Price Stability and Endogenous Productivity

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Abstract

I present a model, where firms' markups are endogenous and are a function of the level of price stability in an economy. Because price signals are noisier in periods of unstable inflation, firms' market power is higher in such periods. By raising their profits, this permits the survival of low productivity firms, thereby reducing aggregate productivity. By contrast, in periods of price stability, firms have less pricing power, and this reduces their markups and profits. As a result, more productive firms survive, while less productive ones either fail or must effect efficiency gains. Overall, the model predicts a negative relationship between productivity and inflation, which is a robust finding in the data, and which has been a notable feature of recent recessions.

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Introduction

Despite the large amount of research on the subject of price setting, the topic of pricing power, and how it may vary over time, has received comparatively little attention in macroeconomics. On the face of it, this is surprising: the issue of pricing power, and how markups change over time, is a staple of the business press, and has significant consequences for firm profitability, strategy, and survival. More generally, the concept of time-varying pricing power has potentially large implications for price dynamics and monetary policy.

By making price increases more salient, periods of low inflation constrain firms' capacity to raise prices. Rather than raising prices, a firm is therefore forced to engage in other profit-enhancing activities such as innovation, market research, or productivity increases. Emphasizing the latter channel, and concerned with its implications for monetary policy, Alan Greenspan (2002) suggested that "*perhaps the return to a low-inflation environment in recent years in itself explains the intensification of competitive pressures, which has been a spur to the growth of productivity.*"[1] Motivated by this insight, the goal of this paper is to formalize this dynamic. I show that an inverse relationship between productivity and the degree of price stability is a natural outcome of a simple model where the only departure from standard theory is uncertainty about the aggregate price level.

In periods of high and unstable inflation, price changes convey less information and relative prices become unstable; this distortion to the price system is the standard text-book cost to inflation. To determine a firm's relative price in an environment of unstable inflation, consumers therefore face a signal extraction problem. Compared to periods of low inflation, in a period of high inflation, the consumer infers that changes in a firm's price partly reflect changes in the aggregate price level. In the model presented here, this confers the firm with more market power, implying a rise in its optimal markup. Because this pricing behaviour raises firms' profits in periods of unstable inflation, relatively unproductive firms can sustain production. Meanwhile, the opposite occurs in a

[1] Discussing pricing behaviour in a relatively high inflation environment, in his 1999 Humphrey Hawkins testimony, he noted that *"through the 1970s and 1980s, firms apparently found it easier and more profitable to seek relief from rising nominal labor costs through price increases."*

period of low inflation, and the correspondingly lower profits render some firms unprofitable. In response to this, these firms leave the market or must seek productivity gains. An implication of the model is a negative relationship between inflation and aggregate productivity.

While the inverse relationship between productivity and inflation has been the subject of much empirical work, the relationship has received little theoretical modelling. One reason for this is that the standard framework for modelling price setting—the New Keynesian model—assumes both the desired markup and the level of total factor productivity are constant. In addition, the model is derived assuming a zero steady state inflation rate. Within the confines of this setting, it is hard to address time-varying changes in markups, market power, and productivity.

This model presented here brings together a number of strands of literature. One especially relevant study is that of Rudebusch and Wilcox (1994), who find that inflation Granger-causes productivity growth. Attempting to rationalize this finding, Sbordone and Kuttner (1994) suggest that it could be due to conventional monetary policy: faced with higher inflation, the monetary authority raises interest rates, inducing a recession. In turn, the recession leads to greater labor hoarding and lower productivity. The issues of time-varying market power and productivity over the business cycle have received more theoretical attention. Taylor (2000), for example, presents a model rationalizing why pricing power is lower in a low inflation environment. As a result of greater central bank credibility, shocks to marginal cost are less persistent in a low inflation environment. Thus, when a sticky price firm sets prices, it will only react a little to a rise in today's marginal cost. Finally, a number of papers examine how productivity might rise endogenously in a recession, as a result of firms devoting more time to reorganization (see e.g., Hopenhayn and Rogerson 2003, Berger 2012) .

I proceed as follows. Section 1 presents the model. After this presentation, Section 2 discusses its implications and some empirical evidence, while Section 3 concludes.

1 The Model

1.1 The Consumer

The model is static and comprises a representative agent and a continuum of firms. The consumer has utility function

$$\mathbf{U} = \int_{\Omega} Q(i)^{\frac{\sigma-1}{\sigma}}\, di,$$

where $\sigma > 1$ and maxmizes this subject to the income constraint

$$\int_{\Omega} p(i)Q(i)\, di = R,$$

where Ω denotes the mass of available goods and R aggregate expenditure. Solving this gives the standard demand curve for good i:

$$Q(i) = \left(\frac{p(i)}{P}\right)^{-\sigma} \frac{R}{P},$$

where P denotes the aggregate price level. Rewriting this in logs gives

$$q(i) = -\sigma r(i) + r - p$$

where $q(i) = \log Q(i)$, $r(i) = \log \frac{p(i)}{P}$, and $r - p = \log \frac{R}{P}$. Here I introduce a friction: at the time of purchase of each good i, the consumer is is unaware of the price level p, yet knows its expected value. This friction could be due to informational frictions, processing costs, and so on. Because of this, the consumer does not know the firm's relative price. Yet, by solving a standard signal extraction problem, the consumer infers that

$$\mathbf{E}\, r(i) = \frac{\sigma^2_{r(i)}}{\sigma^2_{r(i)} + \sigma^2_p} \left(p_i - \mathbf{E}p\right),$$

and assuming certainty equivalence, log demand for good i becomes

$$q(i) = -\sigma \frac{\sigma^2_{r(i)}}{\sigma^2_{r(i)} + \sigma^2_p} \left(p_i - \mathbf{E}p\right) + r - p, \tag{1}$$

where I assume $\sigma\frac{\sigma^2_{r(i)}}{\sigma^2_{r(i)}+\sigma^2_p} > 1$.[2] Compared to the standard demand function, a high degree of price volatility σ^2_p reduces the *effective* price elasticity of demand, σ. When a firm raises its price in a time of price variability, the consumer infers that this is partly a change in the price level. That is, the consumer infers that the change in the firm's relative price is lower. As a result, the firm can raise prices in a high inflation environment, and demand will fall by less than in a low inflation environment. This is observationally equivalent to a lower price elasticity of demand in an environment of price instability; in this sense, the firm has more market power. By contrast, in a period of low inflation variability, changes in a firm's price are more salient, and would thus have a larger negative effect on the firm's demand.

1.2 Firms

There is a continuum of firms, who differ according to productivity ϕ. Productivity is distributed across firms according to the continuous density function $g(\phi)$, with corresponding distribution function G. The firm takes the nominal wage w as given, and prices are flexible. Profits are

$$\pi(i) = p(i)Q(i) - \left(f + \frac{wQ(i)}{\phi_i}\right) = Q(i)(p(i) - \frac{w}{\phi_i}) - f,$$

where f denotes a *common* fixed cost of production. Maximizing profits is equivalent to the maximizing

$$\log \pi(i) = q(i) + \log(p(i) - \frac{w}{\phi_i}).$$

Firm i takes $q(i)$ in Eq. 1 as given and chooses $p(i)$ to maximize this. The solution to this problem gives the firm i's optimal price:

$$p(i) = \frac{\sigma\frac{\sigma^2_r}{\sigma^2_r+\sigma^2_p}}{\sigma\frac{\sigma^2_r}{\sigma^2_r+\sigma^2_p} - 1}\frac{w}{\phi_i}.$$

[2]To ensure the markup is defined, this assumption is necessary. That is, the effective elasticity of demand must exceed one.

As noted above, price variablilty reduces the effective price elasticity of demand. For the firm, this raises its market power, and it exploits that power to raise its markup. This result yields the following implications:

Proposition 1 *The optimal price, markup, and profits are increasing in the volatility of the price level* σ_p^2*.*

Proposition 2 *When prices are stable, the markup reduces to the standard one in a model of CES demand functions—i.e.,* $\frac{\sigma}{\sigma-1}$*. Formally,* $\lim_{\sigma_p^2 \to 0} p(i) = \frac{\sigma}{\sigma-1} \frac{w}{\phi_i}$.

1.3 Firm Dynamics under Price Stability

The modelling of firm dynamics follows from Melitz (2003). In an environment of price stability (i.e., where σ_p^2), it is easily shown that a firm with productivity ϕ_i has profits

$$\pi(\phi_i) = R\phi_i^{\sigma-1}\sigma A - f,$$

where $A = \int_\Omega \phi_i^{\sigma-1}\, di$. This implicitly defines some cutoff $\overline{\phi}$ where

$$\pi(\overline{\phi}) = 0.$$

Therefore, any firm with $\phi < \overline{\phi}$ will make negative profits and will leave the industry.

To complete the model, there is a fixed entry cost D, and upon drawing a productivity level ϕ, firms decide to either enter or leave the industry. In any given period, there is some exogenous probability δ that a firm becomes unprofitable and leaves the industry. When a firm leaves it can make another draw and start afresh. It follows that the equilibrium free entry condition is

$$(1 - G(\overline{\phi}))\frac{\overline{\pi}}{\delta} = D,$$

where $\overline{\pi}$ denotes average expected profits for successful firms; i.e., those with $\phi > \overline{\phi}$. Assuming L workers and full employment, $R = wL$, the final condition implicitly gives the equilibrium number of firms, N:

$$\overline{\pi} = \frac{R}{\sigma N} - f = \frac{wL}{\sigma N} - f.$$

Recognizing that the mass of firms is fixed at N, each period δN firms leave *and* enter.

1.4 Firm Dynamics under Price Instability

Depending on the degree of price variability, relatively unrproductive firms may enter or leave. According to Proposition 1, a rise in σ_p^2 will raise profits for all firms. In turn, this will raise the threshold for firm survival. Therefore:

Proposition 3 *A rise in price variability will lower the threshold productivity for firm survival. Formally,* $\frac{\partial \overline{\phi}}{\partial \sigma_p^2} < 0$*, and this will reduce aggregate productivity.*

More important for this paper is what happens when price variability *falls*:

Proposition 4 *A fall in* σ_p^2 *will raise the survival threshold, causing a rise in aggregate productivity. Assuming a new threshold of* $\phi' > \overline{\phi}$*, firms with* $\overline{\phi} < \phi < \phi'$ *will leave the industry.*

According to the model, greater price stability will reduce firms' profits. For some relatively unproductive firms, they will either cease production or take another draw at cost D. Provided $\phi > \phi'$, the firms can restart production. Within the framework of this model, such firms are new firms: they produce the same product, but with higher productivity.

2 Discussion and Empirical Evidence

This model predicts an inverse relationship between productivity and inflation, as in the data. Most importantly, causation runs from inflation to productivity: because low inflation reduces pricing power, only the relatively more productive firms can survive. Although the model relates higher productivity to low inflation variability, there is a strong positive relationship between inflation and its variability in the data. Another implication of the model relates to price dynamics: it provides an explanation for markup shocks. Significantly, in empirical estimates of the New Keynesian model, such shocks play an important role. For example, in a calibration of the New Keynesian Phillips curve, Ireland (2004) finds that markup shocks are the dominant source of inflation fluctuations. The model presented here is simple, but it could be extended to confer broader insights on economic dynamics; in a non-Walsrasian labour market, for instance, one likely short-run implication of higher productivity is reduced employment.

What is the evidence in support of the model? Because of the endogenity of inflation and productivity, it is hard to identify empirically the channel focussed on here. Nonetheless, there is some suggestive evidence that leads one believe the dynamic would be operative to some degree. One piece of evidence comes from pricing behavior in high inflation economies. This evidence indicates prices are more flexible in such environments (see e.g., Gagnon, 2009). Consistent with this, Neiss (2001) finds that markups are higher in countries with high inflation.Closely related to this is evidence that the degree of pass-through from exchange rate movements to prices is higher in times of high inflation (Devereux and Yetman, 2008.) Such evidence points to an asymmetry, where firms have more pricing power in periods of high inflation. Further evidence comes from firm behavior when firms face the prospect of reduced profits. In such environments, evidence suggests firms raise productivity and reduce costs. A common example of this is the view that a currency appreciation raises firm productivity (Porter 1990, Tang 2010.) This finding suggests that productivity can act as a powerful burden of adjustment in periods of firm duress. Together, the foregoing evidence suggests the dynamic presented here is of at least some significance.

3 Conclusion

This paper has examined the relationship between productivity and inflation. According to the model, price variability distorts price signals, causing consumers to infer that price changes by firms partly reflect changes in the price level, as opposed to relative prices. As a result, a higher degree of price variability effectively makes demand more inelastic, which raises firms' optimal markups and profits. A significant consequence of this is the survival of relatively low productivity firms in the market. By contrast, such firms face more elastic demand in periods of low inflation and either leave the market or become more productive.

The simple model has two broad implications. First, it provides a partial explanation for i) the relationship between inflation and productivity and ii) the strong relationship between the inflation rate and inflation variablility in the data; in the model, inflation variabiility induces higher inflation. Second, the model provides a channel through which monetary policy affects real activity. In the spirit of Lucas (1972), money is nonneutral even in an environment of flexible prices. More concretely, recent empirical work in inflation dynamics points to the important role for markup changes in inflation dynamics. The model here presents a microfoundation for such shocks, and suggests changes in inflation might reflect changes in desired markups, rather than demand shocks. This channel has implications for monetary policy.

Introspection suggests the dynamic would be more relevant at either relatively high or especially low rates of inflation. Yet given endogeneity issues, it is difficult to identify whether the dynamic presented here is operative. A convincing test would at least require firm level data on productivity and pricing from different inflation environments.

References

[1] Berger, David. 2011."Countercyclical Restructuring and Jobless Recoveries." Mimeo, Northwestern University.

[2] Devereux, M. B., Yetman, J., 2008. "Price Adjustment and Exchange Pass-Through." *Journal of International Money and Finance*, forthcoming.

[3] Gagnon, Etienne. 2009. "Price Setting During Low and High Inflation: Evidence from Mexico," *The Quarterly Journal of Economics*, MIT Press, vol. 124(3), pages 1221-1263, August.

[4] Greenspan, Alan. 2002. At the U.S. Department of Labor and American Enterprise Institute Conference, Washington, D.C.

[5] Greenspan, Alan. 1999. Humphrey Hawkins Testimony.

[6] Gwin, Carl R. and Taylor, Beck A. 2004. "The Role of Search Costs in Determining the Relationship Between Inflation and Profit Margins. *Journal of Money, Credit, and Banking*, Vol. 36, No. 1, pp. 139-149.

[7] Hopenhayn, Hugo and Richard Rogerson. 1993. "Job Turnover and Policy Evaluation: A General Equilibrium Analysis, *Journal of Political Economy*, 101, 915938.

[8] Ireland, Peter. "Technology Shocks in the New Keynesian Model." *The Review of Economics and Statistics*, MIT Press, vol. 86(4), pp. 923-936.

[9] Kuttner and Sbordone. 1994. "Does Inflation Reduce Productivity? *Economic Perspectives*, Federal Reserve Bank of Chicago, November.

[10] Lucas, Robert. 1972. "Expectations and the Neutrality of Money". *Journal of Economic Theory*, 4 (2): 103124.

[11] Melitz, M.J. 2003. "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity, *Econometrica*, 71(6), pp. 1695-1725.

[12] Nekarda, C.J. and V.A. Ramey. 2010.“The Cyclical Behavior of the Price-Cost Markup,” Working Paper, UCSD.

[13] Neiss, Katherine. 2001. “The Markup and Inflation: Evidence in OECD Countries,” *Canadian Journal of Economics*, Canadian Economics Association, vol. 34(2), pp. 570-587.

[14] Porter, Michael E. 1990. “The Competitive Advantage of Nations.” New York: New York: Free Press.

[15] Rudebusch, Glenn D., and David W. Wilcox, “Productivity and inflation: Evidence and interpretations,” Board of Governors of the Federal Reserve System, manuscript, 1994.

[16] Tang, Yao. 2010. “Does Productivity Respond to Exchange Rate Appreciations? A Theoretical and Empirical Investigation.” Bowdain College Working Paper Series. December 2010.

[17] Taylor, John. 2000. “Low Inflation, Pass-Through, and the Pricing Power of Firms. *European Economic Review*, vol. 44 issue 7, pp. 1389-1408.