MA Macroeconomics
9. Sticky Prices and the Phillips Curve

Karl Whelan

School of Economics, UCD

Autumn 2014

Back to Price Stickiness

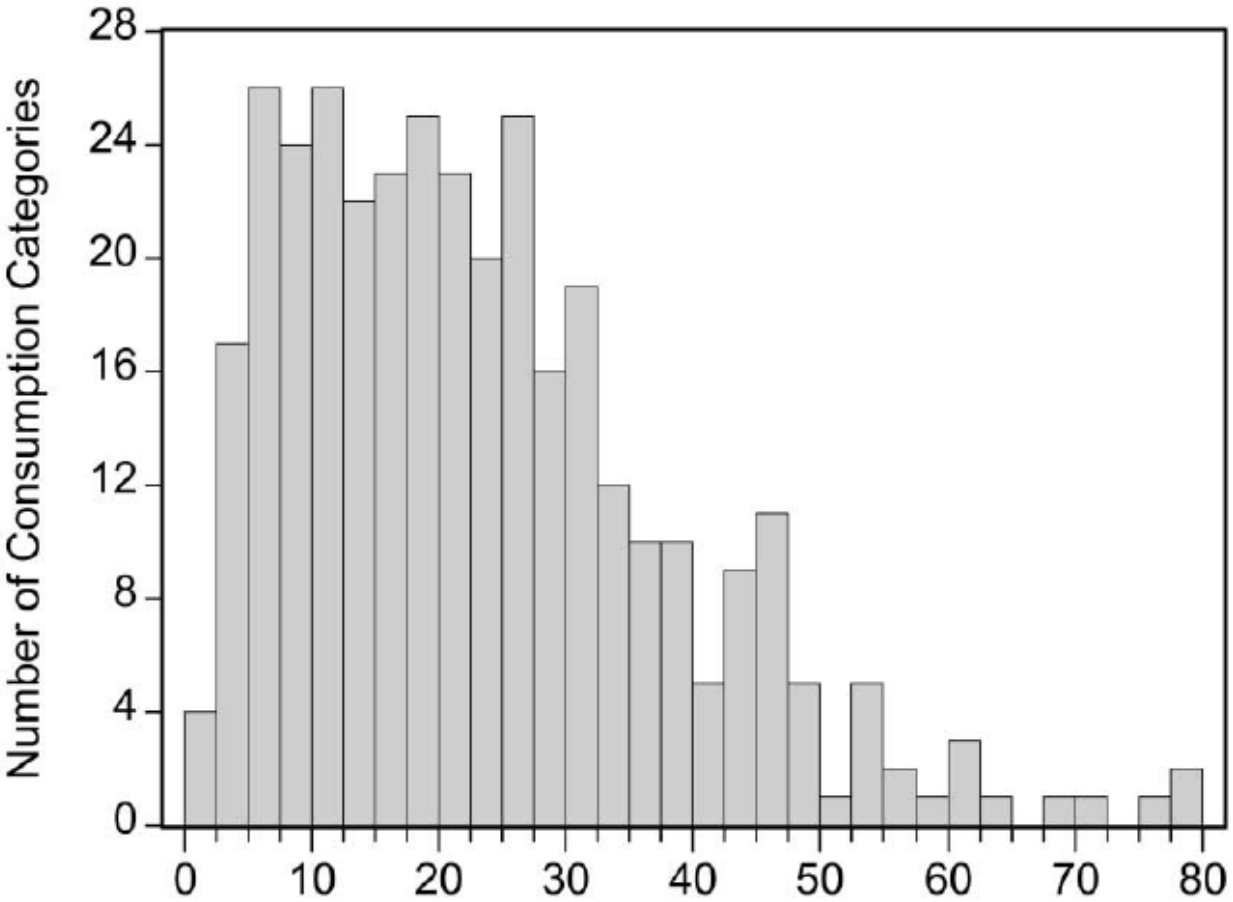
- One of the themes of the first part of this course was that the behaviour of prices was crucial in determining how the macro-economy responded to shocks.
  - **IS-LM**: we assumed prices were "sticky" in the short-run to obtain real effects for fiscal and monetary policy but prices were flexible in the long-run so that the economy returned to its full employment level over time.
  - **IS-MP-PC**: A more formal version of this idea. Prices that adjusted over time in response to the real economy according to a Phillips curve.
- We will now return to the topic of price setting and the relationship over time between inflation and the business cycle.
- We will emphasise the role of price flexibility and expectations.

Evidence on Price Stickiness

- The idea that prices may be "sticky" has a long history in Keynesian macroeconomics but, until recent decades, there was comparatively little evidence on the extent to which prices changed over time.
- This has changed since the statistical agencies have made available the price quote data that underlie Consumer Price Indices. (e.g. the price in April of a bottle of Heinz ketchup at a particular store).
- These individual price quote data can be used to assess how often individual prices are changed. Studies of this type now exist for a large number of countries.
- The data show a very wide range of the frequency with which different prices change but, on average, prices are quite sticky.
  - For the US, the median price duration is about 4 months.
  - For the euro area, the median price duration of 10.6 months.

]

Distribution of Monthly Percent Probability of Price Changes



Evidence on Median Price Durations

TABLE 1
MONTHLY FREQUENCY OF PRICE CHANGES BY YEAR, 1995–2002

Year	Median Frequency (%)	Median Duration (Months)
1995	21.3	4.2
1996	20.8	4.3
1997	19.9	4.5
1998	21.2	4.2
1999	21.4	4.1
2000	21.7	4.1
2001–2	22.0	4.0

New Classical and New Keynesian Macroeconomics

- After Friedman's critique of the Phillips curve, macroeconomists began to pay more attention to the question of how expectations were formed. Lucas and Sargent introduced rational expectations into macroeconomics.
- These early papers assumed prices were perfectly flexible, which limited the ability of fiscal and monetary policy to influence output. This school of thought was labelled *New Classical* economics.
- Lucas model: firms had difficulty in the short-run distinguishing between movements in their prices and movements in the overall price levels. An increase in the money supply that provoked an increase in prices could, in the short-run, provoke higher output. Only *unpredictable* fiscal and monetary policies would have an impact because people with rational expectations would anticipate the impact of predictable policy on the price level.
- With sticky prices, this point no longer holds. Because some prices will not change, policies will have the traditional short-run impacts described in IS-LM even if people have rational expectations.
- Papers by John Taylor and Stanley Fischer, which combined rational expectations with sticky prices, invented what is now known as *New Keynesian economics*.

The Calvo Model

- We will use a formulation of sticky prices known as *Calvo pricing*, after the economist who first introduced it.
- Not the most realistic formulation of sticky prices but it provides analytically convenient expressions, and has implications that are very similar to those of more realistic (but more complicated) formulations.
- Only a random fraction $(1-\theta)$ of firms are able to reset their price; all other firms keep their prices unchanged.
- When firms do get to reset their price, they must take into account that the price may be fixed for many periods. We assume they do this by choosing a log-price, z_t, that minimizes the "loss function"

$$L(z_t) = \sum_{k=0}^{\infty} (\theta\beta)^k E_t \left(z_t - p^*_{t+k}\right)^2$$

where β is between zero and one, and p^*_{t+k} is the log of the optimal price that the firm would set in period $t+k$ if there were no price rigidity.

Explaining the Loss Function

$$L(z_t) = \sum_{k=0}^{\infty} (\theta\beta)^k E_t \left(z_t - p^*_{t+k}\right)^2$$

- $E_t \left(z_t - p^*_{t+k}\right)^2$ describes the expected loss in profits for the firm at time $t+k$ due to the fact that it will not be able to set a frictionless optimal price that period.
- The summation $\sum_{k=0}^{\infty}$ shows that the firm considers the implications of the price set today for all possible future periods.
- $\beta < 1$ implies that the firm places less weight on future losses than on today's losses.
- Future losses are actually discounted at rate $(\theta\beta)^k$, not just β^k. This is because the firm only considers the *expected* future losses from the price being fixed at z_t. The chance that the price will be fixed until $t+k$ is θ^k. So the period $t+k$ loss is weighted by this probability.

The Optimal Reset Price

- What is the optimal price to set? Differentiate $L(z_t)$ with respect to z_t and set equal to zero.

$$L'(z_t) = 2\sum_{k=0}^{\infty}(\theta\beta)^k E_t\left(z_t - p^*_{t+k}\right) = 0$$

- Separating out the z_t terms from the p^*_{t+k} terms, this implies

$$\left[\sum_{k=0}^{\infty}(\theta\beta)^k\right] z_t = \sum_{k=0}^{\infty}(\theta\beta)^k E_t p^*_{t+k}$$

- Now, we can use our old pal the geometric sum formula to simplify the left side of this equation. In other words, we use the fact that

$$\sum_{k=0}^{\infty}(\theta\beta)^k = \frac{1}{1-\theta\beta}$$

The Optimal Reset Price

- To give us

$$\frac{z_t}{1-\theta\beta} = \sum_{k=0}^{\infty} (\theta\beta)^k \, E_t p^*_{t+k}$$

- This implies a solution of the form

$$z_t = (1-\theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k \, E_t p^*_{t+k}$$

- Stated in English, all this equation says is that the optimal solution is for the firm to set its price equal to a weighted average of the prices that it would have expected to set in the future if there weren't any price rigidities. Unable to change price each period, the firm chooses to try to keep close "on average" to the right price.

Incorporating the Frictionless Price

- And what is this "frictionless optimal" price, p_t^*?
- Assume that the firm's optimal pricing strategy without frictions would involve setting prices as a fixed markup over marginal cost:

$$p_t^* = \mu + mc_t$$

- Thus, the optimal reset price can be written as

$$z_t = (1 - \theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k E_t (\mu + mc_{t+k})$$

- Which simplifies to

$$z_t = \mu + (1 - \theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k E_t mc_{t+k}$$

Inflation Dynamics in the Calvo Model

- It turns out that this type of pricing implies a type of Phillips curve.
- Let's re-examine the optimal reset price equation.

$$z_t = (1 - \theta\beta) \sum_{k=0}^{\infty} (\theta\beta)^k E_t (\mu + mc_{t+k})$$

- We have shown that the first-order stochastic difference equation

$$y_t = ax_t + bE_t y_{t+1}$$

  can be solved to give

$$y_t = a \sum_{k=0}^{\infty} b^k E_t x_{t+k}$$

- We can see that z_t must obey a first-order stochastic difference equation with $y_t = z_t$, $x_t = \mu + mc_t$, $a = 1 - \theta\beta$ and $b = \theta\beta$.
- In other words, we can write the reset price as

$$z_t = \theta\beta E_t z_{t+1} + (1 - \theta\beta)(\mu + mc_t)$$

The New-Keynesian Phillips Curve

- The aggregate price level in this economy is just a weighted average of last period's aggregate price level and the new reset price, where the weight is determined by θ:

$$p_t = \theta p_{t-1} + (1-\theta) z_t,$$

- This can be re-arranged to express the reset price as a function of the current and past aggregate price levels

$$z_t = \frac{1}{1-\theta}\left(p_t - \theta p_{t-1}\right)$$

- Substituting in the expression for z_t from previous slide.

$$\frac{1}{1-\theta}\left(p_t - \theta p_{t-1}\right) = \frac{\theta\beta}{1-\theta}\left(E_t p_{t+1} - \theta p_t\right) + (1-\theta\beta)\left(\mu + mc_t\right)$$

- After a bunch of re-arrangements, this equation can be shown to imply

$$\pi_t = \beta E_t \pi_{t+1} + \frac{(1-\theta)(1-\theta\beta)}{\theta}\left(\mu + mc_t - p_t\right)$$

where $\pi_t = p_t - p_{t-1}$ is the inflation rate.

- This equation is known as the *New-Keynesian Phillips Curve*

Inflation in the New-Keynesian Phillips Curve

$$\pi_t = \beta E_t \pi_{t+1} + \frac{(1-\theta)(1-\theta\beta)}{\theta}(\mu + mc_t - p_t)$$

- This equation is known as the *New-Keynesian Phillips Curve*. It states that inflation is a function of two factors:
  - Next period's expected inflation rate, $E_t \pi_{t+1}$.
  - The gap between the frictionless optimal price level $\mu + mc_t$ and the current price level p_t. Another way to state this is that inflation depends positively on *real marginal cost*, $mc_t - p_t$.
- Why is real marginal cost a driving variable for inflation? Firms in the Calvo model would like to keep their price as a fixed markup over marginal cost. If the ratio of marginal cost to price is getting high (i.e. if $mc_t - p_t$ is high) then this will spark inflationary pressures because those firms that are re-setting prices will, on average, be raising them.

The NKPC, Real Marginal Cost and Output

- The model views inflation as depending on $\mu + mc_t - p_t$, i.e. the deviation of real marginal cost from its frictionless level. But we don't observe data on real marginal cost.
- Still, it seems likely marginal costs are procyclical, and more so than prices. Example: Overtime wage premia: Marginal cost of labour jumps once output levels are high enough to require more than the standard workweek.
- Some implement the NKPC using a measure of the *output gap* (the deviation of output from its potential level) as a proxy for real marginal cost. Denoting the output gap as $\tilde{y}_t$, assume

$$\mu + mc_t - p_t = \lambda \tilde{y}_t$$

- And the NKPC becomes

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

where

$$\gamma = \frac{\lambda (1-\theta)(1-\theta\beta)}{\theta}$$

- This approach can be implemented empirically using various measures for estimating potential output.

The "Asset-Price-Like" Behaviour of NKPC Inflation

- The NKPC may look plausible but remember that, combined with rational expectations, it has very strong predictions.
- The equation below is a first-order stochastic difference equation.

$$\pi_t = \beta E_t \pi_{t+1} + \gamma \tilde{y}_t$$

- Thus, we can apply the repeated substitution method to equation (15) to arrive at

$$\pi_t = \gamma \sum_{k=0}^{\infty} \beta^k E_t \tilde{y}_{t+k}$$

- Inflation today depends on the whole sequence of expected future output gaps.
- Thus, the NKPC sees inflation as behaving according to the classic "asset-price" logic that we saw with the dividend-discount stock price model: Past values of all variables, including inflation itself, don't matter, only the present and expectations of the future.

The NKPC and the Lucas Critique

- While evidence for original Phillips curve relationship has disappeared, there is evidence for a relationship of the form

$$\pi_t = \pi_{t-1} + \alpha - \beta u_t$$

  where the lagged inflation term likely reflects how past inflation affects people's expectations

- This relationship is often used and spawned the well-known idea of the NAIRU (the non-accelerating inflation rate of unemployment) defined implicitly by

$$\alpha - \beta u^* = 0 \Rightarrow u^* = \frac{\alpha}{\beta}$$

- If the true model is the NKPC, then the backward-looking Phillips curve might have a good statistical fit because π_{t-1} is likely to be correlated with $E_t \pi_{t+1}$.
- However, NKPC advocates think policy-makers should not rely on this relationship, because changes in policy may produce a break the correlation between $E_t \pi_{t+1}$ and π_{t-1} and at this point the statistical Phillips curve will break down.

The NKPC and Disinflation

- How should a central bank act to reduce inflation? Traditional thinking on this has been heavily influenced by Phillips curves of the form

$$\pi_t = \pi_{t-1} + \alpha - \beta u_t$$

- Because inflation depends on its own lagged values in this formulation means then it would be very difficult to reduce inflation quickly without a significant increase in unemployment. So gradualist policies are the best way to reduce inflation.
- Implications of the NKPC are completely different: Low inflation can be achieved immediately by the central bank announcing (and the public believing) that it is committing itself to eliminating positive output gaps in the future.
- There has been plenty of evidence that reductions in inflation do tend to be costly in terms of lost output and high unemployment.
- Is this because the NKPC is wrong or because governments failed to credibly convince the public of their commitment to lower inflation rates?

Things to Understand From This Topic

1. The evidence on price stickiness.
2. New Classical macroeconomics.
3. New Keynesian macroeconomics.
4. The assumptions of the Calvo model.
5. The optimal reset price in the Calvo model.
6. How to derive the New Keynesian Phillips curve.
7. Real marginal cost and output gaps.
8. The NKPC and the Lucas Critique of the Phillips curve.
9. The NKPC and disinflation.