Speed of price adjustment with price conjectures

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Abstract

We derive a measure of firm speed of price adjustment that is directly inversely related to market power and compare this to the measure derived by Martin (1993). However, both measures are incorrect when firms have non-zero price conjectural variations and treat competing price levels as exogenous. This is because Taylor series expansions of the demand function implicitly assume that firms influence the level of competing prices in a way that is consistent with their conjectures.

1. Introduction

One cause suggested for the stable inflationary environment that has existed in many countries since the late eighties and early nineties is a lower speed of price adjustment by firms (Dwyer and Leong, 2001). Empirical dynamic industry studies often suggest that price adjustment is influenced by the level of industry competition, although not all agree on the direction of that influence (compare Kraft, 1995; and Shaanan and Feinberg, 1995).

As a means of introducing price rigidities into the theoretical model, Rotemberg (1982) includes a quadratic price adjustment cost and minimises loss in

profit due to the incomplete adjustment to the static equilibrium price. Other studies

that derive dynamic pricing equations using this method include Yetman (2003) and

Martin (1993). Alternatively, Kasa (1998) and Worthington (1989) maximise the

profit function with the inclusion of a quadratic quantity adjustment cost.

By employing a Taylor series approximation to actual profit, Martin (1993)

shows that the speed of price adjustment is a function of the second derivative of

profit with respect to price at the static equilibrium price and is negatively related to

market power in the cases of monopolistic competition and oligopoly with quantity

conjectures. Maximising the profit function, we show that an alternative speed of

price adjustment approximation is directly a negative function of market power when

firms are assumed to have quadratic price adjustment costs. However, neither method

correctly derives the speed of price adjustment when firms have price conjectural

variations as usually applied. This discrepancy is resolved if firms believe that they

influence the level of competing prices in ways that are consistent with their

conjectures.

2. Speed of price adjustment and market power

Let the ith firm have the following profit function:

$$\pi(p_{it}) = (p_{it} - mc_{it})q_{it} - \alpha_i(p_{it} - p_{it-1})^2 \qquad (1)$$

where i and t are firm and time subscripts, respectively, and p_{it}, q_{it}, mc_{it}, and α_i

indicate the firm price, output, constant marginal cost (excluding adjustment costs)

and the price adjustment cost parameter, respectively. In the absence of adjustment

costs, the firm charges the static profit maximising price p_{it}^* and produces output q_{it}^*.

In this case, the first order condition is $q_{it}^* + (p_{it}^* - mc_{it})(dq_{it}^*/dp_{it}) = 0$, where

(dq_{it}^*/dp_{it}) is the slope of the demand function in static equilibrium.

Taking a first-order Taylor series approximation of output around the static

profit maximising price gives:

$$q_{it} \approx q_{it}^* + (dq_{it}^*/dp_{it})(p_{it} - p_{it}^*) \tag{2}$$

The following partial adjustment model results after substituting (2) into (1) and profit

is maximised with respect to price:

$$\Delta p_{it} = \lambda_{it}(p_{it}^* - p_{it-1}) \tag{3}$$

$$\lambda_{it} = (-dq_{it}^*/dp_{it})/[(-dq_{it}^*/dp_{it}) + \alpha]$$

where $\Delta p_{it} = p_{it} - p_{it-1}$ and λ_{it} is the speed of price adjustment. Note (3) is derived

with the use of the static first-order condition. Given that the elasticity of demand in

static equilibrium $[\eta_{it}^* = (dq_{it}^*/dp_{it})(p_{it}^*/q_{it}^*)]$ is a measure of market power, (3)

implies that as market power increases, the speed of pricing adjustment decreases for

a given p_{it}^* and q_{it}^*.

The speed of price adjustment derived by Martin (1993) is as follows:

$$\lambda_{it} = (-\pi''(p_{it}^*)/2)\big/[(-\pi''(p_{it}^*)/2) + \alpha] \tag{4}$$

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where $\pi''(p_{it}^*)$ is the second derivative of the profit function at the static equilibrium price when there are no adjustment costs. Generally, however, the speeds of price adjustment in (3) and (4) will not be equal. The exception to this is when the demand function is linear and the Taylor series expansions are exact i.e. $(-dq_{it}^*/dp_{it}) = (-\pi''(p_{it}^*)/2)$. Next we show that even when firms have linear demand functions, neither of the above speed of adjustment measures is correct when firms have non-zero price conjectures but treat competing price levels as exogenous.

3. Speed of price adjustment when firms have price conjectures.

Price conjectural variations are frequently used to model firm conduct in heterogenous product industries (for example, Bloch and Olive, 2003; Allen, 1998; and Dornbusch, 1987). They represent the expected pricing responses of other firms in the industry to a change in the firm's own price. The larger the firm's price conjectures the less competitive its behaviour.

Let the ith firm have the following linear demand function:

$$q_{it} = A_{it} - a_i p_{it} + \sum_{j \neq i} b_j p_{jt} \tag{5}$$

where A_{it} is a demand shift variable, p_{jt} is the price of the jth firm, and a_i and b_j are positive parameters. Taking the derivative of (5) with respect to the ith firm's price gives:

$$dq_{it}/dp_{it} = -a_i + \sum_{j \neq i} b_j \theta_{jit} \tag{6}$$

where $dp_{jt}/dp_{it} = \theta_{jit}$ is the firm's price conjectural variation with respect to the price of the jth firm.[1] After substituting (6) into (3), the resultant speed of price adjustment is $\lambda_{it} = (a_i - \sum_{j \neq i} b_j \theta_{jit}) / [(a_i - \sum_{j \neq i} b_j \theta_{jit}) + \alpha]$. It can be seen that the speed of price adjustment decreases as the weighted sum of the price conjectural variations increases. This speed of pricing adjustment is the same as (4) when demand is linear and the price conjectural variations are constant with respect to price.

An alternative method of estimating the speed of price adjustment is to maximise the profit function from (1) when the ith firm has the linear demand function from (5). The partial adjustment model that results is as follows:

$$\Delta p_{it} = \delta_{it} (p_{it}^* - p_{it-1}) \tag{7}$$

$$\delta_{it} = (2a_i - \sum_{j \neq i} b_j \theta_{jit}) / [(2a_i - \sum_{j \neq i} b_j \theta_{jit}) + 2\alpha]$$

$$p_{it}^* = [A_{it} + \sum_{j \neq i} b_j p_{jt} + mc_{it} (a_i - \sum_{j \neq i} b_j \theta_{jit})] / (2a_i - \sum_{j \neq i} b_j \theta_{jit})$$

where δ_{it} is the speed of price adjustment and p_{it}^* is the equilibrium price in the absence of adjustment costs. While the qualitative impact of the price conjectural variations is the same as above, it is clear that $\delta_{it} \neq \lambda_{it}$.

This discrepancy is resolved if the firm believes that a part of competing prices is endogenous in a way that is consistent with the firm's conjectures. Let the ith firm's belief about the jth firm's price be represented by the following linear relationship:

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[1] Price conjectural variations are most commonly presented as elasticities. However, presenting price conjectures as the conjectured rate of change in a competing firm's price for a marginal change in the firm's own price is analogous to the usual presentation of quantity conjectures.

$$p_{jt} = c_j + \theta_{jit} p_{it} \tag{8}$$

where c_j represents a component of the competing price that the ith firm believes it cannot influence.[2] Then the partial adjustment model becomes:

$$\Delta p_{it} = \lambda_{it} (p_{it}^* - p_{it-1}) \tag{9}$$

$$\lambda_{it} = (a_i - \sum_{j \neq i} b_j \theta_{jit}) / [(a_i - \sum_{j \neq i} b_j \theta_{jit}) + \alpha]$$

$$p_{it}^* = [A_{it} + \sum_{j \neq i} b_j c_j + mc_{it}(a_i - \sum_{j \neq i} b_j \theta_{jit})] / 2(a_i - \sum_{j \neq i} b_j \theta_{jit})$$

Comparing (7) and (9), it can be seen that the makeup of the static equilibrium price and the speed of price adjustment are interrelated. Now all three methods for calculating the speed of price adjustment lead to the same result when firms have linear demand functions.

The discrepancy in speed of price adjustment measures arises because Taylor series expansions of the demand function implicitly assume that a component of competing prices is endogenous in a way that is consistent with firm conjectures. To see this, take the following first-order Taylor series approximation of output around the static equilibrium own price and competing prices:

$$q_{it} \approx q_{it}^* + (\partial q_{it}^* / \partial p_{it})(p_{it} - p_{it}^*) + \sum_{j \neq i} (\partial q_{it}^* / \partial p_{jt})(p_{jt} - p_{jt}^*) \tag{10}$$

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[2] Note that this is different to consistent conjectures that equate the slope of the competing firm reaction functions with its conjectures, although consistent conjectures could be encompassed in this formulation.

where p_{jt}^* is the jth firm's static equilibrium price, $\partial q_{it}^*/\partial p_{it}$ is the own-price partial derivative of demand and $\partial q_{it}^*/\partial p_{jt}$ is the cross-price partial derivative of demand. If the prices of all competing firms are exogenous, as in the conventional conjectural variations model, then the last term in (10) is zero. Substituting (8) into (10) gives:

$$q_{it} \approx q_{it}^* + [\partial q_{it}^*/\partial p_{it} + \sum_{j \neq i}(\partial q_{it}^*/\partial p_{jt})\theta_{jit}](p_{it} - p_{it}^*) \qquad (11)$$

(11) and (2) are equivalent, as the total derivative of the ith firm's output is

$$dq_{it}^*/dp_{it} = \partial q_{it}^*/\partial p_{it} + \sum_{j \neq i}(\partial q_{it}^*/\partial p_{jt})\theta_{jit} \ .$$

4. Conclusion

This paper derives firm speed of price adjustment as a function of the slope of the demand function when firms have quadratic price adjustment costs. This directly inversely relates market power to the speed of price adjustment and provides an alternative to the measure derived by Martin (1993). However, both measures are incorrect when firms have price conjectural variations as they are usually applied. This is because Taylor series expansions of the demand function implicitly suggest that firms divide competing prices into exogenous and endogenous components in a way that is consistent with their conjectures, while the standard method does not make this division. In which of these ways firms behave is an empirical question that is worthy of further consideration.

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