

IS AVERAGE VARIABLE COST A GOOD PROXY FOR SHORT-RUN MARGINAL COST AND WHY IS IT IMPORTANT?

Michael Olive
molive@efs.mq.edu.au

Abstract

Average variable cost is often used as a proxy for short-run marginal cost in empirical studies of manufacturing firm behaviour. Assuming that average variable cost is equal to marginal cost, Cowling and Waterson (1976) derive a model that links industry structure to the industry price-cost margin and Areeda-Turner (1975) provide a test of predatory pricing. However, the research on the relationship between average variable cost and short-run marginal cost mainly comes from survey studies. This paper employs a supply relation similar to Bresnahan's (1982) in order to estimate industry marginal cost divided by industry average variable cost (MC/AVC) for 89 four-digit Australian manufacturing industries during 1971 to 1984. The 3SLS results indicate that MC/AVC is not significantly different from one in 40 percent of industries, but is cyclical in only 30 percent of industries. This suggests that industry average variable cost multiplied by a constant can be used as a proxy for industry marginal cost for a large number of industries over a short period.

JEL classifications: D2; L1; L6

Keywords: marginal cost; average variable cost; manufacturing; supply relation

I. Introduction

For a firm in the marginalist tradition, marginal cost is the appropriate variable to take into consideration in order to maximise profits. However, average variable cost is often used as a proxy for short-run marginal cost in empirical studies of manufacturing firm behaviour. Short-run marginal cost is the change in the cost of variable inputs into production for a marginal change output. As such it is a counter-factual, making it difficult to measure directly. Average variable cost, on the other hand, is a matter of adding up the cost of variable inputs and dividing by the number of outputs. This relative simplicity means that accounting measures of average variable cost (for example, wages and salaries plus materials cost per unit of output) are readily available from official sources. In this paper, the relationship between short-run marginal cost and average variable cost is assessed with regard to the literature and using a statistical model.

One area of research where marginal cost is frequently assumed equal to average variable cost is in the study of price-cost margins. The price-cost margin can be defined as the price of a firm's product minus its average variable cost all divided by the price. An alternative definition is the gross profit per dollar of revenue. When average variable cost is equal to short-run marginal cost, the price-cost margin is equivalent to negative one times the inverse of the perceived elasticity of demand or Lerner's (1934) index of monopoly power. For a homogeneous product industry, Cowling and Waterson (1976) show that the industry price-cost margin is a function of the Herfindahl index of concentration, the elasticity of demand and firm quantity conjectures. Hay and Morris (1991) review the literature that links the price-cost margin to industry concentration. Domowitz et al (1986), Odagiri and Yamashita (1987) and Prince and Thurik (1994) extend this analysis to include the role of the

business cycle, while Bhattacharya and Bloch (1997) examine industry conduct and the price-cost margin.

Industry pricing is another area of research where average variable cost is assumed equal to short-run marginal cost. Lee (1991) outlines the conditions for a formal identity between a pricing equation that employs average variable cost and a profit-maximising monopoly pricing model that employs marginal cost. Industry studies that use this kind of a theoretical underpinning usually find a high level of significance when price is regressed on average variable cost (see Brack (1986) for the US, Weiss (1993) for Austria, Bloch and Olive (1999) for Australia and Olive (2002a) for 11 industrialised countries).¹ In a direct application to industrial law, Baumol (1996) notes that the US courts accept the use of average variable cost as a proxy for marginal cost when carrying out the Areeda-Turner (1975) test of predatory pricing. Also, Haugh and Hazeldine (1999) carry out a test of predatory behaviour by airlines serving the Trans-Tasman air market assuming average variable cost equal to marginal cost.

Turning to the evidence, we see that survey studies of the relationship between average variable cost and marginal cost are mixed. In a survey of 654 UK firms, Hall et al (1997) find that 61 percent of manufacturing firms in the sample recognise constant marginal cost (implying equivalence to constant average variable cost) plays a role in pricing decisions. However, Blinder (1991) finds that only 42 percent out of a sample of 72 US firms report that average variable cost is constant when output rises.²

Recent statistical analysis on the relationship between average cost and marginal cost generally centres on measuring economies of scale. Capital is included in these studies and the interest is in the medium to long run. One method employed

to measure economies of scale is to estimate a specified cost function and then calculate the implied average and marginal cost for particular variable values (for example Morrison, 1992; Park and Kwon, 1995; Intriligator, 1996; and Morrison Paul, 2001). An alternative method is to estimate the economies of scale as a parameter in a statistical model. This relies on a manipulation of the production function and incorporating the profit-maximising equilibrium conditions (for example Haskel et al, 1995; Basu and Fernald, 1997; Linnemann, 1999; and Olive, 2002b). The results of these studies often differ across method and industry category. Basu and Fernald (1997) also suggest that the heterogeneity of units affect the estimates of scale economies at the higher levels of aggregation.

From the first order conditions of a profit-maximising firm, Bresnahan (1982) derives a pricing equation that allows oligopoly conduct to be estimated as a parameter, given the functional form of demand. Other papers that follow this method include Steen and Salvanes (1999), Madden and Savage (2000) and Rosenbaum and Sukharomana (2001). In the present study, we estimate short-run marginal cost divided by average variable cost as a parameter directly from a supply relation that is similar to Bresnahan's. We also determine whether the relationship varies over the cycle. The data is for 89 four-digit Australian manufacturing industries for the period 1971 to 1984.

II. Model

Consider an industry that produces a homogeneous product and faces competition from imperfect substitutes in other domestic industries and from abroad. Following Cowling and Waterson (1976), the profit equation for the i^{th} firm is given as:

$$\mathbf{p}_i = Pq_i - vc_i - f_i \quad (1)$$

where \mathbf{p}_i is profit, q_i is output, vc_i is variable cost, f_i is fixed cost and P is the product price. Differentiating profit with respect to output and setting this to zero satisfies the first-order conditions for a profit-maximising firm, so that:

$$\frac{d\mathbf{p}_i}{dq_i} = P + q_i \frac{dP}{dq_i} - mc_i = 0 \quad (2)$$

where mc_i is the marginal cost. Rearranging (2) so that price is on the left-hand side and incorporating the impact of the i^{th} firm's conjectural variations and share in industry output, we can write:

$$P = mc_i - \left(\frac{q_i}{Q}\right) \left(\frac{dQ}{dP}\right)^{-1} \left(\frac{dQ}{dq_i}\right) Q \quad (3)$$

where Q is the industry output of the homogeneous product, dQ/dq_i are the firm's quantity conjectures and q_i/Q is the share in industry output. Bresnahan (1982) describes (3) as a supply relation.

Weighting (3) by the share in industry output and summing over all firms in the industry gives the industry supply relation:

$$P = \sum mc_i \frac{q_i}{Q} - H(1 + \mathbf{m}) \left(\frac{dQ}{dP}\right)^{-1} Q \quad (4)$$

where the Herfindahl index of concentration is defined as:

$$H = \sum \left(\frac{q_i}{Q}\right)^2 \quad (5)$$

and Cowling and Waterson's (1976) industry conjectural variations are:

$$(1 + \mathbf{m}) = \frac{\sum \left(\frac{dQ}{dq_i}\right) q_i^2}{\sum q_i^2}. \quad (6)$$

The Herfindahl index of concentration is a measure of industry structure, while the industry conjectural variations are a measure of industry conduct.

In order to operationalise (4), it is necessary to define a product demand function. Madden and Savage (2000) and Rosenbaum and Sukharomana (2001) employ linear demand functions. However, in order to make the demand function flexible we incorporate a Box-Cox (1964) transformation of output. The demand function is given as follows:

$$\frac{Q^I - 1}{I} = \mathbf{a}_1 - \mathbf{a}_2 \frac{P}{P_a} + \mathbf{a}_3 \frac{P_f}{P_a} + \mathbf{a}_4 Y_a \quad (7)$$

where P_a is aggregate price, P_f is the price of competing foreign product, Y_a is aggregate demand and $I, \mathbf{a}_1, \mathbf{a}_2, \mathbf{a}_3$ and \mathbf{a}_4 are parameters. The parameters for the relative product price and the exponent for industry output in (7) are assumed to be

positive. It can be seen that the demand function is linear when I is equal to one and is semi-logarithmic in the limit as I moves towards zero.

Because Australia is a small open economy, competing foreign price is included in the demand function as an exogenous variable. Both competing foreign price and aggregate price are assumed to be unaffected by changes in industry price. Also, output is homogeneous of degree zero in prices in equation (7). Olive (2002a) estimates a reduced form pricing equation for Australian manufacturing industries and finds that prices are linear homogeneous, thus implying that relative prices are unchanged for general price movements. Aggregate demand is included in (7) to capture the impact of movements in domestic spending power.

Differentiating both side of (7) with respect to industry output, solving for dQ/dP and substituting into (4) gives:

$$P = \sum mc_i \frac{q_i}{Q} + \frac{H(1+m)P_a Q^I}{a_2}. \quad (8)$$

We can rewrite equation (8) as:

$$P = \left(\frac{MC}{AVC}\right)AVC + \frac{H(1+m)P_a Q^I}{a_2} \quad (9)$$

where industry marginal cost is given by:

$$MC = \sum mc_i \frac{q_i}{Q} \quad (10)$$

and industry average variable cost is given by:

$$AVC = \sum avc_i \frac{q_i}{Q}. \quad (11)$$

Industry average variable cost is a weighted average of each firm's average variable cost, avc , where the weights are the firm's share in industry output.

The focus of this study centres on the nature of MC/AVC in equation (9). A sufficient condition for industry marginal cost to equal industry average variable cost ($MC/AVC = 1$) is for each firm's marginal cost to equal its average variable cost. This situation occurs if firms have excess capacity in the short-run and marginal costs are constant. This in turn implies that variable costs are linear homogeneous in output and average variable costs are independent of output.

Two other situations that result in $MC/AVC = 1$ are when each firm's marginal cost curve intersects its average variable cost curve (resulting in the standard U shaped average variable cost curve) or when each firm's marginal cost curve is tangent to its average variable cost curve (resulting in a turning point in the average variable cost curve). As marginal cost is not constant with respect to output in either of these situations, changes in demand and input prices need to be coordinated in such a way as to maintain this local solution. The condition is not so stringent if the market is perfectly competitive, but then firms are at their shutdown point. Therefore, these possibilities are unlikely.

A sufficient condition for at least one firm to have a marginal cost that is not equal to its variable cost is for industry marginal cost and industry average variable cost to be unequal ($MC/AVC \neq 1$). If firms have either constant scale economies or diseconomies in variable inputs, then MC/AVC will be equal to a non-unitary

constant. An example of this is when variable cost is represented by a Cobb-Douglas function that does not have constant returns. Alternatively, the relationship between marginal cost and average variable cost may alter for changes in demand and input prices. In both of these cases, average variable cost is a function of output.³ It should be noted that $MC/AVC = 1$ is still possible when firms in the industry have a mix of economies and diseconomies in variable inputs.

In order to test a range of possibilities we assume that MC/AVC is a linear function of the business cycle and is given by the expression:

$$\frac{MC}{AVC} = \mathbf{b}_1 + \mathbf{b}_2 BC \quad (12)$$

where \mathbf{b}_1 and \mathbf{b}_2 are parameters and BC is a variable representing the business cycle. There are a large number of empirical studies that find that the business cycle impacts on industry markup in reduced form relationships (some examples include Domowitz et al, 1988; Beccarello, 1996; and Oliviera Martins et al, 1996). This suggests that changes in the business cycle put pressure on demand and input prices. It can be seen from (12) that MC/AVC is equal to one when \mathbf{b}_1 is one and \mathbf{b}_2 is zero; is equal to a non-unitary constant when \mathbf{b}_1 is a number apart from one and \mathbf{b}_2 is zero; and is cyclical when \mathbf{b}_2 is non-zero.

In the short run, we assume that each firm's share of industry output and conjectural variations are constant over time. The former assumption implies that the Herfindahl index of concentration is also constant in the short run. Dixon (1987) finds that the four-firm concentration ratio averaged across 101 Australian manufacturing industries changes by 4.3 percent from 1968 to 1982, suggesting that industry

concentration is stable over the short period. Other studies that assume that conjectural variations are constant over time include Cowling and Waterson (1976), Bloch (1992) and Hyde and Perloff (1995).

Equations (7), (9) and (12) form the basis of the statistical model, which is given as:

$$\frac{Q^I - 1}{I} = \mathbf{a}_1 - \mathbf{a}_2 \frac{P}{P_a} + \mathbf{a}_3 \frac{P_f}{P_a} + \mathbf{a}_4 Y_a + \mathbf{e}_1 \quad (13)$$

and

$$P = \mathbf{b}_0 + (\mathbf{b}_1 + \mathbf{b}_2 BC) AVC + \mathbf{b}_3 P_a Q^I + \mathbf{e}_2. \quad (14)$$

As is usual, output and price are assumed to have stochastic components. These are represented by \mathbf{e}_1 and \mathbf{e}_2 , respectively. A constant term, \mathbf{b}_0 , is included in (14) in order to indicate if there are any unexplained components entering the supply relation. Finally, \mathbf{b}_3 is a non-negative parameter equal to the term $H(1 + \mathbf{m})/\mathbf{a}_2$.

III. Data

Equations (13) and (14) are estimated using annual data for 89 four-digit Australian manufacturing industries for the period 1971 to 1984. This period is of interest as it encompasses the 1973 wage inflation and the 1973 and 1979 oil price surges and represents a particularly turbulent period for input costs. After 1984, the Australian Bureau of Statistics (ABS) went to triennial surveys of the value of

material inputs for manufacturing industries, making annual industry average variable cost data at the four-digit level unavailable.

Output is an index of production, industry price is calculated as the value of output divided by the index of production and industry average variable cost is calculated as wages and salaries plus materials divided by the index of production. The price of competing foreign product is constructed by taking a weighted average of the product prices for the corresponding domestic industries in each of Australia's trading partners and adjusting for import tariffs. Constant dollar GDP is used as a measure of aggregate demand and the GDP deflator is used as a measure of aggregate price. BC in equation (14) is measured as a dummy variable with the recessed periods indicated by a zero. The cycle dates are approximately those calculated by Bodman and Crosby (2002).⁴ For a more detailed explanation of the series see the Data Appendix.

IV. Results

Estimating equations (13) and (14) presents a minor dilemma. If industry average variable cost is not a function of industry output, then the system is most efficiently estimated assuming that industry average variable cost is exogenous. However, if industry average variable cost is a function of industry output, then estimating the system assuming that industry average variable cost is exogenous will give biased estimates.⁵ Estimation is carried out under each of these assumptions using the same estimating method, namely three-stages least squares (3SLS), with each assumption being distinguished by a different instrument list.⁶

The GDP deflator, constant dollar GDP, competing foreign price to GDP deflator ratio, industry average variable cost and the business cycle dummy times

industry average variable cost are used as instruments when industry average variable cost is assumed to be exogenous. When industry average variable cost is assumed to be endogenous, the average wage rate (wages and salaries divided by the number employed in the industry) replaces industry average variable cost in the list of instruments.

The functional form of demand is determined by β , but this parameter is not known *a priori*. In order to test the sensitivity of the regression estimates to the functional form of demand, we make comparisons when β takes on two different sets of values. First, the system is estimated assuming that the demand function is linear and β is equal to one for all industries. Second, β is estimated for each industry using full information maximum likelihood (FIML). These can only be obtained when average variable cost is assumed to be exogenous, as then there are two equations and two endogenous variables (ie industry price and industry quantity). The results indicate that β is positive for all industries except for Petroleum and Coal Products Not Elsewhere Categorised (2780). Aside from this industry, the mean estimate of β is 1.00, with values ranging from 0.14 to 1.58. In the case of 2780, we set β to zero in equation (14) and make the natural logarithm of output the dependent variable in equation (13).⁷

Interpreting the regression estimates is not straightforward because the data series are in index form. When all the data series are in the same units and the estimating equation is linear, then the coefficient estimates are given the same interpretation as in the theoretical model. However, if a dependent and an independent variable are in different units, then the coefficient estimate for the independent variable will capture that difference. Also, the constant coefficient will vary for a

change in the units of the dependent variable. It should be noted that, regardless of the units, the t statistics are unchanged when the null hypothesis is zero.

Only the data for industry price and industry average variable cost are in the same units. Therefore, only the estimates for b_1 and b_2 in equation (14) are easily interpreted. Table 1 presents the median coefficient estimates and median standard errors for these parameters under four different assumptions. These assumptions are: I is one and industry average variable cost is exogenous; I varies and industry average variable cost is exogenous; I is one and industry average variable cost is endogenous; and I varies and industry average variable cost is endogenous. In each case, the median coefficient estimate for industry average variable cost is greater than one and the median coefficient estimate for the cycle dummy times industry average variable cost is positive. This may suggest a tendency for industry marginal cost to be greater than industry average variable cost and for this to increase at the top of the cycle. However, at the median standard errors, the median estimates for b_1 and b_2 are not significantly different from one and zero, respectively, using a two-tailed t test at the 10 percent level of significance.

Table 1

Median coefficients estimates and standard errors for AVC and $BC*AVC$ using 3SLS estimation under four different assumptions

	$I = 1$ and <u>AVC exogenous</u>		I varies and <u>AVC exogenous</u>		$I = 1$ and <u>AVC endogenous</u>		I varies and <u>AVC endogenous</u>	
	<u>AVC</u>	<u>BC*AVC</u>	<u>AVC</u>	<u>BC*AVC</u>	<u>AVC</u>	<u>BC*AVC</u>	<u>AVC</u>	<u>BC*AVC</u>
<u>Median</u>								
- estimate	1.106	0.005	1.103	0.002	1.180	0.006	1.175	0.005
- s.e.	(0.111)	(0.016)	(0.105)	(0.016)	(0.135)	(0.017)	(0.132)	(0.018)

Critical t statistic for a two-tailed t test at the 10 percent level of significance and 20 degrees of freedom is 1.725.

It can be seen that functional form has only a minor impact on these results. The exception is a median coefficient estimate of 0.002 for the cycle dummy times industry average variable cost when I varies and industry average variable cost is exogenous. This is less than half of the other coefficient estimates. Treating industry average variable cost as endogenous has a larger impact on the results, with the median coefficient estimate and median standard error for industry average variable cost increasing by approximately 0.073 and 0.025, respectively. This could indicate that industry average variable cost tends to be a function of output or it could be the result of a less efficient method of estimation.

For each industry, two-tailed t tests at the 10 percent level of significance are carried out for each estimated coefficient in the model under the four different assumptions. Table 2 indicates the number of times a coefficient related to the supply relation is significantly different from zero and positive, significantly different from zero and negative, and not significantly different from zero. A feature of these results is the similarity across the four sets of assumptions, suggesting that the results are robust. However, the constant term is significantly different from zero in approximately half of the industries, indicating an influence on price that is not explicitly accounted for in (14).

It can be seen from the Table 2 that industry average variable cost is significantly greater than zero in 81 to 84 industries and is not significantly different from one in 36 to 46 industries. This evidence suggests that industry marginal cost is not equal to industry average variable cost in at least half the industries during cyclical downturns. However, the cycle dummy times industry average variable cost is only significantly different from zero in 27 to 29 industries, suggesting that industry marginal cost is linearly related to industry average variable cost in most industries.

Table 2

Coefficients estimates for equation (14) under four different assumptions, categorised by number of industries and significance

	T						Wald MC/AVC	
	Test	Constant	AVC	$AVC-1$	$BC*AVC$	$P_a Q^I$	Test	$= 1$
$I = 1$ and <u>AVC exogenous</u>	<-1.725	14	0	11	12	7	S	48
	NS	48	8	45	60	47	NS	41
	>1.725	27	81	33	17	35		
I varies and <u>AVC exogenous</u>	<-1.725	14	0	10	12	8	S	52
	NS	49	7	46	61	46	NS	37
	>1.725	26	82	33	16	35		
$I = 1$ and <u>AVC endogenous</u>	<-1.725	17	0	11	15	11	S	55
	NS	47	5	36	60	46	NS	34
	>1.725	25	84	42	14	32		
I varies and <u>AVC endogenous</u>	<-1.725	17	0	9	15	11	S	50
	NS	44	7	44	62	46	NS	39
	>1.725	28	82	36	12	32		

All result categories relate to t tests for particular coefficient estimates, except for the Wald test results in the last column. <-1.725 (>1.725) indicates the number of industries where the coefficient estimate is negative (positive) and significantly different from zero at the 10 percent level for a two-tailed t test. S indicates that the $MC/AVC=1$ is rejected at the 5 percent level of significance using a Wald test. NS indicates not significantly different from zero for both tests.

In order to test the relationship more fully, a Wald test is used to jointly test the null hypothesis that b_1 is one and b_2 is zero. At the five percent level of significance, the null hypothesis is not rejected in 34 to 41 industries, indicating that it is reasonable to equate industry marginal cost and industry average variable cost over the short period in a substantial number of industries.

It is of interest to look at which two and three-digit industry groups have a large proportion of four-digit industries that reject, or do not reject, the null hypothesis that MC/AVC is equal to one. Four-digit industries in Other Textile Products (235), Transport Equipment (32) and Industrial Machinery and Equipment (336) generally do not reject the null hypothesis. These are industries that produce

substantially transformed industrial inputs. Some perishable consumer goods such as Fruit and Vegetable Products (213) and Beverages and Malt (218) reject the null hypothesis, while others such as Milk Products (212) and Tobacco Products (219) do not reject the null hypothesis. Two notable industries that reject the null hypothesis are Petroleum Refining (277) and Petroleum and Coal Products Not Elsewhere Classified (278), as these industries are most directly affected by the volatility of oil prices over the period.

The estimate for b_3 is positive and significant in 32 to 35 industries, is not significantly different from zero in 46 to 47 industries and is negative and significant in 7 to 11 industries. b_3 is expected to be zero when firms behave competitively and can only be positive when firms exhibit a degree of collusive behaviour. Although this study is not detailed enough to measure industry conduct, the proportion of significant and positive estimates for b_3 is approximately the same proportion of industries that exhibit collusive behaviour in the study of Australian manufacturing by Bhattacharya and Bloch (1997). Also, the small number of industries with the wrong sign may be due to sampling error.

As this study centres on the supply relation, we will only discuss the results for the demand function in brief. For a two-tailed t test at the 10 percent level, aggregate demand is significantly different than zero in 38 to 43 industries. This compares with the small number of industries (14 to 20) where the relative own price is significantly negative. A reason for this could be that real GDP and the GDP deflator are highly correlated, leading to a degree of collinearity between the variables. When real GDP is removed from the estimating equation, the relative own price is significantly negative in 34 to 42 industries.

V. Discussion and Conclusion

As is pointed out above, marginal cost being equal to average variable cost for all firms in the industry is a sufficient but not necessary condition for MC/AVC to equal to one. On the other hand, MC/AVC not equal to one is a sufficient condition for at least one firm in the industry to have marginal cost not equal to average variable cost. This suggests that we can be more certain in our statements when the null hypothesis of MC/AVC equal to one is rejected, than when it is not rejected. The results indicate that approximately 60 percent of manufacturing industries reject the null hypothesis.

While being less certain about the interpretation, the approximately 40 percent of industries that do not reject the null hypothesis is similar in level to the percentage of US firms that indicate constant average variable costs in the Blinder (1991) survey. Given our results and the supportive evidence, constant industry average variable cost equal to industry marginal cost appears relevant to a sizeable number of manufacturing industries. It follows that theoretical work (related to price-cost margins for example) that assumes industry marginal cost is equal to industry average variable cost, can reasonably hope to describe behaviour in approximately 40 percent of industries. However, models that apply this assumption to all industries are likely to founder.

The results also indicate that empirical studies that employ industry average variable cost as a proxy for industry marginal cost are valid in the appropriately selected industry. This has implications, not only for the study of price-cost margins and pricing equations, but also for the measurement of industry conduct. As discussed above, estimating industry conduct from the supply relation usually involves finding a proxy for marginal cost. However, if marginal cost is equal to average variable cost,

then employing the latter as a proxy will give efficient and unbiased estimates of industry conduct.

The other important result to come out of the empirical analysis is that the influence of the business cycle on MC/AVC is significant in approximately 30 percent of industries. A reason for this behaviour could be that neither marginal cost nor the scale economies of variable inputs are constant due to nature of the cost function. However, for approximately 70 percent of industries, the results suggest that a constant multiplied by industry average variable cost is a reasonable proxy for industry marginal cost in the short run. Therefore, for a large number of industries, it is reasonable to carry out pricing studies that employ industry average variable cost in logarithmic form as a proxy for industry marginal cost in logarithmic form. However, industry average variable cost may be endogenous in many cases (see footnote 3), requiring an appropriate econometric technique to be employed.

The analysis in this paper has proceeded on the presumption that wages and salaries plus materials costs per unit of output are the correct measure of average variable cost. If the true average variable cost of firms in an industry includes particular capital services or if firms in an industry engage in labour hoarding, then industry average variable cost may equal industry marginal cost but our results are still likely to indicate that MC/AVC is cyclical.⁸ As the method outlined in this paper is quite general, alternative measures of industry average variable cost could be employed in a similar analysis to determine if it is equivalent to industry marginal cost.

This paper employs a supply relation similar to Bresnahan's in order to estimate industry marginal cost divided by industry average variable cost (MC/AVC) for 89 four-digit Australian manufacturing industries during 1971 to 1984. The 3SLS

results indicate that MC/AVC is not significantly different from one in approximately 40 percent of industries and is cyclical in approximately 30 percent of industries. This suggests that industry average variable cost multiplied by a constant can be used as a proxy for industry marginal cost for a large number of industries over a short period.

Data Appendix

Q – Indices of industry output at the 4 digit Australian Standard Industry

Classification (ASIC) level are taken from Australian Bureau of Statistics (ABS), *Constant Price Estimates of Manufacturing Production* (8211.0).

P – Indices of industry price are calculated by summing industry turnover with the change in stock (ABS, *Manufacturing Establishments, Details of Operations by Industry Class* (8203.0)) and dividing by industry output.

AVC – Indices of industry average variable cost are calculated by dividing industry output into the sum of labour and materials (ABS, *Manufacturing Establishments, Details of Operations by Industry Class* (8203.0)).

P_f – Competing foreign price is a tariff adjusted trade-weighted index of the domestic industry prices for 21 of Australia's major trading partners. For the full details on the construction of this index, see Bloch and Olive (1999).

P_a – The GDP deflator is used to measure aggregate price and is taken from ABS, *Australian National Accounts* (5204.0).

Y_a – GDP in 1978-79 prices is used to measure aggregate demand and is taken from ABS, *Australian National Accounts* (5204.0).

BC – The business cycle dummy variable designates the periods between the peaks and the troughs as zeros and the periods between the troughs and the peaks as ones. The cycle dates are taken from Bodman and Crosby (2002).

References

- Areeda, Phillip and Donald Turner (1975), “Predatory Pricing and Related Practices under Section 2 of the Sherman Act”, *Harvard Law Review*, **88**, 697-733.
- Basu, Susanto and John G. Fernald (1997), ‘Returns to Scale in U.S. Production: Estimates and Implications’, *Journal of Political Economy*, **105**, 249–283.
- Baumol, William (1996), “Predation and the Logic of the Average Variable Cost Test” *Journal of Law and Economics*, **39**, 49-72.
- Beccarelli, Massimo (1996), “Time Series Analysis of Market Power: Evidence From G-7 Manufacturing”, *International Journal of Industrial Organization*, **15**, 123-136.
- Bhattacharya, Mita and Harry Bloch (1997), “Specification and Testing the Profit-Concentration Relationship in Australian Manufacturing”, *Review of Industrial Organization*, **12**, 219-230.
- Blinder, Alan S. (1991), “Why are Prices Sticky? Preliminary Results from an Interview Study”, *American Economic Review*, **81**, 89-100.
- Bloch, Harry (1992), “Pricing in Australian Manufacturing”, *The Economic Record*, **68**, 365-376.
- Bloch, Harry and Michael Olive (1999), “Cyclical and Competitive Influences on Pricing in Australian Manufacturing”, *Economic Record*, **75**, 268-279.
- Bodman, Philip and Mark Crosby (2002), “The Australian Business Cycle: Joe Palooka or Dead Cat Bounce?”, Australian Economic Papers.
- Box, G.E.P. and D.P. Cox (1964), “An Analysis of Transformations”, *Journal of Royal Statistical Society*, **26**, 211-252.
- Brack, John (1987), “Price Adjustment within a Framework of Symmetric Oligopoly”, *International Journal of Industrial Organization*, **5**, 289-301.

- Bresnahan, Timothy F. (1982), "The Oligopoly Solution Concept is Identified",
Economic Letters, **10**, 87-92.
- Cowling, Keith and Michael Waterson (1976), "Price-Cost Margins and Market
Structure", *Economica*, **43**, 267-274.
- Dixon, Robert (1987), "The Role and Consequence of Structural Change in Recent
Australian Economic Growth", *University of Melbourne Discussion Paper*, **No
162**.
- Domowitz, Ian, R. Glen Hubbard and Bruce C. Peterson (1988), "Market structure
and Cyclical Fluctuations in U.S. Manufacturing", *Review of Economics and
Statistics*, **70**, 55-66.
- Hall, Simon, Mark Walsh and Anthony Yates (1997), "How Do UK Companies Set
Prices?", *Bank of England Working Paper Series*, **No 67**.
- Haskel, Jonathan, Christopher Martin and Ian Small (1995), "Price, Marginal Cost
and the Business Cycle", *Oxford Bulletin of Economics and Statistics*, **57**, 25-
41.
- Haugh, David and Tim Hazledine (1999), "Oligopoly Behaviour in the Trans-Tasman
Air Travel Market: The Case of Kiwi International", *New Zealand Economic
Papers*, **33**, 1-25.
- Hay, Donald A. and Derrek J. Morris (1991), *Industrial Economics and Organization:
Theory and Evidence*, Oxford University Press, Oxford.
- Hyde, Charles E. and Jeffrey M. Perloff (1995), "Can Market Power be Estimated?",
Review of Industrial Organization, **10**, 465-485.
- Intriligator, Michael D., Ronald G. Bodkin and Cheng Hsaio (1996), *Econometric
Models, Techniques and Applications*, 2nd ed., Prentice-Hall International,
New Jersey.

- Lee, Frederic S. (1991), "Symposium: The Marginalist Controversy and Post Keynesian Price Theory – Introduction", *Journal of Post Keynesian Economics*, **13**, 233-235.
- Lerner, A. P. (1934), "The Concept of Monopoly and the Measurement of Monopoly Power", *Review of Economic Studies*, **1**, 157-75.
- Linnemann, Ludger (1999), "Sectoral Aggregate Estimates of the Cyclical Behavior of Markups: Evidence from Germany", *Weltwirtschaftliches Archiv*, **135**, 480–500.
- Madden, Gary and Scott J. Savage (2000), "Market Structure, Competition, and Pricing in United States International Telephone Service Markets", *Review of Economics and Statistics*, **82**, 291-296.
- Morrison, Catherine J. (1992), "Markups in U.S. and Japanese Manufacturing: A Short-Run Econometric Analysis", *Journal of Business and Economic Statistics*, **10**, 51-63.
- Morrison Paul, Catherine J. (2001), "Cost Economies and Market Power: The Case of the U.S. Meat Packing Industry", *Review of Economics and Statistics*, **83**, 531-540.
- Odagiri, Hiroyuki and Takashi Yamashita (1987), "Price Mark-ups, Market Structure, and Business Fluctuations in Japanese Manufacturing Industries", *Journal of Industrial Economics*, **35**, 317-331.
- Olive, Michael (2002a), *Price and Markup Behaviour in Manufacturing: A Cross-Country Study*, Edward Elgar, Cheltenham UK.
- Olive, Michael (2002b), "Markup, Returns to Scale, the Business Cycle and Openness: Evidence from Australian Manufacturing", *Macquarie Economics Research Papers*, **2/2002**.

- Oliviera Martins, Joaquim, Stephano Scarpetta and Dirk Pilat (1996), “Mark-Up Pricing, Market Structure and the Business Cycle”, *OECD Economic Studies*, **27**, 71-105.
- Park, Seung-Rok and Jene K. Kwon (1995), “Rapid Economic Growth with Increasing Returns to Scale and Little or No Productivity Growth”, *Review of Economics and Statistics*, **77**, 332-351.
- Prince, Yvonne and Roy Thurik (1994), “The Intertemporal Stability of the Concentration-Margins Relationship in Dutch and U.S. Manufacturing”, *Review of Industrial Organization*, **9**, 193-209.
- Rosenbaum, David I. and Supachat Sukharomana (2001), “Oligopolistic Pricing over the Deterministic Market Demand Cycle: Some Evidence from the US Portland Cement Industry”, *International Journal of Industrial Organization*, **19**, 863-884.
- Steen, Frode and Kjell G. Salvanes (1999), “Testing for Market Power Using a Dynamic Oligopoly Model”, *International Journal of Industrial Organization*, **17**, 147-177.
- Weiss, Christoph (1993), “Price Inertia and Market Structure: Empirical Evidence from Austrian Manufacturing”, *Applied Economics*, **25**, 1175-1186.

Notes

* Thank you to Craig Freedman, Jocelyn Horne, Rod O'Donnell, David Throsby and the audience at the Macquarie University seminar for their helpful comments. I would also like to thank Harry Bloch for releasing the data set used in this paper. This data set is compiled with the financial support of the Australian Research Council. All errors and omissions remain the responsibility of the author.

¹ It should be noted that much of the literature on pricing behaviour prefer alternative devices to account for short-run marginal cost, such as including factor costs as proxies or specifying cost functions in structural models.

² The terms, constant average variable cost and constant marginal cost imply that their respective curves are the same and horizontal ie they do not change value for changes in output demanded.

³ Let the firm have the following Cobb-Douglas variable cost function:

$$C_i = aq_i^g$$

where a is a function of input prices and g is a constant. It can be seen from the variable cost function that $mc_i/avc_i = g$, where $1/g$ are the firm's economies. Also, the firm's average variable cost is given by:

$$avc_i = aq_i^{g-1}$$

which will vary with output, except when $g = 1$.

⁴ Bodman and Crosby (2002) date their turning points by quarters, while the turning points in this study are necessarily annual.

⁵ A Hausman test can be employed to determine whether average variable cost is endogenous, but this has low power in small samples and so is not carried out here.

Alternatively, variable cost can be expressed as a polynomial function of output in order to test whether average variable cost is a function of output demanded.

However, this method is only valid if input prices do not change.

⁶ Full information likelihood (FIML) is a more efficient method of estimation than 3SLS. However, FIML estimation is only possible for the case where industry average variable cost is exogenous. In this case, estimation of the system using FIML invariably does not reject the null that MC/AVC is equal to one, while most other coefficient estimates are not significantly different from zero. The large standard errors are probably due to the small number of observations and the non-linear estimation method. These results are not presented here, but are available from the author.

⁷ The initial value of \mathbf{I} is set to one.

⁸ Let the firm's true variable cost function be:

$$C_i = aq_i + rq_i$$

where r is a function of the price of capital, while a is a function of other input prices and aq_i is the variable cost excluding the cost of capital services. It can be seen that marginal cost is equal to the true average variable cost but marginal cost divided by the measured average variable cost is equal to $1 + r/a$. This term is cyclical if the price of capital services relative to the prices of other inputs varies over the cycle. If firms hoard labour, then part of the measured variable cost is fixed. Dividing this measured variable cost by output causes the measured average variable cost to be a function of the inverse of output.