UNDERSTANDING THE FLATTENING PHILLIPS CURVE

Ken Kuttner and Tim Robinson

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Economic Research Department
Reserve Bank of Australia

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Author: kenneth.n.kuttner@williams.edu and robinsont@rba.gov.au (contact author)

Economic Publications: ecpubs@rba.gov.au

Abstract

Policymakers in the US and a number of other countries recently have called attention to an apparent flattening of the Phillips curve. The policy implications of such a change would be that, while higher levels of the output gap would be less inflationary, reducing inflation would be more costly in terms of foregone output. This paper's objective is to review the evidence and possible explanations for the flattening Phillips curve, using new-Keynesian economic theory as an organising framework. We find that the flattening is not only a reduced-form phenomenon, but also is evident in the baseline "structural" new-Keynesian Phillips curve of Galí and Gertler (1999) (Journal of Monetary Economics). We consider a variety of reasons for this structural flattening, such as data problems, alternative definitions of marginal cost and globalisation, none of which provide an entirely satisfactory explanation.

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1. Introduction

In recent years, inflation appears to have become less responsive to fluctuations in output and unemployment—that is, that the Phillips curve has become "flatter". This has been documented for the United States by Roberts (2006), among others, and a similar phenomenon seems to have occurred in other countries as well (for example, see Beaudry and Doyle (2000) for Canada).

A decline in the output-inflation trade-off, if it has occurred, would have consequences for monetary policy. As discussed in Mishkin (2007) and Bean (2006), a benefit is that higher levels of the output gap, and lower levels of unemployment, would be less inflationary. The problem is that inflation, once established, would be harder to bring down.

While the "stylised fact" of a flatter Phillips curve has been reasonably well established, the precise reasons for this change are not well understood. Firmer "anchoring" of inflation expectations is one possibility, advanced by Mishkin (2007), Roberts (2006) and Williams (2006), among others. (This line of reasoning has tended to emphasize the effects of "anchoring" on inflation persistence, rather than the responsiveness of inflation to fluctuations in real activity.) Others, such as Borio and Filardo (2006) and Razin and Binyamini (2007), cite the effects of globalisation.

The purpose of this paper is therefore to understand why the Phillips curve seems to have become flatter, using insights from "new-Keynesian" macroeconomic theory to dissect the linkages between real activity and inflation. Variants of the new-Keynesian framework are extensively used in macroeconomic models at central banks worldwide (for example at the Riksbank (Adolfson, Laseen, Linde and Villani 2007) and the Bank of Canada (Murchison and Rennison 2007)). According to that perspective, a fruitful way to think about the reduced-form output-inflation nexus is in two stages: first, as a relationship between the output gap and costs; and second, in terms of the linkage between costs (or more precisely, the current and expected *future* costs) and inflation. A reduction in the

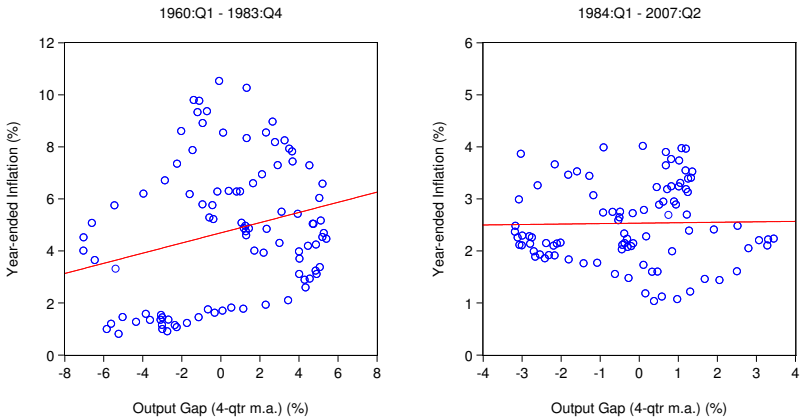
overall sensitivity of inflation to output may result from a change in either one of those two stages.

The paper proceeds as follows. Section 2 (briefly) documents the change in the reduced-form Phillips curve in the US and a small, open economy, namely Australia. Section 3 reviews the new-Keynesian inflation model, and discusses why a change in the reduced-form need not imply a change in firms' price-setting behavior. In an effort to determine whether there may also have been a change in the structural inflation equation, in section 4 we estimate the new-Keynesian Phillips curve, finding that there does appear to have been a reduction in the responsiveness of inflation to marginal costs. Section 5 considers several possible explanations for these findings, none of which are entirely satisfactory.

2. Reduced-form Flattening

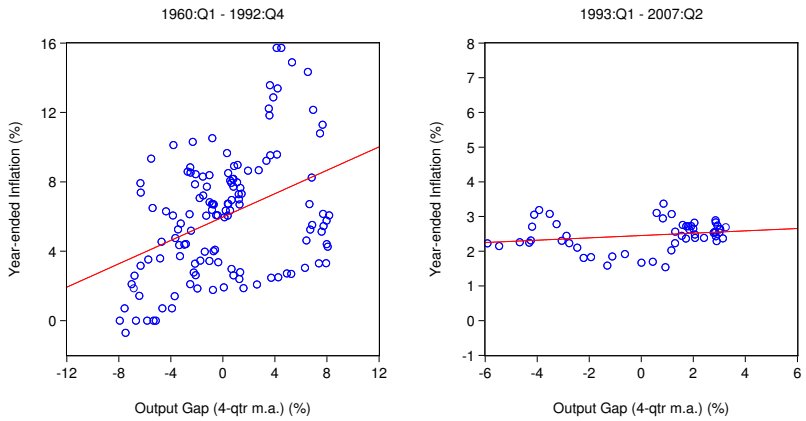
Simple scatterplots of inflation and the output gap are striking. We divide the sample for both countries, with the period after the break displaying a sizeable drop in the volatility of the output gap in each nation.[1] The moderation of the business cycle has been widely studied — see, for example, the papers in Kent and Norman (2005). The accompanying decline in inflation, however, has not been proportional — the reduced-form Phillips curve has flattened.

Figure 1: Inflation and the Output Gap: United States



[1] The break in 1984:Q1 for the US follows Roberts (2006). The break in 1993:Q1 for Australia approximately corresponds to the adoption of inflation targeting. The output gap is constructed using a quadratic trend — see Section 4 for further details on the data.

Figure 2: Inflation and the Output Gap: Australia



Reduced-form estimates of the Phillips curve, like those in Roberts (2006), typically have the specification:

$$\pi_t = a + b(L)\pi_{t-1} + cy_{t-1} + dz_t + e_t \tag{1}$$

where y is (an estimate of) the output gap, L is the lag operator and z represents some exogenous factors affecting inflation. The lags of inflation (we use two) are sometimes interpreted as a proxy for inflation expectations, and more generally help model the observed persistence in inflation.[2] To examine the flattening in the Phillips curve we want to allow c, the coefficient on the output gap, to vary over time. Two simple ways of doing this are to estimate Equation 1 over a 15-year rolling window (Figures 3 and 4), or two specify the process that the output gap coefficient follows (we assume a random walk) and to use the Kalman filter (Figures 5 and 6). The latter has the advantage that it delivers two-sided estimates, that is, at all points of time they use information from the entire sample.

The flattening of the reduced-form Phillips curve is clearly evident for the US using either methodology. In Figure 3 we date the parameter estimates at the end

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2 Often their coefficients are restricted to sum to 1 (and the constant restricted to be zero), in an attempt to ensure that the Phillips curve is vertical in the long-run (this is the "accelerationist" model of inflation). These restrictions impose that inflation is an integrated process, which is implausible when there is a central bank reacting sufficiently aggressively to inflation, and ignore the cross-equation restrictions that would exist in a fully-specified model, a point first highlighted by Sargent (1971). However, whether the Federal Reserve acted sufficiently aggressively to offset inflation in the 1970s is arguable - see Clarida, Gali and Gertler (2000) and Orphanides (2002).

Figure 3: 15-year Rolling Regressions: Coefficient on Gap - United States

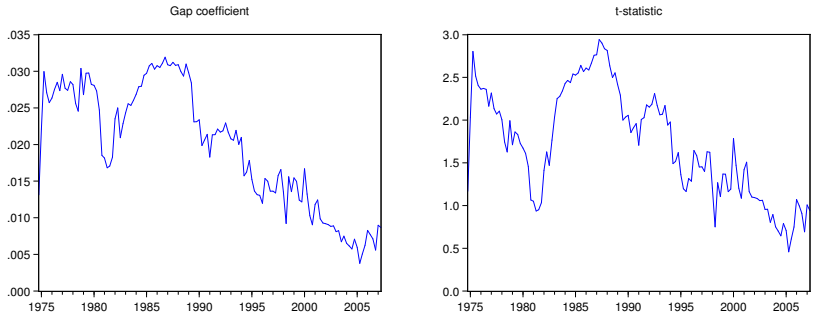
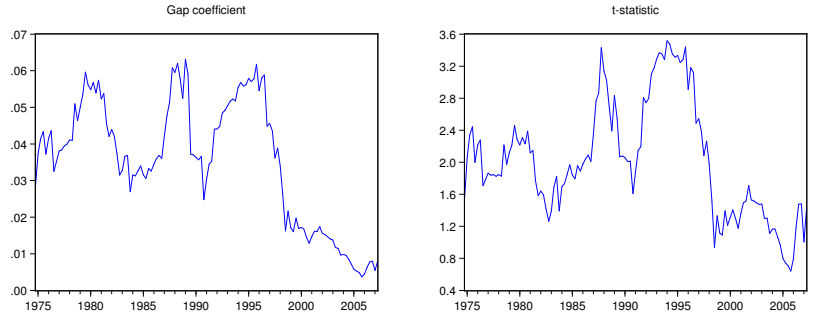


Figure 4: 15-year Rolling Regressions: Coefficient on Gap - Australia



of each rolling window, and consequently the sharp reduction in the output gap's coefficient evident from from around 1989 occurred in the preceding 15 years, and perhaps is better dated in the early 1980s, around the time when the Federal Reserve disinflated the economy. Alternatively, the two-sided estimates in Figures 5 date the flattening in the Phillips curve as beginning in around 1975, and suggest that it has been a very gradual process which continued over the 1980s and 1990s.[3]

The results for Australia are more mixed. The estimates of the coefficient on the output gap fluctuate considerably until the late 1990s, after which a clearly discernable downward trend is evident. Once again, this suggests that the flattening began around the time of a change in monetary policy regime, namely the adoption of inflation targeting. The two-sided estimates, however, date the flattening as beginning far earlier, around 1975, akin to the findings for the US.

3. A Structural Perspective on the Flattening Issue

The problem with the previous results is that, because they come from reduced-form regressions, it is hard to tell whether they represent a change in the true

[3] Naturally this partially reflects our assumption that it follows a random walk.

Figure 5: **Time-varying Estimates of Gap Coefficient +/- 2 S.E. Bands - United States**

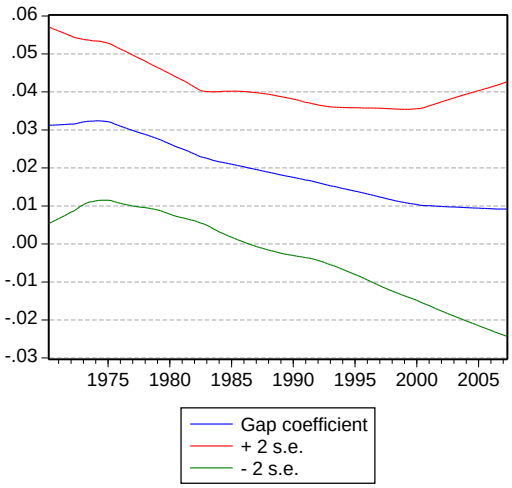
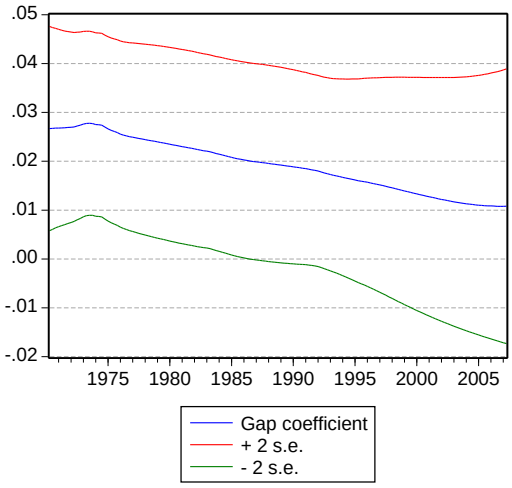


Figure 6: **Time-varying Estimates of Gap Coefficient +/- 2 S.E. Bands - Australia**



responsiveness of inflation to the output gap, as opposed to a change elsewhere in the economy (for example, in the policy rule, if the central bank decided to respond more aggressively to expected inflation). This is just the Lucas critique, (Lucas 1976). Consequently, we now turn to more structural estimates of the inflation process. We adopt the common new-Keynesian framework to examine whether a flattening has occurred, and if so, to review its possible causes.

3.1 A Brief Review of New-Keynesian Inflation Theory

The basic idea of the new-Keynesian Phillips curve is that, in an environment in which there are only occasional opportunities to adjust prices, firms will set their prices in anticipation of expected future costs. The key points are that prices are determined by costs (via a desired price/cost markup), and that there is a forward-looking element to price setting. For an extensive survey of the literature see Òlafsson (2007).

The canonical expression of this theory is the new-Keynesian Phillips curve,

$$\pi_t = \beta E_t \pi_{t+1} + \lambda mc_t \ , \tag{2}$$

as derived in Gali and Gertler (1999), where β is the discount factor, *mc* real marginal cost and λ its coefficient. However, this specification has been found to not capture the observed persistence of inflation. Consequently, it has been generalized by introducing either rule-of-thumb pricing (Gali and Gertler 1999), or indexation (Christiano, Eichebaum and Evans 2005), both of which have the result of introducing a lag of inflation to the Phillips curve:

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

This is commonly referred to as the "hybrid" new-Keynesian Phillips curve, and the γ_f and γ_b coefficients respectively reflecting the degree of "forward lookingness" and inertia in inflation.

What makes Equation 3 attractive is that it can be derived from explicit microeconomic foundations, such as Calvo pricing (Calvo 1983), as sketched in Gali and Gertler (1999).[4] Specifically, let θ represent the probability that a firm is *unable* to adjust its prices in any given period. Furthermore, let ω represent the share of firms who can change their price, but instead of doing so optimally follow a "rule of thumb" and base their price adjustment on lagged inflation, while the remaining $1-\omega$ set their prices optimally.[5] In this case, the γ_f, γ_b and λ

[4] An alternative approach is to use a quadratic adjustment costs; see Rotemberg (1987).

parameters are functions of the deep parameters ω and θ, and the discount factor β as follows:

$$\begin{aligned}\lambda &= (1-\omega)(1-\theta)(1-\beta\theta)\phi^{-1} \\ \gamma_f &= \beta\theta\phi^{-1} \\ \gamma_b &= \omega\phi^{-1}, \quad \text{where,} \\ \phi &= \theta+\omega[1-\theta(1-\beta)] \ .\end{aligned}$$

It is possible to solve the new-Keynesian Phillips curve forward, for example, using the approach of Binder and Pesaran (1995), which yields:

$$\pi_t = P\pi_{t-1} + \frac{\lambda}{1-\gamma_f P}\sum_{i=0}^{\infty}\left(\frac{\gamma_f}{1-\gamma_f P}\right)^i E_t mc_{t+i} \ , \tag{4}$$

where $P = \frac{1\pm\sqrt{1-4\gamma_f\gamma_b}}{2\gamma_f}$, and $|P|<1$.[6]

This highlights that in this framework, abstracting from the lag, it is the expected path of current and future real marginal costs that determines current inflation.

Finally, the closed form can be used to see why the reduced-form estimates may not actually correspond to a structural flattening of the Phillips curve. Suppose, just as an illustration, that real marginal costs follows an AR(1) process,

$$mc_t = \rho mc_{t-1} + u_t \ ,$$

so that

$$\sum_{i=0}^{\infty}\left(\frac{\gamma_f}{1-\gamma_f P}\right)^i E_t mc_{t+i} = \sum_{i=0}^{\infty}\left(\frac{\gamma_f\rho}{1-\gamma_f P}\right)^i mc_t = \frac{mc_t}{1-\frac{\gamma_f\rho}{1-\gamma_f P}} \ .$$

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5 In the steady-state there is assumed to be no inflation, although this is relaxed by Ascari (2004), who argues that the assumption is not innocuous.

6 Note that this does not guarantee a unique solution. For stability we also need $|\frac{\gamma_f}{1-\gamma_f P}|<1$.

Under this assumption, the closed form of the New-Keynesian Phillips curve can be written very simply as

$$\pi_t = P\pi_{t-1} + \frac{\lambda}{1-\gamma_f(P+\rho)} mc_t \ . \tag{5}$$

What's interesting is that, except for the substitution of the real marginal cost mc for the conventional output gap, this is indistinguishable from the reduced-form Phillips curves that are often estimated. As usual, the reduced-form coefficients are complicated functions of the underlying parameters of interest. A flattening in the reduced-form Phillips curve can reflect, in this example, either a change in the slope of the structural Phillips curve (a reduction of λ) or a decrease in the persistence of marginal cost fluctuations. Thus, the reduced-form Phillips curve may become shallower for reasons completely unrelated to any structural change in the relationship between prices and marginal costs.

This is not a new idea. Roberts (2006) examines the implications for estimates of the slope of the reduced-form Phillips curve of changes in the monetary policy rule, and finds that more responsive policy could underly a reduced-form flattening. Similar results were obtained analytically by Carlstrom, Fuerst and Paustian (2007).[7]

Changes in the link between the output gap and marginal costs are another possible source of changes in the relationship between inflation and the output gap. Specifically, if marginal costs have become less sensitive to fluctuations in economic activity, then inflation will be less sensitive to the output gap.

4. Has the New-Keynesian Phillips Curve Become Flatter?

In principle, a correctly specified new-Keynesian Phillips curve model should not be affected by changes elsewhere in the economy, such as in the policy rule, as it is structural.[8] Second, because they typically rely on direct measures of marginal costs, it should not be affected by any changes in the sensitivity of marginal

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[7] Interestingly, Rudebusch (2005) found quantitatively small effects of increasing "aggressiveness" on the reduced-form parameter estimates.

[8] However, we revisit this in section 5.4.

costs to real activity. Determining whether the estimated new-Keynesian Phillips curve has changed is therefore essential to understanding the likely sources of the instability evident in the reduced-form relationship.

To preview: the results reported in this section suggest that the flattening phenomenon is not limited to reduced-form output-inflation models. Rather, there also seems to have been a change in the linkage between marginal costs (or at least their commonly-used proxy) and inflation. Possible reasons for this breakdown will be explored later, in section 5.

4.1 Baseline new-Keynesian Phillips Curve Estimates

We estimate the new-Keynesian Phillips curve using Generalized Method of Moments (GMM), and follow closely Gali, Gertler and Lopez-Salido (2005) and Gali and Gertler (1999). Briefly, assuming that expectations are rational, they will be based on all of the information available, and therefore expectations errors should, on average, be unrelated to the available information (the instruments). In practice, there are several issues with GMM estimation, such as the choice of an appropriate instrument set and lag length to be used in the calculation of robust standard errors and the weighting matrix. Also, when we estimate the deep parameters (e.g. ω, the share of rule-of-thumb price setters) the model is non-linear, and in this instance the GMM estimates are sensitive to the normalization used. Many of these issues and their implications for the new-Keynesian Phillips curve are discussed in detail Guay and Pelgrin (2004), who found that the GMM parameter estimates can be quite sensitive to these modeling choices.

The data used for the US follow Gali and Gertler (1999). We model the GDP chain price index, and the other series (except for the output gap) are for the non-farm business sector. As is standard practice in the literature, real marginal costs are measured using labour's share of income (an assumption which is discussed further in section 5.2). We use average hourly compensation as a measure of wages, and a estimate the output gap using a quadratic trend.

Table 1 presents two sets of estimates of the "reduced-form" hybrid new-Keynesian Phillips curve (equation 3) for the United States. Gali and Gertler (1999) refer to this as the reduced-form as it does not estimate the deep parameters. The first set of results attempts to replicate the results in

Gali *et al* (2005); it is estimated over the sample $1960:Q1-1997:Q4$, uses real-time data from the St. Louis ALFRED database and their instrument set.[9] These results are indeed very similar, although the standard error of λ, the coefficient on marginal cost, is slightly larger. The second set of results estimates exactly the same regression but using the current vintage (2007:Q3) of data. Focussing on the estimates of the slope of the Phillips curve, λ, what is stark is that it has reduced by one quarter entirely due to data revisions, and its significance has decreased.[10] The estimates over the full sample, (1960:Q1 - 2007:Q2), however, suggest that the decrease in λ is not entirely due to data revisions. Similar results are obtained if we constrain the coefficients on inflation expectations and lagged inflation to sum to 1 (which implies that $\beta = 1$). Pagan (2008) shows that this constraint allows the first lag of inflation to be an instrument for variables other than itself, rather than using deeper lags, which may lessen problems with weak instruments.

Table 1: New-Keynesian Phillips Curve - United States

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

	1960:Q1 - 1997:Q4				1960:Q1 - 2007:Q2	
	Real-time Data		Current Data		Current Data	
Coefficient	Value	Standard error	Value	Standard error	Value	Standard error
γ_b	0.362	0.062	0.325	0.089	0.305	0.089
γ_f	0.630	0.058	0.661	0.084	0.689	0.088
λ	0.012	0.009	0.010	0.007	0.007	0.005
			Imposing that $\gamma_b + \gamma_f = 1$			
γ_b	0.361	0.064	0.320	0.091	0.318	0.090
λ	0.011	0.007	0.008	0.006	0.004	0.004

Notes: Estimated using 2SLS with Newey-West standard errors (using 12 lags). Instruments: constant, π_{t-1} to π_{t-4}, lags 1-2 of the output gap, real marginal costs and nominal wages (following Gali, Gertler and Lopez-Salido (2001)).

Repeating the rolling regression exercise, but this time for the new-Keynesian Phillips curve, also suggests that a flattening has occurred.[11] Interestingly,

[9] The price index is the June-1998 vintage; for the non-farm business sector the first vintage available was 1999:Q3.

[10] This has also been noted by Rudd and Whelan (2005) and Guay and Pelgrin (2004). In the context of a conventional, reduced-form specification, Koenig (2003) also found that the significance of unit labour costs was sensitive to data vintage.

[11] An obvious caveat to these results is that GMM is a large sample estimator.

compared to the reduced-form estimates it dates the flattening as having occurred much later, possibly from the early 1990s onwards.

In all, it appears that the flattening of the Phillips curve for the US may not only be a reduced-form phenomenon.

One approach to try to understand what might have caused this flattening is to look at estimates of the deeper "structural" parameters. Table 2 estimates these over the the entire sample (1960:Q1–2007:Q2) and the sub-samples used in the initial scatterplots, namely 1960:Q1–1983:Q4 and 1984:Q1–2007:2. Two findings emerge, and these are uniform in direction across the different normalisations and whether or not β is restricted to be 1.[12] Firstly, the Calvo parameter appears to have increased, which implies that the average duration of price between changes has considerably lengthened. This increases the well-known tension between macro-based estimates, such as these, and the much higher frequency of price changes evident from micro data (see Bils and Klenow (2004)). Indeed, some of the estimates of the duration between price changes (particularly those from the second moment condition) seem implausibly long. The second change which is evident is that the share of rule of thumb firms has decreased. The former change is consistent with a flattening of the Phillips curve, whereas the latter would make it steeper, and overall it appears the impact of the increase in the Calvo parameter dominates.

Another way of trying to gain an intuitive understanding of why this is the case is to look at the data.

Figure 8 suggests the source of this change: in the US, at least, there has been a sharp downward trend in labour's share (i.e., an increase in the markup) since the early 1990s (the date of the flattening identified by the rolling regressions), although it is punctuated by a sharp upward surge late in the decade.[13] Had inflation responded in the usual way (i.e., with the "old" estimate of λ), this would have resulted in a significant decline in the inflation rate; instead inflation fell only modestly over this period, and crept up only slightly in the late 1990s. This is

[12] They also remain if the sample is split later, e.g. in the early 1990s.

[13] Interestingly, as noted by Lawless and Whelan (2007), a comparable downward trend in labour's share is also observed in Euro area countries, with a similarly small drop in inflation.

Table 2: Structural Estimates of the New-Keynesian Phillips Curve - United States

$$\pi_t = \frac{\omega}{\phi}\pi_{t-1} + \frac{\theta\beta}{\phi}\pi_{t+1} + \frac{(1-\omega)(1-\theta)(1-\beta\theta)}{\phi}mc_t$$

Moment condition	$E(\phi\pi_t - \omega\pi_{t-1} - \theta\beta\pi_{t+1} - (1-\omega)(1-\theta)(1-\beta\theta)mc_t\|\Omega_t) = 0$		$E(\pi_t - \frac{\omega}{\phi}\pi_{t-1} - \frac{\theta\beta}{\phi}\pi_{t+1} - \frac{(1-\omega)(1-\theta)(1-\beta\theta)}{\phi}mc_t\|\Omega_t) = 0$	
Coefficient	Value	Standard error	Value	Standard error
		1960:Q1 - 1983:Q4		
θ	0.829	0.037	0.837	0.044
ω	0.214	0.158	0.395	0.160
β	0.999	0.050	0.994	0.056
Implied λ	0.022		0.013	
		Imposing $\beta = 1$		
θ	0.828	0.037	0.837	0.044
ω	0.213	0.162	0.394	0.162
Implied λ	0.022		0.013	
		1984:Q1 - 2007:Q2		
θ	0.914	0.024	0.933	0.025
ω	0.047	0.110	0.310	0.093
β	0.913	0.062	0.879	0.078
Implied λ	0.014		0.007	
		Imposing $\beta = 1$		
θ	0.906	0.037	0.970	0.101
ω	0.020	0.117	0.336	0.096
Implied λ	0.009		0.0005	
		1960:Q1 - 2007:Q2		
θ	0.872	0.034	0.889	0.040
ω	0.180	0.137	0.387	0.153
β	1.000	0.036	0.984	0.040
Implied λ	0.013		0.006	
		Imposing $\beta = 1$		
θ	0.872	0.034	0.889	0.042
ω	0.180	0.141	0.384	0.156
Implied λ	0.013		0.007	

Notes: Ω_t denotes the time t information set; $\phi \equiv \theta + \omega[1-\theta(1-\beta)]$. Estimated using non-linear 2SLS with Newey-West standard errors (using 12 lags). Instruments: constant, π_{t-1} to π_{t-4}, lags 1-2 of the output gap, real marginal costs and nominal wages (following Gali *et al* (2001)).

Figure 7: **15-year Rolling Regressions: Coefficient on Real Marginal Costs - United States**

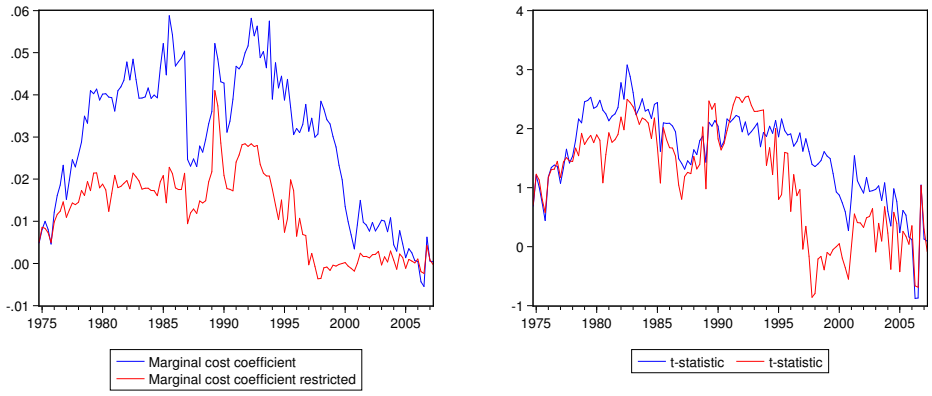
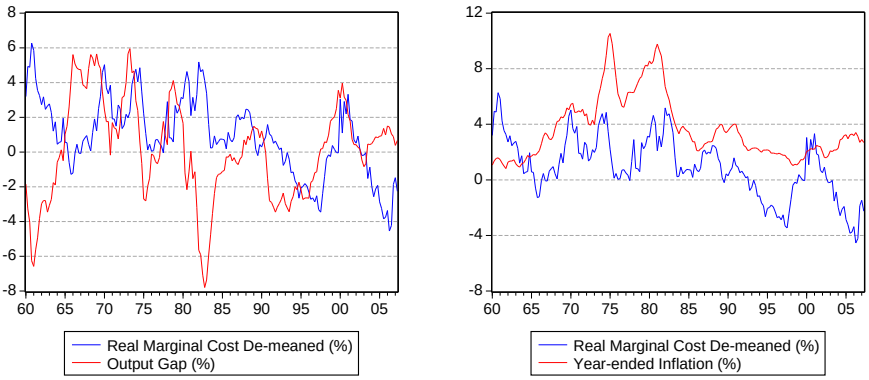


Figure 8: Inflation, Marginal Costs and the Output Gap - United States



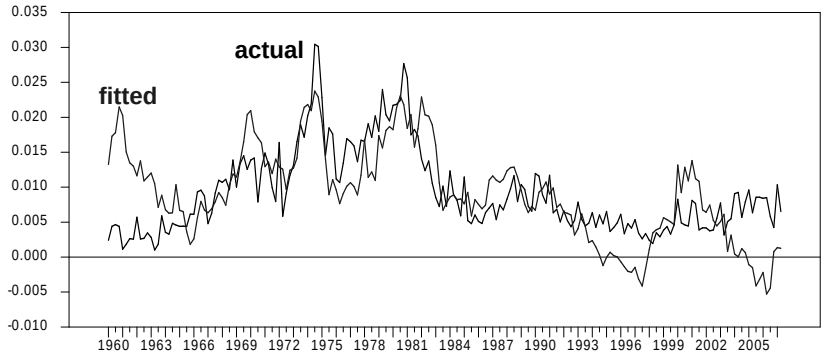
Note: Output gap is estimated using a quadratic trend, following Gali and Gertler (1999).

illustrated in Figure 9, which plots a dynamic inflation forecast from the new-Keynesian Phillips curve, conditional on the observed path of marginal cost.[14] An output-gap based Phillips curve alternatively is unlikely to have forecast such subdued inflation, as the gap is estimated to have been broadly around zero over this period (Figure 8). The lack of co-movement between the output gap and the

[14] This is the "fundamental inflation" plotted in Gali and Gertler (1999) and Gali *et al* (2001).

labour share, however, could reflect that the output gap has been estimated by de-trending output; in a new-Keynesian model, potential output typically is defined as the level of output that would prevail under flexible prices, and this may not be approximated well by de-trending output, a point emphasized by Neiss and Nelson (2005).[15]

Figure 9: Forecasts Conditional on Observed Marginal Costs - United States



5. Explaining the Flattening Phenomenon

The evidence presented in sections 2 and 4 indicates that *something* has changed in the way inflation responds to real marginal costs, as measured by labour's share of income. Also evident is that the relationship between the output gap, when measured by de-trending output, and labour's share of income, is far from tight. We now round up the suspects which have been raised in the literature to see which (if any) can plausibly explain these observations.

The candidate explanations fall into four groups. The first is simply that there are problems with the data, i.e., that the reported labour share is mismeasured in some important way. The second possibility is that the labour share is measured reasonably well — but that it is a flawed proxy for the "true" marginal costs

[15] In the simplest case when the representative firm uses labour as the only factor of production, the flexible-price output gap will move proportionally to the marginal cost (see Gali (2008), chapter 3). When a more general production function is used, however, such a simple relationship between the flexible-price output gap and marginal costs may not exist.

faced by firms. Alternatively, there may have, in fact, been structural changes to price-setting behavior, and the reduction in the estimated sensitivity of inflation to costs is an accurate reflection of those changes. The final possibility is that the price-setting behaviour of firms has been time invariant, but some other aspect of the model is invalid. Both of these final two reasons suggest that the standard new-Keynesian framework that we have used here is too simple, and needs to be modified so as to better capture the inflation process.

5.1 Data Problems

At first glance, an appealing feature of the new-Keynesian framework is that it does not depend on the output gap, which is unobserved and therefore difficult to estimate, particularly in real time (see, for example, Orphanides and van Norden (2002)). However, measuring marginal cost is not straightforward either. As noted above, the conventional measure of real marginal cost is labour's share of nominal output,

$$\frac{W \times N}{P \times Y} \quad ,$$

where W is average per-hour compensation, N is total hours, Y is real output, and P is the price level. This is equivalent to unit labour costs ($(W \times N)/Y$, i.e. productivity-adjusted wages), deflated by the price level. In order to avoid problems associated with measuring the agricultural and government output, standard practice for the US has been to use the labour share of income for the non-farm business sector. However, even when we constrain our attention to the non-farm business sector, considerable possible measurement problems may still exist, many of which are outlined in Krueger (1999). Examples of such issues include what constitutes income (e.g. whether to include stock options, fringe benefits etc.), whether distinctions based on a firm being incorporated or not are useful, and whether proprietors' income should be included in returns to capital or labour. Some of these issues have the potential to not only alter the level of labour's share of income, but also to create long-term trends. An example of this is shift of proprietors to wage employees that occurred in the US in the first half of the 20th century (see Krueger (1999) and the references therein).

It is impossible to know for sure the extent of these data problems, however, they would have to be quite large to account for the shift in labour's share of income that has occurred in the US.[16]

5.2 Labour Share $\neq$ Marginal Cost

Another logical possibility is that the labour share data are sound, but that the labour share is a poor proxy for firms' true marginal cost. It has long been known that the conditions under which labour's share is proportional to marginal cost are highly restrictive: sufficient conditions are that the production function is Cobb-Douglas (or more precisely, isoelastic with respect to labour), and free from complications such as labour hoarding, overhead labour, etc.[17] Rotemberg and Woodford (1999) provide a comprehensive survey of how such complications would affect the cyclicality of labour's share. What Rotemberg and Woodford do *not* consider, however, is the possibility of prolonged, and possibly structural, changes in labour's share of income, like that which seems to have taken place in the US.[18]

5.2.1 Open Economy Dimensions

An obvious reason why labour's share may not capture marginal costs well is that it omits open economy aspects, which are likely to be of importance particularly for small, open economies. To examine whether there still is evidence of a structural flattening once these factors are accounted for we estimate new-Keynesian Phillips curves for Australia.

In introducing the open economy aspects it is useful to distinguish between two stages of pass through of exchange rates to consumer prices: the first being from world prices to import prices "at the docks", and the second from these at the prices at the docks to consumer prices. Past evidence for Australia (for example Dwyer and Leong (2001)) suggests that first stage pass-through is rapid, whereas the second stage is prolonged. Incomplete short-run pass through has also been found for other economies — see Campa and Goldberg (2002). A simple way to introduce this in a new-Keynesian framework was developed by Monacelli (2006).

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[16] Using the labour share for only the nonfinancial corporate sector (where Corrado and Slifman (1999) argue the data problems are less severe) for the US fails to improve the performance of the new-Keynesian Phillips curve in the latter part of the sample.

[17] Overhead labour is labour hired independent of the quantity of output produced.

[18] They do, however, note that there does appear have been a sizeable increase in labour's share in the late 1960s.

In brief, he assumes the CPI can be split into two components, namely prices of domestically produced and foreign goods. Prices of domestically-produced goods evolve as sketched in section 3.1. The law of one price is assumed to hold at the docks, that is, first-stage pass through is complete. Incomplete short-run second-stage pass through is captured by introducing Calvo pricing. Essentially, we obtain two Phillips curves, one each for domestically produced and foreign goods. In the latter, the measure of marginal costs are import prices at the docks relative to the retail price of foreign goods, which Monacelli (2006) terms the "law-of-one-price-gap".

Such a system of Phillips curves have been estimated for Australia as part of a small DSGE model by both Nimark (2007) and Justiniano and Preston (2004). In these models the retail price of foreign produced goods is treated as an unobserved variable, and is estimated using the Kalman filter. Unfortunately a direct measure of these prices is not available, and therefore in order to estimate a Phillips curve using the same methods as above we make the simplifying assumption that the Calvo parameter is the same in the domestically produced and foreign goods. This assumption is not supported by Nimark (2007) and Justiniano and Preston (2004), who find that it differs across the sectors, although interestingly Justiniano and Preston find the duration between price changes to be less for foreign goods, whereas Nimark finds the opposite. The resulting Phillips curve which incorporates import prices is of the form:

$$\pi_t = \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \lambda \left((1-\alpha) mc_t^d + \alpha mc_t^m \right) \quad , \tag{6}$$

where α is the share of foreign goods in consumption, and m denotes imports. Essentially, real marginal costs are a weighted average marginal costs in each sector, with the weights determined by their importance in the consumption bundle. Substituting in our expressions for marginal costs (and letting lower case letters denote natural logs of variables) yields the equation we estimate:

$$\pi_t = \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \lambda \left((1-\alpha)(w_t + n_t - y_t - p_t) + \alpha \left(p_t^m - p_t \right) \right) \quad . \tag{7}$$

This specification of marginal costs is strikingly similar to the long-run term in mark-up error-correction mechanism equations which have traditionally been used

to model Australian inflation (for example de Brouwer and Ericsson (1998)). Interestingly, when modeling the CPI the labour share will be an imperfect measure of real marginal costs, independent of any open economy aspects, as it deflates nominal marginal costs (unit labour costs) by the GDP deflator rather than the CPI.[19] As the weight of imported goods in consumption, α, has been a difficult variable to estimate in the past (see Kulish and Rees (2008)), we also try a variant in which it is calibrated to 0.2. The results presented in Table 3 suggest that even when open-economy aspects are added to the Phillips curve a flattening is evident.

Table 3: Open Economy New-Keynesian Phillips Curve - Australia

$$\pi_t = \gamma_f E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \lambda \left((1-\alpha)(w_t + n_t - y_t - p_t) + \alpha \left(p_t^m - p_t \right) \right)$$

	1960:Q1 - 1992:Q4		1993:Q1 - 2007:Q2		1960:Q1 - 2007:Q2	
Coefficient	Value	Standard error	Value	Standard error	Value	Standard error
γ_b	0.163	0.101	0.385	0.046	0.146	0.095
γ_f	0.804	0.112	0.601	0.049	0.832	0.108
λ	0.005	0.003	0.002	0.004	0.004	0.003
α	0.490	0.515	0.202	0.396	0.441	0.401
			Imposing that $\alpha = 0.2$			
γ_b	0.166	0.101	0.385	0.045	0.148	0.094
γ_f	0.797	0.114	0.597	0.048	0.830	0.109
λ	0.004	0.003	0.002	0.002	0.003	0.003
			Imposing that $\alpha = 0.2$ and $\gamma_b + \gamma_f = 1$			
γ_b	0.162	0.097	0.388	0.049	0.144	0.091
λ	0.002	0.002	0.001	0.001	0.002	0.002

Notes: Estimated using 2SLS with Newey-West standard errors (using 12 lags). Instruments: constant, π_{t-1} to π_{t-4}, lags 1-2 of the output gap, real unit labour costs, real import prices and nominal wages.

The specification above allows for imported consumer goods, but ignores imports of materials. If materials enter the *gross* output production function "isoelastically',' then the materials share is another potential measure of marginal costs (see Rotemberg and Woodford (1999)). If the production function is not of Cobb-Douglas form the labour share may be influenced by intermediate good prices. Batini, Jackson and Nickell (2005) generalise a new-Keynesian Phillips curve for the United Kingdom in many ways, including introducing raw material prices, and argue that this is important for capturing the behavior of UK inflation.[20]

[19] We use the trimmed-mean CPI. Nominal unit labour costs are for the non-farm sector. Import prices are measured as the implicit price deflator from the Balance of Payments.

5.2.2 Changing Sectoral Composition

The observed evolution of labour's share for the US may also reflect changes in the sectoral composition of output. McAdam and Willman (2004) show, using a disaggregated supply side model, that shifts across sectors will affect the aggregate equilibrium markup, and thus labour's share. Their model includes two sources of such shifts: one is differential technical progress across sectors, which induces changes in relative prices and hence demand; the second is changes in the (exogenous) price of exports, relative to foreign goods.

Based on their model, they propose a correction to the measured labour share, which essentially is an adjustment for a time trend (capturing differentials in productivity growth) and the relative export price. They claim that this adjustment makes euro-area marginal cost stationary, and greatly improves the performance of the New-Keynesian Phillips curve. However, the results from Lawless and Whelan (2007), which estimate disaggregated inflation equations based on sectoral-level markups, are less supportive of an important role for sectoral shifts in explaining the behavior of labour's share.

5.3 Structural Changes in Price-setting Behavior

In explaining the apparent flattening of the New-Keynesian Phillips curve, a logical possibility is that there really *has* been a change in underlying price-setting behavior. A number of hypotheses fall under this rubric, and many of these are based on the idea that globalisation has fundamentally changed the economy's behavior.

5.3.1 The Rogoff Hypothesis

Perhaps the best-known of these is that of Rogoff (2003) and Rogoff (2006). His hypothesis incorporates two distinct effects: first, that globalisation has increased pricing "flexibility" (i.e., reduced θ, the share of firms not adjusting in any given period); and second, that increased competition has reduced product markups. Rogoff argues that both of these effects will tend to increase the slope of the

[20] Their model does not use the Calvo framework described above, but is motivated by the quadratic adjustment costs described in Rotemberg (1987).

Phillips curve. Policymakers, now faced with a less-favorable short-term output-inflation tradeoff, will be less tempted to pursue expansionary policies in order to boost output—and this will, in turn, reduce the Barro-Gordon inflation bias.

As pointed out by Ball (2006), the problem with the Rogoff hypothesis is that its implication with regard to the slope of the Phillips curve is precisely the opposite of what one sees in the data: the Phillips curve has become flatter, not steeper. Moreover, the smaller equilibrium markup implied by the increase in competition would imply a larger labour share, and thus is inconsistent with the observed downward movement for the US. Consequently, it seems safe to join Ball in dismissing the Rogoff hypothesis.

5.3.2 Increased Openness of Product and Labour Markets

Another globalisation-related hypothesis is that greater openness means that increases in domestic demand are increasingly satisfied through imports, rather than domestic production. This implies that increases in the output gap will have smaller effects on domestic marginal costs — and hence, muted inflationary consequences. This mechanism has been incorporated in the model developed in Razin and Binyamini (2007), and it is consistent with the view expressed in Borio and Filardo (2006). A corollary is that the *global* output gap has become more important as a determinant of inflation. Similarly, Borio and Filardo (2006) argue that increased openness of labour markets should attenuate the inflationary effects of output fluctuations.

Increased openness, however, probably is insufficient to explain the flattening of the new-Keynesian Phillips curve. The reason is simple: while both developments would tend to weaken the link between the output gap and marginal costs, *neither* are likely to effect the link from expected future costs to inflation. Consequently, estimates of the new-Keynesian specification, which rely on measures of marginal cost rather than the output gap, should be immune to these issues.

5.4 The Need for a Richer Structural Model

A final possible explanation for apparent flattening in the typical new-Keynesian Phillips curve is that the pricing behaviour of firms has not changed, but that the structural model we have estimated is itself is too simple. An example is Ascari (2004), who argues that relaxing the simplifying assumption of no trend

inflation considerably alters the Calvo model. Alternatively, our results suggest that the frequency of price setting may be dependent on the average inflation rate - as price resetting is estimated to have been more frequent in the 1970s than subsequently, an idea also raised by Ball, Mankiw and Romer (1988). This raises a possible indirect way that monetary policy may have influenced the slope of the Phillips curve, namely by achieving lower trend inflation it has created an environment in which firms reset their prices less frequently. While we have interpreted the Calvo parameter as a "deep" parameter, really the Calvo framework imposes a constraint on optimal behaviour in order to produce nominal rigidities rather than providing a truly behavioural reason why they occur. Consequently, it is not implausible that the frequency with which prices are reset may be time-varying. To fully investigate this we obviously need a considerably richer structural model.

6. Conclusions

It is now 50 years after Phillips first observed the relationship between unemployment and wages, variants of which now occupy a critical position in the intellectual framework underpinning monetary policy. Recently, policymakers have observed that fluctuations in activity do not appear to be as inflationary as in the past, which is borne out by our estimates of reduced-form Phillips curves. This paper has attempted to summarize some of the common arguments cited regarding why this has occurred, using the standard new-Keynesian Phillips curve as an organizing framework. Our estimates suggest that there has also been a flattening in this "structural" model, that is, there has been a change in the price-setting behaviour of firms. In particular, it appears that the duration between price resetting may have lengthened. Many of the common explanations for changes in the price-setting behaviour of firms are related to globalisation. While globalisation may alter the relationship between the output gap and marginal costs, it is unclear why it would alter the link between marginal costs and inflation in a way that corresponds to a flattening of the Phillips curve. In a structural model the deep parameters in the Phillips curve should be invariant to changes in the conduct of monetary policy. However, one potential explanation is that lower trend inflation resulting from the improved conduct of monetary policy may account for the more infrequent price resetting and hence the flattening Phillips curve, a possibility which is not accommodated in the benchmark new-Keynesian model.

In all, it appears that after 50 years there is still considerable work to be done in order to fully understand the relationship between aggregate activity and inflation.

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