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EXPLORING THE SHORT- AND LONG-RUN LINKS FROM BANK COMPETITION TO RISK – RECONCILING CONFLICTING HYPOTHESES?

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Abstract: Using a dataset for the EU-27 covering 1998-2012, this is one of the first studies of banking competition and risk to look at the dynamics of the relation between these variables, to take account of a full 6 year period since the onset of the crisis in 2007, as well as a comparable period before it; and to compare and contrast results using two competition indicators, the H statistic and the Lerner index. Using the H statistics, we find that in the crucial pre crisis period, the change in competition has a positive effect on risk (measured by the Z Score), while there is a overall negative effect of the level of competition on risk. The Lerner index provides results supportive of the hypothesis that there are dynamic relations between competition and risk, in that the change in the Lerner index again correlates positively with risk (i.e. narrower margins when competition increases make banks weaker) while the long run effect of heightened competition is also to increase risk. Testing for the reason for differences in long run effects we find that the H and Lerner differ in their impact on the volatility of profits, a key input to the Z Score risk indicator. There are important implications for the interpretation of results in the literature based on these different indicators.

Keywords: Bank competition, financial stability, EU banking markets, Lerner index, Panzar-Rosse H Statistic, Z Score

JEL Classification: G21, G28

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Introduction

The subject of bank competition and risk has returned to the fore with the financial crisis of 2008-9, with a common view being that competition between financial institutions during the preceding boom was at the core of the crisis. This in turn implies that the benefits of banking competition for economic growth and efficiency need to be placed in the balance. On the other hand, there is an extensive literature, generally estimated on pre crisis data, which finds conflicting results on the relation between competition and risk. This follows on the one hand the so-called "franchise value" or "competition-fragility" approach – that more competition reduces the value of a banking licence and requires firms to take more risk as a result; and on the other hand, the "competition-stability" view that with low levels of competition banks may charge excessively high rates of interest on loans and hence generate adverse selection and moral hazard on their loan books. Both types of results have been found in the empirical literature, with also an emerging set of studies suggesting both high and low levels of competition may be adverse for risk i.e. there is a "u" shaped relationship, and that structural and regulatory features may affect the country level trade-off.

A further ambiguity is introduced by the common use of concentration of a banking system as a proxy for competition, when in fact the theory of contestable markets suggests a concentrated system may be highly competitive if there is sufficient potential competition from outside, as may be permitted by regulations allowing new entry as in the EU Single Market. The existing empirical literature mainly covers the period up to 2007 thus leaving open the interpretation of the post 2008-9 crisis world where there are a diminishing number of banks, extensive government intervention and – many would argue - less competition. The existing literature also suggests there are untested assumptions behind proposals for enforced structural change in banking such as the Vickers proposal in the UK.

In this paper, we estimate indices of banking market competition for the UK and other EU countries and then relate them to banking risk. Our aim is to establish whether and to what extent competition and its trade-off with risk has changed with the financial crisis and the more concentrated market structure that has ensued. We test for dynamic as well as long run links from competition to risk. Mainly we use the Rosse-Panzar H-statistic to assess the changing nature of competition in individual markets over time. Among earlier studies using this approach is an analysis of competition in the major EMU countries as compared to the US just prior to EMU (De Bandt and Davis 2001). We also investigate the alternative approaches to measuring competition of Iwata's Lerner Indices (Bikker 2004).

The work is structured as follows. In the first section we briefly examine the theoretical literature and look in more detail at recent empirical work on competition and risk in banking, highlighting that the datasets used are largely during the boom period or before, with very little work on the post crisis period. We note that empirical as well as theoretical work are often contradictory, and seek to probe the reasons why. We question for example, whether global datasets are fully informative for policy in advanced countries. In the

following section, we outline our data and methodology used in the exercise, before going on to our empirical results. We have a two step approach with an estimation of the levels of competition in each market being followed by a test of their impact on risk, dividing between static and dynamic aspects and between results from the H Statistic and the Lerner statistic. The final section draws conclusions.

1 Literature survey

As mentioned, there are two broad approaches to the relation between banking competition and risk. The theory of franchise value (Keeley 1990) or "competition-fragility" suggests that institutions in an uncompetitive banking system have incentives to avoid risk because a banking licence is valuable in such a context with restricted entry and probably large capital cushions (technically, the franchise value is high due to monopoly rents). This typified the highly-regulated situation of banking systems from the war to the late 20th Century where banks had a great deal of market power and there was little financial instability. Then, when there is deregulation, the value of the licence declines as excess returns are competed away by new entrants (also from abroad where permitted) and by more intense competition between existing players. This gives incentives to increase balance sheet risk in order to recover the previous level of profitability as banks in effect shift risks to depositors (or deposit insurers) and banks thus become more vulnerable to shocks. In a context of limited liability, there is also asymmetric risk for owners and managers, which may increase the positive effect of competition on risk. This effect may be intensified by an incentive to underinvest in screening and monitoring since information rents from lending relationships are less valuable, as customers can switch banks more readily (Allen and Gale 2000, 2004). Meanwhile, larger banks in a less competitive system may be better able to diversify risks and are easier to supervise (Allen and Gale 2000, World Bank 2013).

The alternative approach, which is due to Boyd and De Nicolo (2005) is often called the "competition-stability" approach. Whereas lower lending rates in competitive banking markets increase scope for borrowers to repay, higher lending rates in uncompetitive markets lead to adverse selection with only the riskier borrowers seeking funds and moral hazard inducing borrowing firms to take higher risk (as in Stiglitz and Weiss 1981). With perfect correlation of loan defaults, this naturally affects the entire portfolio. Large banks in uncompetitive markets may also be harder to supervise (Beck et al 2006) and vulnerable both to contagion and to "too-big-to-fail" incentives for risk taking which can enhance the competition-stability effect (Mishkin 1998).

An extension of Boyd and De Nicolo (2005) allowing for imperfect correlation in loan defaults can instead generate a U shaped relation between risk and competition (Martinez-Miera and Repullo 2010) as the initial benefit to lower probabilities of default from lower loan rates (risk shifting effect) begins to be offset by lower revenues (margin effect), leading to instability. Wagner (2010) shows that if banks can adjust their loan portfolios, the link from competition to risk taking may be reversed as for example when borrowers become safer, banks choose to shift their portfolio to higher risk borrowers per se. There may be

overcompensation in fact due to loss of franchise value from competition. Meanwhile, Hakenes and Schnabel (2011) show that the effect of capital adequacy on risk taking depends on whether the market is subject to competition-stability or competition-fragility, since capital requirements reduce competition, raise interest rates and may lead banks to choose more correlated loan portfolios. Berger et al (2009) argue that even if loss of market power induces riskier loan portfolios, charter values may not fall if banks protect themselves with higher equity, lower risk securities or use of credit derivatives – this may help to reconcile the two hypotheses.

In the empirical literature, as summarised in Table 1 below, results are mixed for country studies, and it seems that cross country work can give a richer indication of the risk-competition relationship. In effect, cross country work seeks to find the average relation between competition and stability for a set of countries while controlling for country-specific factors. There remains an issue of how homogeneous or heterogeneous the country groups are, however.

There are typically two types of dependent variable, namely banking crises per se (as in Beck et al 2006 and Cihak and Schaeck 2010) and bank indicators of risk, typically the Z-Score (as in Beck et al 2013) measures the number of standard deviations a banks' rate of return on assets must fall for the bank to become insolvent. The Z score is more comprehensive as a measure of bank risk than measures such as NPL ratios which only measure loan market risk, and is bank-by-bank in contrast to banking crises which are of course country wide. As noted by Lui et al (2013) it in effect combines a measure of bank performance (ROA), a measure of risk (standard deviation of ROA) and a measure of safety and soundness (equity/asset ratio). Tabak et al (2012) use a variant of Z-Score which assesses the potential stability of the bank where the Z-Score is the dependent variable of a translog production frontier.

Anginer et al (2012) use a relative distance to default measure where the "distance to default" is the difference between the firm's asset value and the face value of its debt, scaled by the standard deviation of the firm's asset value; Fu et al (2014) use a similar measure. Meanwhile, the "relative" aspect is derived by looking at correlations of changes in this measure, thus capturing systemic rather than individual stability. However, unlike Z-Score this can only be calculated for publicly traded banks. Relevant results for competition and risk also arise from estimates of determination of capital ratios (such as Schaeck and Cihak 2012), while in a merger study, Weiss et al (2012) use as a risk measures the "marginal expected shortfall" and "lower tail dependence" between a merged bank's stock returns and a sector index.

Measures of competition (CEPR 2010) include simple concentration measures such as the Herfindahl index, and many studies have used concentration as a key right-hand side variable (Beck et al 2006). Concentration is clearly of policy interest in the context of banking mergers in the wake of the EU Single Market and also consolidation since the sub-prime crisis. However, concentration measures do not allow for contestability, ownership structure and the possible reverse causality from behaviour to structure (efficient structure

hypothesis). Furthermore they may omit the impact of cross border competition that is key in the EU Single Market. In effect, the theory underlying use of concentration measures is that market structure influences behaviour (structure-conduct-performance) which the "New Industrial Organisation" theory has shown to be only partially the case (Tirole 1988). More relevant may be the contestability of markets, whereby potential "hit and run" entry provides a limit to anti competitive behaviour of incumbents, regardless of the degree of concentration; such potential entry is facilitated when sunk costs of entry (those which cannot be recovered when exiting the market) are low. Arguably, technological changes such as internet banking as well as easing of regulation affecting competition such as the EU Single Market has made banking markets more contestable over time.

The Panzar-Rosse H statistic, which we use as a key measure in our own work, overcomes some of these issues by giving a market wide measure of contestability (response of output to input prices), see De Bandt and Davis (2001), Bikker et al (2012). In perfect competition, increases in input prices translate direct to total revenue and marginal cost but this is not true for imperfect competition. H is thus 1 for perfect competition,, 0 for imperfect competition and -1 for monopoly. However, in principle this measure is only accurate for a market in equilibrium (this can be tested via estimation of the impact of input prices on return on assets, see Schaeck et al 2009).

The alternative Lerner Index (Bikker 2004) shows the ratio of price to marginal cost and can be calculated bank by bank whereas the H Index is a banking-system property. The scope of competition is indicated by the size of the index as zero would show perfect competition while one implies monopoly. However, Lerner must be correctly adjusted for lending risk and may be correlated with the Z Score as a dependent variable (Beck et al (2013) seek to take this into account). Fu et al (2014) use as a variant the efficiency adjusted Lerner which allows for the possibility that in uncompetitive markets, monopoly rents may be reflected in inefficiency instead of high profits (Koetter et al 2012). Some recent studies use the Boone indicator (Boone 2008) which focuses on the impact of competition on structure, as banks that are efficient gain market share and the inefficient lose it. The indicator is the elasticity of market share with respect to marginal cost.

In this context, using global data on 50 countries and the Panzar-Rosse approach, Claessens and Laeven (2004) show countries that permit foreign bank entry and have lesser activity and entry restrictions are more competitive, while they do not find the expected negative link from concentration to competition, implying that contestability is key. World Bank (2013) also probes the factors underlying competition, this time using the Lerner Index for 83 countries and finds again that it is driven by contestability (lower entry barriers), information disclosure, better institutions, foreign bank participation and more liquid stock markets – and not by concentration.

Usually studies control for a number of bank and country level variables in investigating competition-risk relations such as bank size, leverage and profitability (see for example Beck

et al 2013), and structural and regulatory variables (such as private monitoring, restrictions on entry and government ownership, see Barth et al (2012)).

Individual country results of interest include Craig and Dinger (2009) for the US who estimate simultaneously for bank risk, retail funding competition and wholesale rates bank by bank to probe their interrelationship, finding a positive relation between deposit market competition and risk. Dell'Ariccia et al (2012) show that lending standards in the US subprime boom were positively linked to competition, as a higher local Herfindahl index or number of lenders would make for less risky lending with more loan denials in more competitive markets. Jimenez et al (2010) using a sample of Spanish banks show that whereas there is no detectable relation between concentration and risk, there is a positive link between competition as measured by Lerner indices, and bank risk especially in the loan market (NPLs), hence supporting the franchise value theory (albeit not for bank-wide risk given that NPLs only indicate loan market risk).

Some cross country studies suggest that more concentrated banking systems are more stable, implying a benefit to consolidation (Beck et al 2006, Schaeck et al 2009) although they also find a positive impact of competition per se, suggesting an effect of contestability (i.e. a competitive but concentrated system owing to potential competition) and contrary to the franchise value theory. A weakness of Schaeck et al (2009) is that the H-statistic is considered constant from 1980-2005, and their "time-to-crisis" variable may be affected by the onset of deregulation in the different markets. Uhde and Heimeshoff (2009) show that concentration in EU countries measured by the Herfindahl and 5-firm indices raised bank risk as indicated by aggregate Z-Scores over 1997-2005. In contrast, Yeyati and Micco (2007) looking at Latin America found that increased concentration appears to have had no influence on competition or fragility, while foreign penetration weakened banking competition, which is negatively related with bank risk and that, as a result of the previous two findings, foreign penetration induced lower levels of risk. They suggest that foreign banks are seen as imperfect substitutes for domestic ones. Liu et al (2012) examine four South East Asian countries (Indonesia, Malaysia, Philippines and Vietnam) and find concentration is inversely related to bank risk whereas regulatory restrictions positively influence bank risk-taking. Competition measured by the H statistic does not increase bank risk-taking behaviour.

Some banking merger studies are relevant to assessing competition and risk. Vallascas and Hagendorff (2011) using a distance to default measure of risk show increases in risk during mergers are particularly large for cross-border and activity-diversifying deals in the EU. Meanwhile, Weiss et al (2012) find that mergers typically raise merged banks' and their competitors' contributions to systemic risk, although this effect is magnified for regulator-driven mergers during the financial crisis. This raises the question whether demergers as in the UK Vickers proposals would reduce risk (see Armstrong 2012). Relatedly, Barrell et al (2010) find large banks tended to have riskier loan portfolios as measured by NPLs and provisions although this could be offset by diversification. Gropp et al (2013) find that

government bailout probabilities (measured using ratings information) raise the risk level of competitor banks and of government owned banks.

Banks in more competitive systems may hold more capital to compensate for risks (Berger et al 2009, Schaeck and Cihak 2012). Berger et al (2009) find that consistent with competition-fragility, banks with more market power have less *overall* risk exposure, while on the other hand in line with competition-stability, market power does increase *loan* risk in such countries, compensated by higher capital and other risk mitigating methods. Aggregate prudential ratios including those linked to competition such as return on equity may be able to help in identifying weak banking sectors (Cihak and Schaeck 2010).

Corresponding at a global level with Craig and Dinger (2009), Demirguc Kunt and Huizinga (2010) show that banking systems that rely to a high degree on non-deposit financing and non-interest income generation are more risky according to the Z-Score, even during the Great Moderation (the dataset covers 1999-2007). Before the 2007-9 crisis, the banks diversifying funding and income sources in this risk-increasing manner tended to be the large and fastest growing banks. This work gives some support to the argument of Vickers for separation of wholesale and retail banking. Dewally and Shao (2013) show that procyclicality of bank leverage is related to asset growth but also to wholesale funding use, especially for advanced country banks in the run-up to the financial crisis within their sample 1990-2007.

Anginer et al (2012) look, as noted, at the co-dependence of risks across banks by using a relative distance to default measure, noting that Z-Scores are correlated with the Lerner index and show risk only for individual banks not the system. They find greater competition leads to less risk owing to more diversified balance sheets, while concentration and market power increase fragility. Some studies find a nonlinear relationship between competition and risk, with Tabak et al (2012) for Latin America finding that high and low competition reduce fragility, using a stability efficiency measure of risk based on Z-Score and the efficiency frontier. Bank size and capital of large banks is a benefit for banks under competitive conditions, and capital is a benefit of the system in the case of collusive conditions.

A number of studies see regulation as a key addition factor underlying the competition-stability link. For example Anginer et al (2012) find that tighter entry barriers and activity restrictions increase fragility ceteris paribus. Lack of foreign ownership, weak investor protection, and poor standards of supervision and regulation are indicators of a stronger effect of lack of competition on fragility. Beck et al (2006) in an earlier paper also found that restrictions on entry and activities promoted instability. Schaeck and Cihak (2012) use regulatory variables as instruments to account for endogeneity of competition to capital ratios; market power endogeneity is also tested in studies such as Berger et al (2009) and Uhde and Heimeshoff (2009).

In one of the most recent papers on a global sample, Beck et al (2013) seek to control for structural and regulatory factors and hence test for heterogeneity in the global cross-country relationship. They find that the franchise value (competition-risk) effect dominates the

competition-stability effect but in some cases the opposite is true and some structural and regulatory factors may be cited to distinguish between them. In sum, the effect of higher competition on bank fragility is greater with stronger activity restrictions (contrary to Vickers), lower systemic fragility (measured by country level Z-Score), more developed stock exchanges, more generous deposit insurance and better credit information sharing.

We summarise the studies cited in Table 1 below.

Table 1: Summary of recent work on competition and risk in banking

Study (date)	Dependent	Competition variable	Data set	Date of sample	Key result
Anginer et al (2012)	Distance to default	Lerner index	Global bank by bank (publicly quoted institutions)	1996-2009	Competition enhances stability
Beck et al (2006)	Banking crises	Concentration, competition related regulations	Global macroeconomic	1980-1997	More concentrated systems have less crises
Beck et al (2013)	z-Score, sd ROA, E/TA	Lerner index	Global bank by bank (1600 US banks only)	1994-2009	The competition risk trade-off varies with structural and regulatory conditions
Berger et al (2009)	Z Score, NPLs, E/TA	Lerner and concentration (loans and deposits)	Advanced countries (91% US banks)	1999-2005	Banks with more market power take less risk overall but more loan risk
Cihak and Schaeck (2010)	Banking crises	Financial Soundness Indicators (FSI's)	Global macroeconomic	1994-2007	Some FSI's can help identify incipient systemic risks
Craig and Dinger (2009)	Z Score	Deposit rates	US banks	1997-2006	Deposit market competition raises risk
Demirguc Kunt and Huizinga (2010)	Z Score	Non deposit funding share and fee income share	Global bank by bank	1995-2007	Non-traditional funding and lending enhance risk
Fu et al (2014)	Z Score, probability of bankruptcy	Lerner indices, concentration	Asia-Pacific bank by bank	2003-2010	Lower pricing power enhances risk exposure while concentration reduces risk
Gropp et al (2013)	Supervisory ratios	Concentration (control) and guarantees	OECD country banks	2003	Government guarantees raise risk taking

					of competitor banks
Jimenez et al (2010)	Nonperforming loans	Lerner indices	Spanish banks (by province)	1988-2003	Link from interest rate competition to loan risk
Liu et al (2012)	Z score and other measures (provisions/loans. Reserves/loans, ROA volatility)	H Statistic and concentration	Four South East Asian countries	1998-2008	H is either inversely related or unrelated to risk measures
Schaeck and Cihak (2012)	Capital ratios	H-Statistic and banks/population	European bank by bank	1999-2005	Competition boosts capital ratios
Schaeck et al (2009)	Banking crises	H-Statistic	Global bank by bank and macroeconomic	1980-2005	Competitive systems less prone to crisis
Tabak et al (2012)	Z Score	Boone measure	Latin America bank by bank	2003-8	High and low competition enhance stability, medium reduces it
Uhde and Heimeshoff (2009)	Z Score	Concentration	EU countries macroeconomic	1997-2005	Concentration raises risk
Weiss et al (2013)	Marginal expected shortfall, lower tail dependence	Concentration	Global bank mergers	1991-2009	Merged banks have a greater impact on systemic risk
Yeyati and Micco (2007)	Z Score	H Statistic	Latin America bank by bank	1993-2002	Positive effect of competition on risk

2 Evaluation of recent work

The outstanding result from existing work is that there are differing outcomes in terms of the competition-fragility and competition-stability paradigms. Some papers consistently favour the former, and others the latter, while other suggest that the outcome may differ between countries with structural and regulatory factors or even the level of competition itself.

The studies cited generally use data of an earlier period than is now available and this is illustrated in the above table. Accordingly, we are able to undertake new investigations simply by extending the dataset, not only via Bankscope up to 2012 but the new wave of the World Bank Regulation and Supervision database (2011, see Barth et al (2012) and Cihak et al (2012)).

Indeed CEPR (2010) note that many results in the literature might be driven by the trend to consolidation in the Great Moderation and/or may not hold in times of systemic global

distress. Competitive systems might foster stability in normal times, for example, but contribute to bubbles, herding behaviour and use of untested innovations in booms, and credit crunches in times of recession or crisis. This implies a possible distinction between long run and short run effects of competition as well as pre and post crisis that we test in our work. The competition-stability and competition-fragility paradigms might both be valid, but over different horizons and in varying circumstances.

Equally, competition may not have been the key factor underlying risk taking in the Great Moderation – it might rather have been the global liquidity glut and regulatory easing from Basel II as well as disaster myopia (measured for example by the time since the last crisis, as shown for East Asian banks by Craig et al 2006) and risk taking incentives from too-big-to-fail. This can be tested by the significance of competition as a determinant or risk in our regressions. Furthermore, the broad issue of incentives has been little applied in this field although Gropp et al (2013) is an exception.

In this context, a possible reconciliation of the competition-fragility and competition-stability approaches is that the former is characteristic of banking systems that have been recently deregulated, as was the case of the US in the original franchise value study by Keeley (1990). But as time passes the banks become habituated to a deregulated system and the level competition becomes synonymous with stability. Whereas this argument is clearly not fully consistent with the 2000-7 boom, it could be that the underlying relation is overlaid by these additional factors and this can be tested. Again, a corollary may be that the established level of competition is consistent with stability but abrupt changes in competition (as occurred for example after deregulation, but also during periods of prolonged boom or financial innovation) may have a negative impact, i.e. again there is a static-dynamic distinction that has not been tested in the literature to date.

Furthermore, most existing studies are based on global samples. As in Barrell et al (2010) and Davis, Karim and Liadze (2011) we question whether this is the best approach for detecting the competition-risk trade-off since the behaviour of advanced countries (as in the EU) may differ from emerging market economies. Indeed it is telling that in one of the most recent studies it was shown that "an increase in competition is associated with a larger rise in banks' fragility in countries with stricter activity restrictions, lower systemic fragility, better developed stock exchanges, more generous deposit insurance and more effective systems of credit information sharing" some of which are advanced country characteristics (Beck et al 2013 :219). EU countries also have a more homogeneous regulatory framework than a global sample, which helps eliminate one cause of variation in the competition-stability trade-off.[2]

There has not been much discussion in the recent literature of macroprudential policies, for example how the use of new instruments (such as LTV limits) might relate to competition.

[2] In Figure 2 of Beck et al (2013), all EU countries other than Latvia and Luxembourg have a positive trade-off between competition (measured by Lerner) and risk (measured by Z Score) and the positive effect is significant except for the Netherlands, Romania and Ireland (although the significant effects do vary from roughly 0.5 to 3.0).

The prevailing assumptions of macroprudential policies are generally based on the competition-fragility link and do not take into account the variations in the trade-off shown by the literature survey. Also competition in wholesale funding has not been treated in most studies in particular for its relation to risk (one exception is Demirguc Kunt and Huizinga 2010). Studies typically focus on the banking system in a country (or country-by-country) per se. There may be intensive securities market competition, and/or from shadow banking, that may interact with bank risk taking and competition in countries with more diverse financial systems. Hence it is at least important to include indicators of securities market activity as a control variable.

3 Data

We use data from Bankscope for the European Union countries, which ensure a degree of commonality in terms of the regulatory framework. In particular controls on entry should be low helping to ensure a degree of contestability, while common minimum prudential standards are enforced across the Union. We include commercial, savings, cooperative and mortgage banks but not investment banks in our sample. This is in line with Schaeck and Cihak (2012) who tested commercial banks versus a wider sample (not including mortgage banks, however) and concluded "constraining the sample to profit maximising institutions although justified on theoretical grounds is not necessary for the empirical tests" (ibid: 838). There are 6008 banks from the 27 EU countries over the period 1998-2012, thus including substantial periods of time both before and after the crisis. Usable observations are typically around 45,000 in number (details of regression data are shown in Appendix 1). Regression data using variables drawn from Bankscope are Winsorised at the 1% level (as is common in the literature, see for example Anginer et al 2012).

Supplementing the Bankscope data we use macroeconomic data from the World Bank Financial Structure database (Cihak et al 2012), which covers the period 1998-2011 of our sample. In particular, this provides us with data on stock market value traded/GDP to show the degree of securities market competition faced by banks. Equally, we have available dummies for the legal origin of the country as in La Porta et al's revised dataset (2007).

Furthermore, we employ data from the World Bank surveys of bank regulation and supervision that took place in 1999, 2003, 2007 and 2011, and which are summarised in indices from Barth et al (2012).[3] Potentially relevant data include particularly activity restrictions, limits on foreign banks, fraction of applications denied, initial capital stringency, overall index for capital regulation, supervisory power, supervision index, multiple supervisors, private monitoring index, moral hazard index, percent of foreign banks and external governance index. For discussion see Barth et al (2006). We construct a time series for these data as in Beck et al (2013), taking each observation to hold for the preceding year and the two following years.

4 Methodology

[3] The indices are downloadable from http://faculty.haas.berkeley.edu/ross_levine/Regulation.htm

We initially estimate the revenue functions for the Panzar-Rosse H Statistic for the EU and each EU country. According to this approach, market power is measured by the extent to which changes in factor prices are reflected in revenues. With perfect competition, and when banks operate at their long run equilibrium, a proportional increase in factor prices (including the interest rate on liabilities) induces an equiproportional change in gross revenues; output does not change in volume terms, while the output price rises to the same extent as the input price (i.e. demand is perfectly elastic). On the other hand, under monopolistic competition or where potential entry leads to a contestable markets equilibrium, revenues will increase less than proportionally, as the demand for banking products facing individual banks is inelastic (see Tirole, 1988). In the limiting case of monopoly there may be no response or even a negative response of gross revenues to changes in input costs.

Following Bikker et al (2012) and in line with Panzar and Rosse (1987) we use an unscaled revenue function. Bikker et al (ibid) have shown that forms of scaling (such as including assets or equity on the right hand side) or use of a price and not revenue variable on the left (revenue scaled by assets for example) provide an upward bias in the H-statistic (i.e. imperfect competition is rejected too frequently). After extensive testing using 100,000 observations on 17,000 banks in 63 countries over 1994-2004, they found that price and scaled revenue functions cannot identify imperfect competition in the way unscaled revenue functions can and that "this conclusion disqualifies a number of studies since they apply a Panzar-Rosse test based on a price function or scaled revenue function" (ibid: 1016).

Accordingly, our estimating equation is as follows:

$$\text{Log } R_{it} = \Sigma^{J}_{(j=1)} \alpha_j \text{Log } w_{j\,it} + \Sigma^{N}_{(n=1)} \gamma_n \text{Log } X_{nit} + \varepsilon_{it} \qquad (1)$$

For t=1,T, where T is the number of periods observed and i=1,I, where I is the total number of banks. Subscripts i and t refer therefore to bank i at time t. R_{it} is unscaled gross interest revenues. In our case, we have J=3 inputs so that w_{it} is a 3-dimensional vector of factor prices (log interest expense to total debt funding (IED), log personnel expenses to total assets (PTA), log other costs as a proportion of fixed assets(OCF)), consistently with the intermediation approach to banking output measurement where bank liabilities are inputs to produce loans and other earning assets. X_{it} is a vector of exogenous and bank-specific variables that may shift the cost and revenue schedule (business mix). In this context, we have N=4, log loans as a proportion of assets (LAR) showing credit risk (with an expected positive sign as banks compensate for risk); log other nonearning assets to total assets (OTA) reflecting asset composition; log customer deposits as a proportion of deposits plus money market liabilities (CDT) showing liquidity risk (but whose sign is ambiguous); and log equity to total assets (ETA) showing leverage and hence risk preference, (expected to have a negative sign).

We estimate the H-statistic for the EU as a whole and for each individual country. The time periods for evaluating H are the full data sample 1998-2012, separately before and after the

crisis (1998-2006 and 2007-2012) and annual cross section observations as in Schaeck and Cihak (2012) to be used in our second stage regressions. For the annual cross section regressions we take the restriction that there should be at least 12 banks per year. We also undertake the test for market equilibrium using the ROA on the left hand side and testing whether the H-ROA sum of elasticities on inputs is zero. This seeks to verify that input prices are not correlated with industry returns. We estimate using the "within" estimator with both bank and year fixed effects in line with De Bandt and Davis (2001) as well as pooled feasible generalised least squares (FGLS) using the White method to reduce the impact of heteroskedasticity.

In the following section, we then relate this annual competition variable to indicators of bank and systemic risk controlling for relevant variables. Our core results, in line with the bulk of the literature, link sector wide competition each year to the log of the Z-Score for individual banks, which is defined as the return on assets plus leverage ratio divided by the standard deviation of the return on assets over three years. As noted by Lui et al (2013) it is appropriate to log the Z score as the level is highly skewed while the log is normally distributed. We assessed H both in terms of levels and differences so as to distinguish between levels of competition and the change in competition – which to our knowledge has not been done in the literature, and may capture important distinctions between long run and dynamic aspects. The current difference of H (i.e. H_t-H_{t-1}) is complemented by levels of H_{t-2} and H_{t-3}, thus avoiding overlap between levels and differences and possible false conclusions. As H is a country wide variable we did not consider it would be correlated with bank level risk, and accordingly did not instrument the current difference.

We ran three sets of estimates, with bank-level variables only, with bank level variables and country dummies and with additional macro-level control variables. In each case we seek to shadow "best practice" in Beck et al (2013).

$$\text{Log } Z_{it} = a_0 \Delta H_{jt} + a_1 H_{jt-2} + a_2 H_{jt-3} + a_3 CDT_{it-1} + a_4 LAR_{it-1} + a_5 NIR_{it-1} + a_6 \log (TA)_{it-1} + a_7 (PII)_{it-1} + a_8 \Delta \log (TA)_{it-1} + a_9 SMT_{jt} + a_{10} CSI_{jt} + a_{11} ACT_{jt} + a_{12} LO_{jt} + \varepsilon_{it} \quad (2)$$

Accordingly, besides H, bank level variables in the risk function are deposits as a share of short term funding (CDT), loan/asset ratio (LAR), ratio of noninterest revenue/interest revenue (NIR), bank size (log TA), provisions/interest income (PII) and growth rate of assets (d log TA). All bank specific variables (denoted i) are lagged one year to avoid simultaneity.

As regards macro level control variables (denoted j), after testing, apart from H we controlled for stock market turnover (SMT) which indicates the scope for securities market financing, and in terms of regulation, capital stringency (CSI), and activity restrictions (ACT), as well as legal origin (LO). Since EU regulations are relatively homogeneous we do not expect to find major effects of regulation per se in our work.[4] We estimated again using the within estimator with year fixed effects as well as pooled feasible generalised least squares

[4] Indeed, Liu et al (2013) in a study of EU risk and competition going down to regional level omit any regulatory controls from their work.

(FGLS) hence using the White (1980) method to reduce the impact of heteroskedasticity. Given use of lags for bank specific variables we contend that this approach is more appropriate and reliable than GMM.

In a cross checking section, we then estimated the Lerner index for the EU as a whole following Anginer and Demirguc Kunt (2012) and tested it as a competition indicator. Accordingly we first estimate the following translog cost function:

$$\log(C_{it}) = \alpha + \beta_1\log(Q_{it}) + \beta_2(\log(Q_{it}))_2 + \beta_3\log(W_{1,it}) + \beta_4\log(W_{2,it}) + \beta_5\log(W_{3,it}) + \beta_6\log(Q_{it})\log(W_{1,it}) + \beta_7\log(Q_{it})\log(W_{2,it}) + \beta_8\log(Q_{it})\log(W_{3,it}) + \beta_9(\log(W_{1,it}))_2 + \beta_{10}(\log(W_{2,it}))_2 + \beta_{11}(\log(W_{3,it}))_2 + \beta_{12}\log(W_{1,it})\log(W_{2,it}) + \beta_{13}\log(W_{1,it})\log(W_{3,it}) + \beta_{14}\log(W_{2,it})\log(W_{3,it}) + \Theta\text{Year Dummies} + \varepsilon_{it} \quad (3)$$

Where C_{it} is total costs; Q_{it} is the quantity of output and is measured as total assets; $W_{1,it}$ is the ratio of interest expenses to the sum of total deposits and money market funding. $W_{2,it}$ is measured as personnel expenses divided by total assets. $W_{3,it}$ is the ratio of administrative and other operating expenses to total assets. Having estimated this equation we impose the following restrictions again in line with the earlier authors, to ensure homogeneity of degree one in input prices:

$$\beta_3+\beta_4+\beta_5 = 1;\ \beta_6+\beta_7+\beta_8 = 0;\ \beta_9+\beta_{12}+\beta_{13} = 0;\ \beta_{10}+\beta_{12}+\beta_{14} = 0;\ \beta_{11}+\beta_{13}+\beta_{14} = 0 \quad (4)$$

We then use the coefficient estimates from the previous regression to estimate marginal cost for bank i in calendar year t:

$$MC_{it} = \delta C_{it}/\delta Q_{it} = C_{it}/Q_{it} \times [\beta_1 + 2\times\beta_2\times\log(Q_{it}) + \beta_6\times\log(W_{1,it}) + \beta_7\times\log(W_{2,it}) + \beta_8\times\log(W_{3,it})] \quad (5)$$

And the Lerner index for each bank-year is:

$$Lerner_{it} = (P_{it} - MC_{it}) / P_{it} \quad (6)$$

where, P_{it} is the price of assets and is equal to the ratio of total revenue to total assets. This index was tested similarly to H and the reasons for any differences in results was probed. Since Lerner is a bank level variable there is a risk of simultaneity with the Z Score and accordingly we instrumented the current difference of Lerner as highlighted below.

We note that the literature in the area of competition and risk in banking has virtually no reference to panel unit roots, which likely relates to the fact that the time dimension T is small while the number of cross sections N is very large, while most panel unit root testing focuses on T and N of reasonable size as in a cross country macro dataset. Suffice to note that we did run tests for stationarity of the key variables (log Z score at a bank level, H at a country level and Lerner at a bank level) and found that they were stationary on the principal tests (Levin-Lin-Chu, Im-Pesaran-Shin, Fisher ADF and Fisher PP). This justifies our specification with for example the level of the dependent variable.

Finally, as a robustness check, we ran the various regressions with an alternative measure of risk which is impaired loans as a proportion of total loans. In bank-dominated systems as in much of the EU this is a fairly accurate measure of risk for all but the largest banks (which hold proportionately more securities). There were however much less observations especially before 2007 which made the earlier estimates relatively unreliable.

5 Results for H statistic

We show below a typical result for Panzar-Rosse, namely those for the EU as a whole.

Table 2: Panzar Rosse estimates for the EU – log total interest revenue 1998-2012

Variable	Coeff	T value
C	10.27479	113.7
LOG(IED)	0.623713	28.3
LOG(PTA)	-0.407000	-27.4
LOG(OCF)	-0.003823	-0.6
LOG(LAR)	0.212871	16.9
LOG(OTA)	0.010037	1.7
LOG(CDT)	-0.035373	-2.6
LOG(ETA)	-0.359749	-14.0
Adj-R2	**0.983**	
Observations	**43490**	
Banks	**5314**	
Memo: **H STAT**	**0.21289**	(0.034)

Note: White cross-section standard errors & covariance (d.f. corrected); Cross-section fixed (dummy variables) Period fixed (dummy variables). Variables are as follows: IED interest expense to total debt funding; PTA personnel expenses to total assets; OCF other costs as a proportion of fixed assets; LAR loans as a proportion of assets; OTA other nonearning assets to total assets; CDT customer deposits as a proportion of deposits plus money market liabilities; ETA equity to total assets. All variables winsorized at 99%.

We have 43490 usable observations and 5314 out of 6008 banks can be incorporated. The cost of funds variable is positive while the other two cost variables are negative, although the "other cost" variable is not significant. Among the control variables, loans/total assets are positive, with higher risk boosting interest income; the non interest asset share is not significant; the deposit share in funding tends to reduce interest revenue, perhaps reflecting generally lower costs of customer deposits than wholesale funds. And as expected, the equity/assets (leverage) ratio is negative, as it indicates higher risk preference. The H statistic is 0.212 with a standard error of 0.034 indicating monopolistic competition on average across the EU. This is comparable to the 0.216 found for Western Europe over 1994-2004 in Bikker et al (2012).

The basic results over time for the Panzar-Rosse estimation are summarised in Table 3. We estimated separately for the full period 1998-2012, for the pre crisis period 1998-2006 and the post crisis period 2007-2012.

Table 3: Panzar Rosse H Statistics for 1998-2012 and sub periods.

H STATISTICS			
	FULL PERIOD	1998 – 2006	2007 - 2012
WHOLE EU	**0.21**	**0.29**	**0.26**
EASTERN	**0.05**	**0.20**	**0.07**
WESTERN	**0.25**	**0.34**	**0.28**
AT	**0.21**	**0.29**	**0.26**
BE	**0.13**	**0.35**	**0.28**
BG	**-0.38**	**-0.09**	**-0.44**
CY	**0.68**	**0.55**	**0.09**
CZ	**0.57**	**0.77**	**0.51**
DK	**0.15**	**0.34**	**0.25**
EE	**1.07**	**2.02**	**0.96**
FI	**0.95**	**0.68**	**0.58**
FR	**0.45**	**0.53**	**0.56**
DE	**0.11**	**0.22**	**0.23**
GR	**-0.50**	**-0.67**	**-0.15**
HU	**0.01**	**0.14**	**0.28**
IE	**0.00**	**-0.28**	**0.32**
IT	**0.35**	**0.17**	**0.41**
LV	**-0.94**	**-0.08**	**-0.58**
LT	**-0.05**	**-0.17**	**0.75**
LU	**0.17**	**0.42**	**0.04**
MT	**0.25**	**0.19**	**0.53**
NL	**0.60**	**0.52**	**0.27**
PL	**0.29**	**0.57**	**-0.28**
PT	**0.34**	**0.20**	**0.42**
RO	**0.17**	**0.09**	**0.05**
SK	**0.05**	**-0.04**	**0.27**
SI	**-0.13**	**-0.19**	**-0.17**
ES	**0.07**	**0.20**	**0.28**
SE	**0.33**	**0.23**	**0.34**
GB	**0.41**	**0.51**	**0.13**

Eastern European countries have lower levels of competition than Western ones. We find for most countries that there is a fall in the indicated level of competition since 2007, in the wake of the crisis, with the EU as a whole showing a fall in H from 0.29 to 0.26. Among individual countries, in the UK, the H statistic is 0.51 up to 2006 then only 0.13 thereafter, indicating a marked decline in competition. This is also true in countries such as the Netherlands (0.52 before, 0.27 afterwards), Cyprus and Luxembourg. On the other hand, competition is flat or increasing in Germany, Italy and France, perhaps reflecting ongoing structural change. Concerning levels, most countries are shown to have monopolistic competition (H between 0 and 1) whereas some Eastern European countries (Bulgaria, Latvia, Lithuania and Slovenia) have monopoly or oligopoly on average with H below one. This is also indicated to be the case in Ireland (pre crisis) and Greece.

Turning to the market equilibrium test using the log of ROA on the left hand side, we have the following results for Σ αj=0 in Table 4. Most countries are indicated to be in equilibrium, in the full period and also in the sub-periods. The key exceptions are Germany and Sweden, which fail the test in all the sub periods. Latvia and Lithuania also fail in the sub periods, while in the crisis, disequilibrium is shown in Estonia, Italy, Ireland, the Netherlands and Slovenia. The EU as a whole shows equilibrium only in 2007-12. We did further investigation of the result for Germany and found that for large banks with assets of over $1 billion, the market equilibrium is accepted for the two subperiods so it is the smaller German banks (which are very numerous and hence have an impact on the sample) which are out of equilibrium according to this test.

Table 4: Market equilibrium Wald tests for 1998-2012

Country	1998-2012	1998 – 2006	2007 – 2012
WHOLE EU	12.8 (0.003)**	9.4 (0.002)**	0.896 (0.34)
AT	0.807 (0.369)	2.65 (0.103)	0.04 (0.84)
BE	2.56 (0.109)	2.48 (0.115)	2.26 (0.13)
BG	4.92 (0.264)	0.071 (0.79)	3.79 (0.051)
CY	0.001 (0.97)	3.04 (0.08)	47.0 (0.000)**
CZ	0.607 (0.435)	0.0031 (0.96)	0.632 (0.42)
DK	0.71 (0.399)	0.766 (0.38)	1.964 (0.16)
EE	2.16 (0.14)	0.085 (0. 771)	4.85 (0.028)*
FI	0.02 (0.89)	0.16 (0.28)	2.21 (0.14)
FR	1.875 (0.17)	0.639 (0.424)	1.02 (0.31)
DE	136.6 (0.0)**	30.2 (0.000)**	21.5 (0.000)**
GR	3.07(0.08)	0.138 (0.71)	6.38 (0.011)*
HU	1.61 (0.204)	1.99 (0.16)	0.0001 (0.99)
IE	0.226 (0.63)	4.11 (0.043)*	139.3 (0.00)**
IT	1.13 (0.28)	1.51 (0.22)	5.85 (0.015)*
LV	6.19 (0.01)**	1.85 (0.17)	3.02 (0.08)
LT	8.08 (0.005)**	2.52 (0.112)	0.085 (0.77)
LU	0.545 (0.46)	2.48 (0.11)	0.1 (0.75)
MT	0.997 (0.31)	0.264 (0.61)	0.88 (0.348)
NL	3.73 (0.053)	1.18 (0.28)	22.9 (0.00)**
PL	0.04 (0.84)	4.25 (0.039)*	0.106 (0.74)
PT	0.106 (0.745)	5.6 (0.018)*	0.279 (0.6)
RO	1.33 (0.25)	2.02 (0.15)	0.136 (0.71)
SK	0.409 (0.52)	0.029 (0.87)	0.0003 (0.99)
SI	1.414 (0.23)	5.39 (0.02)*	9.11 (0.002)**
ES	0.036 (0.85)	1.68 (0.19)	2.93 (0.087)
SE	11.99 (0.0005)**	7.47 (0.0063)**	3.98 (0.045)*
GB	0.52 (0.469)	0.126 (0.722)	0.02 (0.887)

Albeit not central to this project, we considered it of interest to estimate also the determinants of competition at a macro level as measured by annual H, updating the work of Claessens and Laeven (2004), the results are shown in Appendix 2.

Turning to the relation of competition to risk, which is the core of the current project, we estimated year by year as outlined above to obtain a time series for H for each country. We then chose to Winsorise H at 95% given that there are a number of outliers resulting from the year-by year estimation procedure and the lack of scaling for the revenue function. This gives a range of roughly +1 (behaviour in line with perfect competition) to –2 (monopoly behaviour)

As noted, after experimenting with dynamic specifications, we found that the best results came with the current difference of H and levels at lags 2 and 3. This also avoids spurious results from overlapping differences and levels. This has a natural interpretation in terms of the short run effect of changes in competition being estimated separately from the long run effect of levels of competition, in line with the discussion in Section 2 above. Note that since H is a macro variable we consider it not likely to be highly correlated with individual bank Z scores, so we have not instrumented its current difference. We start with work on the pre crisis period where a link of competition to risk is most relevant, i.e. it would have offered an early warning indicator. We are also aware that since the crisis the competition risk relation may be distorted by forms of government intervention. Accordingly a basic Z-score result for all countries and the pre crisis period 1998-2006 is shown in Table 5 below:

Table 5: Log Z Score results for the EU 1998-2006 (dependent variable: log Z score)

Variable	Coeff	T value
DH	-0.03621	-2.0
H (-2)	0.147965	3.6
H (-3)	0.115447	2.0
CDT(-1)	0.202837	3.2
LAR(-1)	0.611541	7.9
NII(-1)	-0.42659	-17.6
Log TA (-1)	0.013674	0.7
D Log TA (-1)	-0.26942	-2.7
PII (-1)	-0.91606	-4.3
C	3.195342	11.7
Adj-R2	**0.077**	
Observations	**11363**	
Banks	**2701**	

Note: White cross-section standard errors & covariance (d.f. corrected); Period fixed (dummy variables). Variable defined as follows:, H is Panzar Rosse H Statistic for the country and year in question; CDT deposits as a share of short term funding; LAR loan/asset ratio; NIR noninterest revenue/interest revenue; TA bank size (total assets); PII provisions/interest income. All variables winsorized at 99% except H (95%)

Recall that a higher Z Score is an indicator of a less risky bank (i.e. with higher profitability and/or capital and less volatile profits). The core result shows that the difference of H is

negative and significant whereas the lagged levels of H are positive and significant. Accordingly, a change in the level of competition is harmful to banks' solvency, consistent with slow adaptation to change and disaster myopia during periods of apparent high profitability. This result suggests that the level of competition per se is not a cause of risk, banks can adapt to competitive conditions and keep solvent, for example by holding more capital as is found by Schaeck and Cihak (2012) consistently throughout their work.

As regards the other bank-specific variables, a higher share of deposits in total short term funding reduces risk, a result that was strongly borne out later during the crisis of 2007-9 when wholesale funding dried up (Demirguc Kunt and Huizinga (2010) had a similar result). The loan share in total assets also reduces risk, perhaps reflecting volatile holdings of securities or greater risks run by large banks which have lower loan/asset ratios. A higher ratio of non-interest income is negative for solvency (as again in Demirguc Kunt and Huizinga ibid), as the earlier promises that non-interest income could stabilize profits were not borne out over the data period; again it is large banks that tend to have higher non-interest income. The log of total assets is not significant but a rise in total assets strongly raises risk (perhaps reflecting adverse selection when assets rise sharply). Finally the ratio of provisions to interest income is directly and strongly negative for risk. Results for the provisions ratio, change in assets and non interest share are also consistent with Beck et al (2013; Table 5); however, on a global sample they find a positive link of size to stability that is not present in this EU sample. Note also that Beck et al (2013) use the Lerner index and not H as a competition/market power indicator (we experiment with Lerner below).

We now go on in Table 6 to present results for a regression also with country dummies, which hence captures effects on the average Z score that are country specific and not explained by other variables:

Table 6: Log Z Score results for the EU with country dummies 1998-2006

Variable	Coeff	T value
DH	-0.05223	-2.4
H (-2)	0.135174	2.6
H (-3)	0.093433	1.5
CDT(-1)	0.177406	2.8
LTA(-1)	0.461657	6.2
NII(-1)	-0.44705	-21.0
Log TA (-1)	0.017725	0.8
D Log TA (-1)	-0.16778	-1.3
PII (-1)	-0.83	-4.1
C	3.254822	10.3
Adj-R2	**0.1**	
Observations	**11363**	
Banks	**2701**	

Note: White cross-section standard errors & covariance (d.f. corrected); Period fixed (dummy variables). Variables, see note to Table 5. Country dummies (excluding Germany) were included in the regression.

We leave out the dummy for one country (Germany) as is necessary for identification; dummies are not included in the table. Results here are consistent with Table 5 and the H results are again significant at the 95% level for the dynamic term and the second lag levels term although the third lag is insignificant. The coefficient for the growth of total assets also become insignificant in this case.

Our third main set of results is for a regression including macro variables relating to financial structure and regulation, as noted following a search we have included the stock market turnover ratio, the dummies for legal origin and the regulation variables for activity restrictions and stringency of capital regulations.

Table 7: Log Z Score results for the EU with macro variables 1998-2006

Variable	Coeff	T value
DH	-0.07433	-3.8
H (-2)	0.093125	1.8
H (-3)	0.039929	0.5
CDT(-1)	0.179137	2.9
LAR(-1)	0.535173	6.3
NII(-1)	-0.42159	-16.9
Log TA (-1)	0.012068	0.6
D Log TA (-1)	-0.21118	-1.8
PII (-1)	-0.88838	-4.6
C	3.552718	12.9
SMT	0.000752	1.4
LOBRIT	0.246001	2.6
LOSCAND	0.111845	1.0
LOGER	0.080163	1.8
ACT	-0.08217	-2.9
CSI	0.002678	0.1
Adj-R2	0.084	
Observations	**11340**	
Banks	**2686**	

Note: White cross-section standard errors & covariance (d.f. corrected); Period fixed (dummy variables).Variables as in note to Table 5, also SMT stock market turnover; LOBRIT British legal origin; LOSCAND Scandinavian legal origin; LOGER German legal origin; ACT activity restrictions; CSI initial capital stringency

Results here are consistent with Table 5 with the difference of H result significant at the 99% level, while the level effect is now significant at the second lag at the 10% level. Again the total assets variable becomes insignificant. As regards legal origin, we omit the French legal origin as it covers the majority of EU countries, the ones with British and German legal origin are shown to have higher Z Scores on average while those with Scandinavian legal origin are similar to French (note this is the pre crisis period). The authorities imposing tighter activity restrictions have lower Z Scores and hence less stable banks.

It is of interest to see how stable the result is of positive H in the level and negative in the difference. We show a variety of estimates including the later sub period and the full sample in Table 8.

Table 8: Results for H from different time periods (dependent variable, log Z Score)

	Basic (as Table 5)			**Dummies (as Table 6)**			**Macro (as Table 7)**		
Basic	**1998-2006 (1)**	**1998-2012 (2)**	**2007-2012 (3)**	**1998-2006 (4)**	**1998-2012 (5)**	**2007-2012 (6)**	**1998-2006 (7)**	**1998-2012 (8)**	**2007-2012 (9)**
DH	-0.036 (2.0)**	-0.052 (1.1)	-0.081 (1.0)	-0.052 (2.4)**	-0.051 (1.3)	0.0 (0.0)	-0.074 (3.1)***	-0.035 (0.9)	-0.246 (0.4)
H (-2)	0.148 (3.7)***	0.148 (3.4)***	0.11 (1.4)	0.135 (2.7)***	0.075 (1.5)	0.071 (0.8)	0.093 (1.8)*	0.072 (1.8)*	0.074 (1.9)*
H (-3)	0.115 (2.0)**	0.177 (4.2)***	0.206 (3.3)***	0.093 (1.5)	0.126 (3.4)***	0.115 (2.5)**	0.04 (0.6)	0.089 (1.6)	0.11 (1.8)*
Adj-R2	0.08	0.11	0.14	0.1	0.15	0.21	0.08	0.09	0.13
Observations	11363	28301	16938	11363	28316	16973	11340	23246	11906
Banks	2701	4219	3607	2701	4219	3609	2686	4130	3432

Note; additional variables included as in Tables 5-7. H is Panzar Rosse H Statistic for the country and year concerned.

It can be seen that whereas the three specifications have consistent significance for the level and difference across the earlier period 1998-2006 (column (1), which reproduces the results in Table 5-7), this is not the case for the full period (1998-2012) and the later sub period (2007-2012) where the levels effect dominates. We consider however that these results for the dynamics are likely to be affected by government intervention in banks and in market competition and accordingly contend that the original result remains valid. 1998-2006 is the most important period in the sample since after 2007 the crisis supervened, leading to government intervention and greater market disequilibrium (Table 4). In 1998-2006, the run up to the crisis, a discovery of a positive link of competition changes to risk is most relevant for regulators; in the short run there is a need for caution regarding risk when competition increases, in line with the competition-fragility approach which finds wide support elsewhere in the literature. Meanwhile the consistent finding of a positive long run effect of competition on soundness offers support for the competition-stability approach in the long run, in line with studies such as Anginer et al (2012).

We conclude this section with a comparison of control variables pre and post crisis. It can be seen from Table 9 (from equations (7) and (9) in Table 8), that there are some changes in the other right hand side variables during the crisis period, although most remain stable and significant. So for example among the bank specific variables the growth in total assets becomes more significant as a risk factor. However, the other bank specific variables remain positive and highly significant suggesting the crisis did not involve a complete adjustment in

banks' trade off of competition with risk in the fairly homogeneous regulatory environment of the EU. As regards the macro variables, we see stabler banks in countries with a more active stock market only after the crisis, while activity restrictions are only significant before the crisis with restrictions inducing more risk (in line with Beck et al (2006) and Anginer et al (2012)). British and German legal origin countries cease to have an advantage over the French law countries after 2007 and Scandinavian ones have a disadvantage in the post crisis period.

Table 9: Comparing control variables pre and post crisis

Period	1998-2006		2007-2012	
Variable	Coeff	T value	Coeff	T Value
CDT(-1)	0.179137	2.9***	0.138041	2.3**
LTA(-1)	0.535173	6.3***	0.540894	8.9***
NII(-1)	-0.42159	-16.9***	-0.32443	-6.6***
Log TA (-1)	0.012068	0.6	-0.01875	-0.9
D Log TA (-1)	-0.21118	-1.8*	-0.19247	-2.4**
PII (-1)	-0.88838	-4.6***	-1.56828	-4.6***
C	3.552718	12.9***	3.482258	14.5***
SMT	0.000752	1.4	0.00157	3.7***
LOBRIT	0.246001	2.6***	0.027206	0.3
LOSCAND	0.111845	1.1	-0.34361	-2.4**
LOGER	0.080163	1.8*	0.107583	1.5
ACT	-0.08217	-3.0***	-0.00887	-0.3
CSI	0.002678	0.1	0.045932	1.1

Note: Variables defined as in Tables 5 and 7

6 Results for Lerner Index

To compare and comtrast with our results for the H Statistic, we went on to estimate the Lerner index showing price-marginal cost margins for banks in the EU. We did this, following Anginer and Demirguc-Kunt (2012) by estimating a translog production function and then deriving the marginal cost for banks in each year of the sample (see estimates in Appendix 3). The Lerner index then provides an alternative measure of competition in the banking system, with narrower margins tending to accompany a rise in competition.

A natural comparison with the results above then is to include the Lerner index instead of H in the equation for log of Z Score. In the work of Beck et al (2013), for example, the current level of the Lerner index is consistently positive, as a high margin indicates a safer bank and hence a higher Z score and vice versa. However, we would contend that such a result is contestable since as pointed out by the same authors, there is an element of circularity in this argument since the Lerner index itself includes the return on assets which in turn is strongly related to the price-cost margin as shown by the Lerner index (correlation of 0.5). Accordingly, we contend that the Lerner index should at least be instrumented to avoid bias from this simultaneity if the current level is used and otherwise lagged.

Accordingly and in line with our work for H, we included the current difference and the second and third lag for Lerner, winsorised at the 99% level. To avoid simultaneity we

instrument the current difference of Lerner with the first and second lagged differences. The results are as shown in Table 10.

Table 10: Results for Lerner from different time periods

	Basic			**Dummies**			**Macro**		
Basic	**1998-2006 (1)**	**1998-2012 (2)**	**2007-2012 (3)**	**1998-2006 (4)**	**1998-2012 (5)**	**2007-2012 (6)**	**1998-2006 (7)**	**1998-2012 (8)**	**2007-2012 (9)**
Dlerner_inst	0.174 (0.9)	0.33 (1.7)*	0.41 (1.5)	0.4 (2.0)**	0.68 (4.0)***	0.75 (3.3)***	0.41 (2.2)**	0.77 (3.7)***	0.92 (3.1)***
Lerner (-2)	0.744 (3.1)***	0.67 (1.6)*	0.58 (0.9)	0.75 (2.6)**	0.8 (2.7)***	0.71 (1.7)*	0.93 (3.3)***	0.86 (2.7)***	0.77 (1.4)
Lerner (-3)	-0.3 (1.3)	-0.34 (1.0)	-0.31 (0.6)	-0.29 (1.1)	-0.08 (0.4)	-0.04 (0.2)	-0.18 (0.7)	0.05 (0.2)	0.16 (0.5)
Adj-R2	0.07	0.09	0.12	0.1	0.16	0.22	0.08	0.12	0.19
Observations	10193	24263	14070	10173	24259	14086	10142	19559	9417
Banks	2298	3795	3179	2298	3797	3181	2291	3706	3061

Note; additional variables included as in Tables 5-7. Dlerner_inst is the current difference of Lerner instrumented by two lags of itself.

The first difference term is consistent with the result for the differenced H statistic, in the sense that given a positive sign, a rise in competition (reduction in L) leads to a decline in the margin and less stable banks. This result applies consistently across samples in contrast to the dynamic result for H which is largely confined to the 1998-2006 sample, although it is not significant for the basic specification in the two subperiods. Meanwhile it is the second lag which is generally significant, with again a positive sign implying a long run negative impact of competition on risk. Accordingly the Lerner index favours the competition-fragility hypothesis in both the short and long run with the latter being in line with papers such as Fu et al (2014).

Hence we have a similar result between the two competition indicators for the impact of changes in competition on bank risk, namely that a rise in competition leads to a deterioration in banks' soundness as measured by the Z score (competition-fragility). On the other hand, the H statistic consistently shows that there is a long run negative relation between competition and risk (i.e. banks in the long run are safer in competitive markets – competition-stability), while the Lerner statistic indicates a negative long run relation for the same banks (i.e. banks in the long run are less safe in markets with narrower price-cost margins – competition fragility).

As a robustness check to verify this result we ran the basic regressions for both H and Lerner (i.e. with extra variables as in Table 5) for a different dependent variable namely the ratio of impaired loans to total loans. This has a much smaller coverage than the Z Score, with less

than 10000 observations and rather few before 2007. The results for H and Lerner are as shown in table 11 below.

Table 11: Robustness check - results for competition indicators using impaired loan ratio as risk variable

H Statistic	1998-2006	1998-2012	2007-2012
DH	-0.00293 (0.4)	-0.00232 (0.4)	-0.0098 (0.1)
H (-2)	-0.00367 (1.3)	-0.00839 (3.5)***	-0.00959 (3.0)***
H (-3)	-0.0024 (0.3)	-0.00831 (2.2)**	-0.00845 (1.9)**
Adj-R2	0.039	0.32	0.34
Observations	797	7408	6611
Banks	365	2033	1908
Lerner			
Dlerner_inst	-0.0227 (0.8)	-0.022 (1.9)*	-0.023 (2.0)**
Lerner (-2)	-0.1377 (6.1)***	-0.063 (2.6)***	-0.05 (1.9)**
Lerner (-3)	-0.00437 (0.3)	0.067 (2.2)**	0.083 (2.5)**
Adj-R2	0.12	0.33	0.36
Observations	636	5784	5148
Banks	229	1800	1683

Note; additional variables included as in Table 5

As can be seen, there is a broad tendency for the relation of each variable to impaired loan ratios to be negative in the long run. The dynamics are less significant than with Z Score, probably reflecting the lack of observations in the earlier sample. Accordingly, the data are saying that a higher level of competition in the long run (higher H) leads to less impaired loans and hence less risk (competition-stability). On the other hand the Lerner results for both short and long run imply that the narrower the margin (i.e. the more competition), the higher the impaired loan rate (competition-fragility), although this pattern is returned to zero after three years in the later samples, probably reflecting cyclical patterns and the effect of the crisis.

Given the consistent differences in long run effects of H and Lerner, we conclude our work by investigating reasons for such a differing long term result.

7 Assessing the differences in results

There are conceptual differences between H and Lerner as shown by Carbo et al (2009), in that the former is a “difference” term (elasticity of revenue to prices) and the latter a “levels” effect (the price/marginal cost margin). Furthermore, the H is a macroeconomic

index describing the situation in the banking sector as a whole, while the Lerner describes the price cost margin of an individual bank.

We sought to find the reasons for the differing predictions by regressing the level of each indicator of competition on the subcomponents of the Z score (ROA, as noted a measure of performance; capital adequacy, a measure of safety and soundness and volatility of ROA, a measure of risk). This was estimated using a specification similar to Table 5 (i.e. including the basic control variables) and a lagged level of the relevant competition indicator, estimated over the whole sample (we checked and the same results hold over each subsample as well). Results are as shown in Table 12.

Table 12: Relationship between H, Lerner and the components of the Z score (1998-2012)

	Lag H statistic	**Lag Lerner (* -1)**
ROA	**-**	**-**
Capital adequacy	**-**	**-**
SD (ROA)	**-**	**+**
Z score	**+**	**-**

Note: All effects are significant at the 99% level, other variables as in Table 5.

We multiplied the Lerner index by –1 so that in both cases an increase in the indicator is consistent with higher competition. The results show that both H and Lerner * -1 are negatively related to both ROA and capital adequacy. In other words, increased competition on both measures is related to lower profits and lower capital cover, thus reducing Z Score. On the other hand, we find that there is a difference in the relation to the standard deviation of profitability, with H having a negative effect (higher levels of market competition leads to lower volatility of profits) while Lerner * -1 has a positive effect (narrower price-cost margins for the individual bank accompany an increase in the volatility of profits). The outcome of these different effects for the Z score, the overall measure of risk, is that greater market competition (shown by H) leads to less risky positions in the long run, while narrower price-cost margins (shown by Lerner) lead to increased risk. The same results – including the contrast for profit volatility - apply in all cases and with similar significance for the two sub periods (1998-2006 and 2007-2012). In other words it is not an artefact either of the boom period or the later financial crisis.

A full investigation of reasons for these differences is beyond the scope of this paper, suffice to note first that H is a country-wide indicator while Lerner is a bank-specific one. While there is a general tendency for greater competition to lead to narrower margins this need not always be the case (for example if there were previously monopolists seeking a quiet life and taking their rents in terms of inefficiency, Koetter et al (2012)). Numerically it is likely that narrower margins lead to more profit volatility since they are closer to zero, while the link of profit volatility to market competition is less direct, given the latter is measured by response of revenue to input prices.

Taking the results at face value, this section overall suggests a need for caution in drawing policy conclusions from risk-competition studies without careful consideration of the likely impact of a given policy shift. For example separation of retail and wholesale banking or certain macroprudential policies may have different effects on margins (as shown by Lerner) as opposed to market competition (shown by the H statistic). Margin effects consistently increase risk whereas our results suggest that more competition is favourable for soundness in the long run.

Conclusions

This is one of the first studies of banking competition and risk to take account of a full 7 year period since the onset of the crisis in 2007; to allow for changes in competitive conditions as well as levels to impact on risk; and to compare and contrast results using two indicators of competition, the H statistic and the Lerner index. Findings are as follows:

Regarding competition measurement, according to H defined using unscaled revenue functions, most EU-country banking sectors are characterised by monopolistic competition, albeit close to oligopoly; some mainly Eastern countries are subject to oligopoly/monopoly conditions. The crisis entailed a decline in measured competition across EU banking sectors according to average H since 2007, although this was not the case for every country. For most countries, market equilibrium prevailed over the entire period 1998-2012 according to the ROA test and also in the sub period before and after the crisis. The main exceptions are Germany and Sweden, and some crisis-hit countries in the period since 2007.

Results for the trade-off between competition (measured by H at a country level) and risk (measured at a bank level) suggest that in the short run a change in competition has a positive effect on risk , while in the long run there is a negative effect of the level of competition on risk. The dynamic effect was particularly the case in the pre crisis period 1998-2006, while the long run effect is consistent throughout. It can be suggested that this is consistent with banks in a post liberalisation environment adapting appropriately to average levels of competition but being vulnerable to errors in risk management when levels of competition change.

The Lerner index provides results supportive of the hypothesis that there are dynamic relations between competition and risk, in that the change in the Lerner index again correlates positively with risk (i.e. narrower margins as when competition increases make banks weaker) but in this case the long run effect is also for competition to lead to higher risk.

Decomposing the Z Score indicator, we find that the impact of the H statistic and the Lerner index are identical for both profitability (ROA) and for capital adequacy (i.e. components of the numerator). However, they differ in terms of the impact on the denominator, namely the volatility of profitability (measured over three years). Accordingly, the overall long term relation to risk as measured by the Z score has a different sign. The H statistic results suggest consistently that in the long run, higher market competition leads to lower risk. On the other

hand, the Lerner index suggests that narrower margins which may result from more competition lead to higher risk.

In terms of policy, the work consistently suggests that considerable caution is warranted by regulators in the initial period after a rise in competition, since the indicators show consistently that a rise in bank risk accompanies it. On the other hand, in the longer term, there is a need for caution in drawing policy conclusions from risk-competition studies without careful consideration of the likely impact of a given policy shift, given the conflicting results for H and Lerner. So for example it needs to be considered what effect policies such as separation of retail and wholesale banking or certain macroprudential policies will have on margins (as shown by Lerner) as opposed to market competition (shown by the H statistic). An impact directly on margins is shown to be deleterious to risk, while enhancing competition generally tends to enhance soundness.

A number of avenues of further research are implied. One is testing of additional indices for competition such as the Boone index, and further assessment of differences between H and Lerner. What is the relation of the fiscal situation of the government to banking competition and risk, given the well known links of banking difficulties to fiscal problems? Furthermore, in the past EU banking systems have been seen as subject to excess capacity (Davis and Salo 1998) – how does excess capacity impact on competition and risk – and how is it best measured? It may be important to focus separately on Eastern EU countries, given studies such as Uhde and Heimeshoff (2009) found distinct results there over 1997-2005, e.g. in respect of the impact of entry restrictions. In this context, foreign bank ownership may affect the competition and risk trade-off – and which is very important in the New Member States of the EU (Berger et al 2009 included foreign ownership and found no effect, but their sample was 91% US banks). And as noted by CEPR (2010), is it appropriate to blame the universal banking model for risk when investment banks and simple retail banks also took excessive risks? Hence testing for the trade-off of competition and risk by bank type may be a further extension.

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APPENDIX 1 – VARIABLE STATISTICS

Table A1: Variables for H statistic and Lerner

Variable definition/code	Observations	Mean	Standard Deviation	Maximum	Minimum
Total interest revenue*	46148	270522	1041025	8541040	744.9
IED (Interest expense/debt)*	46142	0.027	0.014	2.12	0.004
PTA (Personnel expenses/assets)*	45189	0.014	0.007	0.053	0.0004
OCF (other costs/fixed assets)*	45224	2.2	5.18	38.0	0.18
CDT (deposits/short term funding)*	43563	0.78	0.21	1.0	0.02
LAR (loan/asset ratio)*	43861	0.59	0.18	0.94	0.04
OTA (other nonearning assets/total assets)*	43948	0.016	0.023	0.158	0.001
ETA (equity/total assets)*	43971	0.079	0.052	0.356	0.016
TOTALC (total cost)*	44971	268570	1034403	8508045	1178

Table A2: Variables for risk/competition

Variable definition/code	Observations	Mean	Standard Deviation	Maximum	Minimum
Log Z (Log Z Score)*	32118	3.76	1.06	0.69	6.56
H Statistic*	86774	-0.07	0.82	1.04	-1.9
Lerner index*	40706	0.2	0.106	0.49	-0.15
CDT	43563	0.78	0.21	1.0	0.02

(deposits/short term funding)*					
LAR (loan/asset ratio)*	**43861**	**0.59**	**0.18**	**0.94**	**0.04**
NIR (noninterest revenue/interest revenue)*	**46026**	**0.26**	**0.44**	**3.64**	**-0.06**
Ln TA (log total assets)*	**46842**	**13.6**	**1.8**	**19.3**	**9.8**
PII (provisions/interest income)*	**44128**	**0.09**	**0.12**	**0.69**	**-0.26**
SMT (stock market turnover)	**83664**	**106.9**	**50.7**	**259.6**	**0.14**
CSI (Capital stringency)	**89392**	**1.7**	**0.69**	**3**	**0**
ACT (activity restrictions)	**81915**	**5.5**	**1.74**	**11**	**3**
LOGER (legal origin German)	**90120**	**0.54**	**0.5**	**1**	**0**
LOFR (legal origin French)	**90120**	**0.35**	**0.48**	**1**	**0**
LOBRIT (legal origin UK)	**90120**	**0.06**	**0.23**	**1**	**0**
LOSCAND (legal origin Scandinavian)	**90120**	**0.05**	**0.22**	**1**	**0**

Note: Variables marked * are Winsorized at 99% except for H statistic (95%)

APPENDIX 2: SIMPLE MACRO REGRESSION FOR DETERMINANTS OF COMPETITION

The table below shows an estimate of the determinants of competition in EU banking sectors, using annual macro data on H as the dependent variable, and testing down from a variety of variables in the World Bank supervision and financial structure databases. We use as a dependent variable the average level of H over the three years prior to the observation.

Table A.1.1: Determinants of level of competition (H statistic) 1998-2011

Variable	Coeff	T value
C	-0.654387	-1.2
ACTREST	-0.102496	-1.8
FORBANK	-0.006434	-1.8
MULTSUP	0.436538	1.7
WESTERN	0.773396	2.4
INFLATION	0.066618	3.5
SMCAPGDP	0.005453	1.9
Adj-R2	0.205	
Observations	**215**	
Countries	**23**	

Results suggest that stringent activity restrictions have a negative effect on competition, as does the penetration of foreign banks (this latter may reflect lower competition in Eastern than Western EU countries). Multiple supervisors tend to accompany higher competition and it is also higher in Western European countries than Eastern ones. Higher inflation and more securities market competition, as shown by the stock market capitalisation to GDP ratio also tend to accompany higher levels of competition. We note that banking concentration is not significantly related to H at a macro level.

APPENDIX 3: TRANSLOG PRODUCTION FUNCTION

Table A.2. 1 shows the unrestricted translog production function for EU countries, while Table A.2.2 shows the result of imposing restrictions of homogeneity in line with Anginer and Demirguc Kunt (2012). We estimate across the whole EU using the assumption that technology in banking is broadly similar.

Table A.2.1 Unrestricted translog production function (1998 2012)

Dependent Variable: LNTOTALC_Q
Method: Panel Least Squares
Date: 09/24/13 Time: 16:33
Sample: 1998 2012
Periods included: 15
Cross-sections included: 5136
Total panel (unbalanced) observations: 40805

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.734533	0.080574	9.116265	0
LNTA	1.254531	0.00618	202.9976	0
LNTA2	-0.01175	0.000191	-61.4463	0
LOG(COST_FUNDS_ST_Q)	0.887111	0.025083	35.36718	0
LOG(STAFF_COST_Q)	0.851826	0.015922	53.50112	0
LOG(OTHERCOST_Q)	0.097599	0.009506	10.26725	0
LOG(COST_FUNDS_ST_Q)*LNTA	0.002731	0.001067	2.560698	0.0104
LOG(STAFF_COST_Q)*LNTA	-0.01433	0.000937	-15.298	0
LOG(OTHERCOST_Q)*LNTA	-0.0028	0.000559	-5.00306	0
LOG(COST_FUNDS_ST_Q)*LOG(COST_FUNDS_ST_Q)	0.145048	0.002637	55.00973	0
LOG(STAFF_COST_Q)*LOG(STAFF_COST_Q)	0.086356	0.001253	68.94226	0
LOG(OTHERCOST_Q)*LOG(OTHERCOST_Q)	0.008301	0.000621	13.36733	0
LOG(COST_FUNDS_ST_Q)*LOG(STAFF_COST_Q)	-0.15108	0.002554	-59.1509	0
LOG(STAFF_COST_Q)*LOG(OTHERCOST_Q)	0.028868	0.001172	24.62765	0
LOG(OTHERCOST_Q)*LOG(COST_FUNDS_ST_Q)	-0.03062	0.001666	-18.3764	0

Effects Specification

Period fixed (dummy variables)

R-squared	0.990389	Mean dependent var	10.63747
Adjusted R-squared	0.990382	S.D. dependent var	1.72016
S.E. of regression	0.168697	Akaike info criterion	-0.72071
Sum squared resid	1160.434	Schwarz criterion	-0.71459
Log likelihood	14733.33	Hannan-Quinn criter.	-0.71878
F-statistic	150062.5	Durbin-Watson stat	0.266477
Prob(F-statistic)	0		

Table A.2.2 Restricted translog production function (1998-2012)

Dependent Variable: LNTOTALC_Q
Method: Panel Least Squares
Date: 09/24/13 Time: 16:53
Sample: 1998 2012
Periods included: 15
Cross-sections included: 5136
Total panel (unbalanced) observations: 40805
LNTOTALC_Q = C(1) + C(2)*LNTA + C(3)*LNTA2 + C(4)
*LOG(COST_FUNDS_ST_Q) + C(5)*LOG(STAFF_COST_Q) + (1-C(4)
-C(5))*LOG(OTHERCOST_Q) + C(7)*LOG(COST_FUNDS_ST_Q)
*LNTA + C(8)*LOG(STAFF_COST_Q)*LNTA + (0-C(7)-C(8))
*LOG(OTHERCOST_Q)*LNTA + C(10)*LOG(COST_FUNDS_ST_Q)
*LOG(COST_FUNDS_ST_Q) + C(11)*LOG(STAFF_COST_Q)
*LOG(STAFF_COST_Q) + (0-(0-C(11)-C(13))-(0-C(10)-C(13)))
*LOG(OTHERCOST_Q)*LOG(OTHERCOST_Q) + C(13)
*LOG(COST_FUNDS_ST_Q)*LOG(STAFF_COST_Q) + (0-C(11)-C(13))
*LOG(STAFF_COST_Q)*LOG(OTHERCOST_Q) + (0-C(10)-C(13))
*LOG(OTHERCOST_Q)*LOG(COST_FUNDS_ST_Q)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-1.60908	0.044085	-36.4992	0
C(2)	1.322094	0.005578	237.0135	0
C(3)	-0.01259	0.0002	-62.8348	0
C(4)	0.002989	0.012162	0.245797	0.8058
C(5)	0.850105	0.010301	82.52819	0
C(7)	0.045233	0.000744	60.76917	0
C(8)	-0.03612	0.000709	-50.9729	0
C(10)	0.0297	0.00105	28.29305	0
C(11)	0.013587	0.000684	19.8545	0
C(13)	-0.01808	0.000462	-39.1192	0

R-squared	0.987255	Mean dependent var	10.63747
Adjusted R-squared	0.987252	S.D. dependent var	1.72016
S.E. of regression	0.19422	Akaike info criterion	-0.4394
Sum squared resid	1538.85	Schwarz criterion	-0.43729
Log likelihood	8974.906	Hannan-Quinn criter.	-0.43874
F-statistic	351105.6	Durbin-Watson stat	0.238735
Prob(F-statistic)	0		