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A reappraisal of the inflation–unemployment tradeoff

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Abstract

This paper offers a reappraisal of the inflation–unemployment tradeoff, based on frictional growth, describing the interplay between nominal frictions and money growth. When the money supply grows in the presence of price inertia (due to staggered wage contracts with time discounting), the price adjustments to each successive change in the money supply are never able to work themselves out fully. In this context, temporary nominal rigidities let monetary policy have permanent real effects. Although our theory contains no money illusion, no permanent nominal rigidities, and no departure from rational expectations, there is a long-run inflation–unemployment tradeoff. Our empirical analysis suggests that this Phillips curve may be reasonably flat. We show that the persistence of inflation and unemployment, in response to monetary policy shocks, is related to the slope of the long-run Phillips curve.

JEL classification: E2; E3; E4; E5; J3
Keywords: Inflation; Unemployment; Phillips curve; Nominal inertia; Wage-price staggering; Monetary policy; Business cycles; Forward-looking expectations

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1. Introduction

This paper proposes a reappraisal of the inflation–unemployment tradeoff. Our analysis focuses on the interplay between monetary growth and nominal frictions, frictional growth for short. Our nominal frictions arise from time-contingent staggered nominal contracts. We show that frictional growth can generate a long-run inflation–unemployment tradeoff that is downward-sloping—even though our theory contains no money illusion, no permanent nominal rigidities, and no departure from rational expectations.

Our analysis covers the following themes.

- Although it is well-known that staggered nominal contracts with time discounting imply a long-run Phillips curve tradeoff, it is generally assumed that this tradeoff is negligible in practice, i.e. the Phillips curve is nearly vertical. By contrast, the calibrations of our theoretical model and the simulation results from our empirical model indicate that the long-run Phillips curve can be quite flat under plausible circumstances.
- We also show that the slope of the long-run Phillips curve is related to inflation persistence and unemployment persistence in the aftermath of monetary shocks. Whereas the standard New Phillips curve (downward-sloping in the short run and vertical in the long run) has recognized difficulties in accounting for inflation persistence and often implies implausible impulse-response functions (IRFs) for unemployment, our Phillips curve (downward-sloping in the short, medium and long run) can generate inflation persistence and plausible unemployment IRFs. In particular, our analysis can explain how money growth shocks have a delayed and gradual effect on inflation, and have a quicker effect on unemployment, whose time path is hump-shaped.
- We find that the lower is the discount rate, the steeper is the associated long-run Phillips curve (cet. par.), but the longer it takes for unemployment to converge to its long-run values. Empirically, it may be difficult to distinguish between quick convergence to a flat long-run Phillips curve and slow convergence to a steep one (i.e., between permanent versus very prolonged unemployment effects of money growth shocks).
- The difference between the forward-looking New Phillips curve and the traditional backward-looking Phillips curve does not hinge—as much of the literature suggests—on whether current inflation depends on expected future inflation or on past inflation. The straightforward reason is that expectations of future inflation can be expressed in terms of current and past inflation and unemployment. Doing so, we derive a short-run Phillips curve that looks remarkably like the traditional backward-looking Keynesian Phillips curve. It turns out that the critical difference between the forward- and backward-looking Phillips curves hinges on theoretical parameter restrictions.
- Our analysis suggests a reevaluation of the role of monetary policy in the macroeconomic system (although the details of this reevaluation lie beyond the scope of this paper). It shows that monetary policy can have a long-run effect on unemployment, which is closely related to the short- and medium-run effects.

The paper is organized as follows. Section 2 presents the underlying intuition. Section 3 relates our analysis to the existing literature. Section 4 describes the microfoundations of our macro model. Section 5 presents the corresponding macro model.

Section 6 derives the associated short-run Phillips curve, and Section 7 derives the long-run Phillips curve, showing why it can be reasonably flat under plausible calibrations. In Section 8, we link the short- and long-run Phillips curves by deriving the impulse-response functions of inflation and unemployment to monetary shocks.

Section 9 provides an empirical analysis of the inflation–unemployment tradeoff for the United States and the European Union, allowing for frictional growth. We show that the implied long-run Phillips curves are far from vertical. Finally, Section 10 concludes.

2. The intuition

The intuition underlying our long-run Phillips curve may be summarized as follows. From the microfoundations of staggered nominal contracts,[1] it is well known that, when the time discount rate is positive, current nominal values are influenced more strongly by past than by future nominal values. Consider, for example, two staggered nominal wage contracts, each lasting a year, with one set in January and the other in July. As shown in Fig. 1, the past contract wage (say, for July 2003–June 2004) is W_{t-1}, and the current contract wage (for January–December 2004) is W_t.

- The current (aggregate) price level P_t (say, for January–June 2004) is a markup over the past contract wage W_{t-1} and the current contract wage W_t.
- In turn, W_{t-1} depends on P_{t-1} and P_t; and W_t depends on P_t and P_{t+1}.
- Consequently, the current price level P_t can be viewed as a weighted average of the past and future price levels, P_{t-1} and P_{t+1}. Furthermore, under time discounting, the future price level receives less weight than the current one, i.e. there is an *intertemporal weighting asymmetry.*

In an inflationary environment (with all nominal variables growing), this intertemporal weighting asymmetry has an important implication: *the price level chases after a moving target*. The target price is what the price level would be under instantaneous price adjustment. Since the money supply keeps rising from period to period whereas prices depend more heavily on past prices than future ones, the price adjustments never work themselves out fully. By the time the current price level has begun to respond to the current increase in the money supply, the money supply rises again, prompting a new round of price adjustments.

To analyze the long-run inflation–unemployment tradeoff, we need to consider permanent changes in inflation, associated with permanent changes in money growth (such as those accompanying changes in a central bank's inflation target or other policy rule). Under the intertemporal weighting asymmetry above, a permanent increase in money growth causes the price level to fall further behind its target. Although *inflation*

[1] Regarding Taylor contracts, see, e.g. Helpman and Leiderman (1990), Ascari (2000), and Graham and Snower (2002a,b); for Calvo contracts, see, e.g. Bernanke et al. (2000) and Galí (2003).

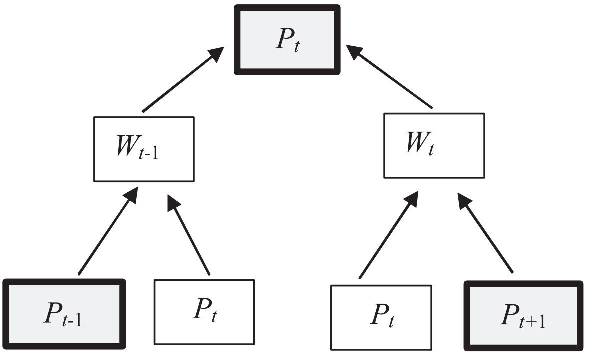

Fig. 1. Intertemporal relations among price levels.

eventually catches up with money growth (so that long-run inflation is equal to money growth), the *price level* does not catch up with the level of the money stock, so that in the long run the price level falls relative to the money supply.

As illustrated in Fig. 2, an increase in money growth ($\Delta M_t \uparrow$) leads to a proportional increase in the target price ($\Delta P_t^T \uparrow$), but the actual price level increases less than proportionately ($\Delta P_t \uparrow$ by less).[2] Thus, comparing the initial and final steady states, the level of real money balances rises ($(M/P)_t \uparrow$) and unemployment falls ($u_t \downarrow$) while inflation rises ($\pi_t \uparrow$). In short, the long-run Phillips curve is downward-sloping.

Underlying this long-run tradeoff is a concept of equilibrium that differs from the textbook notions. In these standard notions, an economic equilibrium is attained when all lagged adjustment processes have worked themselves out. (This may mean, for instance, that expectations have become consistent with the underlying stochastic generating processes, or that other temporary adjustment costs—such as production and employment adjustment costs—have been overcome and thus do not influence the steady-state behavior of economic agents.) In our analysis, by contrast, the macro equilibrium is reached when the untrended macro variables (inflation, unemployment) stabilize; but in this equilibrium, adjustment costs have not worked themselves out. On the contrary, the equilibrium is the long-run outcome of a race between growing variables and lagged adjustment processes. Specifically, in the context of our analysis, the money supply is continually growing and wages and prices are continually in the process of catching up. In the resulting equilibrium, the adjustment processes—the degree of temporary nominal rigidity (e.g., the length of the contract period)—continue to have an important influence on real variables (unemployment, employment, output) in the long run.

Note that the intertemporal weighting asymmetry—generated by time discounting in the intuitive account above—plays a crucial role here. In the absence of this asymmetry, the current price level would depend equally on past and future price

[2] Specifically, in any given time period, the price level falls relative to the money supply. But in the steady state, the money supply and the price level grow at the same rate.

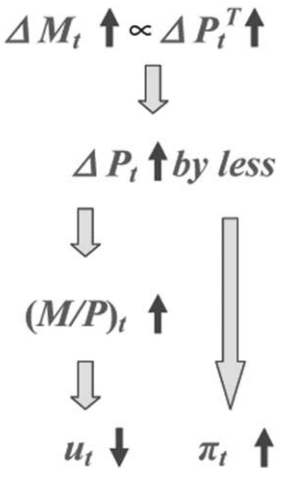

Fig. 2. Prices chasing a moving target.

levels, and thus money growth would no longer cause this price level to lag behind a moving target. At first sight, it may be tempting to believe that since the time discount rate is generally taken to be small (a few percentage points), the price level can never fall far behind the money supply and thus the long-run Phillips curve must always be approximately vertical. But this view is mistaken. The reason is that the slope of the long-run Phillips curve, as we shall see, depends not only on the discount factor, but also on the responsiveness of contract wages to changes in unemployment (or other real variables). It turns out that the less responsive contract wages are, the more sensitive is the slope of the long-run Phillips curve to the discount factor.[3] Since the empirical literature suggests that contract wages are quite unresponsive to changes in unemployment, even moderate discount rates (e.g., ones between 2% and 5%) can generate reasonably flat long-run Phillips curves.

Furthermore, it is worth emphasizing that, in practice, the intertemporal weighting asymmetry depends on more than just time discounting:[4]

- Since future economic conditions are more risky than current ones (i.e., our confidence in our predictions declines as these predictions lie further in the future), risk-averse agents discount the future by a risk premium as well as a time discount rate.

[3] In the terminology of Ball and Romer (1990), the greater is the "real rigidity" (the responsiveness of contract wages to real variables), the stronger is the influence of the "nominal rigidity" (the asymmetric intertemporal weighting of past and future prices) on real variables, and thus the flatter is the Phillips curve. Note, however, that Ball and Romer's analysis is static whereas ours is dynamic, and their notion of nominal rigidity is thus quite different from ours.

[4] Moreover, many applied researchers suggest that, in practice, people often tend to be myopic, and thus act as if they had a very high intertemporal discount rate.

- Furthermore, the higher is the expected separation rate of employees, the less likely it becomes that they will receive the currently negotiated wages that are to accrue in the future. Thus, when the wage contract is negotiated, employees attach greater weight to current remuneration (that depends on wages set in the past) than on future remuneration (that depends on wages set in the future). The average monthly job separation rate in the United States has exceeded 3% for much of the past decade.[5]

For brevity, however, these considerations will remain beyond the scope of our formal model, which relies only on time discounting to generate the intertemporal weighting asymmetry. We show that substantial long-run inflation–unemployment tradeoffs can exist even under reasonably low discount rates.

Another crucial assumption of our analysis is that contract wages are held constant in nominal terms over the contract span, rather than being indexed to the price level. Clearly, if contract wages were fully indexed, then (in the absence of other nominal rigidities) any change in the money supply would lead to a proportional change in contract wages, and thus real variables would remain unaffected. The literature on indexing,[6] however, provides convincing reasons why contract wages are indexed only partially, if at all: whereas it is efficient for contract wages to be fully indexed in the presence of only nominal shocks, full indexation is not efficient in the presence of real shocks that affect relative prices. Since indexation in practice naturally does not allow the relation between contract wage and prices to depend on the nature of the underlying shocks (which cannot be accurately observed), optimal indexation is partial. But in that event, the logic of our analysis continues to hold.[7]

Thus far, downward-sloping long–run Phillips curves have been considered unacceptable on theoretical grounds. In the absence of money illusion—so the conventional argument goes—real economic activities do not depend on the unit of account and, by implication, monetary policy can have no long-term effect on unemployment. Our analysis calls this argument into question. The absence of money illusion implies that real economic activities are unaffected by a proportional change in all nominal variables (past, present, and future). But under circumstances of frictional growth, current nominal variables do not move proportionately to the money supply. An increase in money growth changes the relation between past and future prices, since (as noted) it causes the price level to lag further behind its target value. So the absence of money illusion does not imply money super-neutrality. In short, under the standard classical principles, in which all demand and supply functions are homogeneous of degree zero in all nominal variables, it is still possible for monetary shocks to generate a long-run tradeoff between inflation and unemployment.

[5] Using the Bureau of Labor Statistics' Job Openings and labor Turnover Survey (JOLTS), which begins in December 2000, Hall (2003) reports that the monthly separation rate was 3.4% in December 2000, 3.2 in December 2001, and 3.0 in December 2002. See also Blanchard and Diamond (1990), who examine household data in the Current Population Survey as well as the manufacturing turnover survey from 1968 through 1981.

[6] See, for example, the seminal contribution of Danziger (1988), and the macro model of Blanchard and Fischer (1989, p. 523).

[7] The slope of the long-run Phillips curve can of course be shown to depend on the degree of indexation, and thereby on the magnitude of relative price shocks vis-à-vis nominal shocks.

3. Relation to the literature

The traditional Keynesian expectations-augmented Phillips curve, in its simplest form, may be expressed as $\pi_t = \pi_{t-1} - a(u_t - u^n) + \varepsilon_t$ (where π is the inflation rate, u is the unemployment rate, u^n is the natural rate of unemployment [or NAIRU], a is a positive constant, and ε_t is white noise). It has been called "a fact in search of a theory", since it is in accord with prominent empirical regularities, but has proved difficult to rationalize through microfoundations.

The standard textbook version of the New Phillips curve[8] (NPC) is $\pi_t = E_t\pi_{t+1} - a(u_t - u^n) + \varepsilon_t$,[9] (where E_t denotes expectations set at time t). It is far less successful in explaining the stylized facts. In particular, why inflation is so persistent, with autocorrelations close to unity;[10] why monetary shocks have delayed and gradual effects on inflation and unemployment;[11] and why we usually do not observe "disinflationary booms".[12] So, with some exaggeration, the New Phillips curve might be called "a theory in search of a fact"! These issues are important, since the Phillips curve is central to our understanding of business cycles and widely used in the analysis of monetary policy.[13]

In recent years, various attempts have been made to rectify these predictive deficiencies—generally by bringing the predictions of the NPC more closely into line with the traditional one—but no consensus on the nature of the Phillips curve has yet been reached.[14]

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[8] It is also known as the "New Keynesian Phillips Curve" or the "New Neoclassical Synthesis". For surveys see, for example, Galí (2003), Goodfriend and King (1997), Mankiw (2001), and Roberts (1995).

[9] Alternatively, the unemployment term may be replaced by another real variable, such as the output gap.

[10] Fuhrer and Moore (1995) argue that although the Taylor model can account for slow adjustment of wages and prices, inflation is a jump variable that can adjust instantly (much like the capital stock adjusts slowly even though investment can adjust instantly).

[11] See, for example, Mankiw (2001).

[12] See Ball (1994). When monetary policy is credible, the announcement of a monetary contraction leads firms to expect disinflation, and thus they moderate their price rises even before the money supply slows down. Consequently, real money balances rise, stimulating aggregate demand and reducing unemployment. Conversely, expansionary monetary policy has a contractionary effect on unemployment. In practice the opposite happens; for a recent appraisal, see for example Ball (1997, 1999).

[13] See, for example, Clarida et al. (1999).

[14] The literature is vast; the following are a few examples. Mankiw and Reis (2001) address them in a model where price information disseminates gradually among economic agents. Roberts (1997) constructs a model in which price expectations are not fully rational. Ball (1995) investigates the effects of monetary policy that is not fully credible. Galí (2003) and Galí et al. (2001) examine inflation persistence in terms of price staggering and the cyclical behavior of marginal costs. Lindbeck and Snower (1999) examine the real effects of monetary shocks in the presence of price precommitment and production lags. Huang and Liu (2002) show that wage staggering is more effective than price staggering in amplifying real persistence of monetary shocks. Helpman and Leiderman (1990) and Erceg et al. (2000) examine the interaction between price- and wage-staggering. Some authors, e.g. Estrella and Fuhrer (1998), focus on rigidities such as habit formation in consumption. Other contributors derive real and nominal persistence from complementarities between wage-price staggering and various real rigidities. For instance, Christiano et al. (2001) and Dotsey et al. (1997) examine the interaction between nominal staggering and variable capital utilization. Jeanne (1998) examines the complementarity between price staggering and real wage rigidity. Bergen and Feenstra (2000) investigate the real effects of monetary shocks under staggered price setting in the context of a translog demand structure and roundabout input–output technologies. Kiley (1997) examines the interaction between price staggering and increasing returns in production. Huang and Liu (2001) analyze price staggering in a vertical input–output structure.

Moreover, both the old and new Phillips curves share a further predictive deficiency. It is that *if the NAIRU is reasonably stable through time*, then inflation will change without limit for as long as the unemployment rate differs from this NAIRU.[15] This knife-edge prediction has received little if any empirical support. There is certainly no evidence of limitlessly large deflation when unemployment is high ($u_t > u^n$ in the traditional Phillips curve) or low ($u_t < u^n$ in the NPC). In Europe, the rise in unemployment over much of the 1980s and early 1990s despite stable inflation is not in accord with this interpretation.[16] In the US, the fall in both inflation and unemployment during much of the 1990s does not fit it either.

There are three ways of dealing with the knife-edge problem. One is to assume that the NAIRU varies through time in agreement with the NAIRU hypothesis.[17] Then the NAIRU hypothesis becomes tautologous, lacking explanatory power. The charge of tautology can be avoided only if there is convincing ex ante explanatory evidence for the predicted movements of the NAIRU. But such evidence is often hard to come by. For example, if movements in the NAIRU relative to the actual unemployment rate are inversely related to movements in inflation (in accordance with the traditional Phillips curve), then the NAIRU in many continental European countries must have been rising between the mid-1970s and early 1990s, except for a few years in the late 1980s. But it is far from clear where these NAIRU movements could have come from. The large increases in union density, unemployment benefits and benefit durations, and other welfare state entitlements, the increased stringency of job security legislation, and the big influx of women and young people into the labor force in Europe occurred primarily in the 1960s and early 1970s. By the 1980s and 1990s, these trends had largely ceased and there were even important moves in the opposite direction.[18] The alleged fall in the United States NAIRU in the second half of the 1990s is also difficult to explain.[19] With 20–20 hindsight, it is of course possible always to identify new constellations of economic variables that could plausibly have pushed the NAIRU in any direction required by the underlying theory. But the selective nature of this exercise has made a growing number of economists uneasy.

A second way to avoid the knife-edge problem is to suppose that there are long lags in the adjustment of unemployment to macroeconomic shocks, such as the oil price shocks of the mid-1970s and early 1980s and the interest rate shock of the early 1990s. According to this interpretation, the long-run NAIRU in Europe and the United States was reasonably stable over the past three decades; the divergent unemployment trajectories in Europe and

[15] Specifically, the traditional Phillips curve implies that $\Delta\pi_t = -a(u_t - u^n) + \varepsilon_t$, so that inflation falls (rises) without limit when unemployment is high (low), relative to the NAIRU. By contrast, the New Phillips curve implies that $\Delta\pi_{t+1} = a(u_t - u^n) + \varepsilon_{t+1}$ (where $\varepsilon_{t+1} = \pi_{t+1} - E_t\pi_{t+1}$ is an expectational error), so that inflation rises (falls) without limit when past unemployment is high (low).

[16] The rise of European inflation and unemployment in the mid-1970s and early 1980s is not in agreement with the traditional Phillips curve, with a stable NAIRU.

[17] In other words, the variations in the NAIRU are such that the resulting difference between the NAIRU and the actual unemployment rate is always inversely proportional to variations in the inflation rate, according to the traditional Phillips curve, or directly proportional to the inflation variations, according to the New Phillips curve.

[18] Rising interest rates and tax rates may well have played a role in driving the NAIRU upwards over the 1980s, but the timing of these factors does not always mesh well with the timing of the unemployment increases in various European countries. The relevant literature is voluminous and well-known; an impressive example is Phelps (1994, chap. 17).

[19] This literature is also well-known. See, for example, Phelps (1999) and Phelps and Zoega (2001).

the United States are due to differences in adjustment costs (such as costs of hiring and firing) in the face of some common macroeconomic shocks; and these prolonged unemployment adjustments had little influence on inflation.[20] This approach also has difficulties: the lagged adjustments need to be very long and variable for the explanation to work, and it is not clear why inflation is not sensitive to the prolonged unemployment adjustments.

A third way of avoiding the knife-edge problem is to dispense with the NAIRU altogether. This is the approach pursued here. Our analysis calls into question the conventional view that the long-run Phillips curve is either vertical or nearly vertical and that forward-looking Phillips curves are difficult to reconcile with substantial inflation persistence and unemployment inertia. We show that under plausible empirical assumptions the long-run Phillips curve may be downward-sloping and reasonably flat, and that the flatter this slope is, the more under-responsive is inflation to a money growth shock.

Our analysis is in some respects similar in spirit to the pathbreaking work of Akerlof et al. (1996, 2000), who show that the Phillips curve becomes downward-sloping at low inflation rates when there are permanent downward wage rigidities or departures from rational expectations. But in contrast with these contributions, our analysis indicates that the long-run Phillips curve is downward-sloping even when there are no permanent nominal rigidities, no money illusion, and no departures from rational expectations.

Further notable theoretical analyses of non-vertical inflation–unemployment tradeoffs include Hughes-Hallet (2000) and Holden (2003). Holden shows how an inflation–unemployment tradeoff—again at low inflation rates—can arise in European countries where the nominal wage can only be changed by mutual consent in wage negotiations. Hughes-Hallet's non-vertical Phillips curve is due to aggregation over sectoral/regional Phillips curves with heterogenous short-run slopes. Our analysis does not rely on such strategic considerations or aggregation issues.

It is worth noting that the strictly microfounded version of the NPC is often expressed as $\pi_t = \beta E_t \pi_{t+1} - a(u_t - u^n) + \varepsilon_t$, where β is the discount factor. Although this Phillips curve is not subject to the knife-edge problem, the conventional wisdom is that since the discount factor β is close to unity, it can usefully be approximated by the textbook version above. On this account, β is commonly set equal to unity when the NPC is used for prediction and policy analysis,[21] and attention in the mainstream literature is focused on explaining inflation persistence rather than avoiding the knife-edge behavior. It is certainly true to say that the conventional analyses of the Phillips curve are broadly compatible with the NAIRU and its knife-edge implications.

The existing empirical evidence on the NAIRU hypothesis and the slope of the long-run Phillips curve is distinctly mixed, and has led major contributors such as Mankiw (2001) to be "agnostic" on the issue. Given economists' predilection for the classical dichotomy, it is striking how many well-known recent studies reject it. Ball (1997) shows that countries experiencing comparatively large and long declines in inflation tend also to encounter comparatively large increases in their NAIRUs. Ball (1999) suggests that such a relationship

[20] See, for example, Blanchard and Summers (1986), Lindbeck and Snower (1989, chap. 11), Henry et al. (2000).

[21] See, for example, Galí and Gertler (1999), Romer (1996), Walsh (1998).

may be due to monetary policy: countries with relatively contractionary monetary policy in the 1980s tended to have relatively large increases in their NAIRUs. In Bernanke and Mihov (1998), the estimated impulse-response functions of unemployment to monetary shocks do not go to zero (although the estimated influence is statistically insignificant). Akerlof et al. (1996, 2000) find evidence of a long-term tradeoff between inflation and unemployment at low inflation rates. Dolado et al. (2000) find some evidence of such a tradeoff over the entire range of observations for Spain during 1964–1995. Fisher and Seater (1993), King and Watson (1994), and Fair (2000) find a long-run inflation–unemployment tradeoff as well.

Our analysis will provide theoretical foundation and empirical support for a long-run inflation–unemployment tradeoff. In the process, we will also show that the slope of this tradeoff is closely related to inflation persistence and the dynamic response of unemployment to monetary shocks. We now present a theoretical model which formalizes our central ideas.

4. Microfoundations

Our microfoundations—in the spirit of Ascari (2003), Huang and Liu (2002) and others—are quite standard. The model is based on Graham and Snower (2002b).

Consider an economy in which a continuum of households supplies differentiated labor to a fixed number of identical firms (normalized to one), with the following production function:

$$y_t^{\mathrm{s}} = n_t^{\mathrm{d}} = \left[\int_{h'=0}^{1} n_t^{\mathrm{d}}(h')^{\frac{\theta-1}{\theta}} \mathrm{d}h'\right]^{\frac{\theta}{\theta-1}}, \tag{1}$$

where y_t^{s} is output supplied, n_t^{d} is aggregate employment demanded, $n_t^{\mathrm{d}}(h)$ is labor of type h demanded, and θ is the elasticity of substitution between labor types.

The households are grouped into N wage-setting cohorts, each of which sets the nominal contract wage for N periods. Let $\mathrm{W}_t(h)$ be the contract wage received by household h. Then profit maximization subject to the production function above yields the following labor demand function:

$$n_t^{\mathrm{d}}(h) = \left[\frac{\mathrm{W}_t(h)}{\mathrm{V}_t}\right]^{-\theta} n_t^{\mathrm{d}}, \tag{2}$$

where V_t is the aggregate wage index:

$$\mathrm{V}_t = \left[\int_{h'=0}^{1} \mathrm{W}_t(h')^{1-\theta} \mathrm{d}h'\right]^{\frac{1}{1-\theta}}. \tag{3}$$

Each household maximizes the present value of its utility over the contract period, which depends on consumption demand $q_{t+i}^{\mathrm{d}}(h)$, labor supply $n_{t+i}^{\mathrm{s}}(h)$, $i=0,1,\ldots,N-1$ and real money balances $\frac{\mathrm{M}_{t+i}(h)}{\mathrm{P}_{t+i}}$:

$$\max_{\mathrm{V}_t(h),q_{t+i}(h),n_{t+i}(h),\mathrm{M}_{t+i}(h)} \sum_{i=0}^{N-1} \beta^i \left[\log q_{t+i}^{\mathrm{d}}(h) + \varsigma \frac{(1-n_{t+i}^{\mathrm{s}}(h))^{1-\eta}}{1-\eta} + v\log\frac{\mathrm{M}_{t+i}(h)}{\mathrm{P}_{t+i}}\right],$$

where β is the discount factor, and ς and ν are positive constants. This utility function has the desirable long-run properties (see King et al., 1988). The household's intertemporal budget constraint is

$$\sum_{i=0}^{N-1} \beta^i q_{t+i}^{\mathrm{d}}(h) + \beta^{N-1} \frac{\mathrm{B}_{t+N-1}(h) + \mathrm{M}_{t+N-1}(h)}{\mathrm{P}_{t+N-1}}$$
$$= \sum_{i=0}^{N-1} \beta^i \left[\frac{\mathrm{W}_t(h)}{\mathrm{P}_{t+i}} n_{t+i}^{\mathrm{s}}(h) + \frac{\mathrm{T}_{t+i}(h)}{\mathrm{P}_{t+i}} + \frac{\Pi_{t+i}(h)}{\mathrm{P}_{t+i}} \right] + R_t \frac{\mathrm{B}_t(h)}{\mathrm{P}_t} + \frac{\mathrm{M}_t(h)}{\mathrm{P}_t},$$

where $\Pi_{t+i}(h)$ is its profit income, R_t is the nominal interest factor on its bond holdings $\mathrm{B}_t(h)$, and $\mathrm{T}_{t+i}(h)$ are lump-sum taxes. The household also faces the labor demand constraint (Eq. (2)).

Maximizing the utility function subject to these two constraints, we obtain the consumption function:

$$q_t^{\mathrm{d}}(h) = \frac{1}{\nu} \frac{\mathrm{M}_t(h)}{\mathrm{P}_t}; \tag{4}$$

and the optimal labor supply:

$$(\theta - 1) \sum_{i=0}^{N-1} \beta^i = \sum_{i=0}^{N-1} \beta^i \theta \varsigma n_{t+i}^{\mathrm{s}}(h)(1 - n_{t+i}^{\mathrm{s}}(h))^{-\eta}. \tag{5}$$

Since there are constant returns to labor in aggregate ($y_t = n_t$), the aggregate price level is a unit markup over the aggregate wage:

$$\mathrm{V}_t = \mathrm{P}_t. \tag{6}$$

The product and labor markets clear:

$$y_t^{\mathrm{s}} = q_t^{\mathrm{d}}, \tag{7}$$

$$n_t^{\mathrm{d}} = n_t^{\mathrm{s}}, \tag{8}$$

where $q_t^{\mathrm{d}} = \int_{h'=0}^{1} q_t^{\mathrm{d}}(h')\mathrm{d}h'$ and $n_t^{\mathrm{s}} = \int_{h'=0}^{1} n_t^{\mathrm{s}}(h')\mathrm{d}h'$.

Finally, the government has the following budget constraint:

$$\mathrm{B}_{t+i+1} + \mathrm{M}_{t+i+1} = R_{t+i}\mathrm{B}_{t+i} + \mathrm{M}_{t+i} + \mathrm{T}_{t+i}, \tag{9}$$

where B, M, T are the aggregate amounts of bonds, money, net transfers, and $\mathrm{M}_t = \int_{h'=0}^{1} \mathrm{M}_t(h')h'$.

To motivate the inflation–unemployment tradeoff as transparently as possible, we now move from these microfoundations to a linear macro model.

5. The macro model

To derive our macro model, we log linearize the equations above (around zero inflation)[22] and aggregate them across agents. For simplicity, we assume that there are two wage-setting cohorts.

Log linearizing the wage index and substituting it into the linearized markup equation, we obtain:[23]

$$P_t = \frac{1}{2}(W_t + W_{t-1}). \tag{10}$$

Log linearizing the consumption function, aggregating across households, and setting the resulting aggregate demand equal to aggregate supply (given by the production function), we find[24]

$$N_t = M_t - P_t \tag{11}$$

Substituting the labor demand function and the wage index into the labor supply function and linearizing, we derive the standard Taylor contract equation:[25]

$$W_t = \alpha W_{t-1} + (1-\alpha)E_t W_{t+1} + \gamma(c + \alpha N_t + (1-\alpha)E_t N_{t+1}) + \omega_t, \tag{12}$$

where

$$\alpha = \frac{1}{1+\beta}$$

is the "discounting parameter", γ (a positive constant) is the "demand sensitivity parameter" that describes how strongly the contract wage is influenced by changes in labor demand, and c is the "cost-push parameter" representing upward pressure on wages that is independent of demand. E_t denotes expectations formed in period t, and the contract shock ω_t is a white noise error term.[26] We assume that the wage setters have knowledge of nominal wages and employment up to period t.

The aggregate labor supply, defined as the total amount of time available to all households, is constant, so that it can be normalized to zero: $L_t = 0$. The unemployment

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[22] The nonlinear behavior of the general equilibrium system above is described in Graham and Snower (2002b). Due to the linearization here, the predictions of our theoretical macro model are relevant only to low inflation rates. Our empirical analysis below, however, applies to larger variations, since the estimated behavioral equations are associated with the actual variations in money growth.

[23] P_t and W_t are the log-linearized forms of the price level P_t and the contract wage W_t.

[24] N_t and M_t are the log-linearized forms of aggregate employment n_t and the money supply M_t.

[25] In order to make this contract equation equivalent to the well-known Taylor contract (Taylor, 1980a), we include an error term, which could be motivated by extending our microfoundations model to include stochastic preferences or productivity shocks unanticipated by the households.

[26] We assume that $E_t\omega_t = 0$.

rate (not in logs) can be approximated as $u_t = L_t - N_t = -N_t$. Thus, by Eq. (11), the unemployment equation is

$$u_t = -(M_t - P_t). \tag{13}$$

To close the model, we need to specify the process governing the money supply. Since the analysis of the long-run Phillips curve requires that we consider the unemployment rates associated with different long-run inflation rates, we need to consider permanent shocks to money growth. For simplicity, let money growth follow a random walk:

$$\Delta M_t \equiv \mu_t = \mu_{t-1} + \varepsilon_t, \tag{14}$$

where M_t is the log of the money supply and ε_t is a white-noise error term. We assume that rational agents at time t know the stochastic process generating money growth, and have information up to the shock ε_t, but do not know future realizations of the money growth shock. It is important to note that our qualitative conclusions do not hinge on this random walk assumption. Any money growth process involving a permanent change in money growth (e.g., an $I(0)$ money growth process with a change in money growth regime, or a permanent change in the monetary authority's reaction function) would do.[27]

The macro model above comprises four linear equations in four variables (the price level P_t, the contract wage W_t, employment N_t, and the money supply M_t). The supply and demand sides of the economy are equilibrated through the wage contract Eq. (12): a fall in the demand for labor puts downward pressure on the nominal wage W_t. The fall in the nominal wage, in turn, puts downward pressure on the price level (by Eq. (10)). Thus, given the money supply Eq. (14), real money balances rise and aggregate demand is stimulated.

In the context of this model, we now proceed to derive the Phillips curve, first in the short run and then in the long run.

6. The short-run Phillips curve

To derive the short-run Phillips curve, we substitute the wage contract Eq. (12) into the price mark-up Eq. (10) to obtain the following price equation:[28]

$$\begin{aligned} P_t = {} & \alpha P_{t-1} + (1-\alpha)(E_t P_{t+1} + v_t) + \gamma c + \frac{1}{2}(\omega_t + \omega_{t-1}) \\ & + \frac{\gamma}{2}(\alpha N_{t-1} + \alpha N_t + (1-\alpha)E_{t-1}N_t + (1-\alpha)E_t N_{t+1}), \end{aligned} \tag{15}$$

[27] Karanassou et al. (2002, Appendix 1) show that although the random walk assumption receives some moderate support from the data, the central results can be derived from other money growth processes as well.

[28] To see this, substitute Eq. (12) into Eq. (10) and note that $1/2(E_t W_{t+1} + E_{t-1} W_t) = 1/2(E_t W_{t+1} + W_t) + 1/2(E_{t-1} W_t + W_{t-1}) - 1/2(W_t + W_{t-1}) = E_t P_{t+1} + v_t$.

where $v_t = E_{t-1}P_t - P_t$ is an expectational error term. Recalling that $\alpha = \frac{1}{1+\beta}$, this equation implies the following *forward-looking short-run Phillips curve*:[29]

$$\pi_t = \beta E_t \pi_{t+1} - \frac{\gamma}{2}[u_{t-1} + (1+\beta)u_t + \beta E_t u_{t+1}] + \gamma c(1+\beta) + \eta_t, \tag{16}$$

where $\eta_t = \beta v_t + \frac{(1+\beta)}{2}(\omega_t + \omega_{t-1}) - \frac{\gamma\beta}{2}(E_{t-1}u_t - u_t)$ is a random error term. This equation is quite similar to the standard New Phillips curve (given in Section 2), except that inflation depends not just on current unemployment, but also on past and future unemployment.[30]

In the mainstream literature, it is common to derive conclusions about inflation persistence and the effects of monetary policy from such an equation alone. For example, the influential contribution of Fuhrer and Moore (1995) derives the Phillips curve $\pi_t = E_t\pi_{t+1} + \gamma y_t$, and then states "All of the persistence in inflation derives from the persistence in the driving term y [excess demand] (p. 129)". This approach is misleading, however, since excess demand y—or unemployment u in our model—is an endogenous variable which, along with inflation π, is affected by monetary shocks (and other shocks). Thus, inflation persistence in response to monetary shocks can only be examined in the context of a general equilibrium system, containing both the Phillips curve *as well* as the relation between the real variable (e.g., y or u) and the monetary shock.

For this purpose, we need to embed the Phillips curve (Eq. (16)) in our general equilibrium system above, express the expectations of future inflation in terms of current and past macroeconomic variables, and then derive the impulse response functions of inflation and unemployment to money growth shocks. The first step is to find the equilibrium wage and price level in terms of current and past variables. It can be shown[31] that the equilibrium nominal wage is

$$W_t = (1-\lambda)c + \lambda W_{t-1} + (1-\lambda)M_t + \kappa(1-\lambda)\mu_t + \omega_t, \tag{17}$$

where $\lambda = \left(\frac{\phi_2}{\phi_3} - \sqrt{\left(\frac{\phi_2}{\phi_3}\right)^2 - 4\left(\frac{\phi_1}{\phi_3}\right)}\right)/2$, $\phi_1 = \alpha(1-\frac{\gamma}{2})$, $\phi_2 = (1+\frac{\gamma}{2})$, $\phi_3 = (1-\alpha)(1-\frac{\gamma}{2})$, $\kappa = \frac{\alpha(1+\lambda)}{\frac{\alpha}{1-\alpha} - \lambda} > 0$, and $0 < \lambda < 1$.

The equilibrium price level is

$$P_t = (1-\lambda)c + \lambda P_{t-1} + (1-\lambda)M_t + (1-\lambda)\left(\kappa - \frac{1}{2}\right)\mu_t - \frac{1}{2}\kappa(1-\lambda)\varepsilon_t + \frac{1}{2}(\omega_t + \omega_{t-1}). \tag{18}$$

[29] Add the term $-(1-\alpha)P_t$ to both sides of the previous equation and note that, since we normalize the constant level of the labor force to unity, $N_t = -u_t$.

[30] It has been argued (e.g., Roberts, 1995) that since unemployment has a high degree of serial correlation, the weighted average of past, current, and future unemployment may be approximated by the current unemployment rate. But this argument runs afoul of the Lucas critique: the degree to which current unemployment depends on past and future unemployment is affected by macro policy (the monetary policy Eq. (14)) and thus cannot be specified a priori.

[31] The algebraic manipulations underlying these and subsequent steps in this section are given in Karanassou et al. (2002, Appendix 2).

Thus, the inflation rate is

$$\pi_t = \lambda\pi_{t-1} + (1-\lambda)\mu_t + \frac{1}{2}(1-\lambda)(\kappa-1)\varepsilon_t + \frac{1}{2}\kappa(1-\lambda)\varepsilon_{t-1} + \frac{1}{2}(\omega_t - \omega_{t-2}). \tag{19}$$

Observe that in this equation current inflation (π_t) depends on past inflation (π_{t-1}), the money growth rate, and the monetary and real shocks. It is easy to show that the inflation persistence parameter λ depends inversely on the discount factor β (positively on the discount rate r, where $\beta = \frac{1}{1+r}$, the greater the discount rate the greater the persistence parameter λ). Thus, it is clear that the forward-looking Phillips curve (Eq. (16)) *is* compatible with inflation persistence, given the rest of our general equilibrium system. Note that whereas the persistence parameter λ describes the relation between current and past inflation, it does not by itself provide a description of how fast inflation responds to monetary shocks; for the latter purpose, we also need to consider the stochastic structure of the monetary shocks in the inflation equation (19).

The price equation (18) also implies that equilibrium real money balances are

$$M_t - P_t = \lambda(M_{t-1} - P_{t-1}) + (1-\lambda)\left(\frac{2\alpha-1}{\gamma}\right)\mu_t + \frac{1}{2}\kappa(1-\lambda)\varepsilon_t - (1-\lambda)c - \frac{1}{2}(\omega_t + \omega_{t-1}). \tag{20}$$

Thus, the equilibrium unemployment rate is

$$u_t = (1-\lambda)c + \lambda u_{t-1} - (1-\lambda)\left(\frac{2\alpha-1}{\gamma}\right)\mu_t - \frac{1}{2}\kappa(1-\lambda)\varepsilon_t + \frac{1}{2}(\omega_t + \omega_{t-1}). \tag{21}$$

The Phillips curve may be defined as an equation that translates an impulse response function for inflation (Eq. (19)) into an impulse response function for unemployment (Eq. (21)), and vice versa. Thus, by Eqs. (19) and (21), and the money supply equation (Eq. (14)), we obtain our short-run Phillips curve in closed form:

$$\pi_t = d_0 + d_1\pi_{t-1} - d_2 u_t - d_3 u_{t-1} + d_4 u_{t-2} + e_t, \tag{22}$$

where

$$d_0 = \psi c,\ d_1 = \frac{\psi\kappa}{2},\ d_2 \frac{\psi(1+\kappa)}{2},\ d_3 = \frac{\psi}{2},\ d_4 = \frac{\psi\kappa}{2},\ \psi = \frac{1}{\frac{2\alpha-1}{\gamma} + \frac{\kappa}{2}} \tag{23}$$

$$e_t = \frac{\tilde{\omega}_t}{(1-\lambda B)},\ \tilde{\omega}_t = \frac{1}{2}\left[\left(1 + \frac{\psi(1+\kappa)}{2}\right)\omega_t + \frac{3\psi}{2}\omega_{t-1} - \left(1 + \frac{\psi(\kappa-1)}{2}\right)\omega_{t-2}\right]. \tag{24}$$

The above error term is a moving average process in terms of ω_t, with parameters which are non-linear functions of the theoretical parameters ψ, κ, and λ.[32] Inspection of Eq. (23) shows the following relationships among the slope coefficients of Eq. (22):

$$d_1 = d_4, \text{ and } d_3 = d_2 - d_1. \tag{25}$$

Note that the closed-form Phillips curve (Eq. (22)) looks like the traditional backward-looking Keynesian Phillips curve. Nevertheless, given our macroeconomic model, our closed-form Phillips curve (Eq. (22)) is of course equivalent to our forward-looking Phillips curve (Eq. (16)). This is noteworthy because the standard way of distinguishing the backward-looking from the forward-looking Phillips curves is in terms of lags and leads: in the backward-looking curve, current inflation depends on past inflation, whereas in the forward-looking curve it depends on expected future inflation. Our analysis suggests that this distinction is bogus. Since expectations of future inflation can be restated in terms of the current and past values of the variables, any Phillips curve with forward-looking inflation expectations can of course be transformed into a Phillips curve where current inflation depends on past inflation.

What, then, is the relation between the traditional backward-looking, expectations augmented Keynesian Phillips curve and our forward-looking one? In the traditional Phillips curve, the coefficients on past inflation and on unemployment are unrestricted, with one exception: since the traditional expectations-augmented Phillips curves is compatible with the NAIRU, the coefficient on past inflation was restricted to $d_1 = 1$. In our forward-looking Phillips curve, as we have seen, this restriction does not apply.[33] Instead, the coefficients of this forward-looking Phillips curve must satisfy the restrictions (Eq. (25)) and its error term ($\tilde{\omega}_t$) follows the moving average process given by Eq. (24).[34]

7. The long-run Phillips curve

In the long-run steady state, $\pi_t = \pi_{t-1}$, $u_t = u_{t-1}$, and the white noises error terms ε_t, and ω_t are zero. Thus, by Eq. (19), the long-run inflation rate is[35]

$$\pi_t^{\mathrm{LR}} = \mu_t^{\mathrm{LR}}. \tag{26}$$

[32] ψ, κ, and λ are of course functions of the more basic time-discount parameter α and the demand-sensitivity parameter γ. Eq. (22) can also be expressed as

$$(1 - \lambda B)(1 - d_1 B)\pi_t = d_0(1 - \lambda) - (1 - \lambda B)(d_2 + d_3 B - d_4 B^2)u_t + \tilde{\omega}_t.$$

[33] In this respect, our forward-looking Phillips curve resembles the old-style Phillips curves prior to the "discovery" of the NAIRU. Our long-run Phillips curve is vertical only when the rate of time discount is zero.

[34] These conditions, however, should not be viewed as restrictions imposed on an estimated Phillips curve equation, for two related reasons. First, the restricted equation may not be estimable. Second, as we argue in Section 9, the phenomenon of frictional growth cannot be captured through single-equation estimation of the inflation–unemployment tradeoff, but requires multi-equation estimation, describing how wages and price depend on the money supply and how unemployment depends on the relation between money and prices (or some other relation between real and nominal variables).

[35] Since money growth follows a random walk, the long run money growth rate varies through time (μ_t^{LR} has a time subscript) and the long-run inflation rate is time-varying as well.

Table 1
Slope of the long-run Phillips curve

r (%)	β	α	Slope				
			$\gamma=0.01$	$\gamma=0.02$	$\gamma=0.05$	$\gamma=0.07$	$\gamma=0.10$
1.0	0.990	0.502	−2.01	−4.02	−10.1	−14.1	−20.1
2.0	0.980	0.505	−1.01	−2.02	−5.05	−7.07	−10.1
3.0	0.971	0.507	−0.68	−1.35	−3.38	−4.74	−6.77
4.0	0.962	0.510	−0.51	−1.02	−2.55	−3.57	−5.10
5.0	0.953	0.512	−0.41	−0.82	−2.05	−2.87	−4.10

The long-run unemployment rate is (by Eq. (21))

$$u_t^{\mathrm{LR}} = -\frac{(1-\beta)}{\gamma(1+\beta)}\mu_t^{\mathrm{LR}} + c. \tag{27}$$

Substituting Eq. (26) into Eq. (27), we obtain the long-run Phillips curve:

$$\pi_t^{\mathrm{LR}} = -\frac{\gamma(1+\beta)}{1-\beta}u_t^{\mathrm{LR}} + \frac{\gamma(1+\beta)}{(1-\beta)}c. \tag{28}$$

Note that the slope depends on the discount factor β and the demand sensitivity parameter γ.

The intuition underlying this downward-sloping long-run Phillips curve, given in Section 1, is now easy to confirm. The price level under instantaneous adjustment may be found by letting the time span of each wage contract tend toward zero, so that α tends to 1/2 and μ_t to zero. From the real money balance equation (20), we find that the resulting "target price level" (frictionless price) is $P_t = M_t + c$.[36] However, when the money supply grows in the presence of the intertemporal weighting asymmetry in the wage contract ($\alpha > 1/2$), then the price level lags behind the moving target price level. Specifically, by Eq. (20), the steady state price level becomes $P_t = M_t + c - \frac{2\alpha-1}{\gamma}\mu_t$. Clearly, a permanent increase in money growth (a rise in μ_t) causes the price level to fall below the target price, and consequently real money balances ($M_t - P_t$) rise and unemployment falls.

In the textbook literature on the New Phillips curve,[37] the discount factor is set equal to unity ($\beta = 1$, so that $\alpha = 0.5$ in the contract equation (12), i.e. there is no intertemporal weighting asymmetry), thereby making the long-run Phillips curve vertical and consistent with the NAIRU hypothesis. The underlying reasoning—that the discount rate is just a few percent and thus can be approximated by zero—is misleading because (a) the slope of the long-run Phillips curve depends nonlinearly on the discount factor and (b) the effect of the discount factor on the slope depends on the value of the demand sensitivity parameter γ.

There is little agreement in the literature about the appropriate value of γ. Taylor (1980b) estimates it to be between 0.05 and 0.1; Sachs (1980) finds it in the range 0.07 and

[36] We evaluate the target price in the absence of the white noise shocks ε_t and ω_t.

[37] See, for example, Blanchard and Fischer (1989, p. 395). The authors however express discomfort with this: "Even under lognormality of money and the price level (actually, even under certainty) the optimal rule is not one in which the parameter is equal to a half" (p. 420).

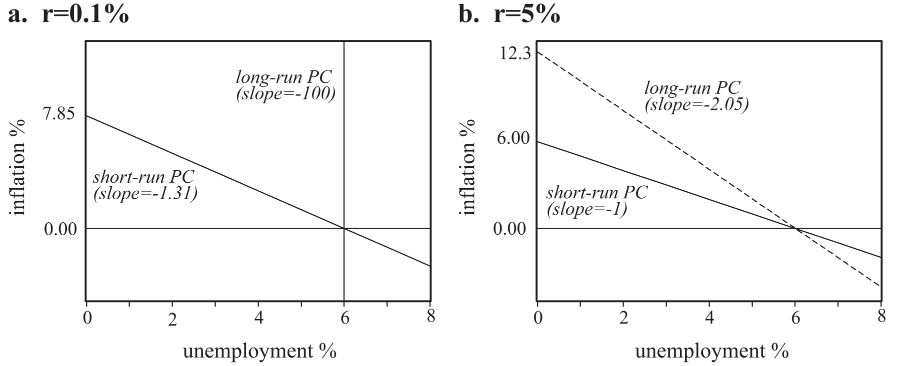

Fig. 3. The short- and long-run Phillips curves ($\gamma = 0.05$, $c = 0.06$).

0.1; Galí and Gertler (1999) estimate it to be between 0.007 and 0.047; calibration of microfounded models (e.g., Huang and Liu, 2002) assigns higher values. Table 1 presents the slope of the long-run Phillips curve associated with various values of the discount rate r (where $\beta = \frac{1}{1+r}$, $\alpha = \frac{1}{1+\beta}$) and the γ parameter.[38]

Observe that, except for combinations of particularly low discount rates and particularly high demand sensitivity parameters γ, the slope of the long-run Phillips curve is quite flat. These results, however, are merely suggestive, since the theoretical model above is obviously far too simple to provide a reliable account of the long-run inflation–unemployment tradeoff under frictional growth. For that purpose, it would be necessary to examine the role of other growing variables in conjunction with other frictions (such as unemployment inertia). The illustrative empirical models in Section 9 are examples of such analysis.

It can be shown that, for plausible parameter values, our short-run Phillips curve has a flatter slope and lower intercept than its long-run counterpart.[39] Fig. 3 provide two examples of associated short- and long-run Phillips curves. Observe that although the long-run Phillips curve is nearly vertical when the discount rate is very low (at 0.1%) and much flatter when the discount rate is high (5%), the short-run Phillips curve remains quite flat in both cases.

8. Theoretical impulse response functions

We now examine the connection between the short- and long-run Phillips curves by deriving the impulse response functions of inflation and unemployment to a permanent monetary shock, i.e. a one-off unit shock to money growth (Eq. (14)), occurring at time

[38] The discount rate applies to a period of analysis which is half the contract span.

[39] In particular, the slope of the short-run Phillips curve (Eq. (22)) is $\frac{\partial \pi_t}{\partial u_t} = d_2 = -\frac{\gamma+\gamma\kappa}{2(2\alpha-1)+\gamma\kappa}$, whereas the slope of the long-run Phillips curve (Eq. (28)) is $\frac{\partial \pi_t^{LR}}{\partial u_t^{LR}} = -\frac{\gamma}{2\alpha-1}$. It can be shown that if, as is plausible, the long-run slope is less than -1, the long-run Phillips curve is steeper than the short-run one. (This is a sufficient but not necessary condition, as shown in Karanassou et al. 2002, Appendix 2). The intercept of the short-run Phillips curve (Eq. (22)) is given by $d_0 = \left(\frac{2\gamma}{2(2\alpha-1)+\gamma\kappa}\right)c$, which is smaller than the long-run Phillips curve (Eq. (28)) intercept: $\left(\frac{\gamma}{2\alpha-1}\right)c$. (For the underlying derivations, see Karanassou et al., 2002, Appendix 2).

$t=0$: $\varepsilon_0=1$ and $\varepsilon_t=0$ for $t>0$. At time $t=0$, economic agents know the process (Eq. (14)) generating money growth, but not the realizations of the error term ε_{t+i}, $i\geq 1$.

Thus, the monetary shock ε_0 is known to the wage setters at time $t=0$, but not at time $t=-1$ (so that the expectations of wage setters at time $t=-1$ are $E_{-1}\varepsilon_0=0$). Since the current wage W_0 depends on the past wage W_{-1}, the current wage W_0 does not adjust fully to the shock ε_0. On this account, the shock has real effects.

Let $R(\pi_t)$ and $R(u_t)$ be the period-t responses of inflation and unemployment (respectively) to the above money growth shock, cet. par. By the inflation equation (19), we find that the inflation responses through time are:

$$R(\pi_0) = 1 - \frac{1}{2}\left[\frac{(1-\lambda)(1-\beta)}{\gamma(1+\beta)} + \frac{1+\lambda}{2}\right] < 1,$$

$$\underset{t\geq 1}{R(\pi_t)} = 1 - \lambda^{t-1}\left(\frac{1-\lambda^2}{2}\right)\left(\frac{1-\beta}{\gamma(1+\beta)} - \frac{1}{2}\right),$$

$$R(\pi_{\mathrm{LR}}) \equiv \lim_{t\to\infty} R(\pi_t) = 1(\text{long}-\text{run response}). \tag{29}$$

By the unemployment equation (Eq. (21)), the unemployment responses through time are:

$$\underset{t\geq 1}{R(u_t)} = -\frac{(1-\beta)}{\gamma(1+\beta)} - \lambda^t\left(\frac{1+\lambda}{2}\right)\left(\frac{1}{2} - \frac{1-\beta}{\gamma(1+\beta)}\right),$$

$$R(u_{\mathrm{LR}}) \equiv \lim_{t\to\infty} R(u_t) = -\frac{(1-\beta)}{\gamma(1+\beta)},\ (\text{long}-\text{run response}). \tag{30}$$

The impulse-response function for inflation always lies above the initial ($t=0$) inflation rate, and the impulse-response function for unemployment always lies below the initial ($t=0$) unemployment rate. Note that the long-run response of unemployment is simply the inverse of the slope of the long-run Phillips curve. The equations above indicate that the medium-term responses of inflation and unemployment to the monetary shocks (viz., inflation and unemployment persistence) are closely related to the long-run Phillips curve tradeoff. In particular, the inflation and unemployment responses fall into two broad classes (by the equations above):

1. *Inflation and unemployment under-shooting*: If $\frac{(1-\beta)}{\gamma(1+\beta)} > \frac{1}{2}$ — so that the absolute value of the slope of the long-run Phillips curve is less than 2 — then inflation gradually rises toward its new long-run equilibrium ($\pi_t<\pi_{\mathrm{LR}}$, and $\pi_{t+1}>\pi_t$ for $t\geq 0$); unemployment gradually falls towards its new long-run equilibrium ($|u_t|<|u_{LR}|$ for $t\geq 0$).
2. *Inflation over-shooting slowly and unemployment over-shooting quickly*: If $\frac{(1-\beta)}{\gamma(1+\beta)} < \frac{1}{2}$ — so that the absolute value of the slope of the long-run Phillips curve exceeds 2 — then inflation rises, over-shooting its new long-run equilibrium after one period, and then gradually falls toward this equilibrium ($\pi_0<\pi_{\mathrm{LR}}$, $\pi_t>\pi_{\mathrm{LR}}$, and $\pi_{t+1}<\pi_t$ for $t\geq 1$). Unemployment falls, over-shooting its new long-run equilibrium, and then gradually rises toward this equilibrium ($|u|>|u_{\mathrm{LR}}|$, and $|u_{t+1}|<|u_t|$ for $t\geq 0$). The

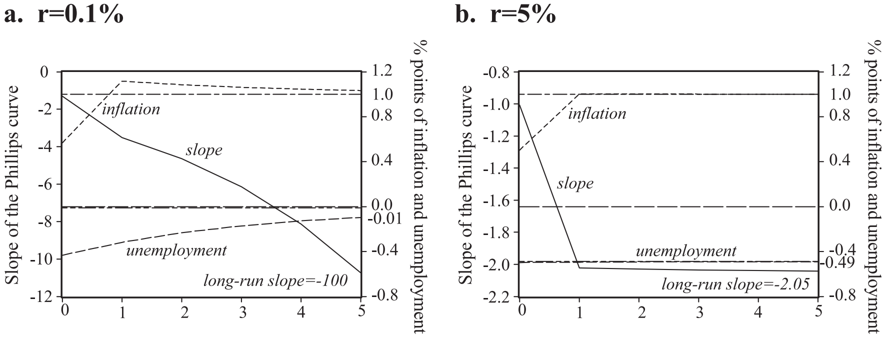

Fig. 4. Impulse response functions. (The shock is a 1% point increase in the money growth rate at t = 0, γ = 0.05).

maximum impact of the monetary shock on unemployment is achieved before the maximum impact on inflation.

For most of the empirically reasonable parameter values given in Table 1, the impulse-response functions can be shown to fall into Class 2, the class that accords with the stylized facts (viz., the inflation responses to monetary shocks are delayed and gradual, the unemployment responses occur more quickly). Fig. 4 depict the impulse response functions for inflation, unemployment, and the slope of the Phillips curve for the same parameter values as in Fig. 3.[40] The horizontal axis measures time; the left-hand vertical axis measures the slope of the Phillips curve; and the right-hand vertical axis measures the inflation and unemployment rates.

Observe that when the discount rate is very low ($r = 0.1\%$), in Fig. 4a, the long-run Phillips curve is virtually vertical, but the short-run Phillips curve at time $t = 0$ is very flat, and it takes a very long time for unemployment, inflation, and the Phillips curve slope to reach their long-run values.

By contrast, when the discount rate is higher ($r = 5\%$), the long-run Phillips curve is quite flat, and it takes a short time for unemployment, inflation, and the slope to reach their long-run values.

It is easy to show that this pattern holds for the full range of discount rates: *The lower the discount rate (for a given value of the demand-sensitivity parameter* γ*):*

- *the steeper is the long-run Phillips curve and*
- *the longer it takes for the slope of the Phillips curve to converge to its long-run value.*

Thus, observationally, it may make little difference whether the long-run Phillips curve is flat—so that an increase in money growth permanently reduces unemployment—or near-vertical—so that the effect is not permanent, but very prolonged. In other words, it may be difficult, if not impossible, in practice to distinguish between a world in which there is quick convergence to a flat long-run Phillips curve and one in which there is slow

[40] The value of c has no effect on the slope of the Phillips curve.

convergence to a steep one. In both cases, money growth shocks have long-lasting effects on unemployment.[41]

9. Empirical analysis

Our empirical analysis is based on multi-equation estimation, since the phenomenon of frictional growth cannot be captured through the usual procedure of estimating a single-equation Phillips curve. When we estimate a traditional or New Phillips curve as a single equation, we are unable to assess how the effects of money growth work their way through the wage-price adjustment process and thereby affect unemployment. Money growth does not enter a single-equation Phillips curve at all; it is substituted out when the impulse-response function of inflation is substituted into the impulse-response function for unemployment to derive the Phillips curve.

On this account, we estimate dynamic multi-equation models, which are able to capture the dynamic influence of money on wages and prices, as well as the influence of the relation between money and prices on unemployment. We do this in two empirical models, the first dealing with the United States and the second with the European Union. The two models differ in several instructive ways, indicating a range of possibilities for estimating Phillips curves. The US model is small, comprising just three equations, which match those of our theoretical model: a wage setting equation and a price setting equation to portray nominal sluggishness (so that changes in money growth lead to changes in real money balances), and the unemployment equation to indicate how the changes in real money balances affect the unemployment rate. The EU model is larger in two respects: (i) it covers a panel of EU countries and (ii) it contains six equations, permitting us to take into account the roles played by capital accumulation, employment, labor force participation, and productivity in generating the Phillips curve tradeoff.

In most of the current empirical literature, by contrast, the Phillips curve is estimated in a single-equation framework.[42] It is customary to use the lead of inflation as a proxy for expected future inflation. Thus, the NPC can be consistently estimated by generalized method of moments (GMM) or, since the model is linear in the parameters, two-stage least

[41] In this context it is also easy to show that we can avoid the counterfactual implication of disinflationary booms, analogously to Mankiw and Reis (2001). In the context of the Calvo (1983) model of random nominal adjustment, Mankiw and Reis avoid disinflationary booms by assuming that only a fraction of agents receives updated information in each period. The analogue in the Taylor model of fixed, staggered adjustment is to assume that all agents receive information about monetary shocks with a one-period lag. It is trivial to see that if monetary shocks are announced one period in advance and if agents' information about these shocks is received one period in arrears, then the resulting model generates precisely the same results as the model above. More generally, our model avoids the implication of disinflationary booms whenever the lead time for monetary announcements is not greater than the lag time in agents' information updates.

[42] The NPC is simply expressed as

$$\pi_t = \beta E_t \pi_{t+1} + \gamma x_t,$$

where β is the discount factor, and the "forcing variable" x_t is a measure of excess demand (unemployment rate, output gap) or a measure of real marginal costs (like the wage share).

squares (2SLS). Bårdsen et al. (2002), show that the empirical results are sensitive to the choice and exact implementation of the estimation method. Overall, there is no agreement in the recent literature about the appropriate method of estimating the NPC and how to test it against the traditional Phillips curve. Consequently, there is disagreement about whether the empirical evidence favors the traditional or New Phillips curves.

The choice of the forcing variable is crucial when estimating the inflation dynamics associated with the Phillips curve. Galí and Gertler (1999) and Galí et al. (2001) find evidence in support of the NPC only when they use labor income share as the forcing variable. Rudd and Whelan (2001) propose using a present value term of the forcing variable in the inflation regression and report results that are consistent with a backward-looking (traditional) Phillips curve.[43]

The choice of instruments can have a strong influence on the GMM estimates of the NPC and their significance. It is widely accepted that the test for overidentifying restrictions as a mean to detect invalid instruments has low power. In addition, Bårdsen et al. (2002), and Rudd and Whelan (2001) argue that the results can be significantly biased by using variables as instruments that actually belong in a well-specified inflation regression. Furthermore, if the forcing variable is regarded as endogenous then it should be instrumented in the estimation. Bårdsen et al. (2002) argue that to derive the dynamic properties of inflation, we require an analysis of the system that includes the forcing variable as well as the rate of inflation, and conclude that "as statistical models, both the pure and hybrid NPC[44] are inadequate".

9.1. The US Phillips curve

As noted, our US model contains a wage, price and unemployment equation. Taking the unresolved empirical issues above into account, and recalling that any forward-looking equation (containing leads) can be translated into a backward-looking one (containing only contemporaneous and lagged variables) by expressing expectations of future variables in terms of present and lagged variables, we specify the wage and price equations solely in terms of current and past variables. (They can, however, be interpreted as the outcome of decisions by forward-looking agents, because these agents' expectations of the future depend on their information about current and past variables and the underlying stochastic processes.) Thus, the empirical wage and price equations may be seen as the counterparts

[43] Since rational expectations are also model consistent, they use repeated substitution to express the NPC as

$$\pi_t = \beta^{k+1} E_t \pi_{t+k+1} + \gamma \sum_{j=0}^{k} \beta^j E_t x_{t+j}.$$

The last term in the above equation is a present value term of the forcing variable and γ is estimated using GMM.

[44] This point is consistent with our argument in Section 4 that inflation persistence in response to monetary shocks can only be evaluated in the context of a general equilibrium system including the Phillips curve, rather than through the Phillips curve alone.

The hybrid specification of the Phillips curve can be expressed as

$$\pi_t = \beta^{\mathrm{b}} \pi_{t-1} + \beta^{\mathrm{f}} E_t \pi_{t+1} + \gamma x_t.$$

Table 2
Definitions of variables

M_t: money supply (M3)	fw_t: financial wealth ($\frac{\text{SP500}}{\text{labor productivity}}$)
P_t: price level	o_t: real oil price
W_t: nominal wages	fd_t: real foreign demand (exports – imports)
u_t: unemployment rate	τ_t: indirect taxes as a % of GDP
pr_t: real labor productivity	b_t: real social security benefits
m_t: real money balances ($M_t - P_t$)	ssc_t: real social security contributions
k_t: real capital stock	

All variables are in logs except for u_t, foreign demand, fd_t, and the tax rate, τ_t.
The variables m_t, ssc_t, b_t, and fd_t have been normalized by working age population.
The financial wealth variable fw_t is defined as in Phelps and Zoega (2001).

of Eqs. (17) and (18), respectively.[45] We solve these three equations as a system and derive the implied inflation–unemployment tradeoff.

9.1.1. Data and estimation

We use US annual time series data, obtained from the OECD and Datastream, covering the period 1966–2000. The definitions of the variables are given in Table 2.

The price setting, wage setting, and unemployment rate equations of our model were initially estimated individually using the autoregressive distributed lag (ARDL) approach to cointegration analysis developed by Pesaran and Shin (1995), Pesaran (1997), and Pesaran et al. (1996). These papers argue that the traditional ARDL approach justified when regressors are $I(0)$, can also be valid with $I(1)$ regressors. An important implication of this methodology is that, since an ARDL equation can always be reparameterized in an error correction format, the long-run solution of the ARDL can be interpreted as the cointegrating vector of the variables involved.

The dynamic specification of each equation was determined by the optimal lag-length algorithm of the Akaike and Schwarz information criteria. The selected estimated equations are dynamically stable (i.e., the roots of their autoregressive polynomia lie outside the unit circle), and pass the standard diagnostic tests (for no serial correlation, linearity, normality, homoskedasticity, and constancy of the parameters of interest) at conventional significance levels.[46] In order to take into account potential endogeneity and cross equation correlation, we then estimated the equations as a system using three stages least squares (3SLS). These results are presented in Table 3.[47] The model tracks the data very well.[48]

In the unemployment equation, product demand-side influences are captured through real money balances and financial wealth[49] (affecting domestic demand), as well as net

[45] More precisely, the empirical model may be understood as a natural extension of our theoretical model to include staggered contracts of both wage and prices. Thus, in our empirical model, past nominal values affect the current wage level differently from the current price level.

[46] See Karanassou et al. (2002, Appendix 3).

[47] Constants and trends are omitted for brevity.

[48] The actual and fitted values of the estimated system are pictured in Karanassou et al. (2002, Appendix 4).

[49] See Phelps (1999), Fitoussi et al. (2000), and Phelps and Zoega (2001).

Table 3
US model, 3SLS, 1966–2000

Dependent variable: u_t			Dependent variable: P_t			Dependent variable: W_t		
	Coefficient	Std. error		Coefficient	Std. error		Coefficient	Std. error
u_{t-1}	0.43	(0.12)	P_{t-1}	1.19	(0.13)	W_{t-1}	0.24	(0.10)
u_{t-2}	−0.30	(0.11)	P_{t-2}	−0.54	(0.08)	ΔW_{t-2}	0.48	(0.10)
m_t	−0.12	(0.03)	W_{t-1}	0.34	(0.10)	P_t	0.68	(0.09)
fd_t	−0.16	(0.05)	M_t	0.01	[a]	M_t	0.09	[a]
Δk_t	−0.01	(0.002)	u_t	−0.72	(0.16)	u_t	−0.41	(0.17)
o_{t-1}	0.01	(0.003)	pr_t	−0.30	(0.06)	pr_t	0.32	(0.09)
fw_t	−0.01	(0.005)	o_t	0.02	(0.004)	b_t	0.05	(0.02)
ssc_t	0.04	(0.02)	o_{t-1}	0.01	(0.004)			
			o_{t-2}	−0.01	(0.003)			
			τ_t	0.02	(0.006)			

Δ denotes the difference operator.
[a] Coefficient is restricted so that there is no money illusion.

foreign demand. Product supply-side influences are captured through the oil price, capital accumulation, and social security contributions. Observe that the sum of the lagged dependent variable coefficients is small and positive, implying a low degree of unemployment persistence. Since the US unemployment rate is trendless, the explanatory variables in the unemployment equation need to be specified as non-trended series as well. On this account, real money balances, social security contributions and benefits, and foreign demand are normalized by working age population, whereas financial wealth is deflated by productivity.

The price and wage equations are quite standard.[50] Prices depend on wages and the money supply, and wages depend on prices and the money supply. Productivity has a positive effect on nominal wages and a negative effect on prices. The unemployment moderates the mark-up of prices on wages, and of wages on prices. The lag structure of our price and wage equations is consistent with our theoretical model.[51] The restriction of no money illusion is imposed on the price and wage equations, so that each equation is homogeneous of degree zero in all nominal variables. Specifically, we restrict the coefficient of money in each of our nominal equations to be equal to one minus the

[50] In order for all variables in our price and wage equations to be integrated of the same order, the equations need to be reparameterized before estimation. For instance, consider the price equation in Table 3: $P_t = a_0 + a_1 P_{t-1} + a_2 P_{t-2} + a_3 W_{t-1} + (1 - a_1 - a_2 - a_3) M_t + \beta' x_t$, where β' is a row vector of parameters, and x_t is a column vector of the real variables. The above can be reparameterized as $(P_t - M_t) = a_0 + a_1(P_{t-1} - M_{t-1}) + a_2(P_{t-2} - M_{t-2}) + a_3(W_{t-1} - M_{t-1}) - (a_1 + a_2 + a_3)\Delta M_t - a_2 \Delta M_{t-1} + \beta' x_t$. These two equations are statistically equivalent. We estimate our price equation using the latter equation, and present the Table 3 results in the format of the former equation. The analogous procedure is applied to the wage equation.

[51] In both the theoretical and empirical models, current wages and prices are explained in terms of past wages and prices and the current money supply. The empirical model may be understood as a natural extension of our theoretical model to include staggered contracts of both wage and prices. Thus, in our empirical model, past nominal values affect the current wage level differently from the current price level.

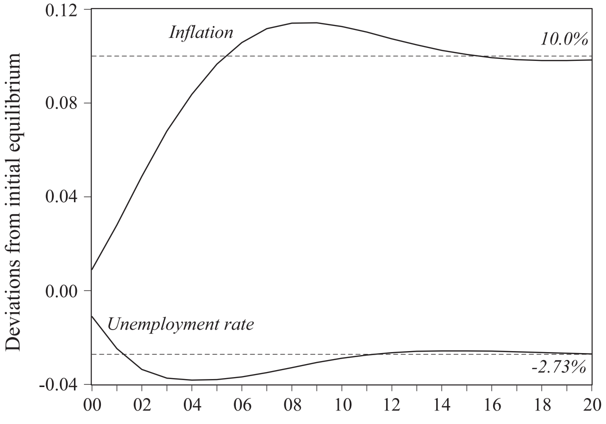

Fig. 5. Impulse-response functions to a 10% permanent increase in the growth rate of money supply.

coefficients of all nominal variables on the right-hand side of that equation.[52] These restrictions could not be rejected at conventional significance levels.

9.1.2. Empirical impulse-response functions

In this empirical context, we examine the influence of a money growth shock on inflation and unemployment through time. Specifically, suppose that the economy is initially in a steady state, with the money supply growing at the constant rate μ. Then, at time $t=0$, the money growth rate increases by a fixed amount to μ'. This shock is unanticipated and may be interpreted as a single realization of the stochastic process generating the money supply.[53] We derive the inflation and unemployment responses to this shock for time $t \geq 0$.[54]

Fig. 5 presents the impulse response functions (IRFs) that correspond to a 10% permanent increase in the growth rate of money supply. The inflation IRF has all the desirable properties, namely, the influence of the monetary shock on inflation is delayed and gradual, and in the long run inflation is equal to money growth. The unemployment IRF also exhibits plausible behavior: the unemployment effect of the monetary shock is also delayed and gradual, but this effect occurs sooner than the inflation effect (e.g., the maximum unemployment effect occurs well before that on inflation.) Also observe that the inflation and unemployment responses take a long time to converge to their long-run values.

The only strikingly unconventional property of the unemployment IRF is that the unemployment effect does not die down to zero; rather, a 10% increase in money growth

[52] For example, the price equation in Table 3 (first equation in the above footnote) is clearly homogeneous of degree zero in M_t, P_t, P_{t-1}, P_{t-2}, and W_{t-1}. The analogous restriction is imposed on the wage equation.

[53] Since the shock is a realization of the actual money growth process, this exercise does not run afoul of the Lucas critique.

[54] We assume that the future values of the exogenous variables are unaffected by the monetary shock (which is obvious, for otherwise these variables would not be exogenous). Thus, given the linearity of our model, the simulation is unaffected by these future variables.

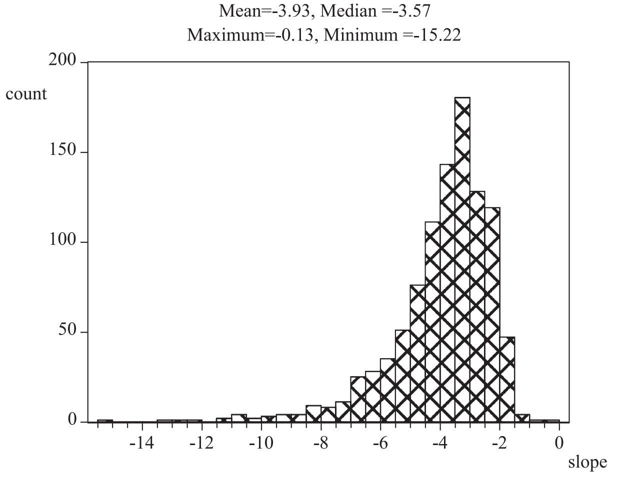

Fig. 6. Slope of the long-run Phillips curve (1000 observations).

leads to a 2.73% fall in long-run unemployment.[55] Thus, the slope of the long-run Phillips curve is $-3.66(=\frac{10}{-2.73})$.

9.1.3. Monte Carlo simulations

To have confidence that our long-run Phillips curve is indeed not vertical, we need to examine whether our point estimate of the slope (− 3.66) is significantly different from infinity. For this purpose, we perform the following Monte Carlo experiment, consisting of 1000 replications. In each replication (i), a vector of error terms $\varepsilon_t^{(i)}=(\varepsilon_{u,t}^{(i)}, \varepsilon_{P,t}^{(i)}, \varepsilon_{W,t}^{(i)})'$, $t=1, 2, \ldots, T$ (of the unemployment rate, price, and nominal wage equations, respectively) is drawn from the normal distribution,[56] $N(0,\Sigma)$. The vector $\varepsilon_t^{(i)}$ is then added to the vector of estimated equations to generate a new vector of endogenous variables $y_t^{(i)}=(u_t^{(i)}, P_t^{(i)}, W_t^{(i)})$. Next, the equations of the model are estimated using the new vector of endogenous variables $y_t^{(i)}$, and the set of exogenous variables. Finally, the simulation exercise of the previous section is conducted on the newly estimated system to derive a new estimate of the slope of the long-run Phillips curve. In this way, each replication (i) yields a new value for the slope: $S^{(i)}$, $i=1, 2, \ldots, 1000$.

Fig. 6 presents the histogram of the 1000 simulated values of the long-run Phillips curve slope. This shows clearly that the estimated slope of the long-run Phillips curve is indeed significantly downward-sloping and reasonably flat, rather than vertical.[57]

[55] Also observe that the unemployment IRF overshoots substantially: the maximum effect on unemployment is nearly 4%.

[56] We used the normal distribution because the assumption of normality is valid in the estimated system of equations. ($\varepsilon_t \sim N(0,\Sigma)$, where Σ is the variance−covariance matrix of the estimated model).

[57] See Karanassou et al. (2002, Appendix 5) for further evidence in support of this result.

9.2. The EU Phillips curve

Our EU model[58] covers a dynamic panel of 11 EU countries.[59] Like the US model, this model may be divided into blocks, one describing how nominal variables are influenced by monetary shocks (the "nominal block") and the other describing how real variables are influenced by the relation between the nominal variables and the monetary shocks (the "real block"). In contrast to the US model, however, the real block is now specified in greater detail. Specifically, it comprises employment, labor force, capital, and output equations.

The data is annual. In addition to the variables defined in Table 2, we now have seven further variables (all in logs): the real wage w_t=($W_t - P_t$), real GDP y_t, employment N_t, labor force L_t, working age population Z_t, and competitiveness c_t (defined as a ratio of import prices to GDP deflator). Our data is annual and, due to data limitations,[60] our sample period of analysis is 1977–1998.

The differences between our models of the US and EU are instructive for the following reason. In the context of frictional growth, our derivation of the long-run Phillips curve requires us to distinguish the long-run equilibrium from the adjustment processes leading to it. On this account, given the limited US data set, we aimed to make the US model small in numbers of variables and equations. Since the EU data set, by contrast, covers a panel of countries, we are able to consider a larger model, provided that the data is pooled appropriately. Specifically, we use a dynamic panel model in which economic activity in each country is described by a system of equations, and cross-country differences are depicted solely by fixed effects (i.e., differing constants in the estimated equations). Panel unit root test statistics indicate that we can proceed with stationary panel data estimation techniques. The estimated system is given in Tables 4a and 4b.

The nominal equations are similar to those in the US model and may be viewed as a natural extension of our theoretical model to simultaneous wage and price staggering. While the wage equation corresponds to the wage contract equation in our theoretical model, the price equation may be understood as the upshot when the labor demand equation is substituted into the product market equilibrium condition (thereby explaining why this price equation is distinct from the labor demand equation below). Once again, we impose money neutrality, i.e. the nominal equations are homogeneous of degree zero in all nominal variables.

The real block includes a labor force and employment equation, and unemployment is approximated as the difference between the two.[61] Unlike the US model, capital accumulation is endogenized here. Given that the EU model rests on a larger data set

[58] The details of the underlying econometric methodology, specification, and properties of the model are discussed in Karanassou et al. (2003).

[59] Austria, Belgium, Denmark, Germany, Finland, France, Italy, Netherlands, Spain, Sweden and the United Kingdom. Due to lack of data, Greece, Ireland, Luxembourg and Portugal are excluded from the analysis.

[60] There are two restrictions on our sample period: (1) 1977 is the first year in which information on French money supply is available from the sources above; and (2) national time series for money supply in the Euro area stopped in 1998, just before the introduction of EMU.

[61] Specifically, the unemployment rate is an approximation of the difference between the log of the labor force and the log of employment.

Table 4a
EU model, 1977–1998

Dependent variable: W_t			Dependent variable: P_t			Dependent variable: L_t		
	Coefficient	Std. error		Coefficient	Std. error		Coefficient	Std. error
W_{t-1}	1.02	0.050	P_{t-1}	1.13	0.068	L_{t-1}	0.82	0.055
W_{t-2}	−0.17	0.049	P_{t-2}	−0.34	0.054	L_{t-2}	−0.17	0.047
P_t	0.87	0.063	W_t	0.21	[a]	w_t	0.025	0.012
P_{t-1}	−0.74	0.065	pr_t	−0.27	0.027	Δw_t	−0.43	0.051
M_t	0.01	[a]	o_t	0.004	0.002	u_t	−0.21	0.035
u_t	−0.36	0.051	y_t	0.15	0.048	Z_t	0.35	[b]
pr_t	0.61	0.064	y_{t-1}	−0.11	0.047			
pr_{t-1}	−0.55	0.062						
o_t	0.004	0.002						
b_t	0.11	0.026						
b_{t-1}	−0.15	0.040						
b_{t-2}	0.10	0.028						

Δ denotes the difference operator.

[a] Restricted coefficient for no money illusion.

[b] Coefficient restricted so that the long-run elasticity with respect to Z_t is unity.

than the US model, this property is desirable since capital and labor are demanded conjointly by firms to produce output. Moreover, productivity in the EU model is also endogenous, given by the difference between the endogenous output and employment equations. Note that wages and prices depend on productivity, which in turn depends on real money balances (via output and employment), which depend on sluggish adjustment of the wages and prices. The coefficient on population in the labor force equation is restricted so that the long-run elasticity of the labor force with respect to population is unity. Finally, we impose constant returns to scale on the production function (i.e., the output function). The fitted values from our estimated model track the data well.

Next, we conduct the same simulation exercise as for the US model, and we thereby derive the Phillips curve for the EU. Fig. 7 illustrates the resulting time path of the slope of the EU Phillips curve and compare it with that for the US. Observe that the depicted

Table 4b
EU model, 1977–1998

Dependent variable: N_t			Dependent variable: k_t			Dependent variable: y_t		
	Coefficient	Std. error		Coefficient	Std. error		Coefficient	Std. error
N_{t-1}	1.04	0.049	k_{t-1}	1.49	0.055	y_{t-1}	0.85	0.040
N_{t-2}	−0.18	0.047	k_{t-2}	−0.51	0.054	N_t	0.10	[a]
w_t	−0.19	0.032	w_t	−0.05	0.015	k_t	0.05	0.024
m_t	0.04	0.007	m_t	0.01	0.003	Δk_t	0.55	0.121
pr_t	−0.72	0.068	pr_t	−0.28	0.030	t	0.002	0.0006
pr_{t-1}	0.82	0.065	pr_{t-1}	0.45	0.038			
c_t	0.02	0.012	pr_{t-2}	−0.13	0.030			
			o_t	−0.003	0.001			
			τ_t	−0.084	0.052			

Δ denotes the difference operator; t is a linear time trend.

[a] Restricted coefficient for constant returns to scale.

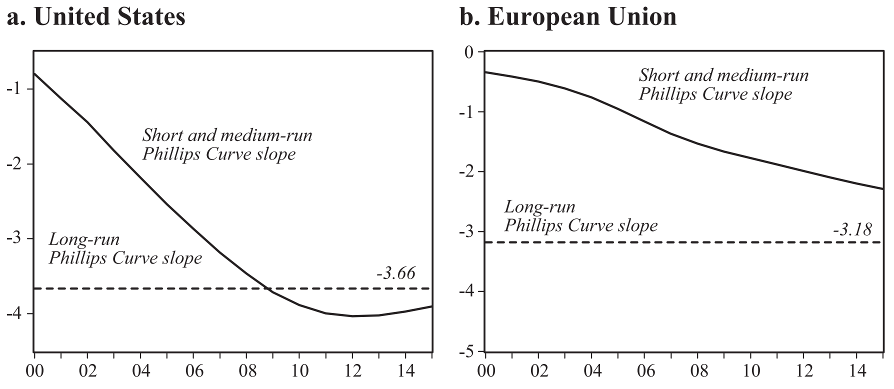

Fig. 7. The slopes of the US and EU Phillips curves through time.

adjustment process is even longer for the EU than the US. Moreover, the EU long-run Phillips curve, with a slope of -3.18, is even flatter than the US long-run Phillips curve.

10. Conclusions

This paper offers a reappraisal of the inflation–unemployment tradeoff on the basis of frictional growth. We have argued that when there are staggered nominal contracts and when there is an intertemporal weighting asymmetry, whereby current nominal values depend more heavily on past nominal values than future ones, then the actual price level chases after a moving target (the perfectly flexible price level). The faster the money supply (and the perfectly flexible price level) grows, the further behind its moving target does the actual price level fall. Thus, real money balances and aggregate demand rise, while unemployment falls. We have shown that along with a long-run inflation–unemployment tradeoff, the intertemporal weighting asymmetry also gives rise to plausible impulse responses of inflation and unemployment to money growth shocks.

While the choice between our analysis and the textbook New Phillips curve is an empirical issue, three of our results suggest that our approach is more closely in accord with the established empirical regularities. First, in our analysis movements of inflation and unemployment do not have the knife-edge property; in fact the long-run Phillips curve may be reasonably flat. The available empirical evidence in the OECD does not appear to support the view that inflation falls without limit when unemployment is above some stable NAIRU (implying a vertical long-run Phillips curve); nor does it seem to show that there is massive deflation when unemployment is high (implying that the long-run Phillips curve is very steep). Second, our analysis can explain how money growth shocks can have a delayed and gradual effect on inflation, so that there is inflation persistence. Third, it shows that monetary shocks usually have a quicker effect on unemployment and the time path of this effect tends to be hump-shaped. Our analysis calls for a reappraisal of monetary policy effectiveness. It suggests that monetary policy can have permanent effects on real economic activities; and thus this policy should not be formulated without regard to these effects. Our approach, however, certainly does not imply that it is appropriate to devote monetary policy to Keynesian-style fine tuning. We have shown, after all, that it can take a long time for the real effects of monetary policy to unfold. From this perspective, it is not surprising that it took over a decade—stretching from the early 1980s to the 1990s—for central banks in many OECD countries to vanquish inflation. On this account, it is clearly vital for monetary policy to pursue long-term inflation objectives. Due to the long drawn-out responses of inflation and unemployment to monetary policy changes, it is inevitably hard to distinguish empirically between the permanent versus prolonged influences of monetary policy. In any case, our analysis suggests that monetary policy may play a more important and durable role in the real economy than the mainstream theories allow for.

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