Aggregate Supply for Industrial Organization Economists

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Abstract

I survey the resent literature on the Phillips curve. Along the way I will try to relate this literature to topics of interest to industrial organization. I will also point out gaps in our understanding and places that more careful microeconomic analysis would be helpful to macroeconomists. In the conclusion, I summarize what an industrial organization economist might take away from this literature.

1. Introduction

When a business cycle economist is asked about industrial organization, a typical response will be something like, "What can we learn about business cycles from the market for yoghurt?" When an industrial organization economist attends a macroeconomics seminar, a typical question will be, "You assume the same elasticity of demand for all goods?" I think that it is fair to say that the two groups tend to talk past each other. This is too bad since there is considerable overlap in topics that the two fields find important. The gap is a reflection of the type of questions that the two groups attempt to answer. IO economists tend to be interested in the interactions among firms in a particular market setting, such as the auction of timber licenses or the pricing of electricity, cement or automobiles, whereas macroeconomists are concerned with the evolution of aggregate quantities, such as the growth of output over time, fluctuations in employment over the business cycle, or the comovement of output and inflation.

These differences in focus lead to differences in model strategy. Because macroeconomist focus on aggregates, their models tend to be dynamic and general equilibrium. Following Lucas' famous critique of policy evaluation, macroeconomists have also found it important that their models have solid microfoundations, since the effects any policy action depends on how agents respond to their new environment. Finally, macroeconomic models are often stochastic, either because they are interested in the effects of uncertainty per se, or because they wish to consider the response of the economy to various economic disturbances.

These four elements – uncertainty, dynamics, general equilibrium, and microfoundations – put strong limits on the complexity of macroeconomic models. The more complex the model, the more difficult it is to solve for the equilibrium dynamics. The more complex the model, the more difficult it is to understand what drives the results. The more complex the model, the more difficult it is to understand what identifies the model in any empirical application.

For this reason, macroeconomists try to make their models complex enough to answer interesting questions about aggregate dynamics, while simple enough that they can be solved and understood. These simplifications, such as a representative consumer or symmetric firms, may seem crude or even laughable to an industrial organization economist used to analyzing a given industry or set of firms, but in macroeconomics every new modelling element must pass a simple test: does it matter for the question at hand? If a question does not appear to depend on the distribution of wealth or consumption across agents, then assume a representative consumer. If a question does not appear to depend on the distribution of markups across firms, then assume that all firms have the same elasticity of demand. As we get better at solving and testing more complex models, we revisit these assumptions and amend the models where needed. Because industrial organization looks with a microscope at particular markets and particular interactions, details become much more important. These details tend to smooth out in the aggregate.

Given that macroeconomics is such a broad field, I will focus on one area of macroeconomics: New Keynesian models of aggregate supply. These models attempt to explain two general empirical regularities linking real and nominal variables: the apparent real effects of monetary policy and the correlation between output and inflation over the business cycle, also known as the Phillips curve. These models explain this link between real and nominal variables by appealing to sticky prices. If prices are sticky than increases in nominal demand will lead to increases in real output. If prices are sticky than increases in real output may pressure firms to raise their prices leading to inflation.

This area of macroeconomics is of particular relevance to industrial organization, because in order to model price rigidity one needs firms that actually set prices. This takes us out of the realm of perfect competition that characterizes many real models of business cycles.

Prices in New Keynesian models are set to achieve desired markups over marginal cost over some specified time horizon. This characterization highlights the three ingredients of the typical model: a model of price frictions, a model of the markup, and a model of marginal cost. Models differ on each of these margins. Some models simply assume that prices are fixed for some given period of time. Other models endogenize the firm's choice of when to change its price; these models typically assume some cost of price adjustment so that the firm balances this cost against the potential benefit of price adjustment. Some models assume desired markups are fixed. Others assume that the elasticity of demand depends on the actions of the firm. Some models assume constant marginal cost. Others assume that marginal cost depends in complex ways on a firm's production, firms' interactions, or adjustment frictions. Still others assume that marginal cost is subject to the same sort of nominal frictions that affect prices.

It is safe to say that the profession has been quite creative in constructing potential models of this interaction between prices and costs. We have been less successful at identifying which of these interactions are important in practice. We are still largely ignorant about the dynamics of marginal cost over the business cycle. Much of the problem is that marginal cost is not directly observable. It must be deduced from a model, and different models give different answers. These models often have fairly similar implications for aggregate dynamics, making it difficult to distinguish between them based on aggregate information along. For the same reasons, we are also still largely ignorant of which strategic interactions are important in price setting.

In what follows I survey some of the resent literature on the Phillips curve. Along the way I will try to relate this literature to topics of interest to industrial organization. I will also point out gaps in our understanding and places that more careful microeconomic analysis would be helpful to macroeconomists. In the conclusion, I summarize what an IO economist might take away from this literature.

2. The New Keynesian Aggregate Supply Curve

2.1. Price setting with Nominal Rigidities

I focus on the supply side of the economy, where nominal rigidities lead to deviations from the frictionless optimum. Time is indexed by t. There is a continuum of firms on unit mass indexed by i. Each firm produces a single consumption good and chooses its nominal price to maximize the present value of profits subject to a pricing friction.

The first ingredient of the model is the pricing friction. There are two popular approaches. Models with time-dependent rules assume that prices are fixed for some exogenous period of time. The two most popular time-dependent rules are "Taylor pricing" (Taylor, 1980) in which a firm resets its price at fixed intervals, and "Calvo pricing" in which firms adjust their price in any given period with some fixed probability $1-\alpha$. The other approach is to allow firms choose when to alter their prices, and to assume that some fixed cost of price adjustment prevents continuous adjustment. These are often referred to as state-dependent rules, since whether or not a firm adjusts its price depends on the state in which it finds itself, or Ss rules since the trigger-target character of the optimal policy is reminiscent of the Ss model of inventory management.

It may seem that state-dependent rules are inherently better than time-dependent rules. State-dependent rules arise out of a well formulated decision problem. Time-dependent rules are ad hoc. State-dependent pricing models are much more difficult to work with, however, since the economy-wide cross sectional distribution of prices becomes a state variable. The greater the number of firms have prices below their optimum the more likely is inflation. Moreover, it turns out that for many applications the distinction between state- and time-dependence does not matter very much. When firms adjust their prices, they tend to adjust them by large amounts – in the neighborhood of 10% on average. This suggests that firms are hit by large idiosyncratic shocks to their desired prices. The timing of price adjustment in many state-dependent models that include idiosyncratic shocks, often depends more on these local shocks than on the aggregate state of the economy. In this sense, the timing of price adjustment is effectively exogenous. The result is that many state-dependent models have dynamic properties similar to time-dependent models, and time-dependent models have the virtue that they are much easier to work with.

It is also not clear that the distinction between state and time dependence matters for the relationship between these models and industrial organization. Here the exact form of price stickiness is less important than the fact that there is some horizon over which prices are fixed.

I will therefore begin by assuming Calvo pricing since it leads to the simplest mathematical formulations. In a later section, I will return to state-dependent pricing models and discuss where and when state-dependence matters.

The second ingredient is the markup. It is common to assume a demand function of the form

$$Y_i = D\left(\frac{P_i}{P}, Y\right) = \left(\frac{P_i}{P}\right)^{-\varepsilon} Y$$

In this formation the demand for firm i depends on aggregate demand Y and the price relative to a price index. The elasticity of demand is constant. This is what would come out of a model with two stage budgeting, such as Dixit and Stiglitz (1977), in which consumers first decide how much to consume and then how to allocate that consumption across goods.

The constant elasticity of demand implies a desired markup that is constant. The industrial organization literature is full of models of time-varying markups. Few of these models have been incorporated in the macroeconomic literature. In the typical New Keynesian model, the markup varies over the cycles, not because the desired markup varies, but because the firms price is fixed and costs vary.

I will begin with the constant elasticity specification. Later I will discuss theories of time-varying markups and how they might be incorporated in macroeconomic models.

The third ingredient is a model of the cost of production. Here I will simply assume that the cost of production depends on the level of production, as well as the level of aggregate activity:

$$C(Y_i, Y) = C\left(D\left(\frac{P_i}{P}, Y\right), Y\right)$$

A firm's marginal cost could depend on its own production through returns to scale or contractual relationships such as overtime pay. It could depend on the level of aggregate activity through factor prices; greater use of a factor raises the price of that factor to all firms.

Putting these elements together, the firms problem of a firm that adjusts at date t is:

$$\max_{P_i} E_t \sum_{k=0}^{\infty} \alpha^k \Lambda_{t,t+k} \left[\left(\frac{P_i}{P_{t+k}}\right)^{-\varepsilon} Y_{t+k} \frac{P_i}{P_{t+k}} - C\left(D\left(\frac{P_i}{P_{t+k}}, Y_{t+k}\right), Y_{t+k}\right)\right]$$

where $\Lambda_{t,t+k}$ is the stochastic discount factor, i.e. the ratio of marginal utility at date $t+k$ to marginal utility at date t, and E_t is the expectations operator conditional on date t information. Note that P_i is fixed and future profits are discounted by α^k, the cumulative probability that the firm has not had an opportunity to change its price. The firm's horizon is the period over which its price is fixed. This is a direct result of the envelop theorem and the absence of any state variable besides prices: adjustment today does not affect profits at any date beyond the date of the next price adjustment.[1]

The first order for this problem is:

$$E_t \sum_{k=0}^{\infty} \alpha^k \Lambda_{t,t+k} \left(\frac{P_i}{P_{t+k}} \right)^{-\varepsilon - 1} \frac{Y_{t+k}}{P_{t+k}} \left[(1-\varepsilon) \frac{P_i}{P_{t+k}} + \varepsilon C_1 \left(D \left(\frac{P_i}{P_{t+k}}, Y_{t+k} \right), Y_{t+k} \right) \right] = 0$$

We get a particularly simple relationship if we log-linearize this equation about a zero inflation steady state. In steady state the stochastic discount factor is simply the discount factor $\Lambda_{t,t+k} = \beta^k$. Let lower case letters represent log-deviations from steady state values, $x = \Delta X / X$, and let mc denote the log of real marginal cost, C_1, the first order condition becomes

$$E_t \sum_{k=0}^{\infty} \alpha^k \beta^k \left[p_t^* - p_{t+k} - mc_{t+k} \right] = 0 \tag{2.1}$$

Rearranging

$$p_t^* = (1 - \alpha\beta) \, E_t \sum_{k=0}^{\infty} \alpha^k \beta^k \left[p_{t+k} + mc_{t+k} \right] = (1 - \alpha\beta) \left[p_t + mc_t \right] + \alpha\beta E_t p_{t+1}^* \tag{2.2}$$

The optimal price is a weighted average of future nominal marginal cost where the weights reflect discounting and the probability that the price will still be charged.

2.2. A Phillips Curve

In the neighborhood of the steady state the price index is a geometric average of individual firm prices

$$p_t = \int p_{it} di$$

Given the assumption of Calvo pricing, a random fraction α continue to charge last period's price and a fraction $1-\alpha$ choose the new optimal price p_t^*. Since the non-adjusters are randomly

[1] If we introduce additional state variables such as a firm specific capital stock subject to adjustment costs or a costomer base that must be built up over time, then today's pricing decision will influence tomorrow's pricing decision through its effect on this state variable. The envelop condition will no longer hold.

selected from the population their average price is just p_{t-1}. The evolution of the price index is therefore:

$$p_t = (1-\alpha)p_t^* + \alpha p_{t-1} \tag{2.3}$$

Combining equations (2.2) and (2.3) yields one version of the "New Keynesian Phillips curve"

$$\pi_t = \lambda mc_t + \beta E_t \pi_{t+1} \tag{2.4}$$

Here $\lambda = \frac{(1-a)(1-\alpha\beta)}{\alpha}$. This equation relates inflation to current marginal cost and expected future inflation. The higher is current marginal cost, the higher are the prices set by firms that adjust their prices and the higher is inflation. The higher is expected future inflation, the higher is expected future marginal cost, the higher are the prices set by firms adjusting their prices, and the higher is current inflation.[2]

In order to compare it to the standard Phillips curve, we need to replace marginal cost with output. Linearizing marginal cost about steady state

$$mc = \omega y_i + \sigma y \tag{2.5}$$

where ω is the elasticity of a firms marginal cost with respect to own output and σ is the elasticity of marginal cost with respect to aggregate output. Linearizing the demand curve gives:

$$y_i = -\varepsilon(p_i - p) + y \tag{2.6}$$

Now substituting (2.5) and (2.6) into (2.2)

$$p_t^* = (1-\alpha\beta)\left[p_t + \left(\frac{\omega+\sigma}{1+\omega\varepsilon}\right)y\right] + \alpha\beta E_t p_{t+1}^* \tag{2.7}$$

which combined with the price index gives

$$\pi_t = \lambda\psi y + \beta E_t \pi_{t+1} \tag{2.8}$$

where $\psi = \frac{\omega+\sigma}{1+\omega\varepsilon}$.[3]

[2] Note that we can iterate (2.4) forward and write current inflation as the expected present value of current and future marginal cost.

[3] Note that we can decompose ψ. $1/(1+\omega\varepsilon)$ relates the marginal cost of firm i to the economy-wide average marginal cost. $\omega+\sigma$ relates average marginal cost to the output gap.

2.3. Output and Inflation

The dynamics of output and inflation depend on $\lambda\psi$. In order to generate large and persistent effects of money on output, it is important that $\lambda\psi$ is small.

To see this suppose that nominal income m is exogenous:

$$m = p + y.$$

Suppose that we begin in steady state and that m rises permanently by 1%. Equation (2.7) implies that firms that adjust their prices adjust them by the present value of:

$$p + \psi y = \psi m - (1 - \psi)p$$

Suppose first that $\psi = 1$ then the target price moves one for one with m. The real effects of money are governed solely by the non-adjustment probability α. k periods following the increase in m, a fraction $1 - \alpha^k$ firms have fully responded to the shock, whereas the remaining α^k of firms remain at their original pre-shock prices. A high value of α therefore increases the real effects of a nominal shock.

If $\psi < 1$, then the firms that adjust their prices raise their prices by less than one percent in response to a one percent increase in m. Their margin costs rise by a weighted average of p and m and since p rises by less than m due to non-adjustment, their marginal cost rises by less than one percent. Since adjusting firms no longer fully incorporate the increase in m into their new prices, convergence may take much longer. It may now take firms many adjustments before a firm's price converges to the new steady state. A low value of ψ therefore increases the real effects of a nominal shock.

Estimates of $\lambda\psi$ tend to be well below one.

2.3.1. What determines λ?

λ depends on the frequency of price adjustment α. There have been many recent efforts to estimate α from data on individual prices. Klenow and Malin (2009) survey the evidence. For the US over the period 1988-2005, prices change on average every 4 months. This implies a value of α in the neighborhood of .4, and a value of λ in the neighborhood of .9.

There are several reasons to believe that this value of α may be inappropriate for macroeconomic analysis. First, as argued by Guimaraes and Sheedy (2008) and Kehoe and Midrigan (2007), we may wish to exclude sales from the calculation. Sales are likely a response to idiosyncratic factors, and firms often return to the presale price after the sale is over. The economy has not responded to the monetary shock until the pre-sale price has responded to the monetary shock. If we exclude sales from the calculation, the average duration of prices in the US rises to 6.9 months, and if we take a broader definition of sales and define a sale to be any deviation from a modal or reference price (Eichenbaum, Jaimovich and Rebelo, 2008), the average duration rises to 10.5 months. Clearly the treatment of sales matters. Whether or not sales respond to aggregate information is an area of active research.

Second, there is great heterogeneity across sectors in the average duration of prices. Prices for durables change on average every 1.8 months. Prices for non-durable goods change every 3.3 months. Prices for services change every 7.7 months. Carvahlo (2006) argues that when this heterogeneity is taken into account the choice of α rises by a factor of three. The intuition is simple: convergence to monetary shocks is governed mainly by the firms that have the stickiest prices. The firms with flexible prices adjust quickly (although if there are significant strategic complementarities they may not fully adjust for the reasons stated above).

Not all considerations argue for higher α. Below we will show that state-dependent pricing models suggest using a smaller α. Gertler and Leahy (2008) argue that this α could be up to one third less than the average in the data.

In sum, given the flexibility of prices observed in the microeconomic data and the real effects of money that we observe in the macroeconomic data, we need ψ to be significantly less than one.

2.3.2. What is ψ?

Given the evidence on λ, a small value of ψ is necessary to match estimates of the New Keynesian Phillips curve. Why ψ should be small, however, it a major gap in the literature. We have little direct empirical evidence on ψ. Rather we have a collection of theories that put potential structure on the strategic complementarities.

The approaches taken in the literature fall in to two camps: mechanisms that work through y_i relative to y and mechanisms that work through y (Kimball, 1995). The basic message is that a low ψ can result either from a high elasticity of real marginal cost with respect to y_i, a high ω, or a low elasticity of real marginal cost with respect to y, a low σ. What follows is a brief review of the major theories and the structure that they place on ψ.[4]

[4] ψ is related to the concept of real rigidity (Ball and Romer, 1990). The first order condition for prices may be written:

$$\Pi_1(p_i/p, y) = p_i/p - mc(p_i/p, y) = 0$$

A low value of σ is associated with elastic factor supplies in the aggregate. For example, consider a world in which labor is the only factor, $Y_i = N_i$, consumption is the only output good, $Y = C = \sum N_i$, and labor is supplied in a single economy-wide labor market. In such a world, real marginal cost is equal to the aggregate real wage. If in addition we assume a representative consumer with the following utility function

$$U(C, N) = \frac{C^{1-\theta} - 1}{1-\theta} - \frac{1}{1+\gamma}\left(\sum N_i\right)^{1+\gamma} \tag{2.9}$$

where θ is the coefficient of relative risk aversion and γ is the inverse Frisch elasticity of labor supply, then the labor-liesure choice implies:

$$\frac{W}{P} = C^{\theta}\left(\sum N_i\right)^{\gamma}$$

Using the production function and aggregate supply and demand:

$$\frac{W}{P} = Y^{\theta+\gamma} \tag{2.10}$$

In this world $\sigma = \theta + \gamma$. Either a high Frisch elasticity of labor supply (low γ) or a low coefficient of relative risk aversion (low θ), will deliver a low value of σ. A high Frisch elasticity means that large changes in the labor supply only generate small changes in marginal cost. A low risk aversion, implies that large changes in consumption generate small changes in the utility value of wages.

There are other ways to get elastic factor supplies each has its proponents in the literature. Some authors like Christiano, Eichenbaum and Evans (2005) and Smets and Wouters (2003) include monopsonistic labor markets in which wages are sticky. Sellers of labor services must meet demand at posted prices thereby flattening marginal cost. Christiano, Eichenbaum and Evans also include variable capital utilization. Basu (1995) and Huang and Liu (2001) consider models with intermediate inputs whose prices are sticky. One could also image constructing a model with external returns to scale as in Baxter and King (1991).

A non-zero value of ω requires some form of diminishing returns to scale at the firm level. This may be assumed directly, by assuming that the production function has diminishing returns, or it may be assumed indirectly, by assuming that some factor such as land or capital is fixed in

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Then

$$\psi = -\frac{\Pi_{12}}{\Pi_{11}}.$$

the short run and that variable costs depend on the other factors which are themselves subject to diminishing returns. Diminishing marginal utility performs much the same function. One popular choice is local labor markets plus diminishing marginal utility of leisure, so that when a firm expands production, it must pay a higher wage and its costs rise.

To see how diminishing returns works, we alter the production function in the example above. Suppose that $Y_i = N_i^\eta$ where $\eta < 1$. It is easy to show that real marginal cost is

$$\frac{1}{\eta}\frac{W}{P}Y_i^{\frac{1}{\eta}-1}.$$

In this example, $\omega = \frac{1}{\eta} - 1$. We want ω to be large so we need η to be small.

To see how diminishing marginal utility works, suppose again that $Y_i = N_i$ but alter the utility function so that utility depends separately on the supply of labor to each firm rather on the sum of labor:

$$U(C,N) = \frac{C^{1-\theta}-1}{1-\theta} - \frac{1}{1+\gamma}\sum N_i^{1+\gamma} \tag{2.11}$$

With this amendment the first order condition for labor becomes

$$\frac{W}{P} = C^\theta N_i^\gamma = Y^\theta Y_i^\gamma \tag{2.12}$$

In this example $\omega = \gamma$. As we want ω to be large we want γ to be large.

It may seem counter intuitive that diminishing returns promotes price rigidity. It seems more natural that firms might want to respond to rapidly rising costs, and that this desire might promote flexibility. It is therefore useful to go through the intuition behind this form of strategic complementarity. Consider a firm that is considering an increase in the price of its good. The price increase will lead to a reduction in demand and production. Because of the diminishing returns, this reduction in production will reduce costs. The reduced costs in turn reduce the firm's desire to raise its price. The more responsive costs, the less the firm raises its price.

Note that pretty much any modification of the model can produce inertia if introduced in the right way. In the above examples, an increase in the inverse Frisch elasticity γ raised ω and reduced ψ with local labor markets, whereas a reduction in γ reduced σ and ψ when there was a single economy-wide labor market. The general rule is that decreasing returns reduce ψ if introduced at the firm level, whereas increasing returns reduce ψ if introduced at the at level of the economy as a whole. This is way it is important not only to have evidence of the importance of a mechanism, but also evidence as to the range over which each mechanism has influence. At this point we lack evidence on both counts.

2.3.3. How big is ψ?

There are at least two reasons that it is difficult to put a number on ψ. First, as should be abundantly clear from the previous discussion, ψ is very sensitive to the precise structure of the economy. Second, ψ depends in some way on every controversial parameter in macroeconomics: the elasticity of intertemporal substitution, the elasticity of labor supply, and the elasticity of demand.

The standard Real Business Cycle model provides a natural benchmark and a useful place to start. Real Business Cycle models typically assume common economy-wide factor markets, so that marginal cost is equalized across firms. If the firms are small, $\omega = 0$ and $\psi = \sigma$. In the example, given by equations (2.9) and (2.10), we get $\psi = \theta + \gamma$. Since the Frisch elasticity is positive, $\gamma \geq 0$. If we assume log utility $\theta = 1$, and $\psi > 1$. Greater risk aversion or introducing capital into the production function only serve to increase ψ. This parameterization does not generate large persistent effects of money on output and points to the need to include additional modelling elements.

On the other extreme, if we assume that labor markets are segmented as in the example given by equations (2.11) and (2.12), then $\psi = \frac{\gamma+\sigma}{1+\gamma\varepsilon}$. Now if $\gamma = \sigma = 1$, and $\varepsilon = 10$, $\psi = .2$.

Note that this example is very dependent on the choice of the elasticity of demand ε. This will be the case in any theory in which $\omega > 0$, so that marginal cost depends on a firms output. ε translates the change in the firms price into the change in the firms output which then affects marginal cost. The elasticity of demand is therefore an important parameter. Unfortunately, the calibration of this parameter differs widely in the literature. Macroeconomic estimates tend to be fairly large. Basu and Fernald (1997) conclude that markups are in the neighborhood of 10% which implies an $\varepsilon = 10$. Microeconomic estimates tend to be much smaller. Broda and Weinstein (2006), for example, estimate elasticities in the neighborhood of 4, which implies a markup of 25%. Barskey et al (2000), and Chevalier, Kashyap and Rossi (2003) estimate markups in the neighborhood of 50%.

It is clear that more work is needed to pin down the value of ε. One calculation that tends to favor high elasticities and low markups is the relationship between markups, returns to scale and profit shares (See Hall, 1990, and Basu and Fernald, 1997):[5]

$$\text{returns to scale} = \mu\left(1 - s_{\pi}\right)$$

Given that profits share s_{π} is less than 3%, and that there is scant evidence for large increasing returns to scale, it is difficult to believe that markups are very large on average.

2.3.4. Why does this matter?

One could argue that we do not care about the microfoundations of λ and ψ. All that matters for aggregate dynamics is the product $\lambda\psi$. We can solve and estimate our macroeconomic models without delving into the details of their construction. Interested parties may back out a set of microeconomic parameters consistent with macroeconomic dynamics may later depending on which microeconomic structure is deemed appropriate. This has been the approach of most resent research.

This view misses two important points. Solid microfoundations help us test and validate our models. It takes a long time series to estimate macroeconomic models with precision. Microeconomic evidence can help choose appropriate functional forms and provide additional information in estimating parameters.

More importantly, even if the macroeconomic dynamics of various microfounded models are similar, their welfare implications may differ. The welfare costs of inflation in New Keynesian models come from the distribution of prices and the resulting misallocation of resources. Both the amount of price dispersion and the costs of resource misallocation depend on the frequency of price adjustment and the sources of strategic complementarity. More frequent price adjustment leads directly to less price dispersion. The effects of complementarity are more subtle. Greater complementarities may reduce price dispersion, by reducing the incentives to change prices by large amounts. Greater complementarities, however, are often associated with greater curvature in utility or production, so that any given level of price dispersion is more costly. Levin, Lopez-Salido, and Yun (2009) show that these considerations may affect the optimal trade-off between output and inflation. Observationally equivalent models from the macroeconomic perspective – but not necessarily the microeconomic perspective – may lead to different monetary policy prescriptions.

[5] Returns to scale are equal to the ratio of average costs to marginal costs. The markup is the ratio of price to marginal cost. The ratio of average cost to price is $1 - s_{\pi}$.

2.4. Inflation inertia

A strange thing happened during the derivation of the New Keynesian Phillips curve. We began with a model of sticky prices, in which some firms are stuck with prices that were chosen in the past, and we ended up with a model that was entirely forward looking. Inflation in equation (2.8) is a jump variable. It depends on current output and expected future inflation.

This characterization of inflation has had a dramatic impact on the way in which we view monetary policy. Issues such as credibility and commitment become much more important when you have a forward looking Phillips curve. Transparency and communication become tools for affecting expectations of future inflation and hence inflation today (Woodford, 2009)

A serious problem with this formulation of the Phillips curve, however, is that equation (2.8) does not appear to fit the well with the econometric evidence on the response of inflation to money supply shocks.[6] A common feature of the data is that inflation responds to monetary policy shocks with a lag. The response of inflation to a monetary policy shock is hump-shaped; there is very little response for up to a year, inflation then rises and peaks after about two years (Christiano, Eichenbaum and Evans, 2005; Mankiw, 2001). Hence $E_t\pi_{t+1}$ initially rises more than π_t when policy is loose. The problem with this is that output must fall in order for equation (2.8) to hold, but we tend to think of loose monetary policy as raising output. It is for this reason that estimates of (2.8) using measures of the output gap often get negative estimates of $\lambda\psi$ and it is for this reason that such estimates have been considered evidence against the specification in equation (2.8) (Gali and Gertler, 1999). Note that the assumption that monetary policy is not credible does not help here, since we are considering the average response of inflation to a monetary shock. Agents should not get this average response consistently wrong.

The typical response to this problem has been to assume that the firms that do not have the opportunity to choose a new price may index their prices to past inflation. This alters both the first order condition for price changers and the price index:

$$\begin{aligned} p_t^* &= (1-\alpha\beta)\, E_t \sum_{k=0}^{\infty} \alpha^k \beta^k \left[p_{t+k} + mc_{t+k} - (p_{t+k-1} - p_{t-1})\right] \\ p_t &= (1-\alpha)p_t^* + \alpha(p_{t-1} + \pi_{t-1}) \end{aligned}$$

The result is a Phillips curve in the change in inflation

$$\pi_t - \pi_{t-1} = \lambda\psi y_t + \beta\left(E_t\pi_{t+1} - \pi_t\right) \tag{2.13}$$

[6] See Mankiw (2001) for a disussion of this point

Now the change in inflation is a jump variable. Rising inflation is now perfectly consistent with an increase in output.

The problem with this specification is that there is little evidence that firms index their prices to past inflation or to anything else. Firms that index change their prices in every period. Instead, the typical pattern of price adjustment shows multiple periods of constant prices and occasional price adjustments. How(2.13) can be made consistent with this evidence is not very clear. Indexing helps models fit the macro facts, but these models lack microfoundations in the sense that the term is usually used, in other words microfoundations that bare some resemblance to the microeconomic evidence.

One possibility is that the problem is more with equation (2.5), which relates marginal cost to output. The New Keynesian Phillips curve which relates inflation to marginal cost (2.4) would appear to be a more robust implication of the model than the New Keynesian Phillips curve that relates inflation to output (2.8), since it is closer to the typical firm's first order condition. For example, if the production function is Cobb-Douglas in capital and labor, then marginal cost is proportional to labor's share. Sbordone finds that equation (2.4) fits reasonably well with this specification of marginal cost. The reason is that labor's share is slightly counter-cyclical.

This raises the issue of the cyclicality of marginal cost, another area rich in theories but slim on answers. Rotemberg and Woodford (1999) survey the literature. They argue that while it is true that labor's share is countercyclical and that labor's share would be the correct measure of marginal cost if the production function were Cobb-Douglas, there are a number of reasons to believe that marginal cost be more procyclical than labor's share and may in fact be procyclical. Overhead labor, overtime, fixed costs of production, factor adjustment costs, all imply that labor's share understates marginal cost in recessions and overstates marginal costs in expansions. Understanding the evolution of marginal cost is clearly important for understanding the New Keynesian Phillips curve.

3. Variable Markups

In the simple model, markups fall as output rises because prices are sticky and costs rise. The desired markup does not change. Countercyclical markups work very much like strategic complementarity.

Consider again the maximization problem of the firm

$$\max_{P_i} E_t \sum_{k=0}^{\infty} \alpha^k \Lambda_{t,t+k} \left[D\left(\frac{P_i}{P_{t+k}}, Y_{t+k}\right) \frac{P_i}{P_{t+k}} - C\left(D\left(\frac{P_i}{P_{t+k}}, Y_{t+k}\right), Y_{t+k}\right)\right]$$

We take the first order condition but do not impose the functional form for D:

$$\max_{P_i} E_t \sum_{k=0}^{\infty} \alpha^k \Lambda_{t,t+k} \frac{D_1\left(\frac{P_i}{P_{t+k}}, Y_{t+k}\right)}{P_{t+k}} \left[\left(1 - \frac{1}{\varepsilon\left(\frac{P_i}{P_{t+k}}, Y_{t+k}\right)}\right) \frac{P_i}{P_{t+k}} - C_1\left(Y_{i,t+k}, Y_{t+k}\right)\right]$$

where $\varepsilon\left(\frac{P_i}{P_{t+k}}, Y_{t+k}\right) = -\frac{\frac{P_i}{P_{t+k}} D_1\left(\frac{P_i}{P_{t+k}}, Y_{t+k}\right)}{D\left(\frac{P_i}{P_{t+k}}, Y_{t+k}\right)}$. Linearizing we arrive at

$$\sum_{k=0}^{\infty} \alpha^k \beta^k \left[p_t^* - \mu_{t+k} - p_{t+k} - mc_{t+k}\right] = 0$$

where μ_{t+k} is the log deviation of $\frac{\varepsilon}{\varepsilon-1}$ from its steady state value.

A simple formulation is due to Kimball (1995) in which ε is a function solely of P_i/P. Let ξ denote the elasticity of the desired markup with respect to the relative price. Then

$$\sum_{k=0}^{\infty} \alpha^k \beta^k \left[p_t^* - \mu_{t+k} - p_{t+k} - mc_{t+k}\right] = \sum_{k=0}^{\infty} \alpha^k \beta^k \left[(1-\xi)\left(p_t^* - p_{t+k}\right) - mc_{t+k}\right] = 0$$

Dividing trough by $1-\xi$ we see that the effect of variable markups is to multiply marginal cost by $1/(1-\xi)$. Hence this formulation leads to a New Keynesian Phillips curve with a coefficient on marginal cost equal to $\lambda/(1-\xi)$. If ξ is negative, which happens if raising P_i relative to P reduces the desired markup, then variable markups work exactly the same way as do strategic complementarities that operate at the level of the firm: the opportunity to raise one's price leads to a reduction in the desired markup which reduces the extent of the price increase.

Variable markups have the same problem of interpretation as do strategic complementarities. As we saw above, complementarities have different effects depending on whether they operate on the firm level or the level of the economy as a whole. The same goes for markups. In the Kimball model, one wants the markup to fall as a firm's price rises above the aggregate price level. In a model with symmetric firms, this is the same as having the desired markup, fall as a firm's output rises above aggregate output. At the aggregate level, however, we would like the desired markup to be negatively correlated with aggregate output, in order to amplify and propagate cycles. To see this assume that μ is a function only of y and that η is the elasticity of the markup with respect to output, so that $\mu = \eta y$. Then combining equations (2.1), (2.5), and (2.3), yields

$$\begin{aligned} \pi_t &= \lambda mc + \eta y + \beta E_t \pi_{t+1} \\ &= (\lambda \psi + \eta)\, y + \beta E_t \pi_{t+1} \end{aligned}$$

If η is negative, so that an increase in output is associated with a reduction in the desired markup, then the coefficient on output is lower. It is even possible for the coefficient on y to be negative.

Bils and Gali build models in which η is negative. The idea is that buyers of durable goods and investment goods are more price sensitive than buyers of non-durable goods, perhaps because these are big ticket items so that buyers spend more time searching for the best deals. Since purchases of investment and durable goods are very procyclical, these goods make up a larger share of aggregate demand during booms. In this way, demand for the typical good becomes more elastic, and desired markups fall.

It is safe to say, that macroeconomists have barely scratched the surface of incorporating variable markups in our business cycle models. There are many theories of cyclical markups. In most of these models the elasticity of demand is a complex object that depends on the current state as well as expectations of the future.

Phelps and Winter (1970) construct a model of in which there is both an extensive and intensive margin to a firm's demand. Lowering the price not only makes a firm's current customers purchase more, it attracts new customers. Customers are a stock variable, and the elasticity of demand is greater in the long run than the short run. Markups in this model depend on the ratio of current to future demand. If demand rising, then the firm may find it in its interest to lower markups and build a customer base. Markups should be low during booms and high during busts. It is unclear how this affects the relationship between output and inflation – amplify early in a boom, choke off late – raise price relative to others.

Another theory is the implicit collusion model of Rotemberg and Soloner. In this model, high prices are supported by the threat of price wars. These treats are more credible when future profits are high relative to current profits. Given the procyclicality of profits, this theory predicts that mark ups are low at the top of booms and the bottom of recessions. This theory can explain propagation.

One theory that has made its way into business cycle models is the theory of procyclical entry. Bilbiie, Ghironi and Melitz (2007) construct a model in which procyclical profits lead to procyclical entry. Entry increases competition and reduces markups, which reigns in price increases during the boom. This theory can explain propagation as well.

4. State-Dependence

Up to this point, I have assumed that the probability of adjustment was constant. The main alternative is the Ss model in which there are fixed costs of price adjustment and firms balance the costs and benefits of price adjustment. Such models are often referred to as state-dependent models since the timing of price adjustment depends on the state in which the firm finds itself. Early models such as Caplin and Leahy (1991,1997) and Caballero and Engel (1991) held out promise that endogenizing the timing of price adjustment would lead to significantly different dynamics. These models show the potential for significant non-linearities in aggregate dynamics. In these models the response of inflation to a shock depends on the entire distribution of prices in the economy; the more firms are near their price adjustment triggers, the more prices respond to shocks.

Recent efforts, however, show more modest differences between Ss models and the Calvo model. The main reason is that idiosyncratic shocks tend to be much larger than aggregate shocks. Hence most adjustment in these models is triggered by shocks that are idiosyncratic to the firm. While the timing of adjustment by be endogenous to the firm's state, it is effectively exogenous to the aggregate state of the economy.

This does not mean that state dependence has no effect. There are at least three important practical implications of state dependence. First, the firms that adjust their prices are not a random selection from the universe of firms as they are in the Calvo model. The firms that adjust their prices at any given point in time tend to be those who most want to adjust. This "selection effect" tends to make the economy look more flexible than one would assume given the observed frequency of price adjustment.

This observation has two practical implications. One is that if one is choosing a probability of price adjustment, one should choose one that is greater than the one that is observed in the data. The other is that in order to match the persistence of real variable to nominal shocks, one needs stronger strategic complementarities.[7]

Second, state dependence may in some cases affect the way in which future marginal costs are discounted in the first order condition (2.2). With Calvo pricing future marginal costs are given exponentially declining weights. This can lead to significant frontloading of price changes

[7] Gertler and Leahy (1998) show how to build an Ss model with strategic complementarities.

in cases in which marginal costs are expected to rise or fall in the future. This frontloading of future movements in marginal costs lies at the heart of the Mankiw puzzle described above: if inflation is expected to rise in the future, it must be because marginal cost is expected to rise in the future, which means prices must rise today unless marginal cost is very low today. Frontloading also lies at the heart of some puzzling results regarding the effects of credible deflations. Ball () shows that a credible commitment to future deflation is expansionary: since prices are expected to fall tomorrow, they must fall today, which reduces markups and hence output today.

There is much less need for frontloading in Ss models. The reason is simple: firms can change their prices whenever they want to. If there is an expected future change in marginal cost, firms can wait and change their prices when costs change, or they can change their prices today and change them again in the future. Dotsey and King (2005) show that this feature of Ss models can help to explain the Mankiw puzzle.

The third implication of state dependence is that it alters the effects of strategic complementarities. With Calvo pricing both complementarities that work through relative price and complementarities that work through aggregate supply, amplify and extend the real effects of nominal shocks. With state-dependent pricing, complementarities that work through relative price have ambiguous effects. They reduce the size of price changes as in the Calvo model, but they also increase the number of firms changing prices. The reason is that complementarities that work through relative prices tend to make costs more sensitive to relative price and this makes the profit function more concave in relative price. Since Ss firms compare the costs and benefits of price adjustment, this increased concavity raises the benefits of price adjustment and leads more firms to adjust. This is like an increase in α. Which effect dominates, the dampening of price changes and the increase in the adjustment frequency, depends on the parameterization of the model. Dotsey and King present examples in which local complementarities lead to greater flexibility.

5. Conclusion

I have attempted to draw connections between the recent literature on money and output and topics of interest to industrial organization.

The following are the lessons for industrial organization economists:

1. Price rigidity is a pervasive phenomenon that should not be ignored.

2. The cyclicality of the markup and marginal cost remain important topics for study.
3. We need to understand better how prices of various firms interact. What are the sources of strategic complementarity that reign in idiosyncratic price adjustment? How are costs passed through to prices? How and when are aggregate shocks passed through to prices?
4. We need general studies that attempt to characterize the economy as a whole rather than studies of particular, and possibly idiosyncratic, industries or firms.

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