomes a function of all lagged values of the gaps. In this case, the effects of monetary policy are more gradual and only an accumulation of many periods of interest rate adjustments can move current inflation toward some desired path. Berg et al. (2006a) refer to this case as an "aircraft carrier" economy.

Steinsson (2003) analyses optimal monetary policy for different values of γ_f and γ_b in a closed economy DSGE model with hybrid price setting in the tradition of Galí and Gertler (1999) and Fuhrer and Moore (1995). He finds that "the main features of optimal policy in the purely forward-looking case, such as the importance of commitment, carry over to this hybrid case", (Steinsson, 1999: 1449). He notes two differences in optimal policy making in the hybrid case. First that a gradual approach to bringing down inflation is optimal and secondly that the trade-off between stabilizing inflation and output variability is altered such that it is optimal to tolerate a larger reduction in output to steer clear of letting too much inflation into the system. Steinsson notes that "[t]hese features of our hybrid cases seem to correspond quite well with actual central bank policy", (Steinsson, 2003: 1449).

Galí and Gertler (1999) find that forward-looking behaviour is more important than backward-looking behaviour (γ_f close to 0.7) and state that: "Our results suggest that, conditional on the path of real marginal costs, the baseline new Phillips curve with forward-looking behaviour may provide a reasonably good description of inflation dynamics", (Galí and Gertler, 1999: 219).

Paloviita (2004) reaches another result using European data. She compares the empirical fit of different new Keynesian Phillips curve specifications using survey-based expectations for proxies of rational expectations. By using survey-based expectations she avoids the problem of simultaneously testing the specification of the Phillips curve and the formation of expectations. Her estimation results suggest that the backward-looking factor dominates the inflation process with γ_b close to 0.6, a considerably higher value than the one reported by Galí and Gertler (1999). In another paper, co-written with David Mayes, the forward-looking weight is found to increase when real-time data, i.e. the data available at each time, is used in the specification of a hybrid Phillips curve, (see Paloviita and Mayes, 2005).

Sbordone (2002) uses a different modelling and estimation approach than Galí and Gertler (1999) but reaches a similar basic supportive conclusion for marginal cost-based Phillips curves and the importance of forward-looking price setting in explaining inflation dynamics: "the rational expectations model of price setting with nominal rigidities does indeed provide a quite good approximation to the actual dynamics of inflation. What is at fault in the New-Keynesian Phillips Curve specification is not the forward-looking model of

price setting but the assumed proportionality between marginal costs and measures of the output gap", (Sbordone, 2002: 283).

Kiley (2005) estimates a purely forward-looking and a hybrid marginal cost-based new Keynesian Phillips curve as well as a sticky information Phillips curve following Mankiw and Reis (2002) and a hybrid sticky information curve. He compares the performance of these versions to a reduced-form forecasting regression. He finds that the purely forward-looking new Keynesian Phillips curve, as well as a simple Galí and Gertler's (1999) type of a hybrid Phillips curve, perform very poorly relative to the reduced-form regression. He finds that the best-fitting hybrid Phillips curve uses a four-quarter weighted average of lagged inflation and that the weight on the sum of inflation lags falls to just above ¼ as the number of inflation lags increase from one to four. This of course draws the attention to what kind of microfoundation can provide a reasonable explanation to so long lags.

6.1.2 What Estimation Approach?

Galí and Gertler (1999) use a GMM estimation approach to estimate the structural parameters θ, ω, γ_f and γ_b which calls for the use of appropriate instruments that are correlated with the variables they represent but uncorrelated with the error term. They use lagged variables as instruments, which relies on the assumption that the model is correctly specified and expectations are indeed rational, as any estimation error reflects expectational errors, which are unforecastable at the current date or earlier. This approach has the disadvantage of testing simultaneously the specification of the Phillips curve and the rational expectations theory. Galí and Gertler use two different specifications of the orthogonality condition to address the sensitiveness of how the orthogonality conditions are normalized when using GMM on small samples. Galí and Gertler (1999) use U.S. data but Galí, Gertler and López-Salido (2001, 2003) extend their analysis to European data.

Sbordone (2002) tests the validity of the sticky price hypothesis by testing implications that depend only upon the firm's optimal pricing problem rather than within a general equilibrium model that requires further structural assumptions. Sbordone (2002) uses a two-step minimum distance estimation procedure along the lines of Campbell and Schiller's (1987) evaluation of present value relationship in finance and uses it to compare actual inflation dynamics to the inflation path predicted by the Calvo model taking as given the dynamics of nominal marginal cost. Rudd and Whelan (2006) note that this approach has

the disadvantage that it cannot be used to obtain statistical estimates of the model's parameter and thus cannot conclude whether the forward-looking components of the new Keynesian Phillips curve are of fundamental importance to observed inflation dynamics. GMM does not suffer from the same problem, but it has problems of its own.

Rudd and Whelan (2005b) criticize the GMM estimation approach used by Galí and Gertler (1999) and state that "their procedure is likely to suggest that forward-looking behaviour is very important even if the true model contains no such behaviour", (Rudd and Whelan, 2005b: 1179). They find that expected future values of the driving variable in a new Keynesian Phillips curve, whether measured by the labour share or the output gap, can only explain a very small fraction of observed inflation dynamics and find that Galí and Gertler's results are also consistent with a backward-looking Phillips curve. They elaborate further on this in a more recent paper: "In practice, inflation can be predicted well from its own lagged value; hence, incorporating lagged inflation into the inflation equation should allow the hybrid model to fit the level of inflation relatively well. However, such a fit could also be obtained by any model that features an important role for lagged inflation—including models that rely on nonrational, backward-looking expectations. In contrast, the hybrid model's predictions for the evolution of $\Delta\pi_t$ are quite clear-cut and allow us to precisely distinguish this model from a traditional backward-looking specification", (Rudd and Whelan, 2006: 304).

Kurmann (2005) stresses the uncertainty surrounding Galí and Gertler's estimates. He argues that it is difficult to assess the importance of forward-looking behaviour in price setting and calls for further research on the determinants of firms' costs and market structure. Lindé (2005) proposes a full information maximum likelihood (FIML) approach as single equation methods, such as GMM used by Galí and Gertler (1999), produce imprecise and biased estimates. He estimates a macroeconomic model with a hybrid Phillips curve using FIML and finds that a output-gap based hybrid version, where backward-looking behaviour is equally or more important than forward-looking behaviour, provides a reasonable approximation of US inflation dynamics.

Kiley (2005) argues for maximum likelihood (ML) techniques as their estimation offers more efficient and less-biased estimates of structural parameters, even in case of misspecification, and provides an explicit measure of fit through the likelihood function enabling assessment of alternative non-nested models.

Rabanal and Rubio-Ramírez (2005) argue for Bayesian estimation procedure on the grounds that it takes advantage of the general equilibrium approach, it outperforms GMM and maximum likelihood in small samples, it does not rely on the identification scheme of the VAR and that even in the case of misspecified models Bayesian estimation is consistent.

Bårdsen et al. (2005) reanalyse the data used in the studies of Galí and Gertler (1999) and Batini, Jackson and Nickell (2000) and claim that the empirical relevance of the new Keynesian Phillips curve on these data is very weak. They state that the goodness-of-fit of the new Keynesian Phillips curve on euro data is no better than a random walk and that the significance of the forward-looking term is misleading.

Barkbu and Batini (2005) use an application of the method by Johansen and Swensen (1999) to estimate a hybrid new Keynesian Phillips curve when inflation is non-stationary using Canadian data and emphasize that GMM and FIML methods are invalid under these circumstances.

Galí, Gertler and López-Salido (2005a) and Sbordone (2005) respond to the criticisms by Rudd and Whelan (2005b) and Lindé (2005) and maintain their former results on the importance of forward-looking price setting behaviour in inflation dynamics. Galí, Gertler and López-Salido (2005a) emphasize that their results are robust across a number of different estimation methods, including the closed form specification stressed by Rudd and Whelan (2005b) and maximum likelihood methods uphold by Lindé (2005). They also criticize Rudd and Whelan's (2005b) dramatization of the potential bias problem of the GMM approach and their choice not to obtain direct estimates of γ_f and γ_b.

A thorough discussion on these estimation approaches is outside the scope of this paper but in addition to the references in this section, the interested reader is referred to e.g. Dufour et al. (2005), Dupuis (2004), Fuhrer (2005), Guay and Pelgrin (2004), Henry and Pagan (2004), Jondeau and Bihan (2005), and Nason and Smith (2005).

6.1.3 Should the Labour Share be used?

Wolman (1999) is critical on the relationship between marginal cost and inflation described by Galí and Gertler (1999). First, he points towards the measurement problem, which he states is more severe for marginal cost than for output: "[T]he researcher must have access to data on marginal cost. But unlike GDP or inflation, marginal cost is not a data series measured by a government statistical agency. Measurement is lacking for good reason: the

appropriate measure of marginal cost depends on characteristics of the economy which are only imperfectly understood. These characteristics include the competitiveness of factor markets and the extent of adjustment costs firm face in hiring new workers and installing new capital", (Wolman, 1999: 39).

Second, Wolman argues that using labour share as a proxy for real marginal costs is not an acceptable solution as it relies on an oversimplification. It assumes that all firms use Cobb-Douglas production technologies and that there is an economy-wide competitive labour market. Third, Wolman compares the Calvo price setting specification used by Galí and Gertler (1999) to a "more reasonable specification" that lets the probability of price adjustment be a smoothly increasing function of time since the last adjustment (i.e. a hazard function), and finds that Galí and Gertler's empirical results are very sensitive to the assumption of Calvo price setting.

Rudd and Whelan (2005b) are also critical of the use of labour share as a proxy for real marginal cost: "Rather than moving procyclically, the labor share … has typically displayed a pattern that would be considered countercyclical, with the series spiking upward during each postwar recession in the United States. … How can the observed behavior of the labor share be reconciled with the theoretical prediction that real marginal cost should be procyclical? Most likely, the answer is that average unit labor costs are simply a poor proxy for nominal marginal cost … there are several reasons to believe that marginal and average cost manifest different cyclical patterns. … By and large, the important measurement issues that surround the use of average unit labor costs as a proxy for marginal cost have been ignored in the recent literature on the [new Keynesian Phillips curve]. Indeed, proponents of the labor share approach such as Galí, Gertler, and Lopez-Salido (2005) generally refer to the labor share series simply as "real marginal cost," as though these two concepts are identical", (Rudd and Whelan, 2005b: 14-15).

In contrast, Batini, Jackson and Nickell (2005) provide evidence that the labour share in the U.K. is positively correlated with inflation. They construct a new Keynesian Phillips curve based on Rotemberg (1982) adjustment cost price setting and extend it to capture employment adjustment costs and the openness of the U.K. economy, as discussed later.

McAdam and Willman (2004) apply a novel approach to improve Galí, Gertler, and Lopez-Salido's (2001) model. They argue that the observed shifts in the labour share of income in Europe are inconsistent with the practice of specifying a standard Cobb-Douglas

production function and then calibrating using the observed labour income share. They discuss the hump-shaped labour income share in GDP in the euro area; after increasing significantly in the 1970s, it decreased continuously in the 1980s and 1990s. They prefer to estimate a multi-sector supply-side model which allows for sectorally differentiated scale and technological progress parameters implying time-varying factor shares. A second important assumption is abandoning Dixit and Stiglitz's assumption of constant price elasticity of demand and using an Almost Ideal Demand System (AIDS) demand function instead to introduce strategic interaction in price setting as competitors' price enters the price equation. They note that this assumption introduces the possibility to incorporate the adverse supply-side shocks of the 1970s into their model, which again is vital to explain the hump-shaped labour share development. A third central issue in their model is that capital is endogenous. These assumptions produces plausible parameter estimates of a hybrid new Keynesian Phillips curve with regard to fixed-price durations, dynamics and a more balanced role for backward- and forward-looking components (both γ_f and γ_b around 0.5).

6.1.4 Are Labour Market Rigidities the Answer?

Sbordone (2005) underlines that "[w]hat has emerged from the copious empirical research on inflation dynamics, in my opinion, is that a full understanding of the Phillips curve can in fact be reached only through an understanding of the dynamics of labor costs, and how these relate to output dynamics. And this is where future empirical research should be focused", (Sbordone, 2005: 1196-1197).

Galí and Gertler (1999) also advocate for further research into real marginal costs, its cyclical behaviour and its connection to unit labour costs. They argue that sluggish behaviour of real marginal costs, possibly due to wage rigidity, may account for the slow response of inflation to output which could possibly explain why disinflations require costly output reductions. Hence, they campaign for further research into both nominal and real rigidities.

Christiano, Eichenbaum and Evans (2005) stress the importance of future research into modelling labour market rigidities and integrating them into DSGE models as they find that wage stickiness is crucial for their model to account for the estimated dynamic response of the U.S. economy to a monetary shock. By their accounts, price stickiness plays a relatively small role. The introduction of labour market rigidities will be discussed in section 6.2.

6.1.5 What About the Output Gap?

Paloviita (2004), as mentioned earlier, examines the empirical performance of different specifications of the new Keynesian Phillips curve using survey-based expectations for proxies of rational expectations on European data. In this approach, the output gap serves at least as good a proxy for real marginal costs as the labour share.

Neiss and Nelson (2005) interpret the results of Galí and Gertler (1999) and Sbordone (2002) differently and suggest that labour market rigidities are not crucial in modelling inflation dynamics. They argue that an output gap-based Phillips curve fits the data about as well as a marginal cost-based Phillips curve, if the output gap is measured in a theory-consistent manner. They point out that potential (or natural) output is usually defined as the output level that would prevail in the absence of nominal rigidities in DSGE models. They argue that potential output is affected by real shocks and does not follow a smooth trend as implied by popular de-trended or filtered measures of the output gap.

This is a part of a wider discussion on output gap estimation. The neoclassical growth model portrays the growth of potential output as a rather smooth process governed by exogenous variables, i.e. technological progress and population growth. This model is the background for various output gap estimation methods that assume a smooth trend in potential output. Kydland and Prescott (1982) were the first to criticize the prediction of the neoclassical growth model of a smooth trend in potential output. They argue that potential output undergoes continuous changes and volatility in actual output mainly reflects changes in potential output. Potential output is thus stochastic instead of deterministic and the real output level simply reflects the variation in the equilibrium output level. This disagreement on the nature and causes of business cycles is well-known. It centres on the following questions: Is potential output a deterministic trend that actual output swings around because of various market failures and information problems or is it a stochastic variable which changes rapidly due to various real shocks? This disagreement refers to output dynamics but it has different monetary policy implications. If trend output is stochastic, for example a random walk, all shocks have permanent effects. If it is deterministic, all shocks have only transitory effects. Econometrics does not provide a definite answer as it is difficult to detect whether a time series of limited length is non-stationary or stationary with high persistence.

Various assumptions regarding output dynamics have been put forward, both regarding the trend and the cycle component, as well as the relationship between the two.[13]

Real business cycle theory explains business cycles with references to stochastic productivity shocks as well as shocks caused by changes in government expenditures. Monetary policy has no stabilization role to play in this kind of model as the economy is continuously in equilibrium. New Keynesian economics disagrees and refers to various types of nominal rigidities and information problems that cause prices and wages to vary from their flexible price equilibrium values. Demand shocks can thus have important effects on output, both in the short and medium term, and they are the main causes of business cycles. By new Keynesians' accounts, monetary policy has a vital stabilization role to play and it is essential to respond immediately to demand shocks as they can stimulate inflation, which harms the efficiency of the economy and hurts economic growth in the long run.

6.1.6 Does the Hybrid Patching Work?

The previous subsections show that there is not an agreement on whether the hybrid marginal cost-based Phillips curve represents the solution to the empirical problems of the new Keynesian Phillips curve. According to Galí, Gertler and López-Salido (2005a) the hybrid marginal cost-based approach works well but they note that there are three unresolved issues: First, the rationale for the role of lagged inflation in the hybrid Phillips curve. Second, further studies have to look at whether Calvo's price setting model is simply too stylized. Finally, they find it important to attain a better understanding of marginal cost dynamics. This has led them, and many others, to search for various methods to introduce real rigidities into their models in order to explain marginal cost dynamics. This is the subject of the next section. Others have focused on amending Calvo's price setting model and an example of this will be discussed in section 6.3. Finally, there are a number of economists that call for a deeper revision of the microfoundation underlying the new Keynesian Phillips curve.

Ball, Mankiw and Reis (2005) discuss the "sorry state of monetary policy analysis" and argue that policymakers should be cautious with regard to the policy implications of the new Keynesian literature, which relies on an unconvincing Phillips curve: "The problems with both the new Keynesian and the accelerationist Phillips curves are increasingly

[13] See for example Nelson and Plosser (1982), Campell and Mankiw (1987a,b), Blanchard and Quah (1989), and Cooley and Dwyer (1998).

understood. This has led some authors to suggest a compromise. According to the so-called "hybrid" Phillips curve, a subset of agents have backward-looking inflation expectations and the rest have rational expectations (e.g., Gali and Gertler, 1999). Yet this compromise may yield the worst of both worlds. Like the new Keynesian Phillips curve, the hybrid model yields an immediate jump in inflation in response to monetary policy shocks (unless all agents are backward looking). Like the accelerationist Phillips curve, the hybrid model fails to explain the absence of inflation inertia under earlier monetary regimes (unless no agents are backward looking). That is, by taking a weighted average of two flawed models, the hybrid model of the Phillips curve ends up with the flaws of each." (Ball, Mankiw and Reis, 2005: 706).

Rudd and Whelan (2006) argue that the hybrid approach to patching up the new Keynesian Phillips curve merely addresses a symptom of a much deeper rooted problem, which is the reliance on a strict form of rational expectations. They seem to agree with Ball, Mankiw and Reis (2005) that further research should be aimed at introducing behavioural economics into the microfoundation of the Phillips curve. This will be discussed in section 7.

6.2 The Need for Real Rigidities

Real rigidity refers to "a lack of sensitivity of desired relative prices to macroeconomic conditions", (Mankiw and Romer, 2002: 1319). Real rigidity amplifies the effects of nominal stickiness and is thus a candidate for a solution to the real output persistence problem. The possible candidates for the sources of real rigidities are many. Special attention has been given to labour market imperfections, capital market imperfections and the firm-customer relationship.[14] Ball and Romer (1990) point out that real rigidity alone does not cause monetary shocks to have real effects. In the case of freely adjustable prices, money is neutral regardless of the degree of real rigidity.[15] Andersen (1998) compares price and wage staggering and concludes that wage staggering holds the potential of being able to solve the persistence problem. This section will discuss some modelling approaches of labour and capital market imperfections.

[14] See section 6.6 on pages 294-302 in Romer (2006) for a textbook discussion on the need for real rigidity.

[15] Dotsey and King (2000) incorporate "real flexibilities" to solve the persistence problem, i.e. supply-side features that allow for more elastic response of output to demand without increasing marginal cost. They do this by including an important role for material inputs, variable capital utilization, and variation in employment along an extensive margin into a macroeconomic model.

6.2.1 Labour Market Rigidity

Wage rigidity was the central ingredient in many early Keynesian models. This view implies countercyclical real wages in response to aggregate demand shocks, a prediction that has failed to find support in empirical research. Keynesian models have thus emphasized price stickiness or combinations of price and wage rigidities.[16] The new Keynesian framework is currently being extended from only allowing for price rigidities to introducing labour market imperfections as well as capital market imperfections.

Blanchard and Galí (2005) introduce real wage rigidity into a new Keynesian model and show how monetary authorities then face an endogenous trade-off between stabilizing inflation and the output gap. Real rigidity is also a source of inflation inertia and costly disinflation in their model. Hence, their model provides a possible solution to Mankiw's (2001) objections to the new Keynesian Phillips curve. The Achilles' heel of the model is that it provides no microeconomic foundation for the real wage rigidity. Blanchard and Galí plan to explore the microeconomic foundation for real wage rigidity in the future, as well as its implications for optimal monetary policy. This is a red-hot research area as many different modelling approaches to incorporate labour market imperfections have been tried.

Hall (2005) discusses the integration of search and matching models, where workers and jobs are heterogeneous, into general equilibrium models used to explain business cycles (see Yashiv, 2006 for a new survey on the use of search and matching models in macroeconomics). Hall says: "The new research offers some new mechanisms that may advance understanding of both business cycle and the important sub-cyclical movements of unemployment and other key variables. Notice that none of the driving forces of unemployment fluctuations discussed here are explicitly transitory. They do not disappear after firms and workers get around to changing prices and wages. They can explain the highly persistent sub-cyclical movements that elude the call-option sticky-price model and neoclassical model", (Hall, 2006: 42).

Walsh (2005) incorporates labour market search, habit persistence and policy inertia, in addition to the conventional sticky price assumption, into a DSGE model and analyses the sources of real effects of monetary policy shocks. Walsh finds that the model gives impulse

[16] See section 5.3 on pages 242-251 in Romer (2006) for a textbook treatment of alternative assumptions on wage and price stickiness in traditional Keynesian models and section 5.6 for an overview of the cyclical behaviour of real wages, which appear to be only moderately procyclical, pointing towards some labour imperfections.

response functions for output and inflation that have the typical hump shaped pattern commonly found in VAR analysis. The labour market imperfection magnifies the real effects of the monetary shock such that less nominal rigidity is needed than in standard new Keynesian models. Interestingly, Walsh finds that policy inertia is the key determining factor for the sizeable output and inflation effects of policy shocks.

Christoffel and Linzert (2005) emphasize that it is not sufficient to model wage rigidities to understand the driving forces behind sluggish marginal costs. Labour market adjustments can happen via the hours of work as well as the employment bargain. They introduce a Mortensen and Pissarides (1994) labour market model with matching frictions into a new Keynesian model to generate equilibrium unemployment, as well as allowing for a so-called right-to-manage wage bargaining, which entails that firms and workers bargain only over wages, taking the firm's labour-demand function as given. This form of bargaining implies a channel through which wages affect marginal costs and hence inflation dynamics. Christoffel and Linzert (2005) demonstrate that wage rigidity in this kind of bargaining framework can contribute to explain a considerable part of the inflation persistence witnessed in the data. In contrast, with traditional Nash bargaining, marginal costs are mainly influenced by the number of hours worked not wages. In that case, wage rigidity does not lead to more inflation persistence. Hence, they emphasize the importance for monetary authorities to understand labour market adjustments and how they influence the transmission mechanism of monetary policy, especially how various "institutional" parameters, which determine employment protection, bargaining power of workers and the natural rate of unemployment, can influence unemployment and inflation dynamics.

Christoffel, Küster and Linzert (2006) extend the intriguing work of Christoffel and Linzert (2005) by providing further quantitative assessment of the role of labour markets for inflation dynamics and monetary policy in an estimated multi-sector DSGE model for a closed economy. They estimate the DSGE model using Bayesian techniques for German data from the late 1970s to present and find that the labour market structure is of major importance. Price setting in the wholesale sector follows the indexation tradition in Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2003) whilst the retail sector, which buys differentiated wholesale goods and turns them into a final consumption bundle, is characterized by perfectly competitive product markets. Wages convert into inflation by increasing the cost of the intermediate good, which enters the new Keynesian

Phillips curve in their model. All else equal, the impact of wages on marginal cost will be larger the less prominent inflation indexation and the larger the portion of wholesale firms allowed to update prices each period.

The quest for the optimal approach to incorporate labour market imperfections into DSGE models continues. Galí, Gertler and López-Salido (2005b) note that "labor market frictions are the key factor … however, the exact form that these frictions may take (e.g. nominal wage rigidity, efficiency wages, search frictions, etc.) is … an open question" (Galí, Gertler and López-Salido, 2005b: 24).

6.2.2 Capital Market Rigidity

Capital accumulation has been a central theme of economics at least since Adam Smith's *Wealth of Nations*. But capital is often assumed either fixed or exogenous in business cycle theory with references to the role of these models as short-run analysis instruments. This was true for the old IS-LM model and it is still a common assumption in the new Keynesian framework.[17] Lately this assumption on exogenous capital accumulation has been questioned.

The exogenous capital stock assumption was defended by McCallum and Nelson (1999) within an optimizing framework with sticky prices. They argue: "In principle it might be possible to incorporate an endogenously determined capital stock, as in Sargent and Wallace (1975). Our interest, however, is in obtaining relationships from optimizing behaviour, and it appears unlikely that such an equation for capital accumulation can be derived that is both analytically tractable and empirically successful. …[W]e adopt the strategy that in a theoretical analysis, one would assume a constant or steadily growing capital stock, while in an empirical application, the behaviour of log investment is approximated by a random walk. … [T]he main justification for our exogenous capital assumption is analytical simplicity", (McCallum and Nelson, 1999: 299-300).

McCallum and Nelson (1999) also cite various studies that have shown that, at least for the U.S., the relationship is weak between the capital stock and output at business cycle frequencies. But Angeloni et al. (2002) find that investment (relative to consumption) plays a larger role in the euro area monetary policy transmission than in the U.S.

[17] In many new Keynesian models, both in a closed economy and an open economy framework, capital is simply ignored.

Woodford (2005) criticizes the exogenous capital accumulation assumption and presents for the first time an analysis of aggregate supply where capital accumulation is both *firm-specific* and *endogenous*. This implies that each firm accumulates capital solely for its own use facing standard (convex) neoclassical adjustment costs. This contradicts the common market assumption where capital inputs are bought on a spot market such that the price of capital is independent of the quantity used by the same firm. This assumption has been used in the literature where capital accumulation has been endogenous, e.g. Yun (1996). Also note that contrary to standard neoclassical investment theory, firms are not price takers in Woodford's model as they produce differentiated goods. The firm-specific assumption is important as the firm's marginal cost will no longer be unaffected by the firm's past decisions, including its past price setting, as in the standard microeconomic foundation specification for the new Keynesian Phillips curve. Thus, price setting cannot be analysed separately from the decision of capital accumulation when capital is firm-specific. This has important consequences for the structure of the Phillips curve.

The aggregation of prices is simplified in traditional staggered price setting models, whether of the Calvo or Taylor type, by the fact that all firms that set their prices in the same period choose the same price. The introduction of firm-specific state variables makes the analysis more complex as Woodford's calculations show. The coefficient ξ in equation (1) becomes more complex in this case and the interpretation of it as simply representing frequency of price changes no longer applies. Woodford (2005) develops an output-gap formulation of a new Keynesian Phillips curve where capital is both endogenous and firm-specific:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa \widetilde{Y}_t - \kappa_I \widetilde{I}_t \tag{6}$$

$\widetilde{Y}_t$ is the output gap, defined as the (log) difference between actual and flexible-price equilibrium output, $\widetilde{I}_t$ is the percentage deviation of investment from its steady-state level, as a share of steady-state output, and κ and κ_I are different functions of ξ and some elasticities. This aggregate supply specification represents a more complex relation between inflation and real activity than the standard new Keynesian Phillips curve.

Woodford (2005) also discusses the importance of modelling the labour market. He distinguishes between two possible assumptions. First, a homogenous labour market where all sectors hire the same kind of labour and there is a single economy-wide labour market, such that all firms face a common wage. Woodford points out that this assumption is very common in the literature and when coupled with the usual exogenous capital accumulation assumption, the marginal cost will be the same for all firms and independent of the quantity produced by any firm. In this case, the pricing decision can be analysed separately as in the standard new Keynesian framework. Eichenbaum and Fischer (2004) assume a common labour market but allow for firm-specific endogenous capital.

The other possibility investigated by Woodford (2005) is to assume a sector-specific labour market. He thus has four possible model assumptions regarding common or specific factor markets by assuming either specific or common markets for capital and labour inputs. In addition, he compares the effects of assuming endogenous and exogenous capital accumulation. He shows through a numerical example how the coefficient ξ in the aggregate supply specification is a different function of the underlying model parameters in each case. A special focus is on the relationship between ξ and the frequency of price adjustments under each possible assumption.

In this setup the parameter ξ becomes a measure of the average degree of strategic complementarity/substitutability of firm pricing decisions. Strategic complementarity $(\xi < 1)$ in price setting exists if firm *i*'s price increase causes an incentive for firm *j* to also increase its prices. Strategic substitutability $(\xi > 1)$, on the other hand, refers to the case where a price increase by firm *i* causes an incentive for firm *j* to lower its prices. According to Fehr and Tyran (2005), strategic complementarity is more common in price competition whereas strategic substitutability is more widespread in quantity (Cournot) competition. Strategic complementarity also plays a role if search frictions, informational frictions or increasing returns are important.

Woodford (2005) finds that the homogenous factor model (where the existence of an economy wide labour market, a common wage and a common rental market for capital is assumed) leads to the highest value of ξ, implying strategic substitutability in price setting in different sectors of the economy. Woodford explains this with reference to the fact that this model has the fewest real rigidities in the terms of Ball and Romer (1990). Price adjustment

is faster in case of demand changes when strategic substitutability prevails. Woodford finds that there are greater real rigidities and the Phillips curve is hence flatter when the labour market is modelled in a specific factor market fashion, even when the common market assumption is still applied to the capital input market. Not surprisingly, real rigidities are even greater and the Phillips curve is flatter when capital inputs are modelled as firm-specific and the case with the greatest real rigidities is when both factor markets are modelled in the specific fashion and capital is exogenously given, i.e. the specific factor market case. Adding the endogenous capital market assumption to this case does not alter the scenario much according to Woodford's calibrated example and his conclusion is that "the implicit assumption of an exogenously evolving capital stock in derivations of the Phillips curve for models with firm-specific capital by authors such as Sbordone (1998) appears not to have been a source of any great inaccuracy", (Woodford, 2005: 32-33).

In short, Woodford finds that the assumption of a firm-specific capital is important whereas the endogeneity of the capital stock is not a vital issue.

Fehr and Tyran (2002) examine how strategic substitutability and complementarity in price setting lead to different price adjustments following a fully anticipated negative money shock. They find that the strategic environment is a decisive factor in determining the dynamics of nominal price stickiness and cause real effects even when no exogenous frictions or adjustment costs are present.

Fehr and Tyran's (2002) results are that when price setting is characterised by strategic substitutability, adjustment after a monetary shock is fast as price expectations are very flexible in this case. If, in contrast, strategic complementarity is the ruling factor in pricing, price expectations are very sticky and the adjustment is long-lasting and can have large real effects. An underlying assumption behind their result is that a fraction of the people is not fully rational and Fehr and Tyran (2002) cite a number of studies that have provided evidence for that assumption. The interaction between rationality and strategic complementarity or substitutability is discussed further in Fehr and Tyran (2005).[18]

6.3 The Hazard Function Approach

The hazard function approach involves improving the new Keynesian Phillips curve by relaxing Calvo's assumption of a constant probability of price adjustment and allowing for an

[18] Steinsson (2005) discusses strategic complementarity in an open-economy model.

upward sloping hazard function for price adjustment. This implies that newer prices are stickier than older ones and the underlying assumption is that firms are more likely to change older than newer prices.

Sheedy (2005) derives a new Keynesian Phillips curve where lagged inflation enters as an independent variable due to the upward sloping hazard function and the coefficient on the distributed lag is more positive when the hazard function becomes more upward sloping. Sheedy notes that "[w]hat turns out to be important for inflation persistence is not how much price stickiness there is on average, but whether there are systematic differences between the stickiness of prices of different ages. In particular, newer prices need to be stickier than older prices in order to explain structural inflation persistence ... In terms of the hazard function for price adjustment, the most important feature influencing structural inflation persistence is the slope, not the level.", (Sheedy, 2005: 32). Sheedy estimates hazard function using aggregated macroeconomic data and finds that the results confirm that they are indeed upward sloping, although they are not monotonic over the entire range which he interprets as evidence that some prices are reviewed on a regular basis.

But although Sheedy's results are promising, they have an empirical problem of their own. A common finding in empirical studies using micro data on consumer and producer prices is that hazard functions for price adjustments are decreasing. Álvarez, Burriel, and Hernando (2005) review the international evidence on hazard functions and explain this result by the existence of heterogeneous price setters, when the heterogeneity is taken into account the negative slope of the hazard function is reduced. Nakamura and Steinsson (2006b) try to account for this heterogeneity in their study, as discussed in section 8.1.

7. The Inattentive Approach and Learning

The novel idea of introducing imperfect information as an important theme in the monetary transmission mechanism comes from Edmund S. Phelps. In 1969 he organised a conference where the role of incomplete information in explaining the sluggish adjustment of prices and wages was a central theme. The proceedings of the conference were published in the well-known Phelps volume in 1970. Phelps (1970) introduces the famous metaphor of an economy consisting of separate islands where agents are unable to observe wage and production decisions made on other islands. Lucas' (1972, 1973) representation of Phelps' island model, where agents in the economy do not know whether a change in the price of his

or her product represents a change in the good's relative price or a change in the aggregate price level, became very popular but its spotlight faded when the VAR literature of the early 1980s showed that the Lucas model had a persistence problem of its own (see Woodford, 2003b). As Krugman notes "Few ideas in economics have been so influential, yet left so little lasting impact, as the idea that nominal shocks have real effects because of 'rational confusion'.", (Krugman, 2000: 38). But recently, limited information has re-entered business cycle models in forms that also have their origin in Phelps' pioneering contribution.

Recent applications of the limited information approach are different from Lucas' representation in at least two ways. First, they emphasize that Phelps did not only stress the uncertainty from uncertain nominal GDP levels but also the uncertainty coming from the unknowability of the expectations of others. This idea has been introduced in price setting models and in these models, prices become a function of not just the state of aggregate demand but also of prices charged by other firms. A second alteration is the staggering of information gathering, either because it is costly to assemble information or because of limited ability to gather information.

Another conference organized by Edmund Phelps, along with Roman Frydman, in 1981 was an important pioneering work that led to more explicit models of how learning affects macroeconomic dynamics. The proceedings of the conference were published in Frydman and Phelps (1983). The literature on learning in macroeconomics is rapidly expanding (see e.g. Evans and Honkapohja, 2001, Bullard, 2006, and Preston, 2006). Orphanides and Williams (2003) show that imperfect knowledge increases inflation persistence and distort the policymaker's trade-off between inflation and output stabilization. Milani (2005a) investigates adaptive learning as a potential source of inflation persistence and derives a promising version of the new Keynesian Phillips curve.

This section will discuss the inattentive approach and the learning approach and how they both seem promising approaches to solving the empirical problems of the new Keynesian Phillips curve. The former upholds the rational expectation assumptions, but introduces information costs such that these expectations are only sporadically updated, whilst the latter relies on a relative modest deviation from rational expectations that nests it as a limiting case.

7.1 The Inattentive Approach

The inattentive approach of limited information is evolving into a fully-fledged macroeconomic model. The basic idea in this approach is that agents have rational expectations but that these expectations are only sporadically updated as it is costly to acquire, absorb and process information. "The limited-information approach argues that following the hallmark of economics of studying choice subject to constraints, information should be treated as a costly good", (Reis, 2006: 794). Information is thus sticky and only gradually dissipates through this inattentive economy.[19] The inattentive literature is expanding rapidly and this approach has very recently been applied to the behaviour of consumers, workers, producers and investors.

Mankiw and Reis (2002) were the first to employ the inattentive approach and used it to model firm's price setting, as discussed earlier, and derive a sticky information Phillips curve. Their model is not a fully-fledged DSGE model; it is basically just a price setting model and even one that lacks microeconomic foundation. They also have a very simple representation of both aggregate demand and monetary policy.

Mankiw and Reis (2003) expand their earlier model and apply the sticky information assumption to the labour market and use it to explain observed variations in unemployment, which they find that the model does quite well. Ball, Mankiw and Romer (2005) discuss optimal monetary policy in the Mankiw and Reis (2002) model and find that price level targeting is optimal. Reis (forthcoming) applies the inattentive approach to model consumption and argues that it helps to explain consumption dynamics. Reis (2006) makes a novel contribution and presents a model for production behaviour based on the inattentive approach with a microfoundation, as will be discussed shortly. Gabaix and Laibson (2001) look at investment behaviour when investors only update their portfolio decisions infrequently and come to the conclusion that it can explain the puzzling premium of equity over bond returns. Mankiw and Reis (2006) explore a macroeconomic business cycle model where the inattentive approach is applied to price and wage setting as well as consumption. They state that "a model with such pervasive stickiness is better at matching some key facts that describe economic fluctuations than is either a benchmark classical model without such

[19] Sims (2003), Woodford (2003b) and Moscarani (2004) follow an alternative model of combining rational expectations with inattentive behaviour, which emphasizes that agents have a limited capacity to absorb information.

informational frictions or a model with only a subset of these frictions", (Mankiw and Reis, 2006: 2).

Kiley (2005) estimates a baseline sticky information Phillips curve as well as a hybrid version, where a fraction of firms set prices according to a rule-of-thumb behaviour as in Galí and Gertler (1999), using ML methods. He finds that the baseline sticky information Phillips curve performs better than a purely forward-looking new Keynesian Phillips curve as the residuals are less serially-correlated and the fit of the model, measured by the log-likelihoods, Bayesian information criterion and R^2, is much better. His estimate of the information lags of roughly two quarters is slightly lower than suggested by Mankiw and Reis (2002) and the estimate presented by Khan and Zhu (2002). But the baseline sticky information Phillips curve performs very poorly compared to a reduced-form regression, as was the case with the purely forward-looking new Keynesian Phillips curve, as discussed in section 6.1.1. The hybrid sticky information Phillips curve performs much better, and the version with four lags of inflation again perform better than the one-lag version. Kiley (2005) thus comes to the conclusion that "the sticky-information model has the same problem as the sticky-price model in generating the importance of lagged inflation for forecasting inflation in the absence of some rule-of-thumb or indexing behavior … the basic lesson from a comparison of the full sample results for the hybrid sticky-price and sticky-information models is that they fit the data approximately as well as each other and as a reduced form equation for inflation … It seems that the close fits of the different models occur because the models are in fact very similar when "hybrid" behavior is allowed", (Kiley, 2005: 21-24).

Reis (2006) develops a continuous time version of the sticky information Phillips curve of Mankiw and Reis (2002). More importantly, he provides a microfoundation for the sticky information model. The only assumption Reis makes is that there is a cost of acquiring, absorbing and processing information in connection with forming expectations and making decisions.[20] He solves a standard profit maximization problem with regard to this new constraint and finds that inattentiveness is the optimal response to such a cost. Agents rationally choose to update their information sets and plans only sporadically at

[20] "It is costly to acquire information in the sense of collecting all the pieces of information that are relevant to assess the current state of the world. It is costly to absorb information in the sense of compiling this information into the relevant sufficient statistics needed to make optimal decisions. And it is costly to process information in the sense of coming up with the optimal action and implementing it", (Reis, 2006: 795).

optimally chosen dates. "Adjustment with inattentiveness is therefore *recursively time-contingent*, independent of the current state, but a function of the state at the last adjustment", (Reis, 2006: 798).

The duration of inattentiveness is determined by the cost of planning on the one hand and the speed of accumulation of losses from being inattentive on the other hand. Thus, larger planning costs induce longer inattentiveness and faster accumulation of losses from inattentiveness shortens the period of inattentiveness. Reis notes that costs from being inattentive increase in line with volatility in the economy, which indicates that updating of plans should be more frequent in an economy with more volatility. This remark is interesting for a small open economy, which tends to be more volatile than larger, more closed, economies.

Reis aggregates the behaviour of many inattentive producers and comes to the remarkable result that the distribution of inattentiveness converges to that of a Poisson process with parameter ρ. At any time, $\rho e^{-\rho x}$ represents the share of firms that have not planned for x periods. The share of producers planning at every instant is constant and equal to ρ. This result is very convenient as aggregate dynamics become tractable, especially the derivation of the Phillips curve:

$$\dot{p}_t = \alpha\rho\left(y_t - y_t^n\right) + \rho\int_{-\infty}^{t} e^{-\rho(t-j)} E\left[\dot{p}_t + \alpha\left(\dot{y}_t - \dot{y}_t^n\right)\right]dj \tag{7}$$

which is a continuous-time version of the sticky information Phillips curve of Mankiw and Reis (2002), where $\dot{p}_t$ is the time derivative of the overall price level p_t, α is the index of real rigidities, and y_t^n is the output in the economy if agents are attentive. This can be written in the discrete time version as in Mankiw and Reis (2002):

$$\pi_t = \left[\frac{\alpha\rho}{1-\rho}\right] y_t + \rho\sum_{j=0}^{\infty}(1-\rho)^j E_{t-1-j}\left(\pi_t + \alpha\Delta y_t\right) \tag{8}$$

As discussed in Mankiw and Reis (2002), this sticky information Phillips curve does not suffer from the same empirical problems as the traditional new Keynesian Phillips curve as

disinflations are always costly in terms of output losses, monetary policy shocks have their greatest impact on inflation with a considerable delay and there is a positive correlation between the change in inflation and the level of economic activity. But Reis (2006) provides additional evidence in favour of this form of a Phillips curve.

First, Reis provides quantitative evidence by showing that the model of inflation with the sticky information Phillips curve (with $\alpha = 0{,}11$ and $\rho = 0{,}25$ implying an average inattentiveness of one year) fits the second moments of post-war inflation in the U.S. very well, both with regard to its variability and persistence. Second, he evaluates the model's forecasting performance by comparing its inflation one-quarter ahead relative to two unrestricted reduced-form models: (i) an unrestricted bivariate VAR on inflation and the growth rate of the output gap and (ii) an AR(2) model of inflation. The model with the sticky information Phillips curve clearly outperforms the other two models.

Reis' third test is more demanding as it looks at whether the model can also explain inflation dynamics during the pre-war period in the U.S. when monetary policy was very different. This test basically investigates whether the model survives the Lucas (1976) critique. He finds that the model does not fit the pre-war data as well as the post-war data, but finds that the model does a good job overall. "It predicts about the right amount of persistence of inflation in the data and it captures well the dynamic relation between inflation and lagged and lead nominal income and lagged and lead productivity … Few (if any) of the existing models of inflation would perform this well across such different periods in history", (Reis, 2006: 812-813).

Future research efforts will undoubtedly focus on the promising inattentive approach and it will be very interesting to follow that development.

7.2 Learning and Inflation Persistence

Expectations play a vital role in the new Keynesian Phillips curve. Is it possible that the main root of its problems fitting to the empirical facts lie in the underlying assumption of rational expectations? Various forms of introducing imperfect knowledge and learning have been tried. Some have focused on the uncertainties that policymakers face due to imperfect knowledge of the evolution of key natural rates, e.g. Collard and Dellas (2004), while others have emphasized the presence of imperfections in expectation formation when private agents have imperfect knowledge of the economic structure or about the monetary

authorities' inflation target (see e.g. Erceg and Levin, 2003, and Orphanides and Williams, 2006).

Milani (2005a) follows an adaptive learning technology to form expectations where private agents are modelled as econometricians, who estimate simple models of the economy and form expectations based on them, but in such a way that they are concerned about potential structural breaks in the economic relationship they need to learn. He derives a hybrid new Keynesian Phillips curve from a traditional new Keynesian model with price indexation as suggested by Christiano, Eichenbaum and Evans (2005), with subjected expectations instead of rational expectations and an added cost-push shock:[21]

$$\pi_t = \frac{(1-\beta\alpha)(1-\alpha)}{\alpha(1+\beta\gamma)} mc_t + \frac{\beta}{1+\beta\gamma}\hat{E}_t\pi_{t+1} + \frac{\gamma}{1+\beta\gamma}\pi_{t-1} + u_t \tag{9}$$

where $\beta \in (0,1)$ is the usual household's discount factor, $0 < 1-\alpha < 1$ represents the fraction of prices that are allowed to adjust in a given period, $0 \le \gamma \le 1$ is the degree of indexation to past inflation and $\hat{E}_t$ denotes nonrational expectations. What is missing from equation (9) is how the subjective expectations are formed. In order to get an expression for those Milani makes a few assumptions. First, he assumes that firms estimate a simple AR(1) model to form their inflation forecast:

$$\pi_t = \phi_{0,t} + \phi_{1,t}\pi_{t-1} + \varepsilon_t \tag{10}$$

Second, that firms update their estimates as new data becomes available according to the Constant-Gain Learning (CGL) formula:

$$\hat{\phi}_t = \hat{\phi}_{t-1} + \kappa R_{t-1}^{-1} X_t \left(\pi_t - X_t' \hat{\phi}_{t-1}\right) \tag{11}$$

$$R_t = R_{t-1} + \kappa\left(X_{t-1}X_{t-1}' - R_{t-1}\right) \tag{12}$$

[21] Milani derives both an output gap-based and a marginal cost-based Phillips curve.

where equation (11) expresses the updating of the forecasting rule coefficients $\hat{\phi}_t = \left(\phi_{0,t}, \hat{\phi}_{1,t}\right)'$ over time and equation (12) describes the evolution of R_t, which is the matrix of the second moments of stacked regressors $X_t = \{1, \pi_{t-1}\}_0^{t-1}$. κ denotes the constant gain, compared with the recursive least squares gain (equal to t^{-1}), a larger κ implies faster learning of structural breaks. Finally, Milani assumes that agents only have access to information up to $t-1$ when forming their expectations in period t, i.e. $\hat{E}_t$ is replaced by $\hat{E}_{t-1}$. Expectations are thus formed as:

$$\hat{E}_{t-1}\pi_{t+1} = \phi_{0,t-1}(1+\phi_{1,t-1}) + \phi_{1,t-1}^2\pi_{t-1} \tag{13}$$

On the basis of these assumptions on expectation formation, the hybrid marginal cost-based new Keynesian Phillips curve becomes:

$$\pi_t = \frac{(1-\beta\alpha)(1-\alpha)}{\alpha(1+\beta\gamma)} mc_t + \frac{\beta\phi_{0,t}(1+\phi_{1,t})}{1+\beta\gamma} + \frac{\gamma+\beta\phi_{1,t}^2}{1+\beta\gamma}\pi_{t-1} + u_t \tag{14}$$

where the reduced-form coefficients are time-varying and convolutions of the structural parameters expressing inflation dynamics and of the parameters denoting agents' beliefs. Milani estimates equation (14) (and an output gap-based version) by nonlinear least squares using quarterly U.S. data on inflation, output and real marginal costs from 1960 to 2003 for three different values of κ.[22] His estimated parameters values are interesting. Inflation indexation, a popular way of introducing inflation inertia, is not supported by the data as his values for γ are small and not significantly different from zero. His estimate of the Calvo fixed duration parameter, α, indicate that prices remain fixed for around three quarters, which fit well with other studies. More importantly, he obtains very low parameter values on lagged inflation and finds that inflation is mostly forward-looking. But given this form of expectation formation, his new Keynesian Phillips curve is equivalent to a completely

[22] In a companion paper, Milani (2005b), he estimates a full new Keynesian model with learning by likelihood-based Bayesian methods instead of this single equation estimation.

backward-looking specification as learning becomes the major source of inflation persistence.

Milani approach is promising, but as noted by him, the results depend crucially on the assumed learning speed of private agents in the economy. He makes a novel contribution by deriving the best-fitting constant gain in the sample and showing that it has changed substantially over time. The latter result limits the robustness of the former as the fact that the learning speed has changed substantially in the past makes a best-fitting estimate less valuable. Bullard (2006) emphasizes the role of policy in determining whether and how fast learnability is attained. Future research will hopefully test the overall performance of this kind of learning models as emphasized by Collard and Dellas (2004) and Kiley (2005).

8. New Empirical Evidence on Price Setting Behaviour and Inflation Persistence

Increased awareness of the importance of price setting behaviour has promoted a large body of empirical research in recent years aimed at attaining better understanding of the characteristics of inflation persistence, the cost of disinflation and the effectiveness of monetary policy. These research efforts have been conducted both at a macroeconomic level and as microeconomic studies. Survey evidence has also been extensively used. What do the results from these studies say about the new Keynesian Phillips curve and the underlying price setting behaviour?

8.1 Empirical Evidence Using U.S. data

Blinder et al. (1998) marked a significant contribution to empirical research into price stickiness using survey methods. Their main conclusions are the following:

First, prices in the U.S. economy are indeed sticky and almost half of all prices are only adjusted no more often than once a year. Second, prices are not more rigid downwards. Third, relatively few firms use forecasts of economy-wide inflation in price setting. Fourth, they portray a hybrid picture with regard to time-dependant or state-dependant price setting: "In the end, the survey responses suggest a world in which firms deal with fixed costs of price adjustment not by adopting [state-dependant] strategies, as optimizing theory suggests, but by setting up a schedule of periodic – and not too frequent – price reviews, which they ignore whenever appropriate!", (Blinder et al., 1998: 301). Fifth, customer relationships are very important in price setting. "About 85 percent of all goods and services in the U.S.

nonfarm business sector are sold to "regular customers" with whom sellers have an ongoing relationship … And about 70 percent of sales are business to business rather than from businesses to consumers", (Blinder et al., 1998: 302).

Blinder et al. (1998) discuss what these results indicate about the validity of various theories of price stickiness. They point towards coordination failure, cost-based pricing with lags, nonprice competition and Okun's implicit contract theory as the most promising. Especially, they emphasize coordination failures due to strategic interaction as firms hesitate to be the first to adjust their prices because they fear that their competitors will not do the same. They also underline a theory that has in their view gotten much less attention than it deserves; the idea that firms have other ways to clear markets than adjusting prices, e.g. varying delivery lags, sales effort and product and service quality.

Bils and Klenow (2004) examine the frequency of price adjustments for 350 categories of goods and services covering about 70 percent of consumer spending. They find much less price stickiness than earlier studies, with half of prices lasting less than 4.3 months or 5.5 months or less if temporary price cuts due to sales are excluded. They also test whether good's inflation rates behave in accordance with time-dependant price setting models. They find that volatility and persistence is much less than predicted by traditional Taylor or Calvo type of time-dependant pricing. "In other words, the popular sticky-price models fail most dramatically to predict inflation's behaviour for goods with the least frequent price changes", (Bils and Klenow, 2004: 949).

Nakamura and Steinsson (2006b) argue that Bils and Klenow's (2004) results are due to retail sales and promotions being included. They use a less aggregated dataset than Bils and Klenow (2004) and find that when sales at the product level are eliminated, the median duration of consumer price is 11 months in 1998-2005. This result is broadly in line with Blinder's results and recent evidence using European data, as discusses later. Nakamura and Steinsson (2006b) also present the first broad-based evidence on price dynamics at the production level in the U.S. and find that the median duration of finished goods producer prices was 8.7 months in 1998-2005.

Nakamura and Steinsson (2006b) examine other issues than the frequency of price changes. A second subject is estimating the portion of price changes that are price increases. They find this share to be roughly two-thirds in both consumer prices excluding sales and finished goods producer prices. They find this feature to point towards a price setting model

where large but relatively brief idiosyncratic shocks to firms represent a significant source to price changes.

A third matter they look at is examining the effects of inflation rate variations on the frequency and size of price adjustments. Not surprisingly, they find that price changes become much more frequent as inflation rises. But they also find that the frequency of price decreases and the size of price increases and price decreases do not respond strongly to inflation. They use this fact as a natural test for their calibrated benchmark menu cost model and find that it matches the data quite well on this point.

A fourth feature of price adjustment that Nakamura and Steinsson (2006b) analyse is the degree of seasonal synchronization. They find the frequency of price adjustments to be highly seasonal both for consumer and producer prices. It is highest in the first quarter and lowest in the fourth quarter. This is a feature that the benchmark menu cost model has problems with fitting and they reckon this to be a time-dependant element.

Finally, Nakamura and Steinsson (2006b) examine the hazard function of price adjustments and consistent with the discussion in section 6.3, they are mainly interested in the slope. They note that their calibrated benchmark menu cost model implies a steeply upward sloping hazard function during the first few months following a price adjustment. A novel initiative is their approach to account for the heterogeneity across products in the level of the hazard function, as it leads to a downward bias in the slope if it is not accounted for. They nevertheless find that the model is inconsistent with the data in at least two important ways. "First, it implies a low and sharply rising hazard in the first few months while the data show a large and slightly falling hazard. Second, the menu cost model does not give rise to a spike in the hazard function at 12 months. It is perhaps most natural to interpret this 12 month spike in the hazard function as evidence that pricing decisions of firms have a time-dependent component, though it may also reflect seasonal movements in costs. The downward slope of the empirical hazard function in the first few months is more difficult to rationalize", (Nakamura and Steinsson, 2006: 4).

Mankiw, Reis and Wolfers (2003) emphasize an issue, which they claim is routinely ignored in monetary policy analysis, the fact that not everyone has the same expectation. They call attention to the sticky information model as it has this disagreement at its heart in contrast to standard sticky price theory where there is no room for such disagreement amongst agents' expectations as people share a common information set and form

expectations rationally. They show that the amount of disagreement in inflation expectations is substantial and it varies over time together with other economic aggregates. They claim that "the sticky-information model, according to which some people form expectations based on outdated information, seems capable of explaining many features of the observed evolution of both the central tendency and the dispersion of inflation expectations over the past fifty years", (Mankiw, Reis and Wolfers, 2003: 49).

Branch (forthcoming) looks at how well alternative models of expectation formation fit survey data on inflation expectations. He compares three alternative models with data from the Michigan survey of inflation expectations: (i) Mankiw and Reis' (2002) static sticky information model, (ii) a discrete choice model of sticky information where agents face a list of forecasting models distinct in the frequency of recursive-updating, which is motivated by Reis' (2006) inattentive model and Brock and Hommes' (1997) analysis on the adaptively rational equilibrium dynamics, (iii) the model uncertainty case analysed in an earlier paper by the author (Branch, 2004). He finds that a sticky information model where the choice of updating probabilities is time-varying fits better than the static approach of Mankiw and Reis (2002). Furthermore, on the basis of ML estimation, he finds that the highest proportion of agents in the Michigan survey update their information sets every 3-6 months, a lower proportion does so every period whilst few agents update their expectations at periods of 9 months or more. These proportions vary over time. "Our results suggest that a structural approach to model uncertainty and inattentiveness along the lines of Reis [2006] may further enhance our understanding of the process of expectation formation", (Branch, forthcoming: 3).

8.2 Empirical Evidence Using European Data

The Eurosystem Inflation Persistence Network (IPN) has performed vast empirical research into price setting behaviour in the euro area. The IPN has an unprecedented data set on macroeconomic and sectoral variables as well as information on price setting behaviour at the individual firm level. The main findings of IPN are the following:

First, macroeconomic research seems to indicate that inflation persistence is much lower than earlier studies have shown, once occasional shifts in the mean of inflation are accounted for (see e.g. Altissimo, Bilke, Levin, Mathä and Mojon, 2006). "Overall, most studies find statistical evidence in favour of shifts in the mean of inflation. Moreover, once

such shifts are allowed for, the ρ-estimates are considerably lower than those reported in the upper panel and generally statistically different from one, indicating that inflation is not highly persistent", (Altissimo, Ehrmann and Smets, 2006: 14). Melick and Galati (2006) note that "[a]veraging across all these studies [by the ECB], the typical result is that persistence has fallen roughly by half. However, there is a substantial degree of dispersion around this average result, with some studies reporting no change in persistence … and others reporting that the inflation process no longer displays any persistence", (Melick and Galati, 2006: 2). These shifts in the mean of inflation could be due to changes in the monetary policy regime. This result is a mixed blessing for the new Keynesian Phillips curve. If inflation persistence is lower in recent periods, the new Keynesian Phillips curve may do better in fitting recent data. But if it still has problems fitting the data for other monetary regimes it is not immune to the Lucas critique.

Second, microeconomic studies have shown that firms' price adjustments are lumpy, a large part of firms keep their nominal prices unchanged for some time, (see Álvarez et al., 2006, for a summary for the euro area). Prices in sectors in the CPI index are left unchanged on average for four to five quarters. Price adjustments are somewhat less frequent in the retail sector compared to the producer sector where the median firm adjusts its prices once a year. These results are similar to Nakamura and Steinsson's (2006b) results for the U.S. but lower than Bils and Klenow's (2004) result. IPN's evidence on the portion of price decreases is also similar to Nakamura and Steinsson's (2006b) result as around 40% of price adjustments in the euro area are price decreases compared to one-third in the U.S. According to Angeloni et al. (2006) and Kiley (2005) this evidence contradicts models of price adjustments that imply continuing adjustments, such as sticky information price setting, the Calvo model with indexation and the Rotemberg (1982) price adjustment cost model.

Third, survey data indicates that a lot of firms adjust their prices in a time-dependant manner but also that they use state-dependant adjustments in response to large idiosyncratic shocks (see Fabiani et al., 2005, for a summary for the euro area). It is much more difficult to include state-dependant price setting in macroeconomic models and still an open question whether it is advisable.

Fourth, price setting surveys also show that the vital causes for price stickiness are *long-run relationship with customers*, *explicit contracts* which are costly to re-negotiate and *coordination problems* resulting from the unwillingness of firms to change prices ahead of their

competitors (Fabiani et al., 2005). These surveys find common arguments for price stickiness, such as menu costs and information costs, less important. These issues are absent in most macroeconomic models and are not part of the microeconomic foundation of the new Keynesian Phillips curve (see Nakamura and Steinsson, 2006a, for a novel approach to explain price rigidity due to consumer lock-in and time-inconsistency problems that firms face in customer markets). Coordination problems are nevertheless one of the classic sources of price stickiness discussed in the Keynesian literature. Blanchard and Fischer (1989) even cite Keynes (see Romer, 2006, section 6.7, for a textbook discussion of the relationship between coordination problems, real rigidities and multiple equilibria).

Fifth, microeconomic studies find that there is significant sectoral heterogeneity in the degree of price stickiness across product categories (Álvarez et al., 2006). These studies point towards the variability of input, especially wage developments, and the degree of competition as two important factors behind the heterogeneity. Structural reforms that increase the degree of competition in labour and product markets can thus possibly reduce price stickiness. This evidence points, as does the findings of Sbordone (2005), Christiano, Eichenbaum and Evans (2005) and Galí, Gertler and López-Salido (2005a), towards wage stickiness as an important ingredient behind price stickiness and inflation persistence (Altissimo, Ehrmann and Smets, 2006). But it can also be supportive to the inattentive model of price setting as these variations in the frequency of price changes across goods seem to be connected to the price elasticity of demand as implied by the inattentive model.

Finally, new macroeconomic studies, e.g. Paloviita, (2004, 2005a,b), have tested the importance of inflation expectations for inflation dynamics and examined the consequences of allowing for bounded rationality in expectations. Paloviita (2004) notes that "although there might be persistence in inflation expectations, simply allowing for non-rationality in expectations is not enough to capture all of the persistence in inflation process properly … lagged inflation is needed", (Paloviita, 2004: 17). Hence, a hybrid Phillips curve performs better empirically than a forward-looking New Keynesian Phillips curve. Her studies do find that backwardness in inflation expectations has been reduced and inflation has become more forward-looking in recent years. Hence, this is promising, at least to a certain degree, for the new Keynesian Phillips curve.

9. The Adaptation of the New Keynesian Phillips Curve to the Open Economy

The previous discussion shows, as mentioned earlier, that disagreement on the Phillips curve centres on three major issues. First, the choice of variables to include in the Phillips curve. Should the Phillips curve include lagged inflation or is the process fully forward-looking? Should real disequilibrium be represented by an output gap or marginal cost-based measure? If the former is chosen, how should the gap be defined and measured? If the latter is chosen, how should real marginal costs be measured?

The second issue centres on the optimal modelling approach to the microfoundation of the Phillips curve. What kind of constraints do firms face in their price setting? Is it rational to model the goods market as imperfect whilst assuming perfectly competitive labour and financial markets? How can real rigidities be integrated into this framework? Is it possible to introduce some inertia in the inflation process without abandoning rationality in price setting?

Finally, there is the issue on the estimation approach to the Phillips curve, discussed briefly in section 6.1.2.

Things become even more complicated in an open-economy framework as *the New Open Economy Macroeconomic (NOEM) literature* has shown. The relationship between marginal costs and the labour share becomes more complicated as producers face a choice between imported and domestic intermediate inputs. Price setting is also more complex as the choice of currency, competition from abroad and the pass-through of exchange rate changes into prices become an issue. Modelling of real rigidities in capital and labour markets is also influenced by the introduction of the openness factor, especially in an era of increased globalization of product, labour and financial markets. It should also be obvious that estimation and forecasting is probably not made any easier with the openness dimension. Favero (2001) discusses how a consensus has been reached in using VAR analysis to derive evidence from economic data in the case of closed economies but not for open economies.

The introduction of open-economy elements into DSGE models marks the frontier of current research. Exchange rate economics is one of the most challenging areas within macroeconomics and a heftily debated issue in monetary policy design. It is a field considered filled with anomalies and puzzles. It is therefore not surprising that model building becomes increasingly difficult when it comes to modelling inflation dynamics in an

open economy where the relationship between inflation and exchange rate is a key concern. In a small open economy setting this becomes even more crucial.[23]

A number of early papers, e.g. Ball (1999) and Clarida et al (2001, 2002), found that optimal monetary policy design was in no important way different in an open-economy environment compared to the closed economy framework. This isomorphic result is based on a number of strong assumptions. The law of one price is assumed to hold and there is full pass-through from exchange rate changes into prices. This is in strong opposition to wide-ranging empirical research and in stark contrast to Johnson's (1974) advice that "[t]he distinction between an open and a closed economy in monetary analysis is fundamental", (Johnson 1974: 223).

Recent research shows that introduction of open-economy factors has important influences for model design, inflation dynamics and monetary policy making. Svensson (2000) notes that "[i]ncluding the exchange rate in the discussion of inflation targeting has several important consequences", (Svensson, 2000: 158). By his account the main implications of introducing the exchange rate are (i) additional channels for the transmission of monetary policy, (ii) further emphasis on forward-looking behaviour and the role of expectations, and (iii) transmission of foreign shocks to the domestic economy. He does not discuss the issue of incomplete exchange rate pass-through.

The NOEM literature represents an attempt to introduce new Keynesian economics into an open-economy framework. NOEM has brought new insights into international transmission of shocks, different price setting behaviour and policy coordination. The models in the NOEM literature are DSGE models, with nominal rigidities and various forms of market imperfections. They are still to a certain degree fragile as the precise modelling approach is not fully established and different approaches yield different policy advice. This is of course also true for their closed economy counterparts, but not in the same degree.

A major strength of DSGE models is that they enable welfare analysis and are thus able to address normative policy questions. A limitation of the early open-economy DSGE models in the NOEM literature was that they modelled monetary policy as a choice of a monetary aggregate instead of short-term interest rate setting. Most modern monetary authorities do not regard the nominal money supply as their policy instrument but instead

[23] In the open-economy macroeconomic literature a *small open economy* denotes an economy that is too small to influence world prices, interest rates or economic activity.

implement policy by the setting of short-term interest rate on the money market.[24] Monetary policy is modelled in the closed economy new Keynesian models as either a simple rule in Taylor's (1993) tradition or derived from a loss function of monetary authorities where an inflation target is often explicitly assumed. This has happened with a lag in the open-economy DSGE models (see Batini, Harrison and Millard, 2001 for an early application of monetary rules in an open-economy framework). Obstfeld (2004) discusses the importance of using interest rate rules instead of monetary aggregates in modelling monetary policy in the NOEM literature. Woodford's (2001) elegant derivation in a closed economy framework has not been done in an open-economy version, i.e. to go from utility maximization by the representative household to the central bank's loss function.

The emphasis on monetary aggregates in the early NOEM literature makes the unpredictability of money demand an important modelling issue and disregards the more significant effects that monetary policy has through the term structure and exchange rates where expectations play a key role.

This section will mainly focus on the open-economy Phillips curve, especially the interaction between exchange rate dynamics, price setting and inflation. Of course, all the issues covered earlier regarding the closed economy Phillips curve are still central in the open-economy approach. The addition of open-economy factors amplifies the complexity as new channels arise, especially the introduction of exchange rate dynamics and shocks from abroad. This is crucial in a small open economy setting where the exchange rate is the most important price as the direct exchange rate channel plays a vital role in the transmission mechanism of monetary policy.

9.1 The Microfoundation of the Open-Economy Phillips Curve

This section looks at a few controversial aspects in the specification of the microfoundation for the open-economy Phillips curve. First, price setting will be discussed and how it is connected to the exchange rate pass-through literature. This leads to a closer look at the role of intermediate inputs. Finally, modelling of real rigidities in labour and capital markets will be considered.

[24] Poole (1970) provides a classic analysis on the instrument choice problem, i.e. whether monetary authorities should choose monetary aggregates or interest rates as their policy tools (see chapter 9 in Walsh, 2003 for a modern textbook treatment).

9.1.1 Price Setting and Exchange Rate Pass-Through

The NOEM literature has grown exponentially in volume since the publishing of the pioneering *redux* paper by Obstfeld and Rogoff in 1995. The models in the early papers of the NOEM literature are deterministic; e.g. Obstfeld and Rogoff (1995) and Betts and Devereaux (1996, 2000). Obstfeld and Rogoff (1998, 2000) introduced uncertainty into the models and this has become standard. Imperfect competition brought price setting behaviour into the spotlight of attention and the confrontation between different pricing rules was a central theme in the first wave of the NOEM literature (see Lane, 2001, for a survey of the first wave of the NOEM literature and Bowman and Doyle, 2003, for its monetary policy implications).

Price setting assumptions are crucial in any DSGE model, whether in a closed or open-economy framework. The early open-economy DSGE models assumed even simpler price setting than the closed economy versions discussed in section 3. Prices were assumed set one period in advance in producers' currencies (Obstfeld and Rogoff, 1995). This price setting assumption was soon challenged by the local currency pricing assumption (Betts and Devereux, 1996), which follows Krugman's (1987) pricing-to-market discussion and assumes international market segmentation. In local currency pricing (LCP), firms set their prices in consumers' currency contrast to the producers' currency pricing (PCP) assumption used by Obstfeld and Rogoff. The PCP and LCP assumptions were confronted with each other until about the year 2002 when more refined models were built. [25]

Two important refinements were made in modelling price setting in open-economy DSGE models. First, *staggered price setting structure* in the tradition of Calvo (1983), Rotemberg (1982), Fischer (1977) and Taylor (1980) replaced the simpler one-period in advance price setting. This allows for richer dynamics effects of monetary policy and is also in line with the tradition in the closed economy new Keynesian models. In the one-period in advance price setting framework prices of all goods can adjust without costs to shocks after one period. Kollman (2001) was the first to introduce staggered price setting into an open-economy

[25] The price setting discussion is also an important issue in the classic debate on the optimal exchange rate regime. Obstfeld and Rogoff (1995, 2000) emphasize the adjustment role of flexible exchange rates through expenditure switching, which is a key subject in their redux model. Expenditure switching refers to the influence of exchange rate adjustments on relative demand through relative price changes across countries. They stress that world demand can be reallocated in an efficient way in case of shocks when exchange rate pass-through is complete, PPP holds and exchange rates are flexible. Exchange rate pass-through is nil in the case of LCP and no expenditure switching can take place. Betts and Devereux (1996, 2000) therefore advocate fixed exchange rates.

DSGE model.[26] The second refinement involved modelling price setting within a *multi-sector framework* to take into account the empirical findings on the deviations from the law of one price (l.o.p.) and exchange rate pass-through, i.e. that there are large short-run deviations from the l.o.p. and a high degree of pass-through into prices of imported goods but not into final consumption goods.[27]

Some models only apply one of these two refinements and Monacelli (2005) was the first to combine both refinements. Devereux and Engel (2006) use multi-sector modelling but in connection with one-period in advance price setting. They model imports and exports as intermediate goods, which are used in the production of final consumption goods. They assume that the l.o.p. holds for the intermediate goods, such that they are priced in the PCP manner, whilst final consumption goods are priced according to LCP. Devereux and Engel (2006) allow for alternative assumptions regarding the degree of price stickiness in both the intermediate and final goods sectors and also, which is important, allow for different degree of substitutability between home and foreign produced intermediates. The extent of expenditure switching is very dependant on this substitutability. Multi-sector models of this kind emphasize that firms at the intermediate level are confronted with a sourcing decision and the exact formulation of this pricing decision has important implications for optimal monetary policy.

Corsetti and Pesenti (2005) use a simple asymmetric price setting assumption where prices are pre-set one period in advance but nevertheless allow for more flexibility than in the earlier PCP and LCP models. Corsetti, Dedola and Leduc (2005) develop a two country quantitative DSGE model with traded and non-traded goods and incomplete exchange rate pass-through that stems from both nominal rigidities (LCP) and price discrimination. Price setting in their model builds on price-adjustment costs in the spirit of Rotemberg (1982).

Galí and Monacelli (2005) model price setting in a Calvo-type manner but do not follow a multi-sector approach and assume complete pass-through of exchange rate changes into final consumption goods prices. They derive a fully forward-looking output gap-based new Keynesian Phillips curve in a small open economy:

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[26] The working paper version of Kollman's paper was published in 1997.

[27] For empirical studies on exchange rate pass-through, see e.g. Engel (1993, 1999, 2002a, b), Taylor (2000), Campa and Goldberg (2002), Campa, Goldberg and González-Mínguez (2005), Freystätter (2003) and Marazzi et al (2005). Devereux, Engel and Storgaard (2004) represent a novel attempt to model endogenous exchange rate pass-through.

$$\pi_{H,t} = \beta E_t\{\pi_{H,t+1}\} + \kappa_\alpha x_t \tag{15}$$

where x_t is the domestic output gap and κ_α is a function of the inverse of the elasticity of labour supply and terms of trade, which is again a function of the degree of openness and the substitutability between domestic and foreign goods. This small open economy new Keynesian Phillips curve corresponds to the closed economy version in equation (1). The openness factor only affects the slope of the Phillips curve, i.e. how inflation responds to changes in the output gap. This brings Galí and Monacelli (2005) to conclude that the only differences between a closed economy new Keynesian model and their small open economy version are "(a) some coefficients of the equilibrium dynamical system for the small open economy depend on parameters that are special to the [open economy] (the degree of openness, and the substitutability across goods produced in different countries), and (b) the natural levels of output and interest rates in the small open economy are generally a function of both domestic and foreign disturbances. In particular, the closed economy is nested in the small open economy model, as a limiting case", (Galí and Monacelli, 2005: 727).

The inattentive approach has not been applied much to open economies. One exception is Khan and Zhu (2002, 2006) who build on Galí and Monacelli (2005) but introduce sticky information price setting in the Mankiw and Reis (2002) tradition. Hence, they derive an open-economy sticky information Phillips curve:

$$\pi_{H,t} = \frac{\lambda}{1-\lambda}\alpha_1 y_t + \frac{\lambda}{1-\lambda}\alpha_2 y_t^* + \lambda\sum_{j=0}^{\infty}(1-\lambda)^j E_{t-1-j}\left[\pi_{H,t} + \alpha_1 \Delta y_t + \alpha_2 y_t^*\right] \tag{16}$$

where λ is a structural parameter representing the degree of information stickiness at a given point of time. As it rises, the number of firms increases that use updated information when adjusting their prices, hence reducing the degree of information stickiness. y_t denotes the domestic output gap, y_t^* is the world output gap and α_i can be interpreted as the degree of real rigidity. Khan and Zhu (2002) find that the average information stickiness is four quarters in the U.S., between four and five quarters in Canada, and over seven quarters in the U.K. The open-economy estimates are very similar to the closed economy ones.

Galí and Monacelli (2005) and Khan and Zhu (2002, 2006) assume that PPP holds and there is complete exchange rate pass-through. How do the different kinds of open-economy Phillips curves look like when exchange rate pass-through is limited?

Monacelli (2005) makes a novel contribution.[28] He combines a Calvo-type staggered price setting with a multi-sector approach where exchange rate pass-through is incomplete. His model is a small open economy DSGE model with imperfect competition and nominal rigidities where incomplete exchange rate pass-through represents a crucial rigidity. The domestic economy is inhabited by infinitely-lived households consuming Dixit-Stiglitz aggregates of domestic and imported goods, domestic firms producing a differentiated good, and a continuum of importing firms that operate as price setters in the local market. All goods are tradable goods.[29] In his model domestic firms set prices in a staggered fashion under a standard Calvo price setting behaviour and domestic inflation is described by a forward-looking new Keynesian Phillips. The novel contribution is found in Monacelli's modelling of the dynamics of import pricing.

Vast empirical research has shown that the degree of exchange rate pass-through is incomplete in the short run, as mentioned earlier. Monacelli (2005) introduces a model to account for the empirical facts on pass-through. He assumes that the domestic market is populated by local retailers who import differentiated goods for which the l.o.p. holds "at the dock". In setting the domestic currency price of these goods the importers solve an optimal (dynamic) mark-up problem. This generates deviations from l.o.p. in the short run, while complete pass-through is reached asymptotically. This import price setting leads to a forward-looking new Keynesian Phillips curve for import goods:

$$\pi_{F,t} = \beta E_t\{\pi_{F,t+1}\} + \lambda_F \psi_{F,t} \qquad (17)$$

[28] His paper was first published as a working paper in 2002 by the ECB.

[29] An important assumption in Monacelli's model is that the size of the small open economy is negligible relative to the rest of the world, so the latter can be treated as a closed economy. This kind of setup allows the explicit modelling of the role of the financial markets and risk sharing and to overcome a typical problem of unit-root in consumption that characterizes traditional small open economy models with incomplete markets (see Schmitt-Grohe and Uribe, 2003, for a further discussion on this).

where $\lambda_F \equiv \frac{(1-\theta_F)(1-\beta\theta_F)}{\theta_F}$, θ_F is the degree of exchange rate pass-through and ψ_F is a l.o.p gap, discussed shortly. According to the Phillips curve above, import price inflation will rise if the world price of imports is higher than the local currency price of the same good. That means that if the domestic currency depreciates and there is incomplete exchange rate pass-through, a wedge will surface between the price that local retailers pay for their goods in the world markets and the local currency price they set in the domestic market. A rise in world prices in terms of the domestic currency, i.e. depreciation, will increase the marginal cost of the local retailers and thus increase foreign goods inflation. The second part of the right hand side of equation (17) is the interesting one. It shows that import price inflation depends on the l.o.p. gap, which again is determined by the degree of pass-through:

$$\psi_{F,t} = q_t - (1-\gamma)s_t = (e_t + p_t^*) - p_{F,t} \tag{18}$$

where $s_t \equiv p_{F,t} - p_{H,t}$ denotes the log terms of trade, i.e. the domestic currency relative price of imports , $e_t \equiv \log \mathrm{E}_t$ is the log nominal exchange rate, q_t is the log real exchange rate, γ is (inversely) related to the degree of home bias in preferences and thus a natural index of openness.[30]

The l.o.p gap is inversely proportionate to the real exchange rate and the degree of competitiveness for the domestic economy. Hence there are two roots of deviations from aggregate purchasing power parity (PPP) in Monacelli's model. First, the heterogeneity of consumption baskets between the small economy and the rest of the world, which effects are captured by the term $(1-\gamma)s_t$, as long as $\gamma < 1$. For $\gamma \to 1$, in fact, the two aggregate consumption baskets coincide and the relative price variations are not required in equilibrium. Second, deviations from the l.o.p., $\psi_{F,t}$, cause deviations from PPP. Hence with incomplete pass-through, the l.o.p. gap contributes to the volatility of the real exchange rate.

Equation (17) can be integrated forward to show that imports price inflation is a purely forward-looking variable:

[30] If γ=0 the small economy is a closed one.

$$\pi_{F,t} = E_t\left\{\sum_{k=0}^{\infty}\beta^k \lambda_F \psi_{F,t+k}\right\} \tag{19}$$

Aggregate inflation, i.e. the sum of domestic goods and imported goods inflation $\pi_t = (1-\gamma)\pi_{H,t} + \gamma\pi_{F,t} = \pi_{H,t} + \gamma\Delta s_t$, is then expressed by the following forward-looking new Keynesian Phillips curve:

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \kappa_y^c \tilde{y}_t + \kappa_\psi^c \psi_{F,t} \tag{20}$$

where $\tilde{y}_t$ is the output gap (defined as the percentage deviation of real output from its natural level, where the natural level is again defined as the one that would be obtained in the case of both flexible domestic prices and complete exchange rate pass-through), and $\psi_{F,t}$ is a l.o.p. gap (the deviation of the world price from the domestic currency price of imports).

Justiniano and Preston (2004) extend Monacelli's (2005) model by allowing for habit formation in consumption and hybrid price setting by indexation in the tradition of Christanio, Eichenbaum and Evans (2005).

9.1.2 The Role of Intermediate Inputs

The introduction of imported intermediate inputs into the production function drives a wedge between marginal costs and the labour share, which are equal within a Cobb-Douglas technology setting. Batini, Jackson and Nickell (2000, 2005) show that in this case, real marginal costs, rmc_t, depends on the labour share, $s_{L,t}$, and on the price of imported materials relative to the price of value added, $(p_{m,t} - p_t)$, (see appendix in Batini, Jackson and Nickell, 2000, for a full derivation of this relationship):

$$rmc_t = -\ln\alpha + s_{L,t} + \mu_3(p_{m,t} - p_t) \tag{21}$$

The price dynamics of imports is thus of great importance for aggregate inflation dynamics in this model. This fits well with the theoretical developments in price setting modelling in the NOEM literature discussed previously.

Time-varying price mark-ups represent a standard result in sticky price models in both closed and open-economy settings, as firms cannot all charge their desired mark-up without cost. But allowing for variations in the equilibrium price mark-up due to external competitive pressures is important in open economies. This is due to the fact that the equilibrium mark-up depends on the elasticity of demand facing the firm and this is affected by the level of competition the firm faces in the product market. Batini, Jackson and Nickell (2000, 2005) note that this competition level is influenced by the degree of foreign competition, secular shifts arising from anti-trust regulation or trade barriers, and the overall state of the domestic economy (which they capture by the output gap, measured in two different ways: a HP-filter method and a Cobb-Douglas production function approach). Their specification of the equilibrium price mark-up is thus:

$$\ln \mu_t^* = \mu_0 + z_{p,t} + \mu_1 (y_t - y_t^*) + \mu_2 (p_t^w - p_t) \tag{22}$$

where $z_{p,t}$ represents long-term secular shifts arising e.g. from changes in the rigor of antitrust regulation, $(p_t^w - p_t)$ is a measure of the weakness or strength of foreign competition, where p_t^w is the world price of domestic GDP in domestic currency terms, and $(y_t - y_t^*)$ denotes the output gap.

9.1.3 Real Rigidities

Amano and Murchison (2005) look at the consequences of introducing both firm-specific capital and adjustment costs to labour into a small open economy model with CES production technology that includes imported intermediate goods. They examine the ability of an open-economy new Keynesian Phillips curve in a hybrid form to capture the key features in Canadian inflation dynamics. They find that it is capable of replicating important moments of Canadian inflation data, both with regard to inflation inertia and price adjustment. This is a novel approach and combines various features that have been found important in modelling the Phillips curve in both closed and open economies, i.e. hybrid

price setting, marginal cost, labour market rigidities and specific factor markets. Future research efforts will undoubtedly stress the role of real rigidities in open-economy DSGE models, the combination of wage rigidities and labour market frictions, as in Christoffel and Linzert (2005), has for example not yet been carried out in an open-economy DSGE model.

9.2 Inflation Dynamics and the Open-Economy Phillips Curve

The success of Galí and Gertler (1999), Galí, Gertler and López-Salido (2001, 2003), and Sbordone (2002) to fit a hybrid, marginal cost based new Keynesian Phillips curve to both U.S. and euro area data led to application in other countries. Nelson (2002) questions the isomorphism result in Clarida et al. (2001, 2002), especially with regard to the open-economy Phillips curve. Kara and Nelson (2002) extend Nelson's (2002) work. They note that when exchange rate pass-through is complete, the open-economy new Keynesian Phillips curve becomes:

$$\pi_t = \beta E_t\{\pi_{t+1}\} + \alpha mc_t + \phi(\Delta q_t - \beta E_t \Delta q_{t+1}) + u_t, \alpha > 0, \phi > 0 \tag{23}$$

such that inflation depends on expected inflation and real marginal costs as in the closed economy case. The introduction of open-economy elements leads to the addition of the term $(\Delta q_t - \beta E_t \Delta q_{t+1})$ to the Phillips curve, i.e. current real exchange rate depreciation relative to the expected depreciation in the next period (where a rise in q denotes a real depreciation of the currency). Kara and Nelson (2002) estimate equation (23) using U.K. data and get an estimated value of ϕ that is of the wrong sign. They note that incomplete exchange rate pass-through cannot explain this feature, whereas backwardness in price setting is a possible explanation. But other problems emerge when they estimate a version of (23) with some backwardness in price setting, although the sign of ϕ is now correct. They thus conclude that "[e]stimates of the New Keynesian Phillips curve fail to deliver interpretable estimates on UK data, because (conditional on costs) they predict a tight relationship between real exchange rate change and inflation that is not supported by the data", (Kara and Nelson, 2002: 11).

Kara and Nelson (2002) investigate whether replacing the real exchange rate with import prices resolves the empirical problems of a Phillips curve of the form in equation (23) but without success. They also try to add the real exchange rate in levels to equation (23) and

find that it is significant and with the right sign. Kara and Nelson note that "the level term can be interpreted as capturing the presence of intermediate imported goods", (Kara and Nelson, 2002: 13).

Batini, Jackson and Nickell (2000, 2005) and Balakrishnan and López-Salido (2002) also estimate a new Keynesian Phillips curve on U.K. data and find that it is crucial for the fit of the curve to extend the model with open-economy factors, especially to allow for imported intermediate goods and variations in the equilibrium price mark-up due to external competitive pressures.[31] Balakrishnan and López-Salido (2002) note that this result reflects the openness of the U.K. economy, which is twice as open as the euro area and triple the U.S. level.[32] Barkbu and Batini (2005) reach a similar result for the Canadian case.

Batini, Jackson and Nickell (2000, 2005) estimate the following open-economy Phillips curve for the U.K. (in levels, they also estimate it in first differences) using GMM:

$$\pi_t = \alpha_0 + \phi E_{t-1}\pi_{t+1} + \alpha_1 E_{t-1} z_{p,t} + \alpha_{11} E_{t-1}(y_t - y_t^*) + \alpha_{12} E_{t-1}(p_t^w - p_t^*) + \alpha_1 E_{t-1} s_{L,t} + \alpha_{13} E_{t-1}(p_{m,t} - p_t) - \alpha_2 \phi E_{t-1}\Delta n_{t+1} + \alpha_2 E_{t-1}\Delta n_t + \upsilon_t \quad (24)$$

where ϕ is a discount factor, p_i^* is the log of the optimal price in the absence of dynamic adjustment costs and Δn_t denotes the change in the (log) employment while the rest of the variables were defined earlier in connection with equation (22). Their results are that these extensions to the hybrid Phillips curve of Galí and Gertler (1999) and Sbordone (2002) are crucial for the fit of the Phillips curve to the U.K. data. Second, they find that inflation is highly forward-looking with a coefficient on expected inflation equal to 0.69. Third, the labour share term is strongly significant and the additional cost elements (real import prices and the change in oil prices) are also important. Fourth, the employment adjustment costs are also very relevant for price setting and for inflation in general. Finally, they do not get significant values for the variables that are supposed to capture the variations in the price mark-up equilibrium value.

[31] Batini, Jackson and Nickell (2000, 2005) also find that employment adjustment plays an important role in generating inflation inertia in the dynamic price setting model underlying the new Keynesian Phillips curve. This introduction makes the labour share an inaccurate measure of marginal cost.

[32] Balakrishnan and López-Salido (2002) measure the degree of openness by the average levels of the sum of exports and imports as a percentage of GDP.

Scott (2004) points towards the need to incorporate strategic interplay to get variations in the equilibrium price mark-up value resulting from competition from abroad, for example in times of exchange rate appreciations. He says: "In particular, for the UK at least, it seems that we need to combine the time-varying mark-up that arises out of the standard sticky price models with tractable models of making mark-ups responsive to strategic interaction between importers and domestic producers", (Scott, 2004: 26). This is of course connected to the strategic complementarity discussion in Woodford (2005) and the price setting model in Devereux and Engel (2006), discussed previously.

Rumler (2005) introduces open-economy factors into a new Keynesian Phillips curve in a model where international trade takes place at two production levels. The price setting is a mixture of Calvo and a rule-of-thumb in the Galí and Gertler (1999) tradition. He compares hybrid marginal cost-based new Keynesian Phillips curves in three different settings: (i) a closed economy case, (ii) an open-economy case with only imported intermediate inputs, similar to the analysis in Batini, Jackson and Nickell (2000, 2005), and (iii) an open-economy case with both imported and domestically produced intermediate inputs, where substitution between the domestic and foreign intermediate inputs is important as in Devereux and Engel (2006). Real marginal cost is thus decomposed into the relative prices of three different production factors: real unit labour costs and the prices of imported and domestically produced intermediate goods. Rumler (2005) estimates the model for nine euro countries and the euro area aggregate. His results support the findings of Batini, Jackson and Nickell (2000, 2005) and Balakrishnan and López-alido (2002) that the open-economy aspects are of vital importance for the performance and fit of the new Keynesian Phillips curve.

Another interesting result in Rumler (2005) is that the price rigidity is systematically higher for the closed economy case than in the open-economy specification where there are only imported intermediate inputs, as in Batini, Jackson and Nickell (2000, 2005). Rumler (2005) proposes a possible explanation for this, "the fact that when firms face more variable input costs as they import from volatile international markets they tend to adjust their prices more frequently", (Rumler, 2005: 5). Allowing for the possible substitution between imported and domestically produced intermediate inputs, increases the degree of price rigidity, measured by the Calvo probability of adjustment in prices.

Guender (2006) introduces open-economy elements into the Phillips curve in a way comparable to Kara and Nelson (2002). His underlying motive is similar to Batini, Jackson and Nickell (2000, 2005), i.e. that competitive pressures from abroad will influence price setting by domestic firms. Guender (2006) does not provide a microfoundation for the introduction of open-economy factors into the price setting by domestic firms in a small open economy (although he derives an open-economy Phillips curve from the Calvo model in an appendix that is very similar to equation (25)). He claims that there exists a benchmark price that the firms face in world markets and that this price affects the optimal price charged by firms, i.e. that the domestic firms adjust their prices in line with the domestic currency price of the final goods charged by its foreign competitors. Guender (2006) hence gets an open-economy Phillips curve of the following form:

$$\pi_t = E_t\pi_{t+1} + ay_t + bq_t + u_t \tag{25}$$

where y_t is the output gap and q_t is the real exchange rate. Thus, in this setting the real exchange rate enters the Phillips curve directly. This has important implications for monetary policy and creates a trade-off between stabilizing inflation and output when the economy is hit by demand-side disturbances and exchange rate shocks. This trade-off arises as disturbances cause the inflation rate and real output to deviate from their target levels and hence amplifies the variance of both variables when the direct exchange rate channel is operative in the Phillips curve. An important assumption in Guender's (2006) model is that exchange rate pass-through is complete and PPP holds.

The Phillips curve in (25) is similar to the one in Svensson (2000) although the lag structure there is different, which is a point stressed in Svensson (2000). He notes that the exchange rate introduces additional channels for monetary policy which work through the economy with different lags.

Hunt (2006) estimates an open-economy small-scale new Keynesian model (without a microfoundation) from Icelandic data using Bayesian methods and uses it to trace out efficient monetary policy frontiers under simple inflation forecast-based monetary policy rules. He finds that the trade-off faced by monetary authorities in Iceland is much less favourable than those faced by central banks in Canada and the U.S. Aggregate supply is

modelled with an output gap-based hybrid Phillips curve where real exchange rate changes enter as an independent variable as in Guender (2006):

$$\pi_t = \delta_1 \pi_{t+4}^4 + (1-\delta_1)\pi_{t-1}^4 + \delta_2 ygap_{t-1} + \delta_3 \Delta z_t + \varepsilon_t^\pi \tag{26}$$

where π is the quarterly annualized rate of CPI inflation, π^4 is a four-quarter moving average of quarterly annualized CPI inflation, Δz is the first difference in the real exchange rate index, and ε^π is the stochastic error process.

10. Concluding Remarks

This paper endeavours to provide a bird's eye view of the vast and fertile literature on the controversial new Keynesian Phillips curve in recent years. The new Keynesian Phillips curve is the dominant approach to model inflation dynamics in macroeconomic theory and plays a key role in small-scale macroeconomic models used for monetary analysis. It can be derived from a model of optimizing price setting firms assumed operating within a monopolistic competition and subjected to barriers to price adjustments. The modelling of its microfoundation is nevertheless a matter of continuous debate as well as its ability to fit the empirical findings on inflation dynamics, as discussed in sections 3 and 4.

A large part of this paper is devoted to discuss the approaches that have been tried to improve the empirical fit of the new Keynesian Phillips curve in closed economies. Three paths can be distinguished, but this paper does not discuss state-dependant pricing in much detail. The spotlight is on mending the traditional sticky price framework or applying a new approach.

The former path to improve the new Keynesian Phillips curve involves staying within the traditional sticky price framework but allowing for some form of backwardness in expectation formation and price setting, as well as using the labour share instead of the output gap as a driving variable representing excess demand. This hybrid form has been heftily debated in recent years. Lately, real rigidities in various forms have been introduced to solve the empirical problems, which still emerge with the hybrid Phillips curve. Novel attempts to introduce search and matching frictions in the labour markets, as well as intriguing efforts to allow for firm-specific capital, give rise to renewed optimism that the empirical problems of the new Keynesian Phillips curve will decline in the near future.

These attempts still confront Krugman's (2000) critique, who asks whether this approach is building a proper microfoundation for aggregate supply or coming up with "micro-excuses". This question is still unanswered. On the other hand, Obstfeld and Rogoff (1995) criticize models which assume imperfect goods market but at the same time take complete financial markets for granted, i.e. the assumption that the economy is sophisticated enough to set up complete capital markets, but not sophisticated enough to avoid nominal rigidities. Christoffel and Linzert (2005) also emphasize the importance of allowing for both rigidities and frictions in labour markets, especially in models applied to policy analysis in Europe.

In this sense, new Keynesian economics has progressed in the last few years as the heterogeneous treatment of markets has decreased. Instead of focusing solely on nominal rigidities, mainly price stickiness in the goods markets, model-builders have widened their horizon and introduced various rigidities and imperfections in other markets and applied multi-sector modelling. This approach has given rise to more complicated inflation dynamics as rigidities in different markets interact and affect aggregate inflation. Hopefully, this increased complexity will bear fruit in terms of better understanding of inflation dynamics and improved inflation forecast.

The problem some see with this first approach to improve the new Keynesian Phillips curve is that the heterogeneous treatment of markets and the "ad-hockery" are still present. Various imperfections are assumed, different kind for each market and the microfoundation behind them is still to a certain degree fragile. Milani (2005) advocates learning as "a potential single mechanism, which can induce persistence without recurring to several modifications in different sides of the economy", (Milani, 2005: 34). Mankiw and Reis (2006) uphold the inattentive approach of limited information with similar arguments. Learning and the inattentive approach represent two novel examples of the latter path that emphasizes a new approach to improve the new Keynesian Phillips curve and new Keynesian economics in general. Both are simple and elegant ideas, although they are somewhat difficult in derivation, and important progress has been made in the last couple of years towards making them fully-fledged and serious macroeconomic models. More empirical studies of these kinds of models are needed before they can be adapted to practical use in monetary analysis. This will undoubtedly be a red-hot research area in the near future

and will hopefully provide better evidence as to which path to follow to improve the new Keynesian Phillips curve. For now, the jury is still out.

The open-economy new Keynesian Phillips curve faces bigger problems than its closed-economy counterpart. It is therefore not surprising that it has further to go. First, the adaptation to the open economy must take into account that price setting is influenced by the choice of currency, competition from abroad and exchange rate pass-through into the prices. Second, the choice of a proper measure for real disequilibrium is more complicated as the relationship between marginal costs and the labour share is influenced by the option that producer have between imported and domestic intermediate inputs. Third, estimation and forecasting is more difficult as exchange rate dynamics and foreign shocks play an important role in the inflation process. Finally, the introduction of real rigidities and various other forms of market imperfections is harder to model in an open-economy framework characterized by increased globalization.

The productive NOEM literature has made important contributions to the adaptation of the new Keynesian Phillips curve to the open economy, especially with regard to modelling price setting and exchange rate pass-through. The works of Batini, Jackson and Nickell (2000, 2005) and Balakrishnan and López-Salido (2002) are good examples of empirical use of some of the theoretical contributions of the NOEM literature. Increased efforts to introduce real rigidities into the microfoundation of the open-economy Phillips curve, in the spirit of what Christoffel and Linzert (2005) and Woodford (2005) have done in the closed economy framework, will surely take place in the near future. Furthermore, the promising new approaches, i.e. learning and the inattentive model, have not yet been applied to open economies to a large extent. Hence, it is obvious that although the adaptation of the new Keynesian Phillips curve to the open economy has far to go, important progress has taken place in the last few years and there are many intriguing paths waiting to be explored.

References

1. Adolfson, Malin, Michael K. Andersson, Jesper Lindé, Mattias Villani, and Anders Vredin, (2005). "Modern Forecasting Models in Action: Improving Macroeconomic Analyses at Central Banks", *Sveriges Riksbank Working Paper Series* No. 188.
2. Adolfson, Malin, Stefan Laséen, Jesper Lindé and Mattias Villani, (2005a). "Evaluating an Estimated New Keynesian Small Open Economy Model", paper presented at the conference: *DSGE Modeling at Policymaking Institutions: Progress & Prospects*, December 2-3, 2005, Federal Reserve Board, Washington D.C.
3. Adolfson, Malin, Stefan Laséen, Jesper Lindé and Mattias Villani, (2005b). "Bayesian Estimation of an Open Economy DSGE Model with Incomplete Pass-Through", *Sveriges Riksbank Working Paper Series* No 179.
4. Adolfson, Malin, Stefan Laséen, Jesper Lindé and Mattias Villani, (2005c). "Empirical Properties of Closed and Open Economy DSGE Models of the Euro Area", mimeo.
5. Altissimo, Filippo, Laurent Bilke, Andrew Levin, Thomas Mathä, and Benoit Mojon, (2006). "Sectoral and Aggregate Inflation Dynamics in the Euro Area", *Journal of the European Economic Association* 4 (2-3), pp. 585-593.
6. Altissimo, Filippo, Michael Ehrmann, and Frank Smets, (2006). "Inflation Persistence and Price-Setting Behaviour in the Euro Area: A Summary of the IPN Evidence", *ECB Occasional Paper Series* No. 46.
7. Alvarez-Lois, Pedro, Richard Harrison, Laura Piscitelli, and Alsdair Scott, (2005). "Taking DSGE Models to the Policy Environment", paper presented at the conference: *DSGE Modeling at Policymaking Institutions: Progress & Prospects*, December 2-3, 2005, Federal Reserve Board, Washington D.C.
8. Amano, Robert and Stephen Murchinson, (2005). "Factor-Market Structure, Shifting Inflation Targets and the New Keynesian Phillips Curve", paper prepared for the Bank of Canada Economic Conference on *Issues in Inflation Targeting*, held in Ottowa April 28-29, 2005.
9. An, Sungbae, and Frank Schorfheide, (2005). "Bayesian Analysis of DSGE Models", paper prepared for a special issue of *Econometric Review*, dated December 7, 2005 (an earlier edition was published as a CEPR Discussion Paper No 5207).
10. Andersen, Torben M., (1998). "Persistency in Sticky Price Models", *European Economic Review* 42, pp. 593-603.
11. Andersen, Torben M. and Niels C. Beier, (2005). "International Transmission of Monetary Shocks under Imperfect Information", *Journal of International Economics* 66 (2), pp. 485- 507.
12. Angeloni, Ignazio, Anil K. Kashyap, Benoit Mojon, and Daniele Terlizzese, (2002). "Monetary Transmission in the Euro Area: Does the Interest Rate Channel Explain All?", *NBER Working Paper Series* No. 9984.
13. Angeloni, Ignazio, Luc Aucremanne, Michael Ehrmann, Jordi Galí, Andrew Levin and Frank Smets, (2006). "New Evidence on Inflation Persistence and Price Stickiness in the Euro Area: Implications for Macro Modelling", *Journal of the European Economic Association* 4 (2-3), pp. 562-574.
14. Álvarez, Luis J., Pablo Burriel, and Ignacio Hernando, (2005). "Do Decreasing Hazard Functions for Price Changes Make Any Sense?", *ECB Working Paper Series* No. 461.
15. Álvarez, Luis J., Emmanuel Dhyne, Marco M. Hoeberichts, Claudia Kwapil, Hervé Le Bihan, Patrick Lünnemann, Fernando Martins, Roberto Sabbatini, Harald Stahl, Philip Vermeulen and Jouko Vilmunen, (2006). "Sticky Prices in the Euro Area: A Summary of New Micro Evidence", *Journal of the European Economic Association* 4 (2-3), pp. 575-584.
16. Balakrishnan, Ravi and J. D. López-Salido, (2002). "Understanding UK Inflation: the Role of Openness", *Bank of England Working Paper* No. 164.
17. Ball, Laurence, and David Romer, (1990). "Real Rigidities and the Non-neutrality of Money", *Review of Economic Studies* 57, pp. 183-203.
18. Ball, Laurence, (1994a). "Credible Disinflation with Staggered Price Setting", *American Economic Review* 84 (March), pp. 282-289.
19. Ball, Laurence, (1994b). "What Determines the Sacrifice Ration?", in N.G. Mankiw (ed.) *Monetary Policy*, University of Chicago Press, Chicago, pp. 155-182.
20. Ball, Laurence, (1999). "Policy Rules for Open Economies", in John Taylor (ed.) *Monetary Policy Rules*, University of Chicago Press, Chicago, pp. 127-144.
21. Ball, Laurence, N. Gregory Mankiw, and Ricardo Reis, (2005). "Monetary Policy for Inattentive Economies", *Journal of Monetary Economics* 52, pp. 703-725.

22. Barkbu, Bergljot Bjørnson and Nicoletta Batini, (2005). "The New-Keynesian Phillips Curve when Inflation Is Non-Stationary: The Case of Canada", paper presented at the Bank of Canada Economic Conference on *Issues in Inflation Targeting*, held in Ottowa April 28-29, 2005.
23. Batini, Nicoletta, Richard Harrison and Stephan P. Millard, (2001). "Monetary Rules for an Open Economy", *Norges Bank's Working Paper* 2001/4.
24. Batini, Nicoletta, Brian Jackson and Stephen Nickell, (2000). "Inflation Dynamics and the Labour Share in the UK", *External MPC Unit Discussion Paper* No. 2.
25. Batini, Nicoletta, Brian Jackson and Stephen Nickell, (2005). "An Open-economy New Keynesian Phillips Curve for the U.K.", *Journal of Monetary Economics* 52, pp. 1061-1071.
26. Berg, Andrew, Phillips Karam, and Douglas Laxton, (2006a). "A Practical Model-Based Approach to Monetary Policy Analysis – Overview", *IMF Working Paper* 06/80.
27. Berg, Andrew, Phillips Karam, and Douglas Laxton, (2006b). "Practical Model-Based Monetary Policy Analysis – A How-To Guide", *IMF Working Paper* 06/81.
28. Betts, Caroline, and Michael B. Devereux, (1996). "The Exchange Rate in a Model of Pricing-to-Market", *European Economic Review* 40, pp. 1007-1021.
29. Betts, Caroline, and Michael B. Devereux, (2000). "Exchange Rate Dynamics in a Model of Pricing-to-Market", *Journal of International Economics* 50, pp. 215-244.
30. Bils, Mark and Peter J. Klenow, (2004). "Some Evidence on the Importance of Sticky Prices", *Journal of Political Economy* 112 (5), pp. 947-985.
31. Binette, André, Stephan Murchison, Patrick Perrier, and Andrew Rennison, (2004). "An Introduction to TOTEM", mimeo dated October 27, 2004.
32. Blanchard, Oliver Jean, and Danny Quah, (1989). "The Dynamic Effects of Aggregate Demand and Supply Disturbances", *American Economic Review* 79 (4), pp. 655-673.
33. Blanchard, Oliver Jean, and Nobuhiro Kiyotaki, (1987). "Monopolistic Competition and the Effects of Aggregate Demand", *American Economic Review* 77 (September), pp. 647-666.
34. Blanchard, Oliver Jean, and Stanley Fischer, (1989). *Lectures on Macroeconomics*. 11th printing 1998, MIT press, Cambridge, Massachusetts.
35. Blanchard, Oliver Jean, and Jordi Galí, (2005). "Real Wage Rigidity and the New Keynesian Model", *CEPR Discussion Paper* No. 5375.
36. Blinder, Alan S., Elie R. D. Canetti, David E. Lebow, and Jeremy B. Rudd, (1998). *Asking About Prices. A New Approach to Understanding Price Stickiness*, Russell Sage Foundation, New York, U.S.A.
37. Bowman, David, and Brian Doyle, (2003). "New Keynesian Open-Economy Models and Their Implications for Monetary Policy", Board of Governors of the Federal Reserve System. *International Finance Discussion Papers*, no. 762.
38. Branch, William A., (forthcoming). "Sticky Information and Model Uncertainty in Survey Data on Inflation Expectations", *Journal of Economic Dynamics and Control,* forthcoming.
39. Branch, William A., (2004). "The Theory of Rationally Heterogeneous Expectations: Evidence From Survey Data on Inflation Expectations", *Economic Journal* 114 (July), pp. 592-621.
40. Brayton, Flint, Andrew Levin, Ralph Tryon, and John C. Williams, (1997). "The Evolution of Macro Models at the Federal Reserve Board", *Carnegie-Rochester Conference Series on Public Policy* 47, pp.43-81.
41. Brock, William A. and Cars H. Hommes, (1997). "A Rational Route To Randomness", *Econometrica* 65, pp. 1059-1096.
42. Bullard, James B., (2006). "The Learnability Criterion and Monetary Policy", Federal Reserve Bank of St. Louis *Review* May/June 2006, pp. 203-218.
43. Bårdsen, Gunnar, Øyvind Eitrheim, Eilev S. Jansen, and Ragnar Nymoen, (2005). *The Econometrics of Macroeconomic Modelling. Advanced Texts in Econometrics*. Oxford University Press, Oxford, U.K.
44. Calvo, Guillermo, (1983). "Staggered Prices in a Utility-Maximizing Framework", *Journal of Monetary Economics* 12 (3), pp. 383-398.
45. Cambell, John Y. and N. Gregory Mankiw, (1987a). "Are Output Fluctuations Transitory", *Quarterly Journal of Economics* 102, pp. 857-880.
46. Cambell, John Y. and N. Gregory Mankiw, (1987b). "Permanent and Transitory Components in Macroeconomic Fluctuations", *Americal Economic Review Proceedings*, May 1987, pp. 111-117.
47. Campa, José Manuel and Linda S. Goldberg, (2002). "Exchange Rate Pass-Through into Import Prices: A Macro or Micro Phenomenon?", *NBER Working Paper Series* No. 8934.
48. Campa, José Manuel, Linda S. Goldberg and José M. González-Mínguez, (2005). "Exchange-Rate Pass-Through to Import Prices in the Euro Area", *NBER Working Paper Series* No. 11632.

49. Cecchetti, Stephan G., and Guy Debelle, (2006). "Inflation Persistence. Does It Change?", *Economic Policy* April 2006, pp. 311-352.
50. Central Bank of Iceland (2006). *Monetary Bulletin*, 2006/1.
51. Chari, V.V., Patrick J. Kehoe, and Ellen R. McGrattan, (2000). "Sticky Price Models of the Business Cycle: Can the Contract Multiplier Solve the Persistence Problem?", *Econometrica* 68 (5), pp. 1151-1179.
52. Christiano, Lawrence J., Martin Eichenbaum and Charles L. Evans, (2005). "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy", *Journal of Political Economy* 113 (11), pp. 1-45.
53. Christoffel, Kai, and Tobias Linzert, (2005). "The Role of Real Wage Rigidity and Labor Market Frictions for Unemployment and Inflation Dynamics", *ECB Working Paper Series* No. 556.
54. Christoffel, Kai, Keith Küster, and Tobias Linzert, (2006). "Identifying the Role of Labor Markets for Monetary Policy in an Estimated DSGE Model", *Deutsche Bundesbank Discussion Paper Series 1: Economic Studies* No. 17/2006.
55. Clarida, Richard, Jordi Gali, and Mark Gertler, (1999). "The Science of Monetary Policy: A New Keynesian Perspective", *Journal of Economic Literature* 37 (4), pp. 1661-1707.
56. Clarida, Richard, Jordi Gali, and Mark Gertler, (2001). "Optimal Monetary Policy in Open Versus Closed Economies: An Integrated Approach", *American Economic Review* 91 (2), pp. 248-252.
57. Clarida, Richard, Jordi Galí, and Mark Gertler, (2002). "A Simple Framework for International Monetary Policy Analysis", *Journal of Monetary Economics* 49 (5), pp. 879-904.
58. Coletti, Donald, Benjamin Hunt, David Rose, and Robert Tetlow, (1996). *Bank of Canada's New Quarterly Projection Model. Part 3. The Dynamic Model: QPM*, Bank of Canada.
59. Collard, Fabrice, and Harris Dellas, (2004). "The New Keynesian Model with Imperfect Information and Learning", mimeo.
60. Cooley, Thomas F. and Mark Dwyer, (1998). "Business Cycle Analysis without Much Theory: A Look at Structural VARs", *Journal of Econometrics* 83, pp. 57-88.
61. Corsetti, Giancarlo and Paolo Pesenti, (2005). "International Dimensions of Optimal Monetary Policy", *Journal of Monetary Economics* 52, pp. 281–305.
62. Corsetti, Giancarlo, Luca Dedola and Sylvain Leduc, (2005). "DSGE Models of High Exchange-Rate Volatility and Low Pass-through", Board of Governors of the Federal Reserve System *International Finance Discussion Paper Series* No. 845.
63. Cùrdia, Vasco, and Daria Finocchiaro, (2005). "An Estimated DSGE Model for Sweden with a Monetary Regime Change", *Institute for International Economic Studies Seminar Paper* No. 740, Stockholm University.
64. Danziger, Leif, (1999). "A Dynamic Economy with Costly Price Adjustments", *American Economic Review* 89, pp. 878-901.
65. Del Negro, Marco and Frank Schorfheide, (2003). "Take Your Model Bowling: Forecasting with General Equilibrium Models", *Federal Reserve Bank of Atlanta Economic Review*, fourth quarter 2003, pp. 35-50.
66. Del Negro, Marco and Frank Schorfheide, (2005). "Monetary Policy Analysis with Potentially Misspecified Models", *Federal Reserve Bank of Atlanta Working Paper Series* No. 2005-26.
67. Del Negro, Marco, Frank Schorfheide, Frank Smets, and Raf Wouters, (2006). "On the Fit of New-Keynesian Models", mimeo dated March, 2006, the paper will serve as the Invited JBES Lecture at the 2006 Joint Statistical Meetings of the American Statistical Assocication in Seattle.
68. Devereux, Micael B., (2001). "Monetary Policy, Exchange Rate Flexibility and Exchange Rate Pass-through", Bank of Canada Conference *Revisiting the Case for Flexible Exchange Rates.*
69. Devereux, Micael B. and Charles Engel, (2002). "Exchange Rate Pass-through, Exchange Rate Volatility, and Exchange Rate Disconnect", *Journal of Monetary Economics* 49, pp. 913–940.
70. Devereux, Micael B. and Charles Engel, (2003). "Monetary Policy in the Open Economy Revisited: Price Setting and Exchange-Rate Flexibility", *Review of Economic Studies*, 70(4), pp. 765-783.
71. Devereux, Michael B., and Charles Engel, (2006). "Expenditure Switching vs. Real Exchange Rate Stabilization: Competing Objectives for Exchange Rate Policy.", ECB Working Paper Series No. 614.
72. Devereux, Micael B., Charles Engel and Peter E. Storgaard, (2004). "Endogenous Exchange Rate Pass-through when Nominal Prices are Set in Advance", *Journal of International Economics* 63, pp. 263– 291.
73. Diebold, Francis X., (1998). "The Past, Present, and Future of Macroeconomic Forecasting", *Journal of Economic Perspectives,* 12 (2), pp. 175-192.
74. Dotsey, Michael and Robert G. King, (2005). "Implications of State-Dependant Pricing for Dynamic Macroeconomic Models", *Journal of Monetary Economics* 52, pp. 213-242.
75. Dotsey, Michael, Robert G. King and Alexander L. Wolman, (1999). "State Dependant Pricing and the General Equilibrium Dynamics of Money and Output", *Quarterly Journal of Economics* 104, pp. 655-690.

76. Duarte, Margarida and Maurice Obstfeld, (2004). "Monetary Policy in the Open Economy Revisited: The Case for Exchange-Rate Flexibility Restored", Working Paper available at: http://elsa.berkeley.edu/~obstfeld/DEnote.pdf
77. Dufour, Jean-Marie, Lynda Khalaf, and Maral Kichian, (2005). "Inflation Dynamics and the New Keynesian Phillips Curve: An Identification-Robust Econometric Analysis", *Journal of Economic Dynamics and Control* 30, pp. 1707-1727.
78. Dupuis, David, (2004). "The New Keynesian Hybrid Phillips Curve: An Assessment of Competing Specifications for the United States", *Bank of Canada Working Paper* No. 2004-31.
79. Edge, Rochelle M., Michael T. Kiley, and Jean-Philippe Laforte, (2005a). "An Estimated DSGE Model of the US Economy", paper provided as background material at the conference: *DSGE Modeling at Policymaking Institutions: Progress & Prospects*, December 2-3, 2005, Federal Reserve Board, Washington D.C.
80. Edge, Rochelle M., Jean-Philippe Laforte, and Michael T. Kiley, (2005b). "Documentation of the 2005 Version of the MAQS Dynamic Stochastic General Equilibrium Model of the U.S. Economy", paper provided as background material at the conference: *DSGE Modeling at Policymaking Institutions: Progress & Prospects*, December 2-3, 2005, Federal Reserve Board, Washington D.C.
81. Edge, Rochelle M., Michael T. Kiley, and Jean-Philippe Laforte, (2005c). "An Estimated DSGE Model of the US Economy with an Application to Natural Rate Measures", paper presented at the conference: *DSGE Modeling at Policymaking Institutions: Progress & Prospects*, December 2-3, 2005, Federal Reserve Board, Washington D.C.
82. Eichenbaum, Martin, and Jonas D.M. Fisher, (2004). "Evaluating the Calvo Model of Sticky Prices", *NBER Working Paper Series* No. 10617.
83. Engel, Charles, (1993). "Real Exchange Rates and Relative Prices: An Empirical Investigation", *Journal of Monetary Economics* 32, pp. 35-50.
84. Engel, Charles, (1999). "Accounting for U.S. Real Exchange Rate Changes", *Journal of Political Economy* 107, pp. 507-538.
85. Engel, Charles, (2002a). "Expenditure Switching and Exchange Rate Policy", *NBER Macroeconomics Annual*, MIT Press, Cambridge, MA.
86. Engel, Charles, (2002b). "The Responsiveness of Consumer Prices to Exchange Rates: A Synthesis of Some New Open Economy Macro Models", *The Manchester School Supplement*, pp. 1-15.
87. Erceg, Christopher, J., Dale W. Henderson and Andrew T. Levin, (2000). "Optimal Monetary Policy with Staggered Wage and Price Contracts", *Journal of Monetary Economics,* 46 (2), pp. 281-313.
88. Erceg, Christopher, and Andrew T. Levin, (2003). "Imperfect Credibility and Inflation Persistence", *Journal of Monetary Economics* 50, pp. 915-944.
89. Erceg, Christopher J., Luca Guerrieri, and Christopher Gust, (2006). "SIGMA: A New Open Economy Model for Policy Analysis", *International Journal of Central Banking* 2 (1), pp.1-50.
90. Evans, George W., and Seppo Honkapohja, (2001). *Learning and Expectations in Macroeconomics*, Princeton University Press, Princeton.
91. Fabiani, Sylvia, Martine Druant, Ignacio Hernando, Claudia Kwapil, Bettina Landau, Claire Loupias, Fernando Martins, Thomas Y. Mathä, Roberto Sabbatini, Harald Stahl, and Ad C.J. Stokman, (2005). "The Pricing Behaviour of Firms in the Euro Area. New Survey Evidence", *ECB Working Paper Series* No. 535.
92. Fehr, Ernst, and Jean-Robert Tyran, (2002). "Limited Rationality and Strategic Interaction. The Impact of the Strategic Environment on Nominal Inertia", *University of St. Gallen Department of Economics Discussion Paper* No. 2002-25.
93. Fehr, Ernst, and Jean-Robert Tyran, (2005). "Individual Irrationality and Aggregate Outcomes", *Department of Economics at the University of Copenhagen Discussion Papers* No. 05-09.
94. Fischer, Stanley, (1977). "Long-term Contracts, Rational Expectations, and the Optimal Money Supply Rule", *Journal of Political Economy* 85, pp. 191-205.
95. Flamini, Alessandro, (2003). "CPI Inflation Targeting and Exchange Rate Pass Through", mimeo.
96. Freystätter, Hanna (2003). "Price Setting Behaviour in an Open Economy and the Determination of Finnish Foreign Trade Prices", *Bank of Finland Studies* No. E:25-2003.
97. Friedman, Milton, (1968). "The Role of Monetary Policy", *American Economic Review* 58 (1), pp. 1-17.
98. Frydman, Roman, and Edmund S. Phelps (eds.), (1983). *Individual Forecasting and Aggregate Outcomes: "Rational Expectations" Examined*, Cambridge University Press, New York.
99. Fuhrer, Jeffrey C. and George R. Moore, (1995). "Inflation Persistence", *The Quarterly Journal of Economics* 110, pp. 127-159.
100. Fuhrer, Jeffrey C., (2005). "Intrinsic and Inherited Inflation Persistence", *Federal Reserve Bank of Boston Working Paper* No. 05-8.

101. Fukac, Martin, and Adrian Pagan, (2006). "Issues in Adopting DSGE Models for Use in the Policy Process", *CAMA Working Paper Series* No. 10/2006.
102. Gabaix, Xavier, and David Laibson, (2002). "The 6D Bias and the Equity Premium Puzzle", *NBER Macroeconomics Annual 2001*, pp. 257-311.
103. Galí, Jordi, and Mark Gertler, (1999). "Inflation Dynamics: A Structural Econometrics Analysis", *Journal of Monetary Economics* 44, pp. 195-222.
104. Galí, Jordi, Mark Gertler, and J. D. López-Salido, (2001). "European Inflation Dynamics", *Europan Economic Review* 45, pp. 1237-70.
105. Galí, Jordi, Mark Gertler, and J. D. López-Salido, (2003). "Erratum to 'European Inflation Dynamics'", *Europan Economic Review* 47, pp. 759-760.
106. Galí, Jordi, Mark Gertler, and J. D. López-Salido, (2005a). "Robustness of the Estimates of the Hybrid New Keynesian Phillips Curve", *Journal of Monetary Economics* 52, pp. 1107-1118.
107. Galí, Jordi, Mark Gertler, and J. D. López-Salido, (2005b). "Markups, Gaps, and the Welfare Costs of Business Fluctuations", draft version from May 2005.
108. Galí, Jordi and Tommaso Monacelli, (2005). "Monetary Policy and Exchange Rate Volatility in a Small Open Economy", *Review of Economic Studies* 72, pp. 707-734.
109. Golosov, Mikhail and Robert E. Lucas, (2003). "Menu Costs and Phillips Curves", *NBER Working Paper* No. 10187.
110. Goodfriend, Marvin, (2004). "Monetary Policy in the New Neoclassical Synthesis: A Primer", Federal Reserve Bank of Richmond *Economic Quarterly* 90 (3), pp. 21-45.
111. Guay, Alain and Florian Pelgrin, (2004). "The U.S. New Keynesian Phillips Curve: An Empirical Assessment", *Bank of Canada Working Paper* 2004-35.
112. Guender, Alfred V., (2006). "Stabilising Properties of Discretionary Monetary Policies in a Small Open Economy", *Economic Journal*, 116 (January), pp. 309-326.
113. Hall, Robert E., (2005). "Separating the Business Cycle from Other Economic Fluctuations", conference paper presented in *The Greenspan Era: Lessons for the Future*, a symposium sponsored by the Federal Reserve Bank of Kansas City, held in Jackson Hole, Wyoming, August 25-27, 2005.
114. Harrison, Richard, Kalin Nikolov, Meghan Quinn, Gareth Ramsay, Alasdair Scott, and Ryland Thomas, (2005). *The Bank of England Quarterly Model*, Bank of England, London.
115. Henry, S. G. B. and A. R. Pagan, (2004). "The Econometrics of the New Keynesian Policy Model: Introduction", *Oxford Bulletin of Economics and Statistics* 66, Supplement, pp. 581-607.
116. Hunt, Benjamin, (2006). "Simple Efficient Policy Rules and Inflation Control in Iceland", *Central Bank of Iceland Working Paper* No. 30.
117. Johnson, Harry G., (1974). "Major Issues in Monetary Economics", *Oxford Economic Papers* 26 (2), pp. 212-225.
118. Jondeau, Eric, and Hervé Le Bihan, (2005). "Testing for the New Keynesian Phillips Curve. Additional International Evidence", *Economic Modelling* 22, pp. 521-550.
119. Joundeau, Eric, and Jean-Guillaume Sahuc, (2006). "Optimal Monetary Policy in an Estimated DSGE Model of the Euro Area with Cross-country Heterogeneity", *Banque de France Working Papers* NER-R#141.
120. Juillard, Michel, Philippe Karam, Douglas Laxton, and Paolo Pesenti, (2005). "Welfare-Based Monetary Policy Rules in an Estimated DSGE Model of the US Economy", Unfinished draft of a paper to be presented at the III International Research Forum on Monetary Policy, European Central Bank, May 2005.
121. Juillard, Michel, Ondra Kamenik, Michael Kumhof, and Douglas Laxton, (2005). "Optimal Price Setting and Inflation Inertia in a Rational Expectations Model", paper presented at the conference: *DSGE Modeling at Policymaking Institutions: Progress & Prospects*, December 2-3, 2005, Federal Reserve Board, Washington D.C.
122. Kara, Amit and Edward Nelson, (2002). "The Exchange Rate and Inflation in the UK", *External MPC Unit Discussion Paper* No. 11, Bank of England.
123. Khan, Hashmat and Zhenhua Zhu, (2002). "Estimates of the Sticky-Information Phillips Curve for the United States, Canada and the United Kingdom", *Bank of Canada Working Paper* 2002-19.
124. Khan, Hashmat and Zhenhua Zhu, (2006). "Estimates of the Sticky-Information Phillips Curve for the United States", *Journal of Money, Credit and Banking* 38 (1), pp. 195-207.
125. Kiley, Michael T., (2002). "Partial Adjustment and Staggered Price Setting", *Journal of Money, Credit, and Banking* 34 (2), PP. 283-298.
126. Kiley, Michael T., (2005). "A Quantitative Comparison of Sticky-Price and Sticky-Information Models of Price Setting", Paper presented at *Quantitative Evidence on Price Determination,* conference held in Washington

D.C. September 29-30, 2005, and sponsored by the Federal Reserve Board and the Journal of Money, Credit, and Banking.
127. Kilponen, Juha, Mika Kuismanen, Antti Ripatti, and Jouko Vilmunen, (2004). "Aino: A DGE Model of the Finnish Economy – Some Modelling Issues", presentation at *Inflation Dynamics in General Equilibrium Macro Models* - a workshop hosted by the Bank of Finland, held in Helsinki, 17-19 May 2004.
128. Kimball, Miles S., (1995). "The Quantitative Analytics of the Basic Neomonetarist Model", *Journal of Money, Credit and Banking* 27 (4), pp. 1241-1277.
129. Krugman, Paul. R., (1987). "Pricing to Market when the Exchange Rate Changes", in Sven Arndt and J. David Richardson eds. *Real-financial Linkages among Open Economies*, Cambridge University Press, U.K.
130. Krugman, Paul R., (2000). "How Complicated Does the Model Have To Be?", *Oxford Review of Economic Policy* 16 (4), pp. 33-42.
131. Kurmann, André, (2005). "Quantifying the Uncertainty About the Fit of the New Keynesian Pricing Model", *Journal of Monetary Economics* 52, pp. 1119-1134.
132. Kydland, Finn E. and Edward C. Prescott, (1982). "Time to Build and Aggregate Fluctuations", *Econometrica* 50 (November), pp. 1345-1370.
133. Lam, Jean-Paul, (2003). "Alternative Targeting Regimes, Transmission Lags, and the Exchange Rate Channel", *Bank of Canada Working Paper* 2003-39.
134. Lane, Philip R., (2001). "The New Open Economy Macroeconomics: A Survey", *Journal of International Economics* 54 (2), pp. 235-266.
135. Laxton, Douglas and Paolo Pesenti, (2003). "Monetary Rules for Small, Open, Emerging Economies", *Journal of Monetary Economics* 50 (5), pp. 1109-1146.
136. Lee, Yoonsok, (2004). "Performance of Monetary Policy Rules in Small Open Economies", mimeo. Available at https://netfiles.uiuc.edu/yoonlee1/www/rules-com6.pdf
137. Leitemo, Kai, (1999). "Inflation Targeting Strategies in Small Open Economies", Department of Economics, University of Oslo, Working Paper 21/99.
138. Lindé, Jesper, (2005). "Estimating the New-Keynesian Phillips Curves: A Full Information Maximum Likelihood Approach", *Journal of Monetary Economics* 52, pp. 1135-1149.
139. Liu, Philip, (2005). "A Small New Keynesian Model of the New Zealand Economy", Paper presented at The Reserve Bank of New Zealand DSGE Workshop in August 2005.
140. Long, John B. and Charles I. Plosser, (1983). "Real Business Cycles", *Journal of Political Economy* 91 (February), pp. 39-69.
141. Lucas, Robert E., Jr. (1972). "Expectations and the Neutrality of Money", *Journal of Economic Theory* 4, pp. 103-124.
142. Lucas, Robert E., Jr. (1973). "Some International Evidence on Output-Inflation Tradeoffs", *American Economic Review* 63, pp. 326-334.
143. Lucas, Robert E., Jr. (1976). "Economic Policy Evaluation: A Critique", *Carnegie-Rochester Conference Series on Public Policy* 1, pp. 19-46.
144. Mankiw, N. Gregory, (2001). "The Inexorable and Mysterious Tradeoff between Inflation and Unemployment", *The Economic Journal* 111, C45-C61.
145. Mankiw, N. Gregory, (2006). "The Macroeconomist as Scientist and Engineer", mimeo. Available at http://post.economics.harvard.edu/faculty/mankiw/papers/Macroeconomist_as_Scientist.pdf
146. Mankiw, N. Gregory and Ricardo Reis, (2003). "Sticky Information: A Model of Monetary Nonneutrality and Structural Slumps", in P. Aghion, R. Frydman, J. Stiglitz and M. Woodford eds., *Knowledge, Information, and Expectations in Modern Macroeconomics: In Honor of Edmund S. Phelps*, Princeton University Press, USA.
147. Mankiw, N. Gregory and Ricardo Reis, (2002). "Sticky Information versus Sticky Prices: A Proposal to Replace the New Keynesian Phillips Curve", *Quarterly Journal of Economics* 117 (4), pp. 1295-1328.
148. Mankiw, N. Gregory and Ricardo Reis, (2006). "Pervasive Stickiness (Expanded Version)", *NBER Working Paper Series* No. 12024.
149. Mankiw, N. Gregory, Ricardo Reis, and Justin Wolfers, (2003). Disagreement About Inflation Expectations", *NBER Working Paper Series* No. 9796.
150. Mankiw, N. Gregory, and David Romer (eds.), (1991). *New Keynesian Macroeconomics*, 2 vols., MIT Press, Cambridge.
151. Marazzi, Marion, Nathan Sheets, and Robert Vigfusson, and Jon Faust, Joseph Gagnon, Jaime Marquez, Robert Martin, Trevor Reeve, John Rogers, (2005). "Exchange Rate Pass-Through to U.S. Import Prices: Some Evidence", *Board of Governors of the Federal Reserve System International Finance Discussion Papers* No. 833.
152. McCallum B. and Edward Nelson, (1999). "An Optimizing IS-LM Specification for Monetary Policy and Business Cycle Analysis", *Journal of Money, Credit and Banking* 31 (3), pp. 296-316.

153. Medina, Juan Pablo, and Claudio Sota, (2005). "Model for Analysis and Simulations (MAS)", preliminary version dated August 2005.
154. Milani, Fabio, (2005a). "Adaptive Learning and Inflation Persistence", *UCI Economics Working Paper Series* No. 05-06-07.
155. Milani, Fabio, (2005b). "Expectations, Learning and Macroeconomic Persistence", *UCI Economics Working Paper Series* No. 05-06-08.
156. Monacelli, Tommaso, (2005). "Monetary Policy in a Low Pass-through Environment", *Journal of Money Credit and Banking* 37 (6), pp. 1047-1066.
157. Moran, Kevin, and Veronika Dolar, (2002). "Estimated DGE Models and Forecasting Accuracy: A Preliminary Investigation with Canadian Data", *Bank of Canada Working Paper* No. 2002-18.
158. Mortensen, Dale T., and Christopher A. Pissarides, (1994). "Job Creation and Job Destruction in the Theory of Unemployment", *Review of Economic Studies* 61, pp. 397-415.
159. Moscarani, Giuseppe, (2004). "Limited Information Capacity as a Source of Inertia", *Journal of Economic Dynamics and Control* 28, pp. 2003-2035.
160. Murchison, Stephen, Andrew Rennison, and Zhenhua Zhu, (2004). "A Structural Small Open-Economy Model for Canada", *Bank of Canada Working Papers* No. 2004-4.
161. Nakamura, Emi, and Jón Steinsson, (2006a). "Price Setting in Forward-Looking Customer Markets", mimeo dated March 21, 2006.
162. Nakamura, Emi, and Jón Steinsson, (2006b). "Five Facts About Prices: A Reevaluation of Menu Cost Models", mimeo dated August 8, 2006.
163. Nason, James M., and Gregor W. Smith, (2005). "Identifying the New Keynesian Phillips Curve", *Federal Reserve Bank of Atlanta Working Paper Series* No. 2005-1.
164. Neiss, Katharine S. and Edward Nelson, (2005). "Inflation Dynamics, Marginal Cost, and the Output Gap: Evidence from Three Countries", *Journal of Money, Credit and Banking* 37 (6), pp. 1019-1045.
165. Nelson, Charles and Charles Plosser, (1982). "Trends and Random Walks in Macroeconomic Time Series", *Journal of Monetary Economics* 10, pp. 139-162.
166. Nelson, Edward, (2002). "Comment on: A Simple Framework for International Monetary Policy Analysis", *Journal of Monetary Economics* 49, pp. 905-912.
167. Obstfeld, Maurice, (2004). "Pricing-to-Market, the Interest-Rate Rule, and the Exchange Rate", Paper prepared for the conference in honour of Guillermo A. Calvo, International Monetary Fund, April 15-16, 2004. Available at http://elsa.berkeley.edu/~obstfeld/calvo_conf.pdf
168. Obstfeld, Maurice and Kenneth Rogoff, (1995). "Exchange Rate Dynamics Redux", *Journal of Political Economy*, 103, 624-660.
169. Obstfeld, Maurice and Kenneth Rogoff, (1996). *Foundations of International Macroeconomics*. MIT Press, Cambridge Massachusetts.
170. Obstfeld, Maurice and Kenneth Rogoff, (1998). "Risk and Exchange Rates", *NBER Working Paper* No. 6694.
171. Obstfeld, Maurice, and Kenneth Rogoff, (2000). "New Directions for Stochastic Open Economy Models", *Journal of International Economics* 50, pp. 117-153.
172. Orphanides, Athanasios, and John C. Williams, (2003). "Imperfect Knowledge, Inflation Expectations, and Monetary Policy", in Ben Bernanke and Michael Woodford (eds.), *Inflation Targeting*, University of Chicago Press, Chicago.
173. Orphanides, Athanasios, and John C. Williams, (2006). "Inflation Targeting Under Imperfect Knowledge", *CEPR Discussion Paper Series* No. 5664.
174. Pagan, Adrian, (2003). *Report on Modelling and Forecasting at the Bank of England*, Bank of England, London.
175. Paloviita, Marita, (2004). "Inflation Dynamics in the Euro Area and the Role of Expectations: Further Results", *Bank of Finland Discussion Paper* No. 21-2004.
176. Paloviita, Marita, (2005). "Comparing Alternative Phillips Curve Specifications: European Results with Survey-based Expectations", *Bank of Finland Discussion Paper* No. 22-2005.
177. Paloviita, Marita, and David Mayes, (2005). "The Use of Real-Time Information in Phillips-Curve Relationships for the Euro Area", *North American Journal of Economics and Finance* 16, pp. 415-434.
178. Persson, T. and G. Tabellini (eds.), (1990). *Macroeconomic Policy, Credibility and Politics*, Harwood Academic, Switzerland.
179. Pesaran, M. Hashem, and Ron Smith, (1995). "The Role of Theory in Econometrics", *Journal of Econometrics*, 67 (1), pp. 61-79.
180. Phelps, Edmund S., (1967). "Phillips Curves, Expectations of Inflation and Optimal Unemployment over Time", *Economica*, 34 (135), pp. 254-281.

181. Phelps, Edmund S., (1970). "Introduction:The New Microeconomics in Employment and Inflation Theory", in E.S. Phelps, A.A. Alchian, CC. Holt, D.T. Mortensen, G.C. Archibald, R.E. Lucas J.r., L.A. Rapping, S.G. Winter, Jr. , J.P. Gould, D.F. Gordon, A. Hynes, D.A. Nichols, P.J. Taubman, and M. Wilkinson (ed.), *Microeconomic Foundation of Employment and Inflation Theory*, Norton, New York.
182. Phillips, A.W., (1958). "The Relation Between Unemployment and the Rate of Change in Money Wages in the United Kingdom, 1861-1957", *Economica* (25), pp. 283-299.
183. Prescott, Edward C., (1986). "Theory Ahead of Business-Cycle Measurement", *Charnegie-Rochester Conference Series on Public Policy* 25 (Autumn), pp. 11-44.
184. Preston, Bruce, (2006). "Adaptive Learning, Forcasd-based Instrument Rules and Monetary Policy", *Journal of Monetary Economics* 53, pp. 507-535.
185. Qvigstad, Jan F., (2005). "Policy-making and Models at Norges Bank", *Norges Bank Staff Memo* No. 2005/5.
186. Rabanal, Pau and Juan F. Rubio-Ramírez, (2005). "Comparing New Keynesian Models of the Business Cycle: A Bayesian Approach", *Journal of Monetary Economics* 52, pp. 1151-1166.
187. Ravenna, Federico and Carl E. Walsh, (2006). "Optimal Monetary Policy with the Cost Channel", *Journal of Monetary Economics* 53 (2), 199-216.
188. Reifschneider, David L., David J. Stockton, and David W. Wilcox, (1997). "Econometric Models and the Monetary Policy Process", *Carnegie-Rochester Conference Series on Public Policy* 47, pp. 1-37.
189. Reis, Ricardo, (forthcoming). "Inattentive Consumers", *Journal of Monetary Economics*, forthcoming.
190. Reis, Ricardo, (2006). "Inattentive Producers", *Review of Economic Studies,* 73, pp. 793-821.
191. Roberts, John M., (1995). "New Keynesian Economics and the Phillips Curve", *Journal of Money, Credit and Banking* 27, pp. 975-984.
192. Roberts, John M., (1997). "Is Inflation Sticky?", *Journal of Monetary Economics,* 39 (2), pp. 173-196.
193. Rogoff, Kenneth, (2003). "Globalization and Global Disinflation", *Federal Reserve Bank of Kansas City Proceedings*, pp. 77-112.
194. Romer, David, (2006). *Advanced Macroeconomics.* 3rd edition, McGraw-Hill Higher Education, New York, USA.
195. Rotemberg, Julio J., (1982). "Sticky Prices in the United States", *Journal of Political Economy* 90, pp. 1187-1211.
196. Rudd, Jeremy and Karl Whelan, (2005a). "Modelling Inflation Dynamics: A Critical Review of Recent Research", *Board of Governors of the Federal Reserve System International Finance and Economics Discussion Papers* No. 2005-66.
197. Rudd, Jeremy and Karl Whelan, (2005b). "New Tests of the New-Keynesian Phillips Curve", *Journal of Monetary Economics* 52, pp. 1167-1181.
198. Rudd, Jeremy and Karl Whelan, (2006). "Can Rational Expectations Sticky-Price Models Explain Inflation Dynamics?", *American Economic Review* 96 (1), pp. 303-320.
199. Rumler, Fabio (2005). "Estimates of the Open Economy New Keynesian Phillips Curve for Euro Area Countries"*, Oesterreichiscke Nationalbank Working Paper* No. 102
200. Sargent, Thomas, (1971). "A Note on the 'Accelaratonist' Controversy", *Journal of Money, Credit, and Banking* 3, pp. 721-725.
201. Sbordone, Argia M., (2002). "Price and Unit Labor Costs: A New Test of Price Stickiness", *Journal of Monetary Economics* 49, pp. 265-292.
202. Sbordone, Argia M., (2005). "Do Expected Marginal Costs Drive Inflation Dynamics", *Journal of Monetary Economics* 52, pp. 1183-1197.
203. Schmidt-Grohe, Stephanie and Martin Uribem (2003). "Closing Small Open Economy Models", *Journal of International Economics* 61, pp. 163-185.
204. Scott, Alasdair (2004). "On Modelling Inflation Dynamics in an Open Economy Setting", paper prepared for the workshop *Inflation Dynamics in General Equilibrium Macro Models*, hosted by the Bank of Finland in Helsinki 17-19 May 2004.
205. Sheedy, Kevin D., (2005). "Structural Inflation Persistence", Job Market Paper at the University of Cambridge, draft version from 15th November 2005.
206. Sims, Christopher A., (2002). "The Role of Models and Probabilities in the Monetary Policy Process", *Brookings Papers on Economic Activity*, 2002 (2), pp.1-62.
207. Sims, Christopher A., (2003). "Implications of Rational Inattention", *Journal of Monetary Economics* 50, pp. 665-690.
208. Smets, Frank and Raf Wouters, (2003). "An Estimated Stochastic Dynamic General Equilibrium Model for the Euro Area", *Journal of European Economic Association* 1, pp. 1123-1175.

209. Smets, Frank and Raf Wouters, (2004). Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach", draft version dated 21 April 2004.
210. Solow, Robert, (1976). "Down the Phillips Curve with Gun and Camera", in *Inflation, Trade and Taxes: Essays in Honor of Alice Bourneuf*, David Belsey ed., Ohio State University Press, Columbus.
211. Spencer, Grant, and Özer Karagedikli, (2006). "Modelling for Monetary Policy: the New Zealand Experience", *Reserve Bank of New Zealand Bulletin* Vol. 69 (2), pp. 18-25.
212. Steinsson, Jón, (2003). "Optimal Monetary Policy in an Economy with Inflation Persistence", *Journal of Monetary Economics* 50, pp. 1425-1456.
213. Steinsson, Jón, (2005). "The Dynamic Behaviour of the Real Exchange Rate in Sticky Price Models", *Central Bank of Iceland Working Papers* No. 28.
214. Svensson, Lars, (1999). "How Should Monetary Policy Be Conducted in an Era of Price Stability", Conference paper presented at *New Challenges for Monetary Policy*, a symposium sponsored by the Federal Reserve Bank of Kansas City held in Jackson Hole, Wyoming, August 26-28, 1999.
215. Svensson, Lars, (2000). "Open Economy Inflation Targeting", *Journal of International Economics* 50, pp. 155-185.
216. Taylor, John B., (1980). "Aggregate Dynamics and Staggered Contracts", *Journal of Political Economy* 88, pp. 1-22.
217. Taylor, John B., (1999). "Staggered Price and Wage Setting in Macroeconomics", chapter 15 in J.B. Taylor and M. Woodford (eds.), *Handbook of Macroeconomics*, Elsevier.
218. Taylor, John B., (2000). "Low Inflation, Pass-through, and the Pricing Power of Firms", *European Economic Review* 44 (7), pp. 1389-1408.
219. Walsh, Carl E., (2003). *Monetary Theory and Policy*, 2nd edition, MIT Press.
220. Walsh, Carl E., (2005). "Labour Market Search, Sticky Prices, and Interest Rate Policies", *Review of Economic Dynamics* 8 (4), pp. 829-849.
221. Walsh, Carl E., (2006). "The Contribution of Theory to Practice in Monetary Policy: Recent Developments", a paper presented at *Monetary Theory: A Journey from Theory to Practice: An ECB Colloquium held in Honour of Prof. Otmar Issing*, in Frankfurt, 16-17 March 2006.
222. White, William R., (2006). "Is Price Stability Enough?", *BIS Working Papers* No. 205.
223. Wolman, Alexander L., (1999). "Sticky Prices, Marginal Cost, and the Behaviour of Inflation", Federal Reserve Bank of Richmond *Economic Quarterly* 85 (4), pp. 29-48.
224. Woodford, Michael (1999). "Revolution and Evolution in the Twentieth-Century Macroeconomics", paper prepared for the conference on *Frontiers of the Mind in the Twenty-First Century*, Library of Congress Washington, June 14-18, 1999.
225. Woodford, Michael, (2003a). *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press.
226. Woodford, Michael, (2003b). "Imperfect Common Knowledge and the Effects of Monetary Policy", in Aghion, Phillipe, Roman Frydman, Joseph Stiglitz, and Michael Woodford eds., *Knowledge, Information, and Expectations in Modern Macroeconomics: In Honor of Edmund S. Phelps*, Princeton University Press, Princeton and Oxford.
227. Woodford, Michael, (2005). "Firm-Specific Capital and the New Keynesian Phillips Curve", *International Journal of Central Banking* 1 (2), pp. 1-46.
228. Woodford, Michael, (2006). "Interpreting Inflation Persistence: Comments", presented at *Quantitative Evidence on Price Determination*, conference held in Washington D.C. September 29-30, 2005, and sponsored by the Federal Reserve Board and the Journal of Money, Credit, and Banking. This version is dated January 18, 2006.
229. Yashiv, Eran, (2006). "Search and Matching in Macroeconomics", *CEPR Discussion Paper Series* No. 5459.
230. Yun, Tack, (1996). "Nominal Price Rigidity, Money Supply Endogeneity and Business Cycles", *Journal of Monetary Economics* 37, pp. 345-370.