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Measuring Competition using the Boone Relative Profit Difference Indicator

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Abstract
This paper suggests a method for implementing the theoretical relative profit difference test for intensity of competition due to Boone (2008). An empirical illustration is given for banking systems in emerging economies

Key words: competition, efficiency measurement

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1 Introduction

There is interest in measuring the strength of competition in different industries. One strand argues that the intensity of competition alters the relationships between the profitability of firms because output is reallocated towards more efficient firms when intensity of competition increases. Boone (2008) developed this idea of the output reallocation effect into a theoretical test, and this paper suggests a procedure for implementing Boone’s test, illustrated with a sample of banks in emerging economies.

2 Theory

Boone (2008) describes an industry where firms compete but differ in efficiency. Initially the firms decide whether to enter the market and then, knowing which firms entered in the first stage, all firms choose strategically to maximise their after entry profits. A sub-game perfect equilibrium is identified where profits are related to the firm's efficiency, and are conditional on the aggressiveness of the firms' conduct. Let $\pi(E)$ denote the profit level of a firm with efficiency level E. Consider three firms with different efficiency levels: $\max E \geq E' \geq \min E$ The inverse relative profit difference (RPD), ρ, represents the ratio of the difference between the profit of the typical firm and the profit of the least efficient firm relative to the difference between the profit of the most efficient and the profit of the least efficient firm:

$$\rho = [\pi(E') - \pi(\min E)]/[\pi(\max E) - \pi(\min E)] \qquad [1]$$

Boone (2008) argues that more intense competition causes the term ρ , the RPD, to fall as the intensity of competition increases. Hence the numerator term is expected to fall more than the denominator; the intuition is that when an industry becomes more competitive firms are punished more harshly the more they are below maximum efficiency, Boone (2008:1246).

Boone establishes a relationship between the relative profit difference, ρ which he calls normalised profits and the corresponding normalised efficiency, symbolised here as η :

$$\eta = [E' - \min E]/[\max E - \min E] \quad [2]$$

This relationship:$\rho(\eta)$ must shift down for all values of the normalised efficiency when competition becomes more intense, Boone (2008: theorem 1). Boone suggests: plot normalised profits against normalised efficiency for the years *t* and *t* + 1. If the area under the curve is smaller in *t* + 1 than it is in *t*, competition has become more intense in year *t* +1.

Using a diagram like Figure 1 Boone represents an increase in competition intensity as a lower value for the integral under the curve: $\rho(\eta)$ i.e.$\int_0^1 \rho(\eta) d\eta$. Boone's test is a sign criterion; in an analytical model the visual comparison of the areas under the relative profit difference graph, or the sign of their difference, is sufficient to determine the relative intensity of competition.

Figure 1

In principle therefore the test is straightforward but requires comparison of the areas under sample scatters of points, i.e. empirical distributions. The discriminating index amongst different competitive regimes need not be related to time, *t*; it could also refer to different regions, or industrial sectors. For example in an industry panel data case study, write E_{it} as the measured cost efficiency of firm *i* at time *t*. Rank the efficiency scores for a related group of firms from highest $\max E_{it}$ to lowest: $\min E_{it}$ and normalising the efficiency scores, construct the following sample points.

$$\eta_{it} = [E'_{it} - minE_{it}]/[maxE_{it} - minE_{it}] \quad i = 1 \dots N; t = 1 \dots T \qquad [3]$$

This variable measures, for each firm observation, the relative efficiency compared to the least efficient firm, normalised by the range of efficiency scores. Associated with each of these normalised efficiency scores will be a relative profit difference observation:

$$\rho_{it} = [\pi(E'_{it}) - \pi(minE_{it})]/[\pi(maxE_{it}) - \pi(minE_{it})] \quad i = 1 \dots N; t = 1 \dots T \qquad [4]$$

The sign version of the test therefore is given by the sign of the difference in the definite integrals computed for two different competition regimes, A and B:

$$\widehat{\Delta} = \int_0^1 \rho_{it}^A(\eta_{it})d\eta - \int_0^1 \rho_{it}^B(\eta_{it})d\eta \qquad [5]$$

3 Sample procedure

The efficiency scores could be computed by stochastic frontier analysis. The basic data are firm observations on efficiency, E_{it} and a measure of profitability, π_{it} transformed as in [3], [4]. Plot these for all pooled observations. A way of implementing the test is the use of polynomial quantile regression analysis (PQR). Since this is an empirical integral it is appropriate to use it to estimate a theoretical integral. A PQR is based on the parameters q the probability level for isolating the proportion of the sample lying on or below the quantile regression line and M the degree of the polynomial. The choice is a compromise between inclusivity of sample points and avoidance of undue outlier impact. Fitting a PQR at the third quartile for a given selection of sample points for example ensures that 75 percent of those sample points lie on or below the fitted line. We suggest that the preferred specification of the PQR should be the one with positive first derivative and negative second derivative over the largest part of the domain of normalised efficiency.

Therefore approximate the relationship between the inverse relative profit difference and the normalised cost efficiency by:

$$\Pr\left(\rho_{it} \leq \rho(\eta_{it}) = \sum_{m=1}^{m=M} \alpha_m \eta_{it}^{m-1}\right) = q$$

[6]

This polynomial quantile regression produces an integral estimate which is a linear function of the quantile regression coefficients:

$$\int_0^1 \left[\sum_{m=1}^{m=M} \hat{\alpha}_m \eta_{it}^{m-1}\right] d\eta = \sum_{m=1}^{m=M} (\hat{\alpha}_m / m) = \mathbf{h}'\hat{\boldsymbol{\alpha}}$$

[7]

Here the $\hat{\alpha}$ terms are the estimated coefficients from the quantile regression and the vector $\mathbf{h}'$ is given by $\left(1, \frac{1}{2}, \dots, \frac{1}{M}\right)$. If the size of this integral differs for different clusters of sample points, then the competition regime differs in intensity between those clusters.

From the variance matrix of the estimated coefficients compute the standard error of this integral:

$$SE\left(\int_0^1 \left[\sum_{m=1}^{m=M} \hat{\alpha}_m \eta_{it}^{m-1}\right] d\eta\right) = SE\left(\sum_{m=1}^{m=M} (\hat{\alpha}_m / m)\right) = (\mathbf{h}' var(\hat{\boldsymbol{\alpha}})\mathbf{h})^{1/2}$$

[8]

For two competition regimes (B: before or benchmark and A: after or alternative) the hypothesis of no difference in the intensity of competition is:

$$H_0 : \Delta = \int_0^1 \left[\sum_{m=1}^{m=M} \alpha_m^A \eta_{it}^{m-1}\right] d\eta - \int_0^1 \left[\sum_{m=1}^{m=M} \alpha_m^B \eta_{it}^{m-1}\right] d\eta = 0$$

$$H_1 : \Delta \neq 0$$

[9]

This can be tested by the use of intercept and slope dummy variables applied to the pooled sample.

$$D_{it} = \begin{cases} 0: \quad i,t \in B \Rightarrow \boldsymbol{\alpha}^B = \boldsymbol{\alpha} \\ 1: i,t \in A \Rightarrow \boldsymbol{\alpha}^A = \boldsymbol{\alpha} + \boldsymbol{\beta} \end{cases}$$ [10]

The PQR form with these dummy variables is:

$$\Pr\left(\rho_{it} \le \sum_{m=1}^{m=M} \alpha_m \eta_{it}^{m-1} + \sum_{m=1}^{m=M} \beta_m (\eta_{it}^{m-1} \times D_{it})\right) = q$$

[11]

Then, for the benchmark and the alternative regimes, test: H_0: $\Delta = \mathbf{h}'\boldsymbol{\beta} = 0$ by using the Wald statistic for one restriction:

$$W = (\mathbf{h}'\widehat{\boldsymbol{\beta}})\left[\mathbf{h}'\left(var(\widehat{\boldsymbol{\beta}})\right)\mathbf{h}\right]^{-1}(\mathbf{h}'\widehat{\boldsymbol{\beta}}) \qquad [12]$$

4 Empirical example

We illustrate with a sample of banking systems in emerging economies: 485 banks in 34 emerging economies over the period 2005-2008 collated from the Bankscope database, see Duygun et al (2013). The banks were the largest in each country and passed filter tests including deposits exceeding loans in order to focus on the commercial banks only.

Using the variables: costs, outputs, i.e. loans, securities and off-balance sheet income, input prices, i.e. price of funds, labour and fixed assets, equity capital and time, we derived a stochastic frontier analysis efficiency measure by estimating the short run total cost function. The error component model includes idiosyncratic error and inefficiency, see Kumbhakar and Lovell (2003). In our example of banks in emerging countries we have derived cost efficiency measures for each bank i in each country at time t, for a range of different efficiency measurement methodologies and measures of profitability, such as net interest margin, return on assets, return on equity and shadow return on equity capital. Using Braeutigam and Daughety (1983) and Hughes et al (2001), we interpret the negative of the elasticity of cost with respect to equity capital as the shadow return on equity. There is a strong argument for using this measure of profitability since it reflects the banks' attitude to the riskiness of their loan portfolios.

We then proceeded by sorting and normalising the data on efficiency E_{it} and profitability π_{it} in order to calculate the normalised efficiency and the relative profit differences[1] for the sample:(η_{it}, ρ_{it}) as shown in equations [3] and [4]. We then estimated the quantile regressions and carried out the Wald test shown in equations [6] to [12] for the hypotheses shown in equation [9].

In the test illustrated here, we focus on a particular part of the sample, the banks in economies preparing for EU and eventual Eurozone entry. There are 10 banking systems[2] in this subsample comprising 496 observations. The annual convergence criteria reports of the European Central Bank, ECB (1996-2014), confirm that from 2004 onwards these countries were engaged in restructuring their banking systems in anticipation of accession to the EU and adoption of the Euro, therefore they represent a subsample of market participants likely to display increasing competitive pressures in an environment where each is opening up to similar external deregulation incentives.

In selecting this subsample for measuring increased competition through the impact on the profit-efficiency relationship we must avoid confusing the picture with the effect of the global financial crisis. The crisis in developed EU banking systems took serious hold from the bank bailouts and the Lehman Brothers collapse which date from late 2008. To ensure that the test is not contaminated by events in late 2008 we first compare two overlapping periods: 2005-2007 and 2006-2008 to calculate RPDs. Then we compare 2006-08 with the base year 2005 for the Wald test. In this way we seek to test whether the whole period 2006-8 can be identified with a change in the strength of competition as the ECB guidance started to have an impact on the banking systems preparing for EU entry and Euro adoption.

Table 1 presents these results. Choosing a quantile value of 0.75 to compromise between inclusivity and avoidance of outliers, we find statistically significant fits for the quadratic quantile regressions. The difference in the RPD integrals comparing

[1] Normalised efficiency observations are in the unit interval, but sample data for RPD need not be.
[2] Bulgaria, Croatia, Czech Republic, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia

2006-08 with 2005-07 is $\hat{\Delta}$ = -0.715, more than four times the individual standard errors.

Comparing 2006-08 with 2005, $H_0: \Delta = 0$ i.e. no increase in the relative strength of competition is rejected at below the one percent significance level. Therefore we may conclude that the statistically significant contraction in the empirical estimates of the RPD integrals is not inconsistent with the hypothesis that competition had strengthened in 2006-08.

Table 1

5 Conclusions

We suggest a procedure for applying the Boone (2008) relative profit difference test of the strength of competition. Boone's test compares the areas under plots of normalised efficiency and normalised profitability, corresponding to two different competition regimes. A pooled sample is separated into clusters by using polynomial quantile regressions for a chosen percentage of the sample points to derive measures of the areas under the curves, together with standard errors and Wald tests of the statistical significance of their difference. We applied this to a panel of banking systems preparing for EU entry prior to the global financial crisis. Our finding that there is a statistically significant shift in the empirical estimates of the RPD integrals is not inconsistent with the hypothesis that competition had strengthened in 2006-8.

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Figure 1: The theoretical relationship between normalised profit (relative profit difference) and normalised efficiency, based on Boone (2008) figure 2, p. 1252

$$RPD \equiv \rho = \big(\pi(E') - \pi(minE)\big)/\big(\pi(maxE) - \pi(minE)\big)$$

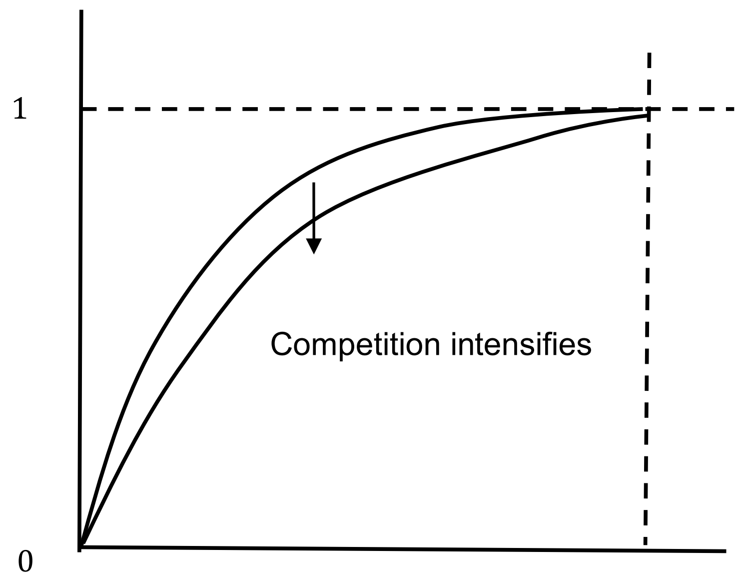

Table 1: Quantile regressions at 75 percent level

Moving windows 2005-7 & 2006-8	RPD (ρ) 2005-7	RPD (ρ) 2006-8
normalised efficiency (η)	6.464**	11.267***
square of normalised efficiency (η^2)	-4.492**	-7.745***
constant	2.799***	0.766
NT	352	356
Boone RPD integral: $\int_0^1 \hat{\rho}(\eta)d\eta$:	4.533	3.818
SE (Boone RPD integral):	0.173	0.174
Difference in RPD integrals: $\hat{\Delta}$:		-0.715
Wald test of 2006-8 compared with 2005		
Difference in RPD integrals: $\hat{\Delta}$:		-1.127
Wald test of H0: Δ= 0	$F(1,465)$:	12.37***
	p-value	0.0005

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$