Competition Indicators for the UK Deposit-taking Sector

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Abstract

We use a new regulatory dataset to estimate competition in the UK deposit-taking sector. The novelty of this study is two-fold. First, the dataset allows us to explore trends in competition intensity over an extended, 24 year period from 1989 to 2013 using data for UK regulated firms which encompasses a wider range of firms than for previous studies. Second, we take a portmanteau approach and estimate a number of different performance-based competition measures common in the literature to support conclusions on the intensity of competition over the period. Our estimates of the Lerner index, the Panzar-Rosse H-statistic and the Boone indicator suggest that competition intensity was strong at the beginning of our sample, but became less intense in the early 2000s. However, the deposit-taker business model bundles together activities in several markets simultaneously, so strong competition in some markets can be offset by the extraction of market rents in others. Importantly, competition intensity decreased (and the ability of UK deposit takers to extract market rents from customers increased) in the period immediately ahead of the financial crisis (2003-2007).

Key words: Competition, Banks, Deposit Takers.

***JEL* classification**: D22, D24, G21, L11, N20.

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1 Introduction

Accurate measures of competition intensity are important in understanding the influence of the banking industry in the wider economy. Anti-competitive practices and other market failures in banking can have negative consequences for productive efficiency and the cost of finance (Goodhart and Wilson, 2004) with implications for consumer welfare and economic growth. Recent studies focus on the way competition can reduce systemic risk (e.g. Schaeck et al., 2009) for which measures of competition are key.

The objective of this paper is to use data on UK banks and building societies (collectively 'deposit takers') to investigate the intensity of competition in this sector over a relatively long time period and using different measurement techniques. Past empirical studies of UK banks competition had narrower focus on either: industry structure (concentration) only; specific (and generally limited) time periods; and individual product types or services offered. For example, Logan (2004) studied concentration in UK bank loans and deposits for the period 1990-2004 and found that concentration in lending increased over the period but is generally more concentrated than retail deposits. Matthews et al. (2007) constructs two (non-structural) measures of competition intensity using an unbalanced panel of 12 large UK bank groups over the period 1980-2003. Using these measures they find that competition in core banking businesses was the same throughout the 1990s as it was in the 1980s and that generally that UK banks are monopolistically competitive. Schaeck and Cihák (2010) measure competition intensity for the period 1995-2005 using a sample of UK and European banks and find that competition between UK banks decreased over the period. Casu and Girardone (2009) use data from 79 UK banks (from a total sample of 2,701 European banks) to study competition and find that competition in the UK improved between 2002 and 2005 although the authors note that there is no evidence of increased competitive pressures across Europe as a whole. Finally, Weill (2013) constructs competition measures for European banks including 56 UK banks over the period 2002-2008 and finds that competition intensity peaked in 2003 and declined for the remainder of the sample period.

The novelty of this work is two-fold. First we use a new UK regulatory dataset of 127 deposit takers covering 24 years from 1989 to 2013. This is a broad dataset covering a period which straddles a number of UK economic cycles and includes the 2008 financial crisis and its aftermath. Second, to draw firm conclusions about the intensity of competition, we take a portmanteau approach by estimating all common measures used in the literature, rather than using a smaller sub-set of measures.

This paper proceeds as follows. First, we review aspects of the literature relevant to this study. Second, we briefly discuss the new regulatory data and highlight the key issues and limitations of using this data. Third, we present our econometric results for the measures of competition. We conclude by reconciling these outcomes with the recent history of the UK deposit-taking sector. Appendices A3 and A4 describe respectively the data and the econometric methodologies to measure competition.

2 Literature review

The structure-conduct-performance (SCP) hypothesis developed by Bain (1951) states that the industry structure determines the competitive conduct and performance of firms within that market. Under this hypothesis, more concentrated industries will be less competitive as the opportunities for collusion improve. The major structural changes in asset composition and market shares of banks and building societies that occurred in the UK following the 'big bang' deregulation of the 1970s and 1980s (Davis and Richardson (2010)) [1] should therefore have signalled changes in the competitive landscape. However, Logan (2004) shows inconsistencies in outcomes for competition between UK banks: between 1989 and 2003 concentration in lending, as measured by the Herfindahl-Hirschman Index, increased (a decline in competition under SCP) while deposit concentration remained unchanged (no change in competition under SCP). But many studies highlight that SCP-based measures fail to consider how firms compete in the markets so they tend to be poor estimates of the intensity of competition (e.g. Claessens and Laeven (2004)).

During the period of our study deregulation freed-up entry in banking services with the 1993 Second Banking Coordination Directive that reduce formal barriers to entry in the EU, allowing European banks to operate in different markets. This increased competition, especially in non-traditional non-interest bearing products, increased efficiency and consolidation (Casu and Girardone, 2006).

Contestable markets theory, now ascendant in the literature, focusses on the influence of both existing incumbents and potential competitors rather than just incumbents on which concentration ratios are focussed (see Baumol et al. (1982)). This theory rejects the mechanistic link from structure to conduct and performance, an outcome borne out in more recent studies of the banking industry (e.g. Bikker et al (2014))[2]. These empirical studies of firm behaviour measure competition directly from performance-based data, such as revenues and costs (e.g. Matthews et al. (2007); Berger et al. (2009); Schaeck and Cihák (2010, 2012 and 2014)). The approaches used in this strand of the literature measure the departure of firms' performance with respect to the outcomes expected under perfect competition.[3] Liu et al. (2013) discuss a range of performance-based measures highlighting that they require careful interpretation to assess competition, and ideally a variety of such indicators should be used.

Appendix 4 review the main measures used in this study: the Lerner index, the Panzar-Rosse H-statistic and the Boone indicator. These performance-based measures are not only theoretically more sound than structural measures but are driven by individual firm behaviour and do not generally require defining a narrow geographic market (Casu and Girardone (2006)). However, there are some caveats when interpreting these measures. The Lerner index assumes that firms are profit maximising but firms do not always operate with perfect technical and allocative efficiency. Koetter et al. (2012) develop adjusted versions of the index to address this problem. The Lerner index is measured with error because they depend on output prices and marginal costs which must be estimated from total cost empirical models (Kumbhakar et al. (2012)). Another problem is that the average mark-up across all

1 Figure 1 in Davies and Richardson (2010) shows the wave of consolidation among large UK banks and building societies, but also shows that the four largest UK groups account for a smaller share of deposit-taking and lending services in 2010 than they did in 1960.

2 Bikker et al. (2014) note that the empirical banking literature shows that concentration is generally a poor measure of competition given that some studies find that competitive conduct is more intense than the industry structure suggests while others find that market power is greater than industry structure suggests. As the authors note, "Since the mismatch can run in either direction, concentration is an extremely unreliable measure of performance."

3 For a description of perfect competition model, see http://www.economicsonline.co.uk/Business_economics/Perfect_competition.html

firms may not capture the degree of product substitutability making difficult to assess changes in competition (Vives (2008)). When measuring firms' mark-ups it is also important to take into account changes in efficiency. This is because firms may fail to minimise their costs introducing an error to empirical measures of the price-cost mark-up (Kumbhakar et al., 2012). New techniques to estimate mark-ups based on the stochastic frontier theory can overcome such limitations. Empirical tests using banking sector data show that these efficiency-corrected measures are highly correlated with return on assets (Coccorese, 2014).

Similarly, the H-statistic also requires careful interpretation. The H-statistic requires additional information about costs and market equilibrium to infer the degree of competition (Bikker et al. (2012)). A joint test of competitive conduct and equilibrium can address some of those problems. However, the test narrows the applicability of the revenue H-statistic to only those periods where the market is in a long-term equilibrium (Shaffer (1982)). More recent research demonstrates that the H-statistic can be sensitive to the way the test is specified, in particular when scaling the regression variables. Bikker et al. (2012) discuss how this problem affects many of the past studies using this technique and explain how to interpret the results in each case. Finally, there are cases when the H-Statistic can fail in which the Lerner index becomes a better indicator of market power (Spierdijk and Shaffer (2015)). Given the novelty of the Boone indicator in the literature, there is less exploration of outcomes than for the H-statistic. One limitation is that the Boone indicator is distorted where firms are not competing to maximise (short-term) profits but rather seek to build market share or where firm outputs are increasingly heterogeneous (van Leuvensteijn et al (2011)).

Table 2.1 below presents a summary of recent empirical studies using the measures discussed above. These studies use a range of methodologies and data, cover UK and non-UK banks and focus on the pre-crisis period.

Most studies include more than one performance-based measure, or combine them with a market concentration index. For example, Matthews et al. (2007) described UK banks as monopolistically competitive based on data from 1980 to 2000. The authors found that competition on core balance sheet activities was the same in the 1990s and 2000s as it was in the 1980s based on estimates of the H-statistic and Lerner index. In contrast, they found that competition in non-core balance sheet activities worsened significantly during the 1990s.

Table 2.1: Recent estimates of competition measures

Study	Region	# UK Banks[1]	Period under study	Measures[2]	Periodicity of estimates
Berger et al (2009)	World	43	2007	HHI, L	Average for period
Bikker et al (2012)	World	73	1994–2004	PRH	Average for period
Carbó et al (2009)	EU	58	1995–2001	HHI, L, PRH	Average for period
Casu and Girardone(2006)[3]	EU	63	1997–2003	CR, PRH	Average for period
Casu and Girardone(2009)	EU	73	2000–2005	L	Annual
Claessens and Laeven(2004)	World	106	1994–2001	PRH	Average for period
Coccorese(2014)	World	116	1994–2012	L	Annual
Fernández de Guevara et al (2007)	EU	45	1993–2000	L	Annual
Goddard and Wilson (2009)	G7	166	2001–2007	PRH	Average for period
Logan(2004)	UK	357	1989–2003	CR, HHI	Annual
Matthews et al (2007)	UK	11	1980–2004	PRH, L	Average for sub-periods
Schaeck and Cihák (2010)	EU	–	1995–2005	B	Annual
Schaeck and Cihák (2012)	EU	43	1999–2005	PRH	Average for period
Schaeck and Cihák (2014)	EU	43	1995–2005	B	Annual
Schaeck et al (2009)	World	–	1998–2005	PRH	Average for period
Weill (2013)	EU	56	2002–2008	L, PRH	Annual
van Leuvensteijn et al (2011)	EU + G2	140	1992–2004	B	Annual

Source: Authors

Notes:
[1] Total number of UK banks reported in the study
[2] Measure(s) of competition used in the study. CR = concentration ratios; HHI = Herfindahl-Hirschman Index; L = Lerner index; PRH = Panzar-Rosse H-statistic; B = Boone indicator
[3] Casu and Girardone (2006) contains a similar table for earlier studies of competition in the banking sector

Fernández de Guevara et al (2007) found that the EU deregulation process did not improve competitive conditions for the period 1993-2000. Their estimate of the Lerner index for the UK shows that market power increased in the late 1990s and early 2000s. Carbó et al. (2009) compared the Herfindahl-Hirshman index (HHI) with the Lerner index for the UK and found these measures are strongly and positively correlated over the period 1995-2001. Girardone and Casu (2006) concluded that the EU financial market is monopolistic competitive based on their study of EU banks for the period 1997-2003. The authors also found that the UK has a low competition score (as measured by the H-statistic) in spite of having a large number of banks compared to other European countries. In addition, they suggest that the banks with highest inefficiencies and costs might also generate the greatest profits in Europe. In a separate study, Girardone and Casu (2009) estimated the Lerner index for a number of European countries over the period 1999-2005 and found that market power in the UK as measured by the Lerner index fell slightly in both 2004 and 2005. They also found that this trend was accompanied by a fall in efficiency from 2000-2005. This is consistent with their main findings that more market power in Europe does not lead to higher inefficiencies.

Schaeck and Cihák (2014) estimated the Boone indicator for several European countries for the period 1995-2005 and found that competition in the UK fell steadily over the period (and consistent with estimates of the Boone indicator for the UK over the period 1994-2004 by van Leuvensteijn (2007)). The authors found that competition improved between 1998 and 2001 but subsequently fell steadily until 2004. The authors concluded that the UK had one of the least competitive banking sectors amongst developed countries. In a separate study, Schaeck and Cihák (2012) estimated the H-Statistic for the UK over the period 1999 to 2005 and found that small banks in the UK were more competitive than large banks over the same period.

Overall these studies suggest that the best representation for UK banks is one of monopolistic competition with firms enjoying some market power. The results also suggest that since the year 2000 competition intensity in the UK deteriorated.

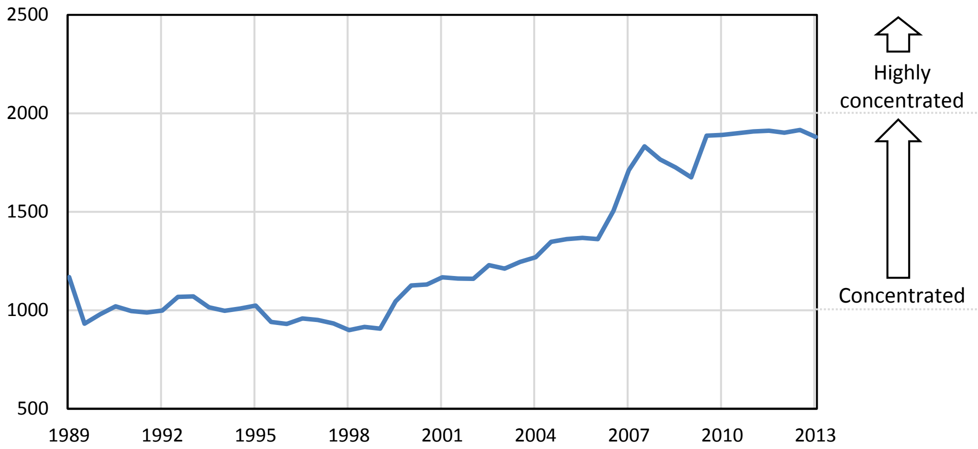
3 Empirical results

In this section, we estimate the performance-based measures discussed in section 2 based on the individual deposit-taker data available in our dataset. Appendices 1 and 3 describe the data used for each indicator and the main characteristics of the database used. All performance-based measures are derived from parameters estimated from panel regressions.

3.1 The Herfindahl-Hirschman Index (HHI)

We calculate the HHI shown in equation (1) (of appendix 4) using data on total assets for traditional model deposit takers. Figure 3.1 below shows the progression of the HHI over the sample.

Figure 3.1: Herfindahl-Hirschman Index – Total Assets[1]



Source: Bank of England, Authors' calculations

Notes:

[1] For deposit-takers using traditional finance model

The value of the HHI for total assets indicates that the deposit taking sector is on the border of being concentrated over the first decade of the sample. Mergers in 2000 (Barclays and Woolwich Building Society; Royal Bank of Scotland and National Westminster Bank) saw the HHI move from 907 at the end of 1999 to 1,130 by end 2000. Concentration then continued to rise steadily reflecting both faster growth by larger banks and the ongoing absorption of smaller banks. The purchase by RBS of the ABN AMRO businesses in 2007 saw the HHI rise by 470 points from 1,362 in 2006 to 1,832 in mid-2008, an increase of more than three times the 150 point increase that competition authorities note could give rise to concerns about competition in an already concentrated ($HHI > 1{,}000$) market. Lastly, the merger of Lloyds Banking Group and HBOS, along with Barclays purchase of Standard Life Bank, increased the HHI by 213 points to 1,887 in the first half of 2010. Concentration subsequently remained high at around 1,900, close to the 2,000 threshold for a highly concentrated industry.

However, the implication of this measure of the HHI for competition are not clear for a number of reasons: the HHI provides no indication of the contestability of the sector; the use of group data means expansion into non-UK markets can distort the measure; and total assets are not representative of any particular banking services market. We calculate the HHI for deposits, total loans, mortgages and unsecured loans in Figure A2.1 of Appendix 2 and find a similar pattern for deposits and total loans (reflecting the selection of the traditional financing model). However, concentration in the unsecured loans sector is considerably higher than for total loans, while concentration in mortgages remained considerably lower than for assets until 2009, after which the increase in concentration reflects a number of mergers (most notably the merger of Lloyds and HBOS in late 2008).

3.2 The Lerner index

We follow Berger et al. (2009) to estimate the marginal cost and output price for the standard approach to the Lerner index (discussed in section 0) and follow Kumbhakar et al. (2012) to measure the Lerner index indirectly using the stochastic frontier approach (see section 0). We estimate a third version of the index using the standard approach which is a market power proxy for credit provision only and excludes other services provided by banks (Kick and Prieto (2013) and Coccorese (2014)). Finally, we provide additional robustness tests by estimating Lerner indices over data sub-periods to help ensure average cost function parameters are well behaved.

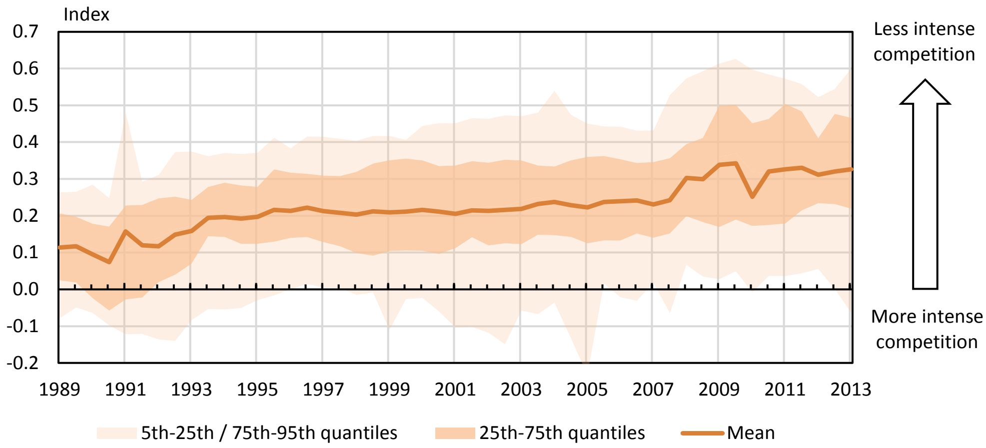
The total cost function in equation (3) (of appendix 4) is estimated using a panel regression with fixed cross-section effects and clustered errors to allow for intragroup effects.[4] We use total expenses related to firms financial intermediation function for total costs ($C_{i,t}$ in equation (3) of appendix 4). For input prices we proxy: staff costs ($W_{1,i,t}$) using the ratio of annual personnel expenses to total assets; physical capital ($W_{2,i,t}$) using the ratio of other operational expenses (non-interest, non-labour) to fixed assets; and average firm funding rate ($W_{3,i,t}$) using the ratio of interest expense to total deposits. We proxy total output ($Q_{i,t}$) by using total assets and use the ratio of total revenue to total assets to proxy banks' output price (P in equation (2) of appendix 4). To ensure linear homogeneity in the input costs, we divide total costs and input prices by the average firm funding rate $W_{3,i,t}$. The Lerner index is calculated for each bank and we take the mean as the aggregate measure. Figure 3.2 shows the evolution of the average Lerner index among all banks and the range measured by the 5th, 25th, 75th and 95th quantiles.[5]

[4] Estimating the Lerner index using other permutations (e.g. time fixed effects) produces similar results.

[5] The Lerner index is calculated for each firm using the estimated relationship. The central estimate of the Lerner index is calculated as the average for all firms at each point in time. The quantiles correspond to the distribution of Lerner index calculations for each firm.

Figure 3.2 shows that the price-cost margin increases steadily over the period, with the average moving from 0.1 in 1989 to just over 0.3 in 2009 at the height of the financial crisis and remains mostly above 0.3 until the end of the sample. The index is stable within a range of 0.21 and 0.24 between 1997 and 2007 suggesting that market power did not change significantly over an extended period of time, although we note that margins were, on average, higher over the second half of this period. Between 1998 and 2007 the values of the index taken by different banks (the quantile range) widens with respect to earlier periods. After the 2008 financial crisis the range widens even further and the average increases.

Figure 3.2: Lerner index – standard calculation



Source: Author's calculations

To check the robustness of the estimated parameters in the marginal cost function, we re-estimate the Lerner index over four sub-periods.[6] The sub-periods are between 6 and 8 years long, overlap slightly and coincide with significant changes in the UK financial and regulatory infrastructure (as described in de-Ramon et al. (2016a) and de-Ramon et al. (2016b)): (1) 1989 to 1996 which covers the first Basel accord; (2) 1996 to 2002 which includes the introduction of the Basel accord market risk amendment to the UK bank regulations, increased trading assets and ends with the bursting of the 'dot.com' bubble; (3) 2002 to 2008 which begins with the creation of HBOS and ends with the onset of the financial crisis; and (4) 2008 to 2013 which includes the post-crisis industry consolidation and subsequent contraction in economic activity.

Figure A2.2 in Appendix 2 shows estimates for each of the four sub-periods along with our central, full sample estimate. We note that the full sample estimate is contained within the 25-75% quantile range of all the sub-period estimates (and coincides exactly with the sub-period (3) estimate). Moreover, while the estimates in sub-periods (1), (2) and (4) do not coincide with the level of the full sample estimate, the patterns within sub-periods (1) and (2) are the same – that is, market-power increases over time. Sub-period (4) also broadly moves in line with the full-sample estimates, although market power starts to decline at the end of this sub-period. One trend to highlight is the drop from 0.29 to 0.21 in the estimated index between sub-

6 Other sub-periods investigated included fixed four and six year averages. The conclusions drawn were the same in all cases.

periods (2) and (3). This change is difficult to interpret as different cost function parameters are estimated for each period and thus different values are predicted for the same data point (e.g. 2002). We could argue that average market power fell as production technology changed between the two sub-periods. However, the trend between 2002 and 2007 is one of increasing market power with the Lerner index back at 0.3 by the end of the period. We can conjecture that the estimates in sub-periods exaggerate underlying changes in technology which are better integrated in the whole period estimates. Alternatively, the differences in the level could simply reflect noise in the data.

We implement further robustness tests on these results following Berger et al. (2009) by adding year fixed effects and robust standard errors to capture the specificities of each firm through time. In addition, following Matthews et al. (2007) we add environmental variables and period dummies to the regression to control for other factors that may evolve over time and affect the cost function parameters. In general, the alternative Lerner index estimates follow a similar trend and increase over the whole period and the conclusion that market power increased steadily over the period remains.

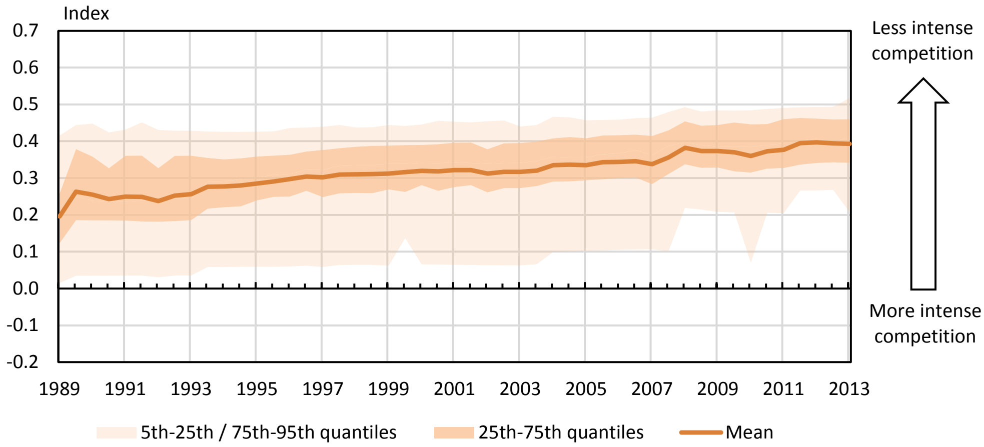
We now estimate the Lerner index using the stochastic frontier approach (discussed in Appendix 4) using: the ratio of total revenue to total costs ($RC_{i,t}$) as the dependent variable and as regressors we use total assets as a measure of output and input prices for labour, funding and fixed capital as before.[7] The results in Figure 3.3 below show that industry margins rose steadily through the period. We note in particular that there is a clear increase in the index over the 4 year period leading up to the financial crisis, with the index rising from 0.32 in the first half of 2003 to 0.36 in the first half of 2008.

As a check on our results, we also estimated an alternative formulation of the Lerner index using the standard estimation methodology. For this estimate, we narrowed the measure of bank output by constructing a mark-up proxy for competition in credit provision only (i.e. excluding other bank services), following Kick and Prieto (2013) and Coccorese (2014). We assume that the appropriate measure of output for the total cost function is total loans and that the price of output is only interest and fee income per loan.[8] The corresponding Lerner index is shown in Figure A2.3 in Appendix 2 and shows two peaks in 1994 and 2004 and two troughs in 2001 and 2008. Otherwise the average index remains fairly stable over the period within a range of 0.39-0.47. The pre-crisis period (2005 to 2008) shows a narrowing of the range of mark-up values suggesting fewer deposit takers were able to maintain higher margins. These results, in combination with the estimates of the Lerner index for all activities, suggest that competition in credit provision was relatively stable but saw periods of stronger competition even as the overall market power of deposit takers increased over the period 1989-2013. This observation is consistent with Matthews et al. (2007) who find that competition in the non-interest element of banking weakened between 1991 and 2004 implying that British banks altered their business models to increase their collective market power.

7 We do not need a proxy for the output price P under this approach.

8 These results need to be interpreted with caution as the price of output includes income from fees and may overstate the true price of loans at different points of time.

Figure 3.3: The Lerner index – stochastic frontier approach



Source: Author's calculations

3.3 The Panzar-Rosse H-statistic

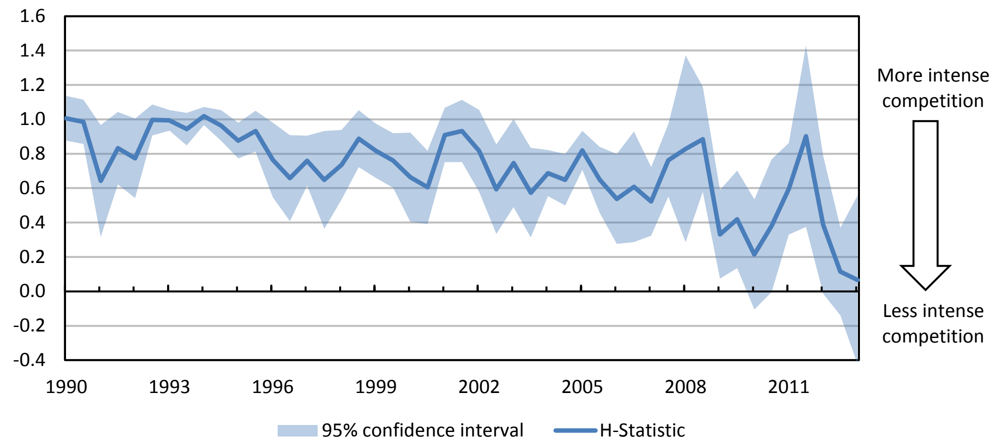
We estimate the Panzar-Rosse H-statistic using an unscaled measure of total revenues[9] ($TR_{i,t}$ in equation (9) of Appendix 4), following the methodology set out in Bikker et al. (2012).[10]. The key financial sector costs for the regression are labour, physical capital and funding,[11] defined as above in the Lerner index calculations. We also included a number of firm-specific factors as control variables that reflect deposit-taker behaviour and risk profile: average risk weights, the ratio of provisions to assets, the ratio of tier 1 to total capital, the ratio of loans to assets, the ratio of non-financial deposits to total deposits, the ratio of non-earning assets to total assets and UK real GDP growth. Finally, we include firm specific and time specific fixed effects. We used a panel regression with fixed time effects and clustered errors (to allow for intragroup effects) to estimate the H-statistic at each point in our time series.

9 The choice of control variables $X_{i,t}$ in equation (9) usually includes some measure of assets which, in effect, acts as a scaling variable for total revenues $TR_{i,t}$. Bikker et al. (2012) review many studies and demonstrate that using a scaled revenue specification yields inconsistent measures of the H-statistic.

10 Bikker et al. (2012) estimate the Panzar-Rosse index for a number of countries between 1994 and 2004 including bank specific effects. For the UK their preferred estimate is significantly below 1 but they also find that UK firms are not in long term equilibrium through the whole of that period.

11 This choice is in line with past Panzar-Rosse applications to banking, for example Bikker et al. (2012), Goddard and Wilson (2009) or Shaffer (2004).

Figure 3.4: Panzar-Rosse H-statistic – rolling period estimates



Source: Author's calculations

Figure 3.4 above shows the central estimates of the H-statistic using rolling fixed time panels of two data periods (one year), with the outcome shown in the second period, and including the 95% confidence interval. Figure 3.4 suggests that there was very strong competition between UK banks up to 1994 but that market power subsequently increased over time bringing the H-statistic significantly below one.

However, the H-statistic needs to be estimated where there is a long-run competitive equilibrium if estimates are to be valid. Shaffer (1982) shows that, where there is a long-run competitive market equilibrium, the return on assets should be equalised across firms regardless of input costs.[12] We follow the test formulated by Shaffer to establish periods when the market was in long-run equilibrium. The test is performed by substituting the ratio of total net income to total assets (a measure of return on assets) for total revenue in equation (9) of Appendix 4 and calculating the modified H-statistic, H^{ROA}, as before. Where we cannot reject the hypothesis that $H^{ROA} = 0$, there is a long-run competitive equilibrium and measures of the H-statistic are valid.[13]

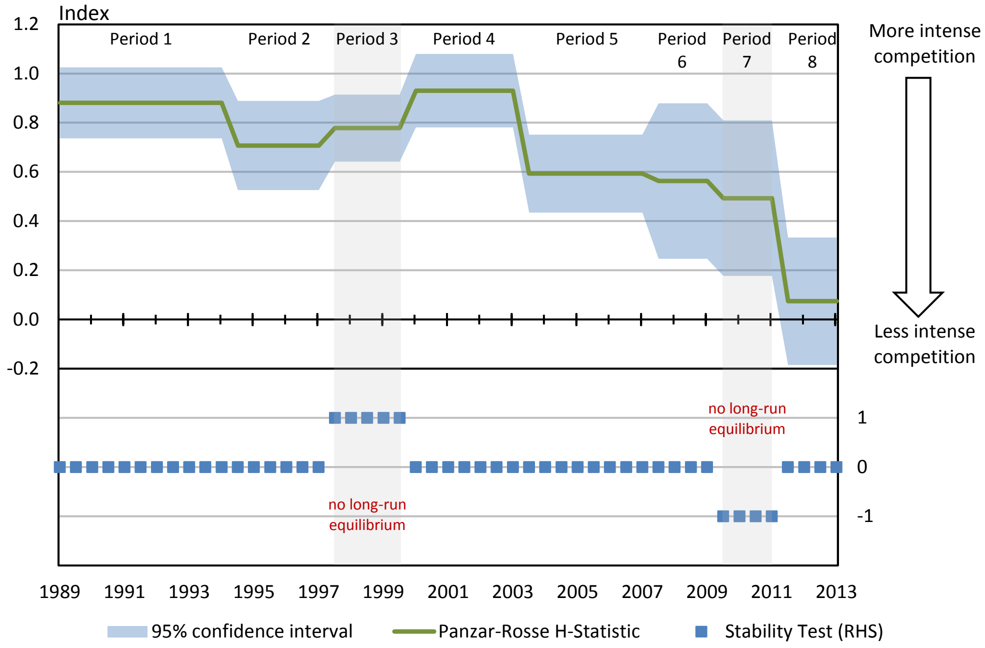
We use rolling time windows of varying size to determine the long-run equilibrium sub-periods within our full sample. The strategy is first to construct the stability test for rolling four-year periods – for example, using all data between 1989 and 1992, then all data between 1990 and 1993, etc. – then increase the size of the window by adding an additional time period and note in which sub-periods and for which window size we reject the long-run equilibrium hypothesis. At the end of the process we were left with the largest possible windows that do not reject long-run equilibrium. We then estimate the H-statistic for each of these periods.

[12] Bikker et al. (2012) estimate the H-statistic for a number of countries for the period 1994 to 2004 including bank specific effects. For the UK, their preferred estimate is significantly below 1 but they also find that UK firms are not in long-term equilibrium throughout the estimation period

[13] The stability test is a two-sided t-test and H^{ROA} can take negative and positive values. Shaffer (1982) notes that, when $H^{ROA} < 0$, an increase in input prices reduces return on assets with the implication that, in the short run, the firm it cannot immediately pass on higher costs. Where $H^{ROA} > 0$, an increase input prices *increases* return on assets. Shaffer postulates that this may arise if demand pull factors forces the firm to bid up the price of inputs, although this explanation remains conjecture.

This process yields eight separate periods: two separate periods of disequilibrium, the first from 1998 to 2000 ($H^{ROA} > 0$) and the second from 2010 to 2011 ($H^{ROA} < 0$); and six periods where long-run equilibrium is present (1989 to 1994, 1995 to 1997, 2000 to 2003, 2004 to 2007, 2008 to 2009 and 2012 to 2013). The periods of disequilibrium may reflect two disruptive influences in the UK financial sector: the cluster of building society demutualisations in the mid-1990s, and the immediate aftermath of the 2008 global financial crisis.

Figure 3.5: Panzar-Rosse H-statistic and stability test



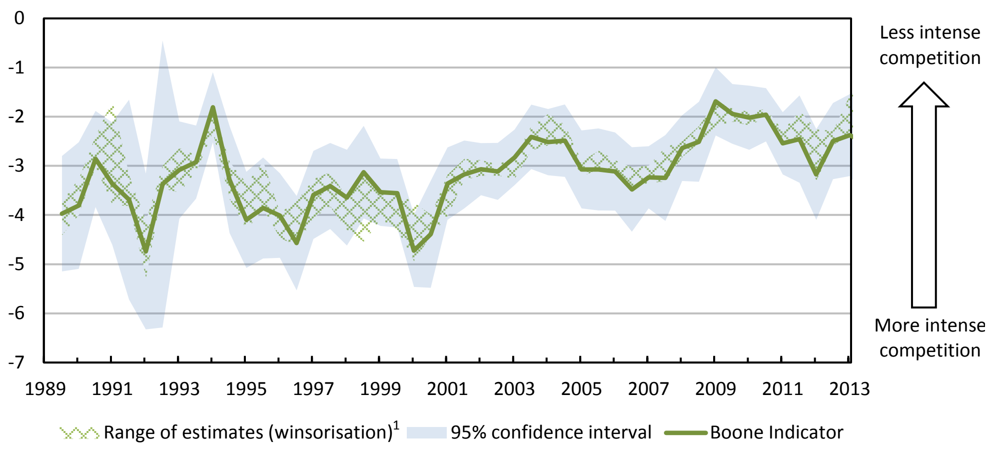
Source: Author's calculations

Figure 3.5 above shows our estimates of the H-statistic including the 95% confidence interval and the outcome of the stability test for the eight periods identified. We find that the H-statistic is close to one for much of the period from 1989 to 2003, excluding only the two years from 1995 to 1997 (and ignoring the disequilibrium period 1998-2000). We then find that the H-statistic moves to a much lower level for the period 2004 to 2009 and lower again for the period 2012-2013 (again ignoring the disequilibrium period 2010-2011). Note also that the 95% confidence interval widens substantially at the end of the sample, most likely reflecting volatility around the time of the financial crisis. One final observation is that the move lower in the H-statistic in the period 2004-2008 suggests that competition intensity between deposit takers declined prior to the financial crisis, consistent with the findings from the Lerner index.

3.4 The Boone indicator

The approach we follow for estimating the Boone indicator is that of Schaeck and Cihák (2014). We use a panel regression with fixed bank-specific effects, robust errors and allowing for intra-group clustering. Variable profits ($\pi_{i,t}$ in equation (11) of appendix 4) are measured as total income reported by deposit takers scaled by total assets, while variable costs ($c_{i,t}$ in equation (11)) are measured as total costs scaled by interest received and income from foreign exchange, investment, fees and other sources. We use similar bank-specific controls as those used for the H-statistic, including average risk weights, the ratio of provisions to assets, the ratio of tier 1 to total capital, the ratio of loans to assets, the ratio of non-financial deposits to total deposits, the ratio of non-earning assets to total assets and UK real GDP growth. To estimate the Boone indicator over the sample, we construct a dummy variable for each time period and include it and the interaction with costs in the estimation. The Boone indicator is extracted as the coefficient in each time period of the interaction variable. Finally, we exclude the largest regression outliers using a standard winsorisation process.[14]

Figure 3.6: Boone Indicator



Source: Author's calculations

Notes:

[1] Hatched area shows the range of winsorised estimates for the Boone indicator, where data points generating largest errors are sequentially removed. The range shows the maximum and minimum estimates for up to 20 iterations of the winsorisation process.

The final estimates for the Boone indicator are shown in Figure 3.6 above. We include in the chart the 95% confidence interval around the central estimates of the Boone indicator, which is relatively stable across the entire period. The Boone indicator is more volatile than the other measures, but nevertheless shows a pattern of less intense competition (exercise of greater market power) from the early 2000s through to end of the period. As a further robustness check, we also show how the winsorisation process changes the central estimates. Successively removing the outliers does not substantially change the estimate, but does has the effect of making the overall upward trend in the Boone indicator more pronounced, particularly over the last decade of the sample where the winsorisation tends to result in higher estimates of the Boone indicator (hatched area in Figure 3.6).

We implement a further robustness check for the Boone indicator using an alternative sub-sample. Following van Leuvensteijn (2011) we exclude specialised deposit takers such as investment banks that do not create loans. This alternative statistic reflects the reallocation of profits from less to more efficient banks that compete more directly on loans. The estimation results are shown in Figure A2.4 of Appendix 2 and show a clear trend over time towards less intense competition.

[14] We calculate the fitted values from the estimated model and exclude observations less that are less than 1% or greater than 99% of the distribution. This process is undertaken iteratively. Our central estimate involves two iterations of the winsorisation process.

Looking at sub-periods, the Boone indicator for lenders during the first half of the 1990s was around -5 suggesting that competition was more intense than in any other period. After 1994 there is a sudden shift towards less intense competition but it is a stable period until 2001 with a value of around -4. Subsequently, the indicator trends towards less intense competition until 2005 with a slight rebound before the financial crisis. In the final period the indicator shifts again towards less intense competition settling around a value of -2.

3.5 Comparison across competition indicators

Table 3.1 below shows the average value for each of the competition measures for the eight periods derived for the H-statistic.

Table 3.1: Combined measures of competition intensity[1]

	Lerner index[2]		H-Statistic[4]	Boone Indicator[5]	*Note*: HHI[6]
	Standard	Efficiency[3]			
Period 1 (1989–1994)	0.14	0.25	0.88	-3.36	1021
Period 2 (1995–1997)	0.21	0.29	0.71	-3.90	969
Period 3 (1998–2000)[7]	0.21	0.31	0.78	-3.46	971
Period 4 (2000–2003)	0.21	0.32	0.93	-3.52	1154
Period 5 (2004–2007)	0.23	0.34	0.59	-2.92	1396
Period 6 (2008–2009)	0.30	0.37	0.56	-2.52	1749
Period 7 (2010–2011)[7]	0.31	0.37	0.49	-2.12	1896
Period 8 (2012-2013)	0.32	0.39	0.07	-2.63	1898

Source: Bank of England, Authors' calculations

Notes:
[1] Periods are derived from the Panzar-Rosse H-statistic stability test used for calculating the long-run equilibrium sub-periods
[2] Lower values of the Lerner index indicate greater competition intensity
[3] Efficiency adjusted measure of the Lerner index
[4] Higher values of the H-statistic indicate greater competition intensity
[5] Lower values of the Boone indicator indicate greater competition intensity
[6] HHI index for total assets.
[7] Periods where the stability test associated with the H-statistic indicates that there is no long-run competitive equilibrium

Estimates of the H-statistic show that, at the beginning of the sample, competition intensity was strong in periods 1 through 4. This is supported by the more negative values for the Boone indicator. The Lerner index suggests competition was more intense early in Period 1. However, periods five and six (highlighted in the table) show a distinct reduction in the intensity of competition from earlier periods across all measures.[15] Most pertinently, this includes the four years immediately prior to the 2008 financial crisis (period 5, from 2004 to 2007) and the period of the crisis itself (period 6, from 2008 to 2009). There is less consensus between the measures for the periods after the crisis (periods 7 and 8, from 2010 to 2013) most likely reflecting

[15] We discuss the possibility of intense competition in credit provision as suggested by the Lerner index on loans in section 3.2

the considerable economic uncertainty and regulatory change undertaken over these periods.

We can quantify the statistical significance of these differences for some measures. From our estimates of the H-statistic in section 3.3 we know that during periods 1 and 4 the statistic is not significantly different from one (the perfect competition outcome), but significantly different from one during periods 5, 6 and 8 (with period 8 being statistically indistinguishable from zero). Table 3.2 below shows statistical tests based on the Boone indicator for periods 1 to 8 identified for the H-statistic. The table reports the probability from a Wald test of the hypothesis that one period (denoted in rows) is statistically different from another period (in columns). The table shows that the average Boone indicator estimated for periods 1 to 4 (1989-2003) is statistically different from those of periods 5 to 8 (2004-13). The estimated average Boone indicators for periods 1 to 4 are not-statistically different from each other and most differences in consecutive periods are not statistically different from zero. However, period 5 (2004-07) is significantly different from 4 (2000-03) and period 8 (2012-13) is significantly different from period 7 (2010-11).

Table 3.2: Boone Indicator – tests for statistical difference between periods[1,2,3]

	Period 1	Period 2	Period 3	Period 4	Period 5	Period 6	Period 7	Period 8
Period 1 (1989–1994)	–	0.920	0.664	0.632	0.100	0.032**	0.001***	0.005***
Period 2 (1995–1997)	–	–	0.341	0.428	0.021**	0.004***	0.000***	0.000***
Period 3 (1998–2000)	–	–	–	0.945	0.052*	0.018***	0.000***	0.002***
Period 4 (2000–2003)	–	–	–	–	0.015**	0.003***	0.000***	0.000***
Period 5 (2004–2007)	–	–	–	–		0.296	0.001***	0.021**
Period 6 (2008–2009)	–	–	–	–	–	–	0.013**	0.125
Period 7 (2010–2011)	–	–	–	–	–	–	–	0.502
Period 8 (2012-2013)	–	–	–	–	–	–	–	–

Source: Bank of England, Authors' calculations

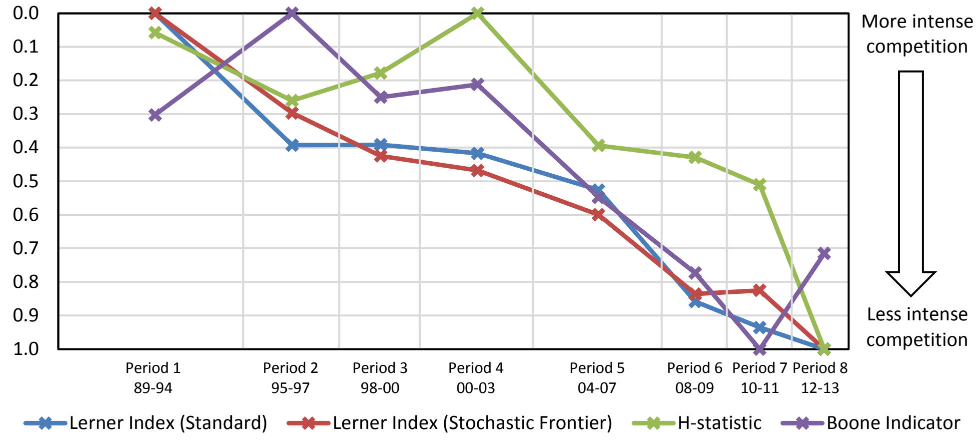
Notes:
[1] Periods are derived from the Panzar-Rosse H-statistic stability test used for calculating the long-term equilibrium sub-periods
[2] Asterisks indicate probability from hypothesis test $H_0\colon Period\ i \neq Period\ j$ for $i \neq j$ where $p < 0.1$ = *; $p < 0.05$ = **; $p < 0.01$ = ***
[3] Test are Wald tests of composite linear hypotheses on the Boone regression estimated parameters and variance-covariance matrix.

Figure 3.7 below provides a visual representation of the combined outcomes of the four performance-based measures. All measures are normalised such that values lie between zero and one[16] with zero indicating the value where competition intensity for each measure is at its maximum and one indicating the value where competition

[16] The measures are normalised using the formula $x^{norm} = (x - \underline{x})/(\overline{x} - \underline{x})$ where x is the average value of the measure in each sub-period, $\underline{x}$ is the minimum value of the averages for the sub-periods and $\overline{x}$ is the maximum average value.

intensity is at its minimum over the sample. The eight periods correspond to the long-term equilibrium sub-periods calculated for the H-statistic[17] (as noted in section 3.3). On this scale, the consistent trend towards less intense competition in general over the entire period is clear.[18]

Figure 3.7: Combined measures of competition[1,2]



Source: Author's calculations

Notes:

[1] Periods are derived from the Panzar-Rosse H-statistic stability test used for calculating the long-term equilibrium sub-periods

[2] Measures are normalised such that zero corresponds to the most competition intensity and one the least competition intensity for each measure

4 Conclusion

The measures of competition intensity calculated in this study suggest that the firms in our dataset are able to extract market rents and earn positive economic profits. The H-statistic, Boone indicator and Lerner indexes indicate that firms, while initially experiencing a period of more intense competition, were increasingly able to extract market rents from customers in the period leading up to the financial crisis and in the post-crisis period.

De-Ramon and Straughan (2016) compare the outcome of these measures with observed trends in the UK deposit-taking sector. They explore in more detail how competition intensity has evolved over time, in particular since the significant reforms enacted in the 1980s and the periods immediately before and after the financial crisis. They find three main sub-periods that more or less corresponds to the empirical findings: consolidation period from 1989 to the early 2000s. post-millennium, pre-crisis period with strong competition in certain market; and the crisis/post-crisis period characterised by banks' ability to extract market rents.

[17] As the H-statistic is not valid for periods 3 and 7, any average that partially included these periods will also be invalid. The average of other measures of competition are valid for these sub-periods.

[18] A similar pattern is observed when the sample is split up into equal periods of 3 years (8 sub-periods) and 4 years (6 sub-periods) although, as noted above, averages for the H-statistic are not valid for averages that include the periods 1998-2000 or 2010-2011

We performed direct tests of the departure from the 'perfect competition' outcomes of UK deposit takers using performance-based measures of competition. Our results indicate that, along with increasing concentration, there was an overall trend of increasing market power / falling competition intensity over the sample from 1989-2013. We note that care needs to be taken when interpreting the performance-based measures, pointing out where the theory and data are ambiguous. In particular, these indicators are less useful in assessing the statistical significance of small movements in competition, especially during small or consecutive time intervals.

The ability to earn super-normal profits by these firms does not necessarily imply that competition is low in all markets which these firms supply products. The performance based measures can be adapted to study competition at a more granular level, e.g. for specific markets such as unsecured loans or mortgages. The differences in the measured price-cost margin for all firm activities (as measured by the Lerner index) versus an inspection of interest rates on individual lending activities suggests that the intensity of competition is higher for some deposit takers' lending activities (and most likely strongest in the market for mortgages than other loans) than for other sources of income (including sales from bundled products, advice and 'investment banking' activities). Using a loan- specialised Boone indicator we show that the competition among those banks may have been more intense during certain periods but also find an overall decreasing trend in competition over time. These more granular estimates are sensitive to a number of assumptions, caveats and uncertainties. We recommend using a battery of indicators also considering the structure of the specific market and existing barriers.

Many studies focus on the number of firms participating in specific financial services markets to proxy the short-term evolution of competition. We show that these structure measures may not be adequate to identify competition outcomes in the UK. In particular, they may not provide a good indicator of how competition affects efficiency and financial stability due to the complexity of the banking business and the many sources of income (and risk). The performance-based measures of competition offer alternative methodologies that take into account the interaction between firm efficiency and competition.

It is also important to complement empirical studies with a good understanding of the regulatory, structural and technological constraints that drive competition. De-Ramon and Straughan (2016) show that UK policy initiatives on those constraints led to mixed long-term outcomes. For example, that lifting barriers between banks and building societies and promoting European banks to compete in a single financial market did not deliver improvements in competition within the UK banking sector. Due to the complex nature of banking business and the possibility of increased market share through consolidation, policy makers need to undertake ex-post assessments of the competition implications of their policies. In addition, changes in competition due to prudential policy may be important for the long-term prospects of financial stability (e.g. an enlarged non-bank sector as a result of capital and funding requirements on regulated banks).

The measures we have calculated also suggest that the relationship between competition in those markets in which deposit takers participate and financial stability is not straightforward. Our results suggest that intense competition in some markets can coexist with an increasing ability of firms to extract market rents when operating across multiple markets. Moreover, our estimated measures of competition intensity suggest periods in which financial instability coincides with both stronger (i.e. early 1990s small banks crisis) and weaker (i.e. 2008 financial crisis) competition.

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Appendix 1 Key Data for Regressions

Table A1.1: Data and assumptions used in regressions[1]

Indicator	Version	Perfect competition outcome	Model assumptions	Dependent variable	Explanatory variables	Environ-mental factors	Reference
Lerner	Standard price-cost margin measure	Output price convergence with marginal cost	Output mix and price, translog cost function, homogeneity	Total Cost	Cost input prices, core Tier 1 capital, total assets	For robustness checks	Casu and Girardone (2009)
	Mark-up adjusted price-cost margin measure	Output price convergence with marginal cost after considering efficiency of each firm	Output mix, translog cost function, homogeneity, half-normal efficiency distribution	Revenue to total cost ratio (revenue per each pound spent)	Input prices, core Tier 1 capital, total assets	For robustness checks	Kumbhakar et al. (2012) Coccorese (2014)
Panzar-Rosse	Test of competitive market equilibrium	Profits correlated with input prices under perfect competition	Translog production function	Profits (return on assets)	Input prices	Yes, for robustness checks	Bikker et al. (2012)
	H statistic of market power	No pricing market-power	Translog cost function	Total Revenue (unscaled)	Input prices	For robustness checks	Bikker et al. (2012)
Boone		Competition increases profit share of most efficient firms	Linear relationship	Profits (return on assets)	Efficiency (proxied by total cost to total revenue ratio)	Yes	Schaeck and Cihák, (2010)

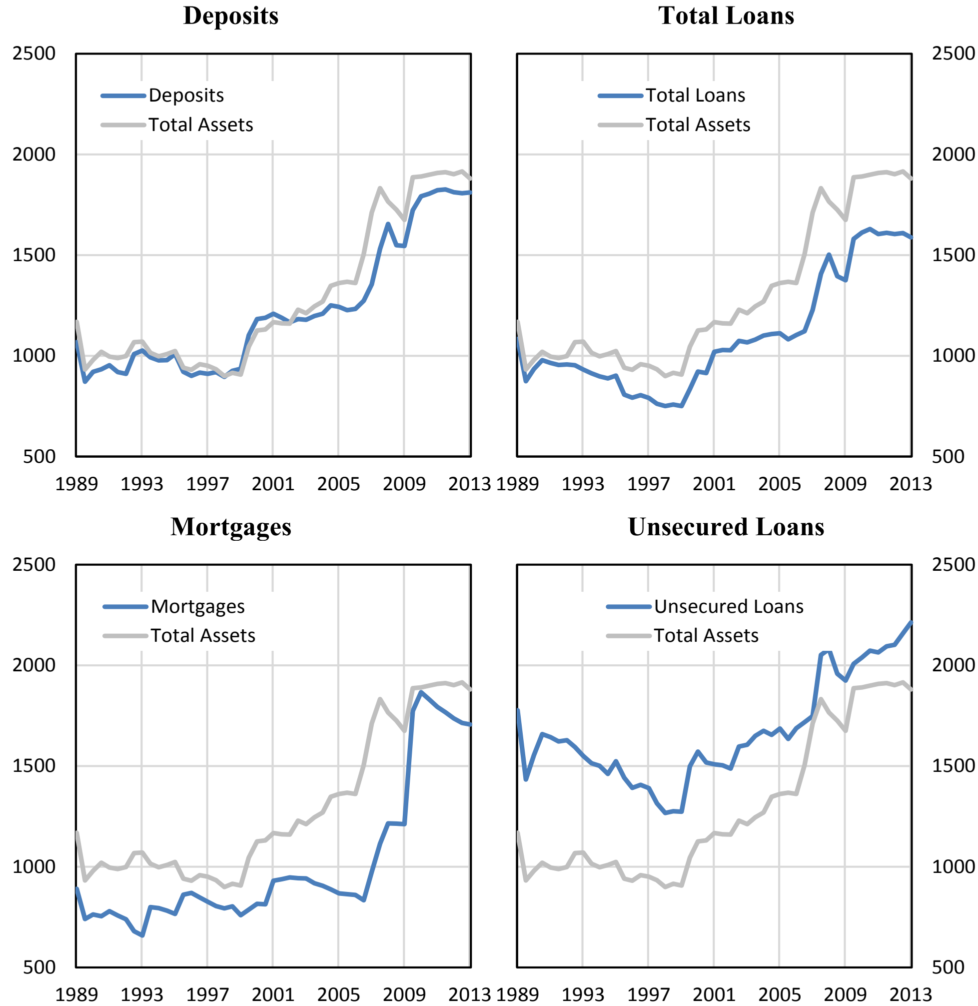
Source: Authors

Note(s):

[1] All five empirical measures are transformation of fixed effects panel regression parameters; fully loaded regressions (time and bank effects) were also implemented. The data panel consists of banking group data regarding UK and non-UK balance sheet exposures and income account information. Environmental factors are: average risk weight, provision ratio, Tie1 capital ratio, loan to assets ratio retail deposit ratio of liabilities other non-earning assets ratio, group size, GDP growth, period dummies.

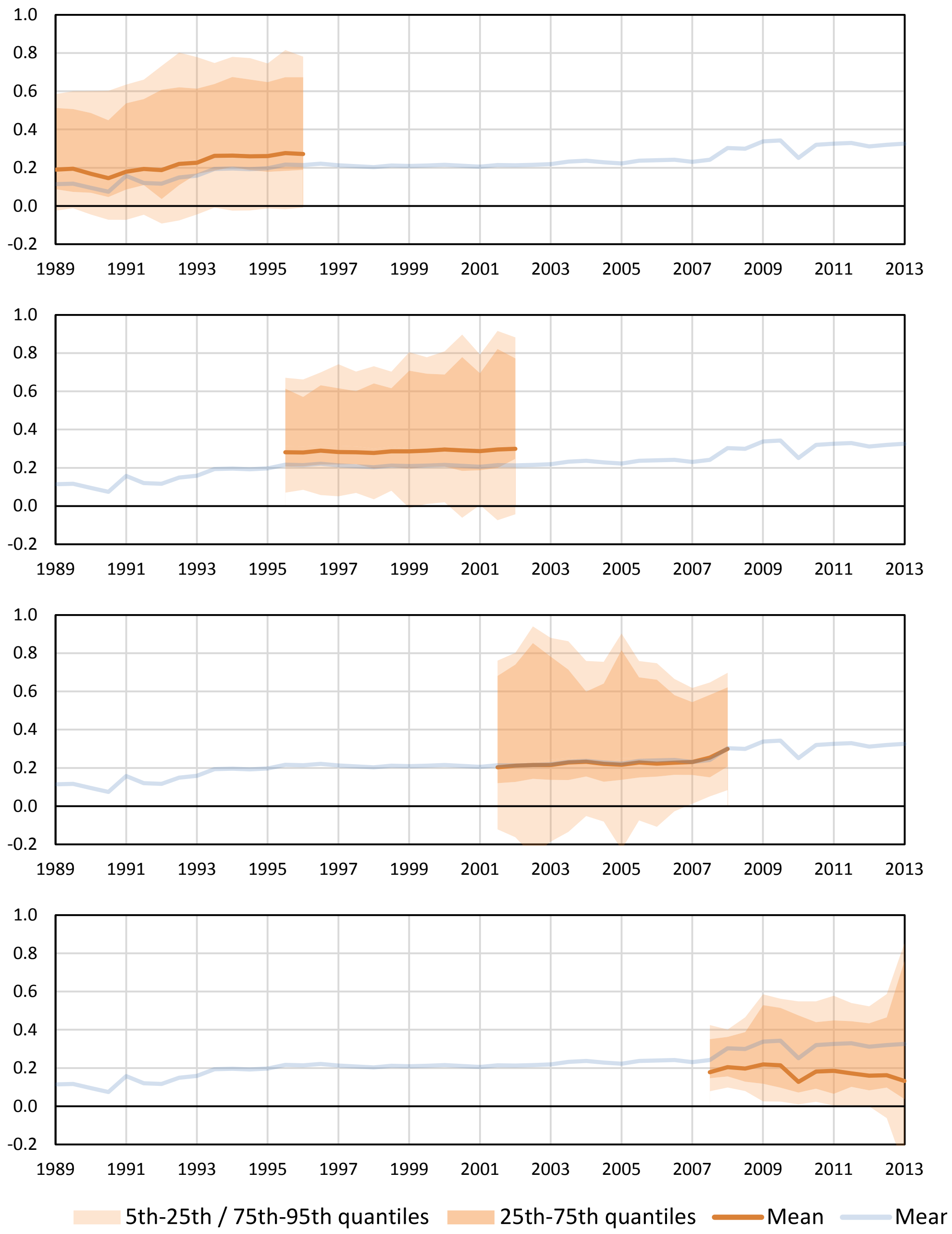
Appendix 2 Additional Indicators

Figure A2.1: HHI Index of sectors – traditional banking model



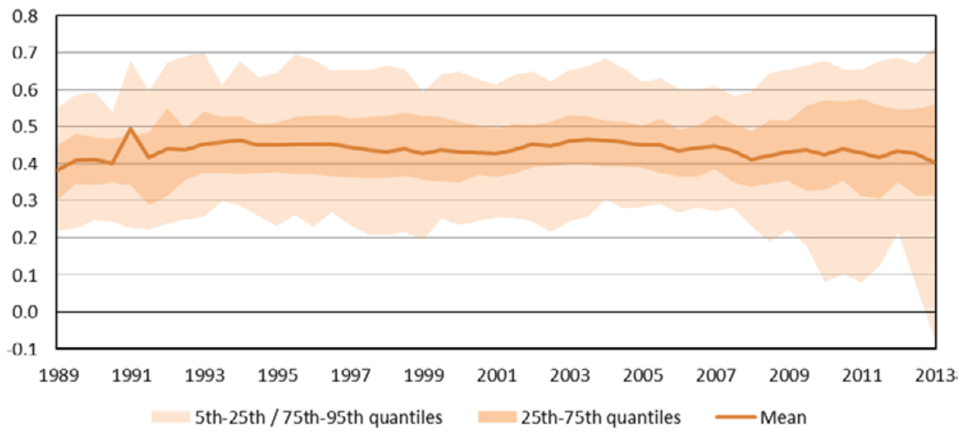
Source: Bank of England, Authors' calculations

Figure A2.2: Estimation of Lerner index over sub-samples



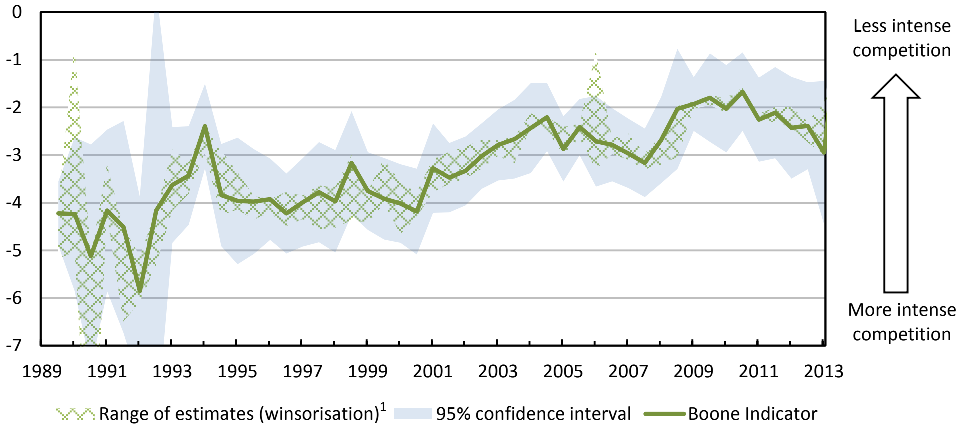
Source: Bank of England, Authors' calculations

Figure A2.3: Lerner index for Total Loans



Source: Bank of England, Authors' calculations

Figure A2.4: Boone indicator for Total Loans



Source: Bank of England, Authors' calculations

Appendix 3 Data for the UK regulated deposit taking sector

We use a newly-compiled dataset of the UK deposit-taking sector in this study (de-Ramon et al. (2016a)). The dataset is drawn from regulatory reports generated by a number of different agencies to produce a large, unbalanced panel dataset that includes all UK-regulated deposit takers. Regulatory data was collected by three different agencies – the Bank of England, the Financial Services Authority (FSA) and the Financial Conduct Authority (FCA) – over the period 1989-2013. In addition, there were a number of changes to the data collected resulting from changes to the regulatory regime, in particular the move from Basel I to Basel II, which needed to be reconciled.

Deposit takers include two distinct business models: banks and building societies. Banks are incorporated and have freedom to undertake a wide range of activities (including non-financial business); building societies have a mutual ownership structure and have restricted funding and lending requirements. Building societies are owned by their deposit holders (members), 75% of business assets must be loans fully secured on residential property and 50% of the funds (liabilities) must be held by members. The data is reported on a semi-annual basis for the period 1989 to 2013 and includes firms' balance sheet and profit and loss data.

We also focus on firms that undertake traditional financial intermediation roles – that is transforming deposits into loans. We have excluded those firms that either do not fund their activities significantly with deposits or use their funding to provide loans. We exclude those firms that have a loan-to-assets ratio of less than 10% and a deposit-to-assets ratio less than 20%, consistent with other studies focussed on competition between deposit takers. The excluded firms are largely focussed on trading activities or other financial market products, and in general are not competing with the more traditional role of financial intermediation. Where firms have operated both traditional and non-traditional models at different points in time, we have excluded only those observations where the non-traditional model was dominant. Table A3.1 provides a summary of the types of firms in the data.

Table A3.1: Regulated firms by business models

	Number of:	
	firms	Observations
By business model		
Banks	105	2967
Building societies	21	545
By activity		
Traditional model[1]	74	2080
Non-traditional model	27	551
Mixed model[2]	25	881
– proportion of traditional activity[3]		55%
Total	126	3512

Source: Bank of England, Authors' calculations

Notes:

[1] The traditional model is defined where firms loan-to-assets ratio is greater than 10% and a deposit-to-assets ratio is greater than 20%

[2] Firms that operated under both traditional and non-traditional models at different points in the sample

[3] Average proportion of observations for which mixed model firms operated under the traditional model

Table 0.2: Selected data[1]

	Mean	Standard deviation	Median	Minimum	Maximum
Key variables[2]					
Total expenses	1609.8	5243.7	199.3	0.8	62527.5
Input costs					
(i) Staff costs	333.8	1437.5	33.9	0.1	14761.5
– ratio to total assets (%)	1.631	3.110	0.941	0.030	54.894
(ii) Physical capital	342.8	1430.8	25.9	0.3	15283.2
– ratio to total fixed assets (%)	340.9	1349.0	126.9	1.3	37194.5
(iii) Funding costs	934.7	2789.0	123.8	0.1	34009.0
– ratio to total deposits (%)	5.686	5.639	4.904	0.060	159.711
Total revenue	2056.4	7023.7	248.8	1.0	91521.4
– ratio to total expenses (%)	124.8	18.8	120.6	16.6	235.8
– ratio to total assets (%)	8.582	6.530	7.418	0.239	111.154
Variable profits	449.9	1963.5	38.4	-336.1	34778.5
– ratio to total assets (%)	0.599	1.055	0.489	-14.303	9.223
Variable costs	1272.9	4011.7	169.9	0.4	61674.5
– ratio to total revenue (%)	66.89	13.19	69.16	34.59	89.13
Control variables[2]					
Total assets	47734	203137	3474	1.7	1925711
Average risk weight (%)	56.08	19.22	52.20	3.88	136.13
Provisions to assets ratio (%)	1.401	3.622	0.655	0.003	53.060
Tier 1 to total capital ratio (%)	83.23	21.25	81.83	34.12	237.62
Total loans to assets ratio (%)	53.82	26.12	58.40	0.00	99.33
Non-financial deposits to total deposits ratio (%)	73.94	26.86	82.76	0.00	100.00
Non-earning assets to total assets ratio (%)	2.593	4.718	0.899	0.001	82.688

Source: Bank of England, Authors' calculations

Notes:

[1] Data is for firms with traditional model defined where loan-to-assets ratio is greater than 10% and deposit-to-assets ratio is greater than 20%

[2] All data in £ million unless otherwise specified

Group consolidated versus solo level data. Regulatory data for deposit takers is collected on both a group consolidated and solo basis for UK regulated firms. Solo level data reflects both the operations of stand-alone firms and of subsidiary level entities within a wider group, including operations within a narrow geographic definition of the UK. In contrast, the group consolidated data includes all global exposures for the group. Using solo data would allow us to focus on the operations within the clearly defined UK geographic boundary. However, groups operating in the UK use their global operations to source funding and otherwise provide competitive advantage to firms. Omitting global operations would exclude this information from the data. One additional advantage of using group consolidated data is that, where two solo-level firms are part of the same group, we can avoid distorting measures of competition where coordination by the group means that these firms may not compete with each other. We have consistently used group consolidated data throughout which means that the data includes both UK domestic and international exposures.

Treatment of mergers. In the regulatory data base, deposit-takers that merge sometimes continue to report data for both entities, using one entity as the merged group and the other as a solo entity, or report both entities on a solo basis and submit data for a third entity as the group. De-Ramon et al (2016a) discuss the reasons why firms were required to continue to report solo data for subsidiaries following a merger. We use the group consolidated data from the point at which the merger is effective and exclude subsidiaries that are included within the group but that continue to report solo data. As with the use of group consolidated data noted above, this can avoid any distortion of competition measures where coordination within the group might affect individual firm behaviour. It is possible that some information on competitive conduct could be excluded where the influence of group decisions does not immediately affect the conduct of newly acquired subsidiaries. Even so, it is not possible to determine subsequently when any influence might be exerted by group management so we use group data from the date of the merger.

Appendix 4 Measures used in this study

In this appendix, we review the measures from the literature that we use in this study to understand trends in competition. We begin with a measure of industry concentration, the Herfindahl-Hirschman index (HHI), and then discuss three performance-based measures: the Lerner index, the Panzar-Rosse H-statistic and the Boone indicator.

The Herfindahl-Hirschman Index (HHI)

The HHI is constructed directly from data and is generally straightforward to calculate. The HHI calculates concentration as the sum of the square of each firms' share in an industry or market, that is:

$$HHI = \sum_{i=1}^{N} s_i^2 \tag{1}$$

where s_i is the share of firm i in the market and N is the total number of firms. As firm share is calculated on a scale between 0 and 100, the HHI ranges from close to zero (a very large number of firms with very small market shares) to a maximum value of 10,000, in which a single firm holds a monopoly.

The HHI provides background on industrial sectors and/or markets, although it tells us little about the intensity of competition. Competition authorities in the UK (and elsewhere) make use of the HHI as an indicator of the *likelihood* that there could be a competition issue worthy of investigation. For example, an industry with an HHI of greater than 1000 is considered concentrated (and potentially worth of investigating) while an HHI of greater than 2000 is considered highly concentrated (CC (2014)). Competition authorities also use the HHI to signal whether merger activity warrants investigation under competition powers. A horizontal merger generating an increase in the HHI of less than 250 in a concentrated market is not likely to give cause for concern while in a highly concentrated market, an increase in the HHI of less than 150 is not likely to give cause for concern (CC and OFT (2010)). More generally, any event that generates increases in the HHI as noted above could also be worthy of investigation. There are a number of mergers in our dataset so these reference points are worth noting.

The Lerner index

The Lerner index is a measure of price-cost margin and is premised on the outcomes that: in perfect competition the output price (equal to marginal revenue) equals marginal cost (i.e. economic profits should be zero); and in a quantity-setting, Cournot static oligopoly model price rises above marginal cost as firm market power increases. Consequently, divergence of measured price-cost margin from zero should be an indicator of market power (Lerner (1934)).

The standard approach

Under the standard approach used in the literature, the aggregate Lerner index (L) is computed as:

$$L = \frac{P - MC}{P} \tag{2}$$

where P is the output price and MC is the marginal cost, aggregated for all firms.

For the financial sector, the difficulty in measuring prices of output goods and marginal costs is particularly acute. Deposit takers are involved in multiple activities, some of which can be defined as both outputs and inputs. For example, Berger and Humphrey (1997) propose a 'production approach' to banking, where deposits are a product providing services to customers while Freixas and Rochet (1998) propose an 'intermediation approach' in which deposits are an intermediate input in the production of loans. We take the approach common in the literature that deposit-takers predominantly have an intermediation role and that deposits are an input to the production of other products (such as loans). In line with the empirical literature we take a single output approach (Berger et al. (2009), Fernández de Guevara et al. (2007)) using total assets as the output measure while revenue associated with outputs is interest and non-interest income. We also consider total loans as a single output alternative (Kick and Prieto (2013), Coccorese (2014)) on the basis that credit intermediation is the main activity for banks.

Marginal cost MC is not directly observable for a particular firm or for individual products supplied by a firm. Empirically, standard estimates of the Lerner index are therefore derived by estimating the parameters of a total cost function from individual firm data and deriving the marginal costs from the equation parameters. For deposit-taking firms, the Lerner index is commonly calculated by assuming a total cost function of the form:

$$\begin{aligned}\ln\left(C_{i,t}\right) = {} & \alpha_0 + \alpha_1 \ln Q_{i,t} + \frac{\alpha_2}{2}\left(\ln Q_{i,t}\right)^2 + \sum_{j=1}^{3} \beta_j \ln\left(W_{j,i,t}\right) + \frac{1}{2}\sum_{k=1}^{3}\sum_{j=1}^{3} \alpha_{kj} \ln W_{k,i,t} \ln W_{j,i,t} \\ & + \sum_{j=1}^{3} \delta_j \ln\left(W_{j,i,t}\right). \ln Q_{i,t} + \lambda_1 E_{i,t} + \frac{\lambda_2}{2} E_{i,t}^2 + \theta_1 T + \theta_2 T^2 + \sum_{j=1}^{3} \lambda_j T \ln\left(W_{j,i,t}\right) \\ & + \Phi' X_{i,t} + \varepsilon_{i,t}\end{aligned}$$

where $C_{i,t}$ is total cost (or expenses) for bank i at time t, $Q_{i,t}$ is total assets, a proxy for bank output, $W_{j,i,t}$ are input prices reflecting labour costs (W_1), physical capital (W_2) and funding costs (W_3), $E_{i,t}$ is bank capital, T is a time trend and $X_{i,t}$ contains a number of control variables which may impact on the firm production technology (e.g., period fixed effects, as in Berger et al. (2009)). Most studies use total assets as an output measure as income by type of bank activity is not always be available. See, for example, Fernández de Guevara et al. (2007), Berger et al. (2009) or Weill (2013). As a robustness check of our results we use total loans as a proxy for output in section 3.2.

The measure of marginal cost used in the calculation of the Lerner index is then derived from the estimates in equation (3) as:

$$MC_{i,t} = \frac{\partial C_{i,t}}{\partial Q_{i,t}} = \left(\alpha_1 + \alpha_2 \ln Q_{i,t} + \sum_{j=1}^{3} \delta_j \ln\left(W_{j,i,t}\right)\right)\frac{C_{i,t}}{Q_{i,t}} \tag{4}$$

Finally, we follow the empirical literature and measure output price P in equation (2) using the ratio of interest and non-interest income to total assets as a proxy.

The stochastic frontier approach

We also construct an alternative estimate of the Lerner index following Kumbhakar et al. (2012). These authors note that if $P \geq MC$ then $P.\left(\frac{Q}{C}\right) \geq MC\left(\frac{Q}{C}\right) = \left(\frac{\partial C}{\partial Q}\right)\left(\frac{Q}{C}\right) = \frac{\partial \ln C}{\partial \ln Q}$.Therefore, price must be greater than marginal cost, the relationship between price, marginal cost and output can be written as:

$$\frac{P_{i,t}Q_{i,t}}{C_{i,t}} = \frac{\partial \ln C_{i,t}}{\partial \ln Q_{i,t}} + u_{i,t}, \qquad u_{i,t} \geq 0 \tag{5}$$

where $P_{i,t}Q_{i,t}/C_{i,t}$ is the ratio of total revenue ($P_{i,t}Q_{i,t}$) to total costs and $u_{i,t}$ is n alternative measure of the markup applied by the firm over marginal cost.

Assuming a total cost function similar in form to that in equation (3), the mark-up $u_{i,t}$ can be estimated directly from the following relationship using the stochastic frontier methodology:

$$RC_{i,t} = \gamma_1 + 2\gamma_2 \ln Q_{i,t} + \sum_{j=1}^{3} \mu_j \ln(W_{j,i,t}) + \rho T + \eta E_{i,t} + u_{i,t} + v_{i,t} \tag{6}$$

where $RC_{i,t}$ is the ratio of total revenue to total cost and $v_{i,t}$ is the error term. One advantage of this approach is that it does not require a separate estimate of output prices as for the standard Lerner index in equation (2). However, it requires an additional behavioural assumption for the mark-up term $u_{i,t}$ which can only be positive and is restricted to be the positive half of a normal distribution. Together, the mark-up term $u_{i,t}$ and the error term $v_{i,t}$ make up the compound error term as commonly set out in the stochastic frontier literature. We follow the suggestion in Kumbhakar et al (2012) and assume that $u \sim N^{+}(0, \sigma_u^2)$ and $v \sim N(0, \sigma_v^2)$ where N^{+} is the normal distribution truncated at zero from below. The error term $v_{i,t}$ is a two-sided random process that does not reflect market power but rather uncertainty on the part of the firm when pricing their products. Kumbhakar et al. (2012) then show that the Lerner index can be calculated using the relationship between the estimated one-sided mark-up ($\hat{u}$) and the elasticity of total cost to output ($\mathrm{E}_{TC,Q}$) as follows:

$$L = \frac{\hat{u}}{\mathrm{E}_{TC,Q} + \hat{u}} \tag{7}$$

where the elasticity of total cost to output term ($\mathrm{E}_{TC,Q}$) is derived from the deterministic element of equation (6) as follows:

$$\mathrm{E}_{TC,Q} = \hat{\gamma}_1 + 2\hat{\gamma}_2 \ln Q_{i,t} + \sum_{j=1}^{3} \hat{\mu}_j \ln(W_{j,i,t}) + \hat{\rho} T + \hat{\eta}\, E_{i,t} \tag{8}$$

The Panzar-Rosse H-statistic

The Panzar-Rosse H-statistic considers the transmission of input costs through to firms' revenue as estimated by the sum of the elasticities of revenue to the underlying input prices. Weak pass-through of costs to revenues is interpreted as a greater exercise of market power, while full pass-through is indicative of highly competitive markets. To understand the intuition behind the H-statistic, it is useful to consider the two extremes cases of perfect competition and monopoly.

Under perfect competition, each firm in equilibrium earns zero economic profits. Costs are homogeneous of degree one in input prices, so any change in input prices induces an equal change in marginal costs. A sustained increase in input costs will generate negative economic profits in the short term. To restore zero economic profits, some firms exit the market, reducing aggregate supply and raising output prices such that remaining firms' revenues exactly offset the increase. The elasticity of firms' revenue to costs will therefore be unity in the perfect competition case.

In contrast, a monopolist sets prices in the market where demand is elastic as this is where marginal revenue is positive. Total Revenue is equal to price times quantity, $TR = P \times Q$. Marginal revenue can be derived using the product rule as $MR = \frac{\partial(PQ)}{\partial Q} = P + Q\frac{\partial P}{\partial Q} = P\left[1 + \frac{\partial P}{\partial Q}\frac{Q}{P}\right]$. The elasticity of demand is defined as $\mathrm{E}_D = \frac{\partial Q}{\partial P}\frac{P}{Q}$, so marginal revenue becomes $MR = P\left[1 + \frac{1}{\mathrm{E}_D}\right]$. Demand is elastic where $-\infty < \mathrm{E}_D < -1$ which implies a positive marginal revenue, while inelastic demand (where $-1 < \epsilon^D < 0$) implies negative values for marginal revenue. A monopolist will always set production on the elastic part of the demand curve where marginal revenue is positive.

The monopolist responds to an increase in input costs by reducing production and so total revenue falls as demand is elastic and the resulting increase in price is not sufficient to offset the reduction in the output. The elasticity of the monopolists revenue to costs is therefore negative. Intermediate values for the H-statistic reflect varying degrees of monopolistic competition with the intensity of competition diminishing as values move from one (perfect competition) towards zero (increasingly imperfect / monopolistic competition) (see Rosse and Panzar (1977) and Panzar and Rosse (1987)). The H-statistic will be negative for a perfect monopoly, although in practical terms the index generally varies between one (strong competition) and zero (weak competition).

The H-statistic is derived from a fixed effects panel regression of the following form:

$$\ln(TR_{i,t}) = \alpha + \sum_{j=1}^{J} \beta_j \ln(C_{j,i,t}) + \theta' X_{i,t} + \eta_{i,t} \tag{9}$$

where $TR_{i,t}$ is the total revenue for firm i at time t, $C_{j,i,t}$ is input cost factor j and $X_{i,t}$ is a vector of exogenous control variables. The H-statistic itself is calculated as the sum of the coefficients on each factor cost, i.e.

$$H = \sum_{j=1}^{J} \beta_j \tag{10}$$

The Boone Indicator

The intuition behind the Boone indicator relies on the output-reallocation effect. When competition intensity increases, more efficient firms are able to expand their output at lower cost than less-efficient firms, leading to higher profits. As competition becomes more intense, less-efficient firms become increasingly unprofitable and leave the market, leaving more efficient firms able to expand output and profitability. An increase in competition intensity can arise from either greater interaction between incumbent firms or lower barriers to entry. Formally, for any three firms in a market with levels of efficiency $n'' > n' > n$, an increase in the intensity of competition benefits more efficient firms such that the ratio $[\pi(n'') - \pi(n)]/[\pi(n') - \pi(n)]$ rises. Boone demonstrates that this relationship between efficiency and output is consistent with a broad set of models of competition which include, but are not limited to, competition based on quantities (Cournot) and price (Bertrand) (e.g. Boone (2008)).

Empirically, the measures of variable profits and efficiency are determined as follows. First, variable profits are defined in terms of total revenues and costs directly related to production but excluding costs such as R&D and capital stocks. This is because R&D and capital stocks are indicative of expenditure that change future efficiency, which will show up in the measure in future periods (see Boone (2008) for discussion of variable definitions). Efficiency is measured in terms of average variable costs, defined as variable cost (as above) divided by a measure of output. For the financial sector, output is usually proxied by revenue derived directly from financial market activities, such as interest and investment income received.

In practice, the Boone indicator is estimated as the time fixed effects coefficient on variable costs using an equation of the form (Boone et al. (2007)):

$$\pi_{i,t} = \alpha + \beta_t \ln(c_{i,t}) + \Phi X_{i,t} + \eta_{i,t} \tag{11}$$

where $\pi_{i,t}$ are the variable profits, $c_{i,t}$ are average variable costs and $X_{i,t}$ are control variables for each firm i at period t. The Boone indicator is the estimated coefficient β_t derived for each period t, allowing comparisons through time.

Interpretation of performance-based measures

The performance-based measures provide us with different perspectives on the divergence of outcomes from what we would expect from highly competitive (perfectly competitive) markets. Each measure has a different theoretical foundation, focussing on a different aspect of competition outcomes. Table A4.1 sets out the key characteristics of each of the measures we consider in this study.

Table A4.1: Characteristics of measures of competition intensity

Measure	Theoretical Range	Value at perfect competition	Direction indicating increasing intensity of competition	Concept underpinning perfect competition outcome
Lerner index	0 to 1	0	↓	Economic profits driven towards zero
H-Statistic	0 to 1[1]	1	↑	Full pass-through of costs to revenue
Boone indicator	-∞ to 0	Increasingly negative	↓	Output reallocated to more efficient firms

Notes:

[1] The H-statistic can take on negative values for a pure monopoly but for practical purposes is bound between 0 and 1

The theoretical outcomes for perfect competition against which these measures are benchmarked are generally those that arise in the absence of market failures, such as information asymmetries and externalities. These market failures tend to raise entry and exit barriers, introduce sunk costs and limit the propagation of production technologies. Moreover, these market failures are also a key source of instability in the financial sector, which is a key focus of financial market regulators. In this sense, the perfect competition outcomes embedded within the performance-based measures we consider are consistent with the definition of effective competition espoused by the PRA and which can be a relevant indicator for measuring progress against financial stability objectives. In general, competition is considered to be effective when: (i) suppliers compete to offer a choice of products or services on the most attractive terms to customers and appropriately price in the risks associated with their businesses; (ii) customers have the confidence to make informed choices are based on those quality attributes that are easy to observe at a price that allows suppliers to earn a return on their investment commensurate with the level of risk taken; and (iii) effective entry, expansion and exit is possible in the market. See Dickinson et al (2015) for further discussion.