

A Suggested Modification to the New Keynesian Model

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Abstract

The standard new Keynesian framework is often criticised for its inability to generate inflation inertia, as well as its implied absence of an inflation/output stabilization tradeoff in the presence of supply shocks. We argue that real wage rigidities are a natural ingredient that helps overcome those shortcomings. We propose a tractable modification of the new Keynesian framework that incorporates real wage rigidities. We also derive the model's implied relation between inflation and unemployment, and estimate it using US data.

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1 Introduction

A standard New Keynesian model has emerged. On the supply side it consists of Calvo price and/or wage staggering. On the demand side, it is composed of an Euler equation and a Taylor rule. With more solid microeconomic foundations than its Keynesian ancestor, and more useful than its RBC predecessor, it has become the workhorse in discussion of fluctuations, policy and welfare.

But it has, in its standard form, two implications that feel wrong:

- One positive: the lack of inflation inertia
- One normative: the divine coincidence, i.e. no trade-off between stabilizing inflation and stabilizing the welfare relevant output gap in the presence of supply shocks.

Both have led to various ad-hoc corrections: appending a cost-push shock, or adding lagged inflation in the inflation/output relation. Such corrections are often motivated by assumptions that we view as unrealistic or unlikely to be central. Examples include shocks to desired markups (Smets and Wouters (2003)), backward-looking indexation (Christiano et al. (2005)), or rules-of-thumb in price setting (Galí and Gertler (1999)).

We argue that both come from not incorporating an important *real* imperfection: the slow adjustment of real wages to underlying labor market conditions. That feature, combined with price staggering, leads to:

- Inflation inertia, with past inflation playing a role in the determination of current inflation.
- The end of the divine coincidence: in the presence of supply shocks, a trade-off between inflation stabilization and stabilization of *the welfare-relevant* output gap.

The resulting model fits the data better, and has more plausible policy implications, in particular in response to supply shocks. The introduction of this additional imperfection is still ad-hoc, but shows the direction.¹

2 The Standard Model

To discuss “supply shocks” we introduce a non-labor input, with exogenous endowment M . Leave out technological shocks; one to one mapping with endowment shocks in the Cobb Douglas case. An important difference: endowment shocks are reflected in the relative price of inputs, providing a clearer mapping with “observable” supply shocks, like oil price disturbances.

¹See Hall (xx) for a recent formalization.

Technology. Many monopolistically competitive firms with differentiated products, and production function:

$$Y = M^\alpha N^{1-\alpha}$$

Letting lower case letters denote the natural logarithms of the original variables, the implied real marginal cost is given by:

$$\begin{aligned} mc &= w - mpn \\ &= w - (y - n) - \log(1 - \alpha) \end{aligned}$$

where w is the (log) real wage, which is assumed to be taken as given by the firm.

Preferences. Time separable, with period utility given by

$$U(C, N) = \log(C) - \chi \frac{N^{1+\phi}}{1+\phi}$$

where C is composite consumption, with elasticity of substitution between goods equal to ϵ , N is employment, and $\chi \equiv \exp\{\xi\}$ is a (possibly time-varying) preference parameter.

The implied marginal rate of substitution (in logs) is given by:

$$mrs = c + \phi n + \xi \tag{1}$$

2.0.1 Flexible Price Equilibrium

From the worker side, perfect competition in labor market implies

$$\begin{aligned} w &= mrs \\ &= y + \phi n + \xi \end{aligned} \tag{2}$$

where we impose the market clearing condition $c = y$.

From the firm side, optimal price setting implies $mc = -\mu$, where $\mu \equiv \log \frac{\epsilon}{\epsilon-1}$ is the optimal markup. Hence,

$$w = y - n + \log(1 - \alpha) - \mu$$

We use subscript "1" for first best (efficient) levels, "2" for second best, defined as flexible price equilibrium levels. Under flexible prices, equilibrium employment n_2 is given by:

$$(1 + \phi) n_2 = \log(1 - \alpha) - \mu - \xi \tag{3}$$

which, under our assumptions, is independent of m , but may vary as a result of changes in the preference parameter ξ .²

²More generally, ξ can be interpreted as reflecting exogenous variations in equilibrium wage markups or labor-related tax wedges, in addition to shifts in preferences. As argued in Galí (2005), the existence of low frequency movements in such factors is necessary in order to account for the low frequency (non business cycle) variations in hours per capita or employment rates in industrialized economies. Notice, however, that neither movements in wage markups nor tax wedges would affect the efficient level of employment, in contrast with preference shocks.

The first best level of employment (corresponding to a zero markup), denoted by N_1 , satisfies:

$$(1 + \phi) n_1 = \log(1 - \alpha) - \xi \quad (4)$$

Notice, however, that while both first and second best employment may vary over time, the gap between the two remains constant and given by

$$n_1 - n_2 = \frac{\mu}{1 + \phi} \equiv \delta \quad (5)$$

2.1 Staggered price equilibrium

We assume that price decisions are staggered à la Calvo. As is well known, in that case inflation fluctuations in a neighborhood of the zero inflation steady state are described by the difference equation

$$\pi = \beta E\pi(+1) + \lambda \widehat{mc} \quad (6)$$

where $\widehat{mc} \equiv mc + \mu$ denotes the log-deviation of real marginal cost from its steady state value, and $\lambda \equiv \theta^{-1}(1 - \theta)(1 - \beta\theta)$, with θ representing the fraction of firms not adjusting their price in any given period.³

Substituting (2) in (??) and using (3) we obtain:

$$\widehat{mc} = (1 + \phi)(n - n_2)$$

Combining the previous two equations we derive a version of the celebrated new Keynesian Phillips curve (NKPC):

$$\pi = \beta E\pi(+1) + \lambda(1 + \phi)(n - n_2) \quad (7)$$

Equivalently, we can write

$$\pi = \beta E\pi(+1) + \lambda(1 + \phi)(n - n_1 + \delta)$$

We recall two well known implications of the NKPC:

- *No inflation inertia*: no role for past inflation in the determination of current inflation; the latter depends on current and anticipated employment gaps.
- *The divine coincidence*: stabilizing inflation is equivalent to stabilizing the employment gap, i.e. the distance of log employment from both first and second best. There is no trade off between those two objectives.

³See Galí and Gertler (1999), Galí, Gertler and López-Salido (2001) and Sbordone (2002) for a (largely favorable) empirical assessment of the previous inflation equation.

3 Introducing Real Wage Rigidities

Next we assume that real wages respond sluggishly to labor market conditions, as a result of some (unmodelled) imperfection/friction. Specifically, we assume the partial adjustment model:

$$w = \gamma w(-1) + (1 - \gamma)mrs$$

where γ can be thought of as an index of real rigidities. [remark: may want to allow for a positive steady state wage markup, to rule out slavery].

By construction, first best employment is unchanged, and given by (4).

3.1 Flexible price equilibrium

From above, using (1), market clearing, and our assumptions on technology, we have

$$w = \gamma w(-1) + (1 - \gamma)(\alpha m + (1 - \alpha + \phi)n + \xi)$$

As before, from the firm side:

$$w = \alpha(m - n) + \log(1 - \alpha) - \mu$$

Putting the two together and reorganizing we can solve for second best employment n_2 as a function of the first best and the two exogenous driving forces:

$$(1 - \gamma)(1 + \phi)(n_2 - n_1 + \delta) = \gamma\alpha[\Delta m - (\Delta n_2 - \Delta n_1) + (1 + \phi)^{-1}\Delta\xi] \quad (8)$$

Or equivalently:

$$n_2 - n_1 + \delta = \Theta_\gamma [n_2(-1) - n_1(-1) + \delta] + \Theta_\gamma[\Delta m + (1 + \phi)^{-1}\Delta\xi] \quad (9)$$

where $\Theta_\gamma \equiv \frac{\gamma\alpha}{\gamma\alpha + (1 - \gamma)(1 + \phi)} \in [0, 1]$.

Notice that Θ_γ is increasing in γ thus implying that the size and persistence of deviations of the gap between second and first best employment are increasing in the degree of real rigidities. The effects of an adverse supply shock (an unexpected permanent decrease in m) is to decrease employment (relative to an unchanged first best) initially by Θ_γ , with employment returning to zero as the wage decreases over time. On the other hand, in response to a preference shock that lowers first best employment (an increase in ξ), second best employment falls by less, since the assumed real rigidities prevent the real wage from adjusting upward sufficiently to support the lower efficient level of employment.

As discussed below, such fluctuations in the gap between first and second best employment have important implications for policy.

3.2 Staggered price equilibrium

From the firm side, price setting gives the same equation as before:

$$\pi = \beta E\pi(+1) + \lambda \widehat{mc}$$

where

$$\begin{aligned} \widehat{mc} &\equiv mc + \mu \\ &= w - \alpha(m - n) - \log(1 - \alpha) + \mu \end{aligned}$$

From the workers' side, as before:

$$w = \gamma w(-1) + (1 - \gamma)(\alpha m + (1 - \alpha + \phi)n + \xi)$$

Combining these two equations, and reorganizing:

$$\begin{aligned} \widehat{mc} &= \gamma \widehat{mc}(-1) + (1 - \gamma)(1 + \phi)(n - n_1 + \delta) - \gamma \alpha(\Delta m - \Delta n) \\ &= \gamma \widehat{mc}(-1) + (1 - \gamma)(1 + \phi)(n - n_1 + \delta) + \gamma \alpha(\Delta n - \Delta n_1) - \gamma \alpha[\Delta m + (1 + \phi)^{-1} \Delta \xi] \end{aligned} \quad (10)$$

Replacing in the inflation equation:

$$\pi = \beta E\pi(+1) + \frac{\lambda}{1 - \gamma L} \{ (1 - \gamma)(1 + \phi)(n - n_1 + \delta) + \gamma \alpha(\Delta n - \Delta n_1) - \gamma \alpha[\Delta m + (1 + \phi)^{-1} \Delta \xi] \} \quad (12)$$

This is the central equation of the model. It gives inflation as a function of expected inflation, and a distributed lag of the (welfare relevant) employment gap (i.e., gap relative to first best), changes in employment, and supply shocks.

4 Policy Tradeoffs

Can we express inflation as a function of the employment gap, $n - n_2$, as we did in the standard case? The answer is yes.

To see why, notice that by setting $\widehat{mc} = \widehat{mc}(-1) = 0$ in (10) we can derive:

$$0 = (1 - \gamma)(1 + \phi)(n_2 - n_1 + \delta) - \gamma \alpha(\Delta m - \Delta n_2)$$

which can be subtracted from (10) to yield

$$\widehat{mc} = \gamma \widehat{mc}(-1) + (1 - \gamma)(1 + \phi)(n - n_2) + \gamma \alpha(\Delta n - \Delta n_2)$$

Thus, we see that deviations of employment from second best, even if transitory, have persistent effects on inflation.

Use it to rewrite (12) as:

$$\pi = \beta E\pi(+1) + \frac{\lambda}{1 - \gamma L} [(1 - \gamma)(1 + \phi)(n - n_2) + \gamma \alpha(\Delta n - \Delta n_2)]$$

Note that neither m nor ξ appear anymore. The equation gives us a relation between inflation and the employment gap, the log distance of employment from second best employment. It is more complicated than before, in terms of dynamics. But it has the same key implication: keeping the employment gap equal to zero leads to constant inflation. So, again, there is no trade-off between stabilization of inflation and the employment gap.

How useful is this result for policy? Much less than in the standard model, because, in terms of welfare, what matters is distance of employment from first best, and the distance between first best and second best is no longer constant. So, while one could try to keep the employment gap equal to zero, there is no point in doing it.

The relation between inflation and the distance of employment from first best is given instead by (12). This shows that there is a trade-off between inflation stabilization and stabilization of the (welfare relevant) employment gap, as long as $\gamma > 0$. The reason for this is simple: the gap between first best and second best employment is no longer constant in the latter case. This gives a non-trivial role to optimal policy.

To illustrate this let us look at the two extreme policies. For convenience let us assume $\xi = 0$ and a random walk process for the non-labor input endowment, so that $\Delta m = \varepsilon_m$ is a white noise process. Notice that in that case first best employment is constant.

Suppose that the central bank stabilizes the welfare relevant employment gap, i.e., the distance from first best, at a level consistent with zero *average* inflation. That requires $n = n_1 - \delta$ at all times. It follows from (12) that:

$$\pi = \beta E\pi(+1) - \frac{\lambda\gamma\alpha}{1 - \gamma L} \varepsilon_m$$

Solving gives:

$$\pi = \gamma\pi(-1) - \frac{\lambda\gamma\alpha}{1 - \beta\gamma} \varepsilon_m$$

So, the employment stabilizing policy implies a potentially strong accommodation of adverse shocks through inflation, followed by a slow (if γ is high) return to normal.

Suppose that central bank stabilizes inflation instead, so $\pi = E\pi(+1) = 0$. Then

$$(1 - \gamma)(1 + \phi)[n - n_1 + \delta] + \gamma\alpha(\Delta n - \Delta n_1) - \gamma\alpha\varepsilon_m = 0$$

Or equivalently

$$n - n_1 = -(1 - \Theta_\gamma)\delta + \Theta_\gamma [n(-1) - n_1(-1)] + \Theta_\gamma\varepsilon_m$$

Not surprisingly, this policy replicates the second best, with large fluctuations in employment.

To the extent that the central bank attaches some weight to stabilization of both inflation and the gap from first best, we can expect optimal policy to be somewhere in between [note: needs to be analyzed explicitly].

5 Real Rigidities, Supply Shocks and Inflation Persistence

Estimates of the inflation/unemployment relationship generally point to a substantial degree of inflation inertia, with lagged inflation showing up as an important determinant of current inflation⁴. In addition, many authors have stressed the need to include the change in oil prices or similar measures of cost shocks when estimating those empirical relationships (Gordon (JEP),...).

Does the presence of real wage rigidities help explain the inflation inertia uncovered in empirical Phillips curves, as well as the role of oil price shocks? The answer is clearly yes.

To see this, notice that we can rewrite (??) as follows.

$$\pi = \gamma\pi(-1) + \beta(E\pi(+1) - \gamma E(\pi|-1)) + \lambda((1-\gamma)(1+\phi)(n-n_1+\delta) - \gamma\alpha(\Delta m - \Delta n))$$

which can in turn be rewritten as

$$\pi = \frac{\gamma}{1+\gamma\beta}\pi(-1) + \frac{\beta}{1+\beta\gamma}E\pi(+1) + \frac{\lambda}{1+\beta\gamma}((1-\gamma)(1+\phi)(n-n_1+\delta) - \gamma\alpha(\Delta m - \Delta n)) + \zeta$$

where $\zeta \equiv \frac{\beta\gamma}{1+\gamma\beta}(\pi - E(\pi|-1))$ is orthogonal to variables dated -1 or earlier.

We do not observe m , but we observe its price v . Furthermore, under cost minimization

$$m - n = w - v + \log(\alpha/(1-\alpha))$$

So replacing in the Phillips curve relation:⁵

$$\pi = \frac{\gamma}{1+\gamma\beta}\pi(-1) + \frac{\beta}{1+\beta\gamma}E\pi(+1) + \frac{\lambda}{1+\beta\gamma}((1-\gamma)(1+\phi)(n-n_1+\delta) + \gamma\alpha(\Delta v - \Delta w)) + \zeta \quad (13)$$

Notice that the previous representations of inflation dynamics take a form similar to the so-called hybrid New Keynesian Phillips curve. As γ increases, the coefficient on past inflation increases from 0 (no inflation inertia) to $1/(1+\beta)$, which is slightly greater than $1/2$. On the other hand, the coefficient on expected inflation declines from β (when $\gamma = 0$) to $\beta/(1+\beta)$ (when $\gamma = 1$), which is slightly less than $1/2$.

⁴Such findings contrast with estimates of the marginal cost-based NKPC, which find a much smaller, often insignificant, role for lagged inflation, thus implying that equation (6) can be interpreted as a reasonable first approximation. See, e.g., Galí, Gertler and López-Salido (2001) and Sbordone (2002).

⁵Alternatively, we use the fact that $m - n = \frac{1}{\alpha}(y - n)$ to substitute productivity growth for the change in relative input prices.

6 Explaining the Inflation-Unemployment Relationship

An important caveat in the estimation of an equation like (13), stressed by Galí and Gertler (1999), among others, is that the employment gap $n - n_1$ may not be easy to measure, at least to the extent that first best employment fluctuates in response to different types of shocks (as emphasized by RBC models). In that case, detrended employment or similar measure may be poor proxies for the employment gap, since they implicitly assume that first best employment is a smooth function of time. Notice also that using unemployment rate (with the sign switched) will not do either since, strictly speaking, measures of the labor force used to construct the unemployment rate are conceptually different from first best employment n_1 . Nevertheless, as we discuss next, we can carry out a simple transformation that allows us to derive an inflation equation in terms of a variable conceptually close to empirical unemployment rate measure, and hence, one that can be compared with empirical estimates of the inflation unemployment relationship.

Let us first define the unemployment rate u as

$$u \equiv n_s - n$$

where n_s is in turn implicitly defined by

$$w = y + \phi n_s + \xi$$

In words, n_s measures the quantity of labor households want to supply given the currently prevailing real wage and marginal utility of income.⁶

Next we derive a simple relationship between marginal cos, the unemployment rate (defined as above), and the employment gap:

$$\begin{aligned} \widehat{mc} &= w - (y - n) - \log(1 - \alpha) + \mu \\ &= (y + \phi n_s + \xi) - (y - n) - \log(1 - \alpha) + \mu \\ &= \phi u + (1 + \phi)(n - n_1 + \delta) \end{aligned}$$

Using the previous expression to substitute the employment gap in (10) and rearranging terms we obtain

$$\widehat{mc} = \widehat{mc}(-1) - (\gamma^{-1} - 1)\phi u + \alpha(\Delta v - \Delta w)$$

Furthermore, we can use the relation

$$\begin{aligned} w &= \gamma w(-1) + (1 - \gamma)(y + \phi n + \xi) \\ &= \gamma w(-1) + (1 - \gamma)(w - \phi u) \\ &= w(-1) - (\gamma^{-1} - 1)\phi u \end{aligned}$$

⁶Notice that those two conditioning variable would generally differ in a first best equilibrium, which explains why, in general, $n_s \neq n_1$

to substitute for Δw in the expression above thus implying

$$\widehat{mc} = \widehat{mc}(-1) - (1 - \alpha)(\gamma^{-1} - 1)\phi u + \alpha\Delta v$$

which can be combined with (6) to yield the inflation equation

$$\pi = \frac{1}{1 + \beta}\pi(-1) + \frac{\beta}{1 + \beta}E\pi(+1) - \frac{\lambda(1 - \alpha)(\gamma^{-1} - 1)\phi}{1 + \beta}u + \frac{\alpha\lambda}{1 + \beta}\Delta v + \zeta \quad (14)$$

We estimate the previous equation using instrumental variables. We use annual U.S. data on inflation (measured by the percent change in the GDP deflator), the civilian unemployment rate and the percent change in the PPI raw materials index (relative to the GDP deflator). Our instrument set consist of four lags of the previous three variables. The sample period is 1960-2004. The resulting estimated equation is (standard errors in brackets):

$$\pi = \frac{0.66}{(0.09)}\pi(-1) + \frac{0.42}{(0.06)}E\pi(+1) - \frac{0.20}{(0.08)}u + \frac{0.018}{(0.001)}\Delta v + \zeta$$

which accords, at least qualitatively, with (14). In particular all the estimated coefficients have the right sign and are statistically significant. Furthermore the theoretical restriction that the sum of coefficients on lagged and expected inflation equals one cannot be rejected at the 5 percent level (though not by much). When we impose that restriction the resulting estimated equation is:

$$\pi = \frac{0.52}{(0.05)}\pi(-1) + \frac{0.48}{(0.05)}E\pi(+1) - \frac{0.08}{(0.05)}u + \frac{0.014}{(0.009)}\Delta v + \zeta$$

which again matches well the theoretical specification, though the coefficients on unemployment and raw materials prices are significant at a level slightly above 10 percent now.

[to be completed]

7 Sticky Wages

[incomplete]

Could a model with nominal wage stickiness deliver similar results? Consider the model with staggered wage setting, as in Erceg et al. (2000). Wage inflation is described by the difference equation:

$$\begin{aligned} \pi^w &= \beta E\pi^w(+1) - \lambda_w(w - mrs - \mu^w) \\ &= \beta E\pi^w(+1) - \lambda_w(w - \alpha m - (1 - \alpha + \phi)n - \xi - \mu^w) \\ &= \beta E\pi^w(+1) - \lambda_w(w - w_2) + \lambda_w(1 - \alpha + \phi)(n - n_2) \end{aligned}$$

where μ^w is a constant frictionless markup

Price inflation is still given by

$$\begin{aligned}
\pi^p &= \beta E\pi^p(+1) + \lambda_p(mc + \mu^p) \\
&= \beta E\pi^p(+1) + \lambda_p(w - \alpha m + \alpha n - \log(1 - \alpha) + \mu^p) \\
&= \beta E\pi^p(+1) + \lambda_p(w - w_2) + \lambda_p\alpha(n - n_2)
\end{aligned}$$

Define $\pi \equiv \frac{\lambda_w \pi^p + \lambda_p \pi^w}{\lambda_w + \lambda_p}$. It follows that

$$\pi = \beta E\pi(+1) + \kappa(n - n_2)$$

where $\kappa \equiv \frac{\lambda_w \lambda_p (1 + \phi)}{\lambda_w + \lambda_p}$.

Using the fact that

$$n_1 - n_2 = \frac{\mu}{1 + \phi} \equiv \delta$$

where $\mu \equiv \mu^p + \mu^w$, we can rewrite the equation above as

$$\pi = \beta E\pi(+1) + \kappa(n - n_1 - \delta)$$

Hence the divine coincidence emerges again, though in a different disguise: stabilizing the welfare-relevant employment gap is equivalent to stabilizing a weighted average of inflation.

As originally shown by Erceg et al. (2000) the utility-based loss function needed to evaluate alternative policies is a weighted average of the squares of the output gap, price inflation and wage inflation. In that context strict price inflation targeting is generally suboptimal, and often involves welfare losses that are several times larger than other, better designed policies. Interestingly, while strict output gap stabilization (and hence stabilisation of the composite inflation index) is exactly optimal only for a specific parameter configuration, it has been shown to be nearly-optimal for a large range of parameter values (Erceg et al. (2000), Woodford (2003), chapter 6). Hence, and for all practical purposes, the policy tradeoff in that case is nonexistent in that case.

will price inflation display (intrinsic) inertia in this case? It is unlikely. To see this notice that we can write real marginal cost as:

$$\begin{aligned}
\widehat{mc} &= mc + \mu^p \\
&= w - (y - n) - \log(1 - \alpha) + \mu^p \\
&= (w - mrs - \mu^w) + (1 + \phi)(n - n_2) \\
&= \lambda_w^{-1}(\beta E\pi^w(+1) - \pi^w) + (1 + \phi)(n - n_2)
\end{aligned}$$

Plugging the previous expression into (6) we obtain:

$$\pi^p = \beta E\pi^p(+1) + \lambda_p(1 + \phi)(n - n_1 - \delta) + (\lambda_p/\lambda_w)(\beta E\pi^w(+1) - \pi^w)$$

Letting $\beta > 1$, we get

$$\pi^p = E\pi^p(+1) + \lambda_p(1 + \phi)(n - n_1 - \delta) + (\lambda_p/\lambda_w)E\Delta\pi^w(+1)$$

which attaches no weight to past inflation, and with the additional term $E\Delta\pi^w(+1)$ unlikely to be a source of much inflation inertia beyond that inherited from the employment gap.

8 Conclusions

[to be written]

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