FACULTEIT ECONOMIE EN BEDRIJFSWETENSCHAPPEN
DEPARTEMENT CENTRUM VOOR ECONOMISCHE STUDIËN
DEPARTEMENT KWANTITATIEVE BELEIDSMETHODEN EN BELEIDSINFORMATICA
DEPARTEMENT ACCOUNTANCY, FINANCE & INSURANCE

KATHOLIEKE
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THE EFFECT OF STATE AID ON COMPETITION IN THE BELGIAN BANKING SECTOR

PIETER REYNDERS
THOMAS VERBIST

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Promotor : Prof. Dr. P. Van Cayseele
Copromotor: Prof. Dr. M. Vandebroek
Werkleidster: Ellen Coosemans

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Abstract: Employing bank-level data, we apply the Panzar and Rosse (1987) methodology to estimate a competition measure that reflects the extent to which input prices affect total income. Then, in a second stage, we relate this competition indicator to a number of factors, so as to estimate the competition effect of state aid given during the 2008-2009 financial crisis, focusing on the Belgian case. We find that state aid, measured by both direct state capital injections and time dummies, has a significantly positive effect on competition in the Belgian banking market. Our findings emphasize the distinct characteristics of state aid in the financial sector, and suggest that state aid competition policy could be more complex than previously thought.

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1 Introduction

The competition effects of the state aid granted to banks in the 2008-2009 financial crisis have commanded a great deal of attention from financial sector players, competition authorities, policymakers and academics. This attention is not out of place, with the European Commission (EC) estimating in September 2009 that, in the EU alone, over €3.5 trillion of state aid in various forms has been granted to financial institutions since September 2008 (EC, 2009). Some financial sector players that did not receive state aid argue that financial institutions that did now hold a competitive advantage, whilst those companies refute that claim by noting that they are paying a high price for this government support. The competition authorities, then, are frustrated as they have had to relax their state aid rules and were forced to take ex post compensationary measures in 2010. Policymakers are unsure of the competition consequences of their actions, since, taken aback by the climate of distrust among financial institutions after the Lehman Brothers collapse, their decisions on many of the rescue operations had to be taken in a few days, if not hours. Academics, finally, debate the consequences but grope in the dark since no quantitative study has investigated the effects the 2008-2009 state aid on competition yet. In fact, to the best of our knowledge, there are to this day no empirical studies that assess the effect of government support in general on competition quantitatively[1]. We aim to fill part of this gap with our research on the impact of state aid to banks during the 2008-2009 period, focusing on the Belgian case.

Whilst state aid is intuitively seen as affecting competition negatively, this might not be the case for state aid in the financial sector. If an aviation company receives government support, its resources grow and its competitive position is strengthened. However, state aid to one bank might help other banks as well by avoiding financial distress and interbank loan defaults. Therefore, this paper is also an empirical test on which competition implications dominate in the financial sector.

How to measure competition has been the subject of intense debate in the industrial organization literature. We go over the most cited methods and give an overview of their advantages and disadvantages. From this comparison, the Panzar and Rosse (1987) (hereafter denominated as PR) methodology emerges as the preferred competition measuring model. Indeed, since a number of years, the PR methodology has become the most commonly used approach to measure competition in the banking sector. It provides us with a competition indicator, the H-statistic, that measures to what extent changes in input prices are reflected in the total revenues of a firm. Since we also employ this model to measure competition, we go over its characteristics conscientiously.

Using quarterly bank-level data over the 1999-2009 period, we propose a two-staged approach to measure the state aid effect, employing the Panzar-Rosse model to estimate 41 four-quarterly rolling H_t-statistics in a first stage, then, in a second stage, regressing these H_ts on various state aid measuring variables and a number of competition affecting factors as control variables. The data set is provided to us by the National Bank of Belgium with the explicit support of the 61 included banks. They own 94.5 percent of the total assets of the Belgian banking market,

[1] Cheng and Van Cayseele (2009), however, look for a conduct change as a result of state aid in China.

ensuring our data set is representative of the Belgian banking market.

We find that state aid *heightens* competition strongly and significantly over all different specifications of the state aid measuring variable. We suggest a number of possible reasons for this positive effect. Firstly, banks that receive state aid have to pay a price for this. Our results seem to indicate that the prices charged are at least fair.

Secondly, this result confirms the special situation of the financial sector with regards to state aid. Government support reduces the probability of financial distress in the market, and, as the bank sector is closely interwoven through the interbank lending market, it allays fears of interbank loan defaults.

Lastly, governments will normally only be inclined to rescue banks that they consider too big to fail, as they prefer to let market forces play. Indeed, in Belgium only three of the largest banks on a total of more than 100 received direct state aid from Belgian governments. State aid could send a signal to consumers that the bank is in a more troublesome situation than previously thought, harming its reputation further. This could lead them to turn towards safer, non-state aid banks (i.e., banks that did not receive state aid) for financial services. Coupled with the fact that the state aid banks are already less likely to make use of their dominant position as this could further upset governments and the public, a more level playing field can be established. The non-state aid banks now have an incentive to compete more fiercely with strong market share gains within sight, again increasing the competition in the industry. An indication of this last possible reason is found in the strong capital transfer of household depositors from the four largest Belgian banks to many smaller banks in the aftermath of the financial crisis[2], possibly inducing stronger competition.

These results suggest that state aid policy could be more complex than previously thought. If the state aid conditions imposed by governments at the conclusion of the state aid deal (such as pricing) have a stronger than anticipated mitigating influence on the competition disrupting effects of state aid, both governments and competition authorities should rely more on those than on ex post measures.

This paper is structured in the following way. Section 2 serves as an introduction to the financial crisis and its implications, after which it provides a short overview of the Belgian banking sector. Section 3 gives a general and financial sector specific overview of competition effects of state aid, followed by a summary of the state aid given by Belgian governments during the financial crisis. Sections 4 through 6 discuss the most cited competition measurement methods, before Section 7 digs deeper into the features of our chosen method, the Panzar and Rosse model. In Section 8, we describe our data set. Section 9, then, deals with the methodology of our first-stage equation, the PR reduced form revenue equation, and provides a rundown of its results. The second-stage equation methodology and results can be found in Section 10, in which we regress the Panzar-Rosse competition statistic on a number of state aid measuring variables and other competition impacting factors as control variables, in order to assess the competition impact of

[2]This assertion is based on deposit comparisons between the different banks in our data set, and is confirmed by various market players.

the government support granted in 2008-2009. We deduce tentative policy implications from these results in Section 11. Section 12 concludes by summarizing our main results, highlighting the added value of our paper to the existing literature and suggesting future research topics in this matter. A number of appendices give further insight into the statistical means and methods employed, and contain the results of various robustness checks.

2 The 2007-2009 financial crisis

The banking sector faced one of the gravest crises in its history in the period 2007-2009 after incurring large U.S. subprime mortgage losses. At its peak, after the Lehman Brothers collapse in September 2008, suspicions were raised over banks' liquidity positions and as a result, the interbank lending market collapsed. The liquidity concerns became a self-fulfilling prophecy and several banks quickly became cash-strapped. The magnitude of the crisis was illustrated by the collapse of Lehman Brothers, one of the world's largest investment banking firms, marking the largest bankruptcy case in U.S. history (Spector *et al.*, 2010). Governments and central banks were forced to intervene, the former bailing out banks, the latter providing cash lines at near zero cost[3].

In the economic bull market of the period 2003-2006, banks and other lenders overplayed their hand by investing heavily in U.S. mortgages to subprime segment clients, which was made possible by the rising U.S. housing prices (appreciating 80 percent in nominal terms between 2000 and 2006 (EEAG, 2009)). Since most market participants believed that price appreciation in the U.S. housing market would continue, even at the price peak (Mayer, 2010)[4], a foundation for very lax lending standards was established. In this way, lenders felt assured that even if subprime mortgage borrowers defaulted on their loans, they would still make a profit since their clients' houses, the asset which backed their loans, would have appreciated.

In a bid to minimize regulatory capital requirements and diversify their risk, many lenders securitized large parts of their mortgage portfolio as Asset Backed Securities (ABSs) such as Collateralized Debt Obligations (CDOs) and Credit Default Swaps (CDSs). The initial mortgage loans were transferred from these lenders to investment banks, subsequently put into a pool of loans (usually becoming an own entity, named a Special Purpose Vehicle), then securitized and ultimately sold to a variety of investors (Peterson, 2007). Many scholars have pointed out that the credit ratings given to these ABSs were too rosy to reflect the risks inherent to them (Mayer, 2010), which misled investors. Furthermore, these investors either misunderstood these products due to their high complexity (Ashcraft and Schuermann, 2008), or seemed to underestimate or ignore their high level of risk (Mayer, 2010), which resulted in excessive risk taking. When the inflated U.S. housing bubble burst in 2007 and adjustable rate mortgages were reset at higher rates[5], many Americans had no option but to default on their mortgage loans. At this time,

[3]The responses from central banks differed across regions, but all provided liquidity at very low cost. For more details, see Reinhart and Felton (2008).

[4]Shiller (2008) found that even in October 2006, stress tests by Freddie Mac assumed that the highest possible drop in housing prices would be 13.4 percent.

[5]In a statement for the U.S. Senate Committee on Banking, Housing and Urban Affairs on February 7, 2007,

it became clear that banks had lowered their lending standards too drastically, such that their subprime mortgage portfolio ran at a huge loss. Consequently, due to the low risk that was wrongly attributed to them, the ABSs were highly overpriced (Mayer, 2010) but, due to their high returns, widely spread in the global banking market. Obliged to adjust the value of their assets to the market value, banks had to write down their subprime mortgage ABSs dramatically: the writedowns totaled $1 trillion worldwide (EEAG, 2009). This left them requiring large liquidity inputs, mostly provided by government state aid, so as to keep satisfying their capital requirements.

The Belgian banking sector did not escape from this financial crisis. The 2009 Belgian market is strongly concentrated, as the market is dominated by four large players. Three of those four large players received direct state aid from the various Belgian governments. All four lost a considerable part of their market value, coupled with a strong decrease in total assets. Their relative dominance also decreased: at the end of 2009, they own 75.62% of the total assets of all Belgian banks, whereas this was still 82.75% in 2007[6]. They were also forced to change their strategy, bringing their main focus back to the domestic market and to more traditional banking activities, to the detriment of their investment banking and trading activities[7].

At the end of 2009, 103 banks reside in Belgium, coming from 154 in 1992[8]. Apart from the four largest players, the market is taken up by mid-size Belgian players, mid-size branches of big foreign players and small, local players.

In Figure 1, an evolution of the number of banks residing in Belgium is shown. The number of banks remains stable throughout our sample, with the major Belgian mergers having taken place before 1999.

3 State aid

This section deals with the possible competitive effects of state aid, before going into specifics on the state aid from the various Belgian governments to Belgian banks during the financial crisis.

3.1 General

When one firm receives state aid, its resources grow and it thereby strengthens its competitive position in the market. Usually, even if the price paid for this state aid is high, other competitors are put at a disadvantage as they cannot capture part of the market share of the state aid firm. Moreover, they might even lose market share to it. Furthermore, state aid can reduce a firm's marginal cost of some of its activities below the true social cost. Also, state aid can stimulate excessive risk-taking if it signals to firms that they will ultimately always be saved by their government, inducing moral hazard. As government support allows less efficient firms to survive, it ultimately hurts the industry system.

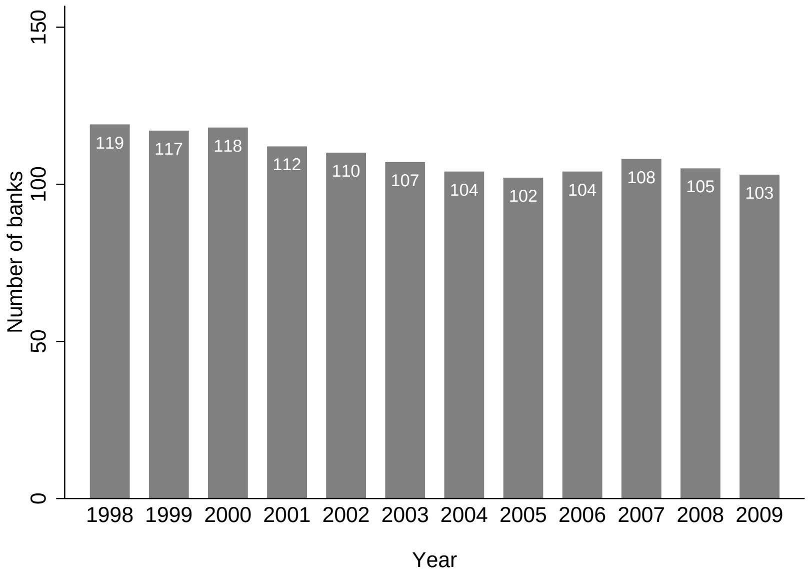
Chairman Chris Dodd pointed out that about 80% of subprime mortgages were adjustable rate mortgages.

[6]Based on own calculations combining the Belgostat database with our data set.

[7]The detailed strategy changes can be found in the 2009 Annual Reports of these players.

[8]This is based on statistics provided by the National Bank of Belgium.

Figure 1: The evolution of the number of banks in Belgium (1999-2009)



We can conclude that state aid for one firm usually has negative implications for its competitors in most sectors, however, state aid fundamentals in the banking sector are different from those in other sectors, as there are also specific issues to consider.[9]

Firstly, a bank bailout can have positive externalities on that bank's competitors, as either systemic problems are avoided, or the competitors are direct creditors of this bank. This means that a bank bailout can well happen without compensationary measures against this bank being needed to restore competitive equilibrium.

Secondly, bank's lending needs to be stimulated to support the larger economy. A stable financial system is vital for a healthy economy, and therefore governments have a strong incentive to save banks.

In sum, many different factors impact the competition effects resulting from banking state aid, and it is very difficult to assess and estimate these effects without the necessary empirical research, hence the purpose of this study.

3.2 The 2008-2009 Belgian state aid to the banking sector

The direct government state aid granted to Belgian banks by the various Belgian governments consisted of the following: capital injections (totaling €27.1 billion at the end of 2009), which includes recapitalization and liquidity support, state guarantees for funding and state guarantees for the losses on the ABSs portfolios above a certain threshold. The fact that banks which received state aid have to pay for this, and that the European Commission (EC) has taken measures against these banks are both mitigating the competition effects of the granted state aid.

[9]This paragraph is broadly based on Beck *et al.* (2010).

However, given that the bailout decision regarding a number of Belgian banks was taken in a very short time frame, the possibility exists that governments wrongly priced the different state aid measures, since they had to prioritize saving financial institutions over minimizing distortions to competition. The EC measures have been the topic of intense debate amid pressure from the different EU nations (see for example Harvey and Motte (2010) and Beck *et al.* (2010)), thus its implications and correctness are also unclear.

4 Overview of competition models

Two main categories exist in competition measuring models: the Traditional IO methods (also known as structural methods) and the NEIO approach or non-structural methods (see Bikker (2004) and Degryse and Ongena (2008)). Structural measures of competition represent the traditional way of measuring competition. These methods study the relationship between return (with respect to either profitability or price) and structure (Coccorese, 2002), and start from market structure to explain competition. In reaction to empirical and theoretical deficiencies found within structural methods, the NEIO approaches (non-structural methods) were developed. The NEIO methods employ a more direct measurement of the degree of competition and focus on *behavior* instead of structure (Degryse *et al.*, 2009). They do not make any assumptions about market structure and see competition and market structure as parallel variables, instead of the former determining the latter.

This terminology should not be confused with the difference between structural and reduced form models. Structural models start from a theoretical profit function and rigorously deduce equations from that theory, whereas reduced form models try to explain variables with a regression that takes into account theory but is not strictly deduced from it. For the purpose of this paper, only the difference between Traditional IO and NEIO methods is considered, and any reference to structural or non-structural methods is a reference to Traditional IO or NEIO, respectively.

Without undue complexity, a short description of the different methods and approaches will be given in order to understand why we choose to perform our study with the Panzar and Rosse approach.

5 The traditional IO methods

There are three main structural methods: the Structure-Conduct-Performance paradigm, the efficiency hypothesis, and studies of scale and scope economies.

The Structure-Conduct-Performance (SCP) analysis, originally formalized by Mason (1939) and developed by Bain (1956)[10], assumes that an exogenously given market structure (concentration) determines conduct (competition) (Bikker and Haaf, 2002). The SCP approach states

[10]See also Stigler (1964) and Scherer (1970).

that the degree of competition in a market is a direct function of the number of firms and an inverse function of the average market share (Coccorese, 2002). It asserts that higher concentration (exogenously) leads to less competitive conduct and thus higher profitability on the firm level (Bikker and Haaf, 2002).[11]

However, the SCP approach has its difficulties. For a start, a clear benchmark to define competitive returns is nonexistent (Coccorese, 2002). Profound criticism has been voiced on the application of the SCP model to the banking literature as it disregards the fact that markets can be highly competitive even if they are supplied by only a few companies. The opposite possibility (contestability theory) - the fact that markets can lack competition even if there is a large amount of nearly equally sized firms - is also neglected by the SCP approach (Gischer and Stiele, 2009). The model's one-way causality (Bikker, 2004) - from market structure to market performance - and the fact that it neglects the effect of potential competition (Gischer and Stiele, 2009), for instance the threat of substitute products or services, are two additional criticisms on the application of the SCP model to the banking sector. Substantial methodological critiques to conventional SCP studies are formulated by Kirnmel (1991) and Shaffer (2002). Lastly, Shaffer (2004b) points out that even if the SCP hypothesis were true for a number of industries, empirical evidence shows that banks' pricing is not as strongly related to market concentration as the case may be in some other industries.

Demsetz (1973) and Peltzman (1977) propose an alternative and advanced explanation of the relation between market structure and bank profitability. Their efficiency hypothesis examines whether market performance and market share of leading banks are enhanced by their own superior efficiency. If a profit maximizing firm becomes more cost efficient than other banks in the market, it will reduce prices and thereby gain market share (Molyneux and Forbes, 1995). Therefore, as opposed to the SCP approach, the market structure is shaped endogenously by bank efficiency. In this way, the higher efficiency of the leading banks brings about the concentration result (Vesala, 1995).

Again, this model suffers from conceptual flaws. To begin with, it finds that both performance and structure, whilst the former influences the latter, are determined by efficiency (Degryse *et al.*, 2009). Berg and Kim (1994) build on this observation in their study of Norwegian banks, and stress that conduct has profound effects on both efficiency and scale measurements - making the estimation of these problematic, as they are performed independently of market structure and conduct.

Finally, studies of scale and scope economies are a third traditional way of measuring competition (Degryse and Ongena, 2008). They investigate whether banks comply with their optimal output mix, both from a size and composition perspective.

To their detriment, these models are generally too simplified to truly measure competition effects, as only economies of scale and scope are taken into account as competition determining factors.

[11] See also Berger and Hannan (1989), Rhoades (1995), and Hannan (1997), who employ this methodology to the banking sector.

6 NEIO approaches

As opposed to the structural methods, the non-structural NEIO methods are based on the concept of contestability and refrain from deducing the degree of competition indirectly from market structure. Rather, they aim to infer the degree of competition directly through a number of alternative methodologies. Logically, they are categorized as non-structural measures of competition. We highlight the four most important NEIO approaches below: the Conjectural-Variations Method in its two different forms, the Characteristics-based Demand Approach and the Panzar-Rosse Model.

In banking literature, the various non-structural methods have become the standard models used to identify the degree of competition in the banking sector, judging by the number of studies that employ these methods. The choice for a specific non-structural method does not only depend on the research question, but also on the availability of the data (Shaffer, 2004b). Conjectural-variations methods, such as the demand and supply equations in the model of Iwata (1974) and the mark-up test of Lau (1982), Bresnahan (1982) and Bresnahan (1989) require extensive and often unpublished data (Gischer and Stiele, 2009). The same issue arises for the characteristics-based demand approach. Contrarily, the reduced form revenue model developed by Rosse and Panzar (1977) and Panzar and Rosse (1987) only requires total revenues, a vector of input prices, and some bank-specific variables.

6.1 Conjectural-Variations Methods

This methodology is based on the reaction curve: it assumes that when firms choose their optimal output, they take into consideration the likely "reaction" of their rivals. Through a first-order condition, the conjectural variation elasticity λ is estimated. λ represents the percent change in market supply as a reaction to a one percent increase, compared to its equilibrium value, in the supply of a certain bank (Degryse *et al.*, 2009). In other words, the actual degree of market competitiveness of the average bank can be deduced, as this parameter describes the whole range of average market power in the industry, starting from perfect competition (λ=0) to monopoly or perfect collusion (λ=1). Different estimation equations have been used by Iwata (1974) and Bresnahan (1982, 1989) and Lau (1982).

Iwata's Approach The Iwata model assumes that all banks are supplying a homogeneous product in an oligopolistic market to estimate conjectural variation values for individual market players (Iwata, 1974). These values can only be obtained after estimating cost functions of individual banks as well as a market demand function. Since micro-data of the cost and production of homogeneous goods or services and the individual cost structure of banks is scarce, applications of this method are difficult (Bikker, 2004). Consequently, hardly any empirical applications of the Iwata model to the banking sector exist[12].

Bresnahan's and Lau's Approach Bresnahan (1982, 1989) and Lau (1982) propose a short-run model to determine the market power of an *average* firm by estimating a static simultaneous-

[12]However, Shaffer and DiSalvo (1994) research a two-banks market by applying the Iwata (1974) model.

equation model that relies on the condition of general market equilibrium. Their equilibrium assumption entails that profit-maximizing firms' marginal costs equal their marginal revenues, with the latter corresponding to the demand price in the case of perfect competition and to the industry marginal revenue in the case of perfect collusion or monopoly. Therefore, by using the profit function and the long-term demand function, a conjectural variation parameter (λ) can be estimated.

Bresnahan's and Lau's approach holds a strong advantage compared to Iwata's approach, as this coefficient can be estimated by using either bank level or industry level data (Claessens and Laeven, 2004). Although empirical applications of this model are rare, some studies on competition in the banking sector do use this method[13]. Finally, Steen and Salvanes (1999) developed a dynamic extension of the simultaneous-equation model to correct the misspecification problems of the latter.

A second advantage of the Breshanan and Lau model is its direct analysis of the conduct of each market player, instead of focusing on the overall market structure. This approach avoids the use of indirect indicators of concentration and thus does not make indirect inferences about the market situation Coccorese (2002).

However, the main deficiency of the Breshanan and Lau model is the amount of information on demand and cost structure needed to estimate the model. Furthermore, Degryse *et al.* (2009) argue that the Breshanan and Lau model assumes that banks are price takers in the deposits market, which is a very strong assumption to make in markets that are not characterized by perfect competition. Finally, Shaffer (2004a) enunciates that the Bresnahan-Lau model can suffer from an anticompetitive bias, in the case that the sample does not entail the complete market.

6.2 The Characteristics-based Demand Approach

The characteristics-based demand approach by Dick (2002) assumes that consumers are inclined to select a particular bank by comparing both prices and bank characteristics. Her methodology inherits elements from the discrete choice literature as it derives a demand model from a consumer's utility function. Furthermore, by introducing bank heterogeneity, her model controls for product differentiation, which ultimately allows being able to determine a price-cost margin through a model of firm conduct (Degryse and Ongena, 2008). However, problems arise with regards to data availability, as consumer utility data are not readily available. The main problem with this model, though, is that it does not test for market power (Molnár, 2008), but defines each bank's market share and price-cost margin, and therefore we will not consider it further.

6.3 The Panzar and Rosse Model

Panzar and Rosse (1977, 1987) developed a method, henceforth abbreviated as the PR method, that uses cross-sectional firm data to determine the level of competition faced by market participants (see Rosse and Panzar (1977) and Panzar and Rosse (1987)). Their test makes use of the fact that a bank will price differently in reaction to a change in its factor prices and thus

[13] See for example Shaffer (1989), Shaffer and DiSalvo (1994) and Coccorese (1998).

costs, depending on the extent of the market power it enjoys (Shaffer, 1994). The PR model uses a reduced form revenue equation which regresses revenues on factor prices and individual bank variables. From this regression, it draws an H-statistic that is equal to the sum of the input price elasticities that the market faces. It can be used to distinguish between monopoly or perfectly collusive oligopoly, monopolistic competition and perfect competition.

Although the PR model was initially developed to test competition in the US daily newspaper industry (Panzar and Rosse, 1987), it was successfully adapted to the banking industry and is used in a large number of banking studies (see Bikker *et al.* (2006) and Degryse *et al.* (2009)). Its main advantages are its strong design that is adaptable to the banking industry and its low and relatively available data requirements (Degryse *et al.*, 2009). The PR model has become the standard competition measuring method in the banking industry, and we thus decide to employ it in our study. Hence, in the following Section, we will go into more detail on the features of this model. The Section starts off with placing the PR model in the industrial organization literature. After discussing the model in detail, we will consider the advantages and disadvantages of the PR method further below.

7 Discussion of The Panzar-Rosse Model

In this Section, we examine every aspect of the PR model, starting off by formally deducing the PR model.

7.1 The PR Model

In order to fully explain how the PR model works, we deduce it theoretically for the case of monopolistic competition[14]. To yield the correct equilibrium output and equilibrium number of banks, a crucial assumption of the PR approach is that the firms are pursuing a profit maximizing strategy both at the bank and at the industry level. This means that for every bank i marginal revenue equals marginal cost:

$$R_i^{'}(x_i, n, z_i) - C_i^{'}(x_i, w_i, t_i) = 0 \tag{1}$$

for $i = 1, ..., n$ and $t = 1, ..., T$
(see Bikker and Haaf (2002) and Vesala (1995))

in which R_i, the revenue function of bank i, is determined by the output x_i of bank i, the number of banks n and a vector of exogenous variables z_i that shift the bank's revenue function. C_i refers to the costs of bank i and depends on x_i, on the vector w_i that consists of q factor input prices of bank i, and on t_i, which is also a vector of exogenous variables that have a shifting effect on the cost function C_i. The profit maximization function further implies that the economic profit is zero at the market level, following the Chamberlinian tangency condition that

[14] For the interested reader, the deductions in the monopoly and perfect competition cases can be found in Panzar and Rosse (1987) and in Vesala (1995).

entry and exit of additional banks will take place until the zero economic profit assumption is achieved:

$$R_i^*(x_i^*, n^*, z_i) - C_i^*(x_i^*, w_i, t_i) = 0 \tag{2}$$

for $i = 1, ..., n^*$ and $t = 1, ..., T$
(see Bikker and Haaf (2002) and Vesala (1995))

with * denoting equilibrium values. The equilibrium values of R_i^*, x_i^* and n^* are now in reduced form function of z_i, w_i and t_i (Vesala, 1995). Starting from equation (2), a reduced form revenue function can be derived formally[15]:

$$\ln TI_{i,t} = \alpha_i + \sum_{j=1}^{q} \beta_j \ln FP_{i,t}^j + \sum_{k=1}^{r} \gamma_k \, BSV_{i,t}^k + \epsilon_{i,t} \tag{3}$$

for $i = 1, ..., n$ and $t = 1, ..., T$

with $TI_{i,t}$ being the total income for bank i at time t, $FP_{i,t}$ the q factor prices, α_i a bank specific constant and $\epsilon_{i,t}$ the error term. $BSV_{i,t}$ denotes the vector with r bank-specific variables (to control for credit risk, asset composition, the funding mix, differences in risk preference, . . .). Further below, we will specify equation 3 for our study in detail.

From equation 3, a comparative static measure, called the H-statistic, is calculated by Rosse and Panzar (1977) and Panzar and Rosse (1987) to examine the extent to which changes in factor input prices are reflected in equilibrium bank-specific $TI_{i,t}$ or industry total income $\sum_{i=1}^{n} TI_{i,t}$ (Coccorese, 2004). Therefore, this H-statistic is exactly the parameter that is used to quantitatively assess the competitive nature of banking markets (Bikker and Spierdijk, 2008). The estimated H-statistic is therefore a market, not a bank-specific parameter, which achieves an assessment of market competition.

In summary, H denotes the percent change in total income $TI_{i,t}$ as a result of a unit percent increase of all q factor prices $FP_{i,t}^j$, with H estimated so as to be equal for all banks in the studied sample. The stronger the effect of changes in the q factor prices on each bank i's $TI_{i,t}$, the larger H becomes and the more competitive the market is. As we will elaborate on below, the H-statistic is used to distinguish between monopoly or perfectly collusive oligopoly, monopolistic competition, and perfect competition. More specifically, H equals the sum of revenue elasticities with respect to each firm i's q input prices, or factor prices, $FP_{i,t}^j$:

$$H = \sum_{j=1}^{q} \beta_j \tag{4}$$

H can be estimated over the whole sample period (thus, H is equal for all t) or over subperiods. In our study, we estimate equation 3 on a rolling four quarter basis, so as to obtain a rolling yearly H-statistic.

[15]For the formal derivation, see Panzar and Rosse (1987), Vesala (1995) and Bikker and Haaf (2002).

7.2 About the H-statistic

Based on a number of assumptions (see Subsection 7.3), the magnitude of H serves as an inverse parameter for monopoly power and can be interpreted as a measure of competition (see Bikker and Haaf (2002) and Claessens and Laeven (2004)). Hence, the higher the values for H, the more competitive the banking market, implying that H is not solely used to reject certain types of market behavior. Therefore, the H-statistic is a scale statistic with special values $H \leq 0$, $0 < H < 1$ and $H = 1$. Below, an analysis of these different values is provided.

H≤0 *Monopoly equilibrium (collusive competition)*

Panzar and Rosse (1987) prove that the H-statistic yields a non-positive value in the monopoly case, in which each bank operates independently, maximizing profits as if acting as a monopolist. An increase in factor prices by one percent will shift the monopolist's marginal costs function upwards. Hence, either the monopolist reduces his output and subsequently, revenues will decrease (Claessens and Laeven, 2004), or he will augment his price, which affects his revenues negatively as e exceeds one (Degryse and Ongena, 2008). Bikker and Haaf (2002) elucidate that neither in a perfectly collusive oligopoly nor in a conjectural variations short-run oligopoly does H exceed zero.

0<H<1 *Monopolistic competition (Chamberlinian equilibrium)*

In monopolistic competition, also called the Chamberlinian equilibrium, firms still enjoy market power, as production is still at a point where average cost exceeds its minimum, and the equilibrium price exceeds marginal cost. However, no market player earns supranormal profits, since banks still price at average cost (Vesala, 1995). A priori, the banking market is most likely to be characterized by monopolistic competition as this model allows for product differentiation (Bikker and Haaf, 2002). More precisely, the observation that all banks have different advertisement strategies and differ in product quality is in adherence with monopolistic competition, even if the banks' core business is fairly homogeneous.

Under monopolistic competition, H can take values between zero and one (Panzar and Rosse, 1987). Vesala (1995) finds a positive relationship between the perceived demand elasticity e and the H-statistic, again proving that the higher the H-statistic, the more competitive the banking market. Specifically, each individual bank is producing more than would be individually optimal, and the price is lower than it would be under individual profit maximization, but higher than it would be under perfect competition. Indeed, this is consistent with the equilibrium price exceeding marginal cost.

H=1 *Perfect competition*

Nathan and Neave (1989) enunciate that H cannot exceed unity under perfect competition. This means that an increase in factor prices augments both marginal and average costs without altering the optimal output level of any individual bank. Since a few banks will leave the market, there is a positive shift in the perceived demand of each of the remaining banks which leads to an increase in prices and revenues to the same extent as the rise in costs (Nathan and Neave, 1989).

7.3 Assumptions of the PR Model

The correctness of the H-statistic hinges on a number of fundamental assumptions, which we explore in this section.

The first assumption is that banks are single product firms (Gischer and Stiele, 2009), following the intermediation approach that sees banks as loan producing firms with a number of inputs[16]. Although banks offer various products and services, this approach is not unrealistic as overall, banks are in the business of paying for liquidity and then selling it again. Secondly, their production functions need to be homothetic or the cost structure of market participants should be linearly homogeneous in the factor prices (Hempell, 2002). Thirdly, Hempell (2002) also draws attention to the supposition of free entry and exit. Furthermore, the actions of all market players have an influence on the individual performance of banks (Bikker, 2004), which is a seemingly fair assumption to make in the banking industry. In addition, the PR model assumes that factor prices are exogenous to the individual firm (Hempell, 2002). A sixth, plausible assumption, made by Panzar and Rosse (1987) in order to assess the monopolistic competition case, is that the elasticity of perceived demand e which an individual firm faces, is nondecreasing with the number of rivals.

Lastly, in order to correctly test for perfect competition and in particular to correctly interpret the degree of market conduct in the case of monopolistic competition, it is indispensable that the observed banks operate in long-term equilibrium (see Panzar and Rosse (1987) and Nathan and Neave (1989)). This assumption implies that the number of banks should be endogenous in the PR model (Bikker, 2004), given that the market is characterized by free entry and exit (Hempell, 2002)[17]. Coccorese (2004) emphasizes the importance of the long-term equilibrium assumption. He employs an equilibrium testing method suggested by Shaffer (1982), which is applied by most studies[18]. We also perform this test on our sample and explain the method further below.

Although the PR model is still only a model and thus does not reflect reality perfectly, it is the leading method in competition literature, showing that its assumptions are not over stringent.

7.4 Misspecifications of the PR Model

How to empirically translate the PR approach into a specific econometric equation is open for debate, as there is a certain amount of freedom to be exercised in the specification of the variables to be used.

Bikker *et al.* (2006) point to a number of misspecifications that have been employed in numerous banking studies using the PR model. Firstly, most studies use a ratio of revenues to total

[16]See Hempell (2002) for a more thorough discussion on the intermediation approach.
[17]This assumption is not needed in the monopoly case, see Panzar and Rosse (1987).
[18]See for example Claessens and Laeven (2004), Bikker *et al.* (2006) or Gischer and Stiele (2009).

assets, instead of just revenues, as the dependent variable in equation 3. Vesala (1995), Bikker *et al.* (2006) and Gischer and Stiele (2009) argue that this changes the nature of the model, as it transforms the revenue equation into a price equation (seeing the dependent variable as a price of the assets). Consequently, the model suffers from overestimation; Bikker *et al.* (2006) point out that regressing a price equation instead of a revenue equation results in a bias of the H-statistic towards one, whilst also affecting the standard errors of H. Secondly, Bikker *et al.* (2006) and Bikker *et al.* (2009) observe that many studies add scaling variables as explanatory variables to equation 3, to account for scale effects (such as economies of scale). They reason that this brings about the same overestimation problems as using the ratio of revenues to total assets, and should therefore also be avoided[19]. A last misspecification is employed by nearly all PR studies but is, according to the best of our knowledge, not contested in the literature thus far. It involves the use of ratios as independent, bank-specific variables (e.g., *equity to total assets*). In equation 3, the natural logarithm of these variables could be taken, which would mean that if a ratio is employed, a doubling of 1% to 2% would have the same effect as a doubling of 10% to 20%. Clearly, this does not make much sense as the second change is usually much more drastic. Therefore, as taking natural logarithms of these bank-specific variables is neither technically nor economically needed, we use them without this transformation in our estimation of equation 3.

For the sake of completeness, it is important to note that we will employ total income as the dependent variable, staying true to Panzar and Rosse (1987). A number of studies use interest income as the dependent variable (see Vesala (1995)). However, total income is not only the standard dependent variable in the PR model (see Panzar and Rosse (1987)), it is also the more suitable option as total income, unlike interest income, accounts for the increased revenue stream coming from merchant banking activities (Coccorese, 2009).

7.5 Advantages and disadvantages of the PR Approach

Although the PR model is applied multitudinously in studies of competition in the banking sector, it is important to be aware of both the deficiencies and the advantages of this approach. We will start off with an overview of the deficiencies, followed by a summary of the advantages.

Bikker and Spierdijk (2008) point out that the PR model measures competition of the whole banking market, disregarding different banking submarkets and their specific competitive situation. In submarkets (individual products, local areas), deviating competition results may appear. It is nearly impossible, however, to get enough data to measure competition effects of single product markets (Bikker and Spierdijk, 2008), and the PR outcomes only serve as general measures of banking competition. Furthermore, by measuring the input prices indirectly through proxies (all certain expenses divided by their respective volume, e.g. the ratio of interest expenses to deposits), the real variation in prices might be overstated (Mountain and Thomas, 1999). Genesove and Mullin (1998) and Shaffer (2004b), however, dismiss those claims (see below). Hempell (2002), then, suggests that some downward bias in the components of H (namely, the estimated factor price elasticities) may occur due to different maturity structures of differ-

[19]Bikker *et al.* (2006) and Bikker *et al.* (2009) formally derive their reasoning.

ent banks' asset portfolios. Changes in pricing are delayed when longer maturities in fixed rate contracts prevent banks from making immediate price adjustments, possibly implying that the estimated elasticities contain a downward bias.

Despite these deficiencies, the PR approach has a lot of advantages associated with it. To begin with, this model employs bank-level data[20] and incorporates bank-specific differences in its production function (Claessens and Laeven, 2004), resulting in stronger data availability since data on revenues, costs, assets and liabilities are more likely to be found than output prices or actual, specific cost data (Hempell, 2002). Moreover, it allows one to investigate competition differences between certain categories of banks (Claessens and Laeven, 2004). A further advantage of the PR model, in comparison to the conjectural-variations approach, is that it does not use direct prices as variables, and subsequently there is no need for quality corrections (Bresnahan, 1989).

We choose to perform our study with the PR model as it carries the more advantages and less deficiencies than the other models, making it the most widely used model in the banking literature.

7.6 The PR Model applied to Belgium

In this Section, we study the existing PR employing literature that investigates competition in the Belgian banking market. Table 1 exhibits the most important results of Panzar-Rosse competition studies on the Belgian banking market.

Table 1: Different H-statistics from studies on the Belgian banking sector

Authors	*H*	*Sample period*	*Number of banks studied*	*Total observations*
Bikker and Groeneveld (2000)	0.92	1989-1996	55	316
Bikker and Haaf (2002)	0.89	1991-1997	85	479
Claessens and Laeven (2004)	0.73	1994-2001	76	371
Bikker et al. (2006)	0.48	1987-2004	92	596
Bikker and Spierdijk (2008)	0.54	1987-2004	77	596

Generally, monopolistic competition is the most commonly found market structure in the European banking sector (Bikker *et al.*, 2006). Bikker and Groeneveld (2000) investigated fifteen European banking markets (1989-1996) and proved that the monopoly case is rather unlikely. According to Claessens and Laeven (2004) however, Belgium is less competitive afterwards (1994-2001) as H equals 0.73. Bikker *et al.* (2006) even find an H-statistic of 0.48. This result is probably lower because Bikker *et al.* (2006) correct certain misspecifications of earlier studies

[20]The exact data needs depend on the eventually estimated reduced form revenue equation.

(see below for an extensive review of these). From the level of competitiveness for large (0.86), medium-sized (0.88) and small Belgian banks (0.95) calculated by Bikker and Haaf (2002), we can conclude that the degree of competition is stronger for the small banks. Their H-statistic for the overall banking market equals 0.89. H did increase over the sample period; however, they found this change to be insignificant. Differences across studies might occur for a variety of reasons: number of banks studied, the research period, etc.

8 Data sources and description

Our sample, provided to us by the National Bank of Belgium with the explicit support of the included banks, consists of quarterly observations of 61 banks (52 after data adjustments) over 44 quarters (Q1 1999 until Q4 2009), yielding us 1816 observations[21]. The banks in our sample own 94.5 percent of the total assets of the Belgian banking market, ensuring that our data set covers almost the whole market. As noted in Section 2, the number of banks varies over our sample period, and this variance brings about an unbalanced sample. This is due to entry, exit or merging of banks during our sample period. Indeed, many authors use unbalanced data sets (see for example Claessens and Laeven (2004), Bikker and Spierdijk (2008) and Cheng and Van Cayseele (2009)). De Bandt and Davis (2000) actually find roughly the same results for a balanced and an unbalanced sample.

The variables used are reported on a corporate basis, meaning that they are limited to the Belgian market (foreign branches that are not separate legal entities are also included, but rare). We choose to use these data as we only want to study competition in the Belgian market, excluding foreign subsidiaries.

We make a number of conceptual and outlier corrections to our original data, to ensure correctness of the observations that are used for our estimation. These data adjustments can be found in Appendix A. The way bank mergers are dealt with is the following: the two merging banks are seen as two separate banks until they merge and from that point on, the takeover bank is the only one left. This means that we assume that the behavior of that bank does not change after the merger[22]. We see this as a more plausible option than treating the merging banks as one throughout the sample. Moreover, only few mergers took place since 1999, with the four largest banks founded before that year. Most mergers after 1999 are takeovers, where one of the merging firms is clearly larger, making the assumption that the conduct of the larger firm dominates the merged firm realistic.

In the remainder of this paper, we present our data analysis. In order to investigate the competition effect of state aid in the Belgian banking sector, we employ a two-staged approach. We start by estimating a first-stage equation, the Panzar-Rosse reduced form revenue equation, to estimate rolling H_t-statistics on a four quarter basis (with t denominating the first quarter of

[21] Due to entry, exit and mergers and acquisitions, not all banks exist throughout the whole sample.

[22] Many studies employ this same assumption when working with bank mergers. See Hempell (2002) and Bikker *et al.* (2006) for examples.

the four quarters used for the estimation). We then regress these H_ts on a number of factors, including state aid, in our second-stage equation. In Section 9, we give further details on this first-stage equation and discuss its results. The second-stage equation methodology and results are elaborated on in Section 10.

9 The first-stage equation

In this Section, we discuss the details of the first-stage equation, the Panzar-Rosse reduced form revenue equation, before looking into the results of this equation and describing the competitive evolution of the Belgian banking sector on the basis of the H_t-statistic. We end by showing that our results satisfy the long-term equilibrium assumption.

9.1 Methodology

We reiterate the general Panzar-Rosse reduced form revenue equation, established in Section 7:

$$\ln TI_{i,t} = \alpha_i + \sum_{j=1}^{q} \beta_j \ln FP_{i,t}^{j} + \sum_{k=1}^{r} \gamma_k \, BSV_{i,t}^{k} + \epsilon_{i,t} \tag{5}$$

for $i = 1, ..., n$ and $t = 1, ..., T$

with $TI_{i,t}$ being the total income for bank i at time t, $FP_{i,t}$ the q factor prices, α_i a bank specific constant and $\epsilon_{i,t}$ the error term. $BSV_{i,t}$ denotes the vector with r bank-specific variables (to control for credit risk, asset composition, the funding mix, differences in risk preference, . . .).

We specify the factor price proxies we use in Table 2, and the bank-specific variables we use in Table 3. In Table 4, the descriptive statistics of the factor price proxies and bank-specific variables are given.

Table 2: Used Factor Price proxies

Label	*Name*	*Proxy for the Factor Price of ...*	*Formula*
FR	Funding Rate	Funding	$\frac{\text{Interest Expenses}}{\text{Total Liabilities} - (\text{Equity+Reserves})}$
CPA	Cost of Personnel A	Personnel	$\frac{\text{Personnel Expenses}}{\text{Total Number of Payroll Employees}}$
CER	Capital Expenditure Ratio	Fixed Assets	$\frac{\text{Property Expenses}}{\text{Fixed Assets}}$

Since we cannot directly observe the factor prices, we use proxies which best approximate the real factor prices. Most studies try to estimate at least three input prices (for the definition of the proxies, see Table 2). Firstly, the price of funding, for which we use the funding rate as a

Table 3: Used Bank-Specific Variables

Label	*Name*	*Formula*
CR	Capital Ratio	$\frac{\text{Equity}}{\text{Total Assets}}$
FS	Financing Structure	$\frac{\text{Interbank Deposits}}{\text{Interbank Deposits + Non-bank Deposits}}$
ORB	Other Role of Banks	$\frac{\text{Other Income}}{\text{Interest Income}}$
BDR	Bad Debt Ratio	$\frac{\text{Bad and Doubtful Debt}}{\text{(Cash to Central Banks + Interbank Loans +Loans to Non-banks)}}$
TA	Total Assets	Total Assets

Table 4: Descriptive statistics of first-stage equation variables. Subdivision by dependent variable (top), factor prices (middle) and bank-specific variables (bottom).

	Mean	StDev	5th Percentile	95th Percentile
TI[a]	1.372	4.800	.002	9.395
FR	.014	.052	.004	.023
CPA[b]	19.412	7.137	11.669	33.353
CER	.043	.045	.002	.126
CR	.042	.044	.005	.123
FS	.271	.272	.000	.854
ORB	.026	.143	.000	.084
BDR	.004	.008	.000	.021
TA[a]	25.701	74.788	.155	178.032

[a] In billion euro.
[b] In thousands of euro per employee.
All other variables are dimensionless.

Notes:
TI, Total Income; FR, Funding Rate; CPA, Cost of Personnel A; CER, Capital Expenditure Ratio; CR, Capital Ratio; FS, Financing Structure; ORB, Other Role of Banks; BDR, Bad Debt Ratio; TA, Total Assets.

proxy. Secondly, the price of personnel/employment, for which we employ the cost of personnel as a proxy. And finally, the price of fixed assets, for which the capital expenditure ratio is used as proxy.

The relative size of the estimated coefficients of these factor prices is similar for the vast majority of the studies. They find that the proxy for the price of funding has the largest coefficient in equation 5 and is also the most significant variable. The proxy for the price of personnel, then, also has a substantial coefficient in equation 5 and is usually significant. The proxy for the price of fixed assets, finally, only has a small coefficient in equation 5 and is sometimes significant and sometimes insignificant. Overall, the price of fixed assets only has a marginal impact on the H-statistic, and its changes therefore do not impact interest income significantly. Fisher and McGowan (1983) show that the price of fixed assets is unreliably measured when the proxy is based on accounting data, therefore, this observed marginal impact could be partially due to incorrect measurement of the price of fixed assets.

Although estimating these input prices correctly can be difficult, Genesove and Mullin (1998) show that NEIO measurements of competition are empirically robust to estimation error of marginal cost and of demand. Shaffer (2004b) confirms this assertion empirically as he makes the input prices quasi-fixed and still finds similar results as in the normal, non-fixed case. The standard practice of using these proxies is thus reliable, and we proceed likewise.

Before moving on to the ultimately estimated reduced form revenue equation, it is important to note that although the payroll employment numbers before Q4 2002 are estimated numbers (see Appendix A for more details on the estimation method of the payroll employment numbers), we decide to employ the proxy $\frac{\text{Personnel Expenses}}{\text{Total Number of Payroll Employees}}$ for the factor price of personnel instead of the more widely used $\frac{\text{Personnel Expenses}}{\text{Total Assets}}$ (denoted as the Cost of Personnel B), as the first is a conceptually superior proxy (for an elaboration on this discussion, see Appendix B). As a robustness check, we also perform the estimation equation with the Cost of Personnel B as the proxy for the factor price of personnel (see below).

We thus specify equation 5 to estimate the following reduced form revenue equation:

$$\ln TI_{i,t} = \alpha_i + \beta_1 \ln FR_{i,t} + \beta_2 \ln CPA_{i,t} + \beta_3 \ln CER_{i,t} + \gamma_1 CR_{i,t} + \gamma_2 FS_{i,t} + \gamma_3 ORB_{i,t}$$

$$+\gamma_4 BDR_{i,t} + \gamma_5 TA_{i,t} + \epsilon_{i,t} \tag{6}$$

for $i = 1, ..., n$ and $t = 1, ..., 44$

with $TI_{i,t}$ being the total income[23] for bank i at time t and α_i a bank-specific constant. The factor prices are: the Funding Rate FR, the Cost of Personnel A CPA and the Capital Expenditure Ratio CER. For the bank-specific variables, we find CR, the Capital Ratio, FS, the Financing Structure, ORB, the Other Role of Banks, BDR, the Bad Debt Ratio and TA, Total Assets. The definitions of these factor prices and bank-specific variables can be found in Table 2 and Table 3, respectively. Finally, $\epsilon_{i,t}$ is the error term.

To account for the serial correlation that is present in our data set, we first-difference equation 6 and then estimate the resulting equation with pooled OLS (for an elaboration on the choice of the employed statistical methods and the performed tests, see Appendix C). The bank-specific effect α_i in equation 6 is eliminated after first-differencing. The eventually regressed equation is:

[23]We follow the Organisation for Economic Co-operation and Development (OECD) data methodology. The specific data definitions can be found in OECD (2007).

$$\Delta \ln TI_{i,t} = \beta_1 \Delta \ln FR_{i,t} + \beta_2 \Delta \ln CPA_{i,t} + \beta_3 \Delta \ln CER_{i,t} + \gamma_1 \Delta CR_{i,t}$$

$$+\gamma_2 \Delta FS_{i,t} + \gamma_3 \Delta ORB_{i,t} + \gamma_4 \Delta BDR_{i,t}$$

$$+\gamma_5 \Delta TA_{i,t} + \Delta \epsilon_{i,t} \quad (7)$$

for $i = 1, ..., n$ and $t = 1, ..., 44$

We estimate this equation on a rolling four quarter basis, which provides us with rolling four-quarterly H_t-statistics. We do this in order to retain enough observations to estimate a second-stage equation where we regress these H_ts against a number of factors to assess the impact of state aid on competition. This means that the first period for which we estimate equation 6 is the year 1999, the subsequent estimation period is the last three quarters of 1999 and the first quarter of 2000, and so on. For the remainder of this study, H_t refers to an estimated rolling four-quarterly H-statistic, with t denominating the first of the four quarters that are used to estimate this H_t. As our data set contains 44 quarters, we estimate 41 H_ts. We only use H in general terms, or when this H is only estimated over the whole sample period of a study.

To the best of our knowledge, our study is one of the first to estimate H_t-statistics on a four-quarterly basis and the first to thoroughly examine the evolution of competition over a longer period[24]. Almost all previous research applying the PR model to banking use H-statistics over a large number of years to draw conclusions. Whilst this research is valuable, it is questionable whether these H-statistics are valid numbers. It is troublesome to assume that a competition measure of, say, ten years is a meaningful statistic. Firstly, the banking sector is a very dynamic sector in which entry, exit and mergers and acquisitions occur frequently, thus a ten year average is *in se* not a reliable measure and does not tell us very much[25]. Secondly, even if it were reliable, it does not provide us with an average of the competition situation over ten years as the statistical mechanisms that produce this H will never calculate a real average[26] (see Appendix D for a reasoning on this assertion).

In sum, evolutionary short-term H_t-statistics are not only more interesting to examine in our case, but are also the only conceptually correct numbers to infer conclusions from. Indeed, Bikker *et al.* (2009) acknowledge that it is better to allow for changes in competition over time. It is an interesting research question in itself which estimation period delivers H_t-statistics that best reflect the competitive situation, but yearly estimates seem plausible and we thus use those.

[24]Hempell (2002) does report H_t-statistics for six different years but focuses her study on the competition differences between types of banks for two periods; Nathan and Neave (1989) look at H_t-statistics for three different years but also focus on the competition differences between bank categories. Most studies investigate the competition differences between countries or between bank categories, not the competition evolution.

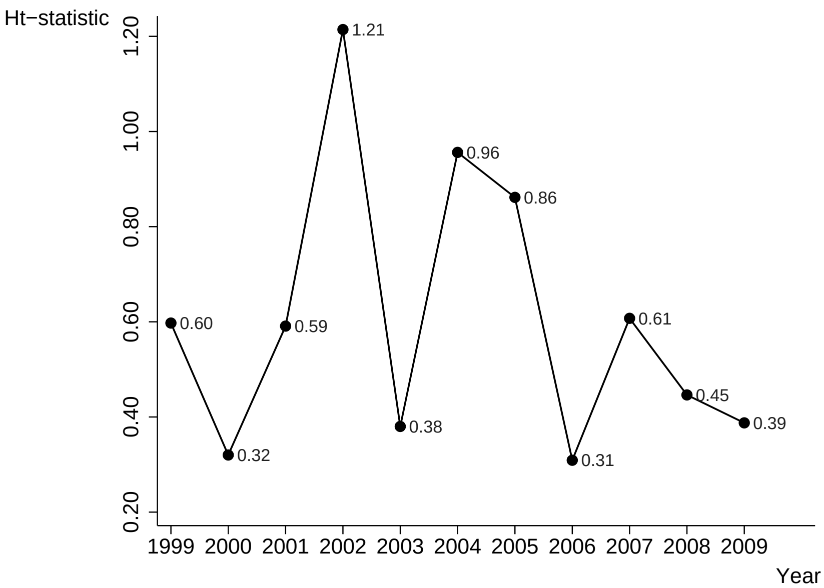
[25]For example, it is unclear what an overall H-statistic of 0.60 tells us if, when the period H_ts are calculated, an H_t-statistic of 0.90 in the first period and of 0.10 in the last period is found.

[26]The only correct arithmetic average H would be found by calculating $\frac{1}{10}\sum_{t=1}^{10} H_t$.

9.2 Results: evolution of the competitive landscape

Whilst we use all rolling H_t-statistics to estimate the second-stage equation, a graph of the 41 rolling H_ts to look into the competition evolution of the Belgian banking sector would be disorderly and more complex to interpret, and we thus only discuss a graph with the 11 yearly H_ts here. A graph for the rolling H_t estimates can be found in Appendix E. Therefore, in Figure 2, we show the evolution of competition in the Belgian banking market over the period 1999-2009.

Figure 2: Evolution of H_t on a yearly basis



Judging from the point estimates, the Belgian banking sector is virtually in constant monopolistic competition, albeit the actual level of competition fluctuates considerably (see also Table 5). Two tests indicate that for at least seven out of eleven years, the Belgian banking market finds itself in monopolistic competition: the one-tailed monopoly test and the one-tailed perfect competition test.

Firstly, the one-tailed monopoly test in Table 5 below tests H_0: $H_t = 0$ versus H_A: $H_t > 0$. In ten out of eleven years (2006 being the exception) H_0 (and thus monopoly, as $H_t \leq 0$ in the monopoly case) is rejected.

Secondly, The one-tailed perfect competition test in Table 5 below tests H_0: $H_t = 1$ versus H_A: $H_t < 1$. In eight out of eleven years (2002, 2004 and 2005 are the exceptions) H_0 (and thus perfect competition, as $H_t = 1$ in the monopoly case) is rejected.

Table 5: Pooled OLS estimates of the yearly (four-quarterly) Panzar and Rosse measure of competition H_t, first-differenced data, period 1999-2009.

$\Delta ln(TI)$	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Δln(FR)	.424***	.242*	.717***	1.111***	.477**	.658***	.503***	.254	.580***	.249**	.351***
	(.14)	(.13)	(.05)	(.22)	(.21)	(.20)	(.14)	(.25)	(.13)	(.12)	(.08)
Δln(CPA)	.166*	.108	−.092	.302	−.070	.257**	.329**	.055	.019	−.089	-.003
	(.10)	(.09)	(.09)	(.26)	(.10)	(.10)	(.16)	(.09)	(.07)	(.13)	(.14)
Δln(CER)	.008	−.029	−.035	−.198	−.028	.041	.030	.000	.008	.286***	.087
	(.05)	(.02)	(.04)	(.19)	(.05)	(.08)	(.09)	(.05)	(.03)	(.10)	(.06)
ΔCR	−.370	−.626	−8.699***	−3.885**	−11.200	−4.764	−10.205**	.304	−3.020***	−8.774***	.634
	(2.74)	(1.40)	(2.55)	(1.94)	(9.78)	(3.25)	(4.18)	(.22)	(1.02)	(2.05)	(2.28)
ΔFS	.269	.112	.796**	1.311*	.685	.565	1.275**	−.258	.120	−.185	−1.040
	(.29)	(.39)	(.32)	(.76)	(.79)	(.41)	(.53)	(.36)	(.53)	(.47)	(.80)
ΔORB	.709	1.405***	.111	.408***	.408***	.734***	.528***	.610***	.663**	4.769	.912
	(.72)	(.35)	(.15)	(.07)	(.10)	(.10)	(.08)	(.09)	(.32)	(3.98)	(.60)
ΔBDR	−10.759	−1.466	24.729***	7.872	−11.852	−7.955	36.490*	20.449	12.891	3.226	−9.745
	(6.96)	(1.69)	(9.24)	(9.83)	(14.00)	(17.18)	(21.55)	(16.30)	(16.55)	(3.26)	(13.18)
ΔTA	.000	.000	−.000	.000	−.000	.000	.000*	.000	.000**	−.000*	.000**
	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)
$p(F\text{-test})^a$	.048	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
Observations	110	140	130	118	137	140	115	124	129	119	124
$\hat{H}_t$	.60	.32	.59	1.21	.38	.96	.86	.31	.61	.45	.43
se($\hat{H}_t$)	(.19)	(.17)	(.09)	(.33)	(.23)	(.28)	(.31)	(.24)	(.14)	(.21)	(.19)
$p(H_0 : \hat{H}_t = 0)^b$	.001	.028	.000	.000	.047	.000	.003	.096	.000	.017	.022
$p(H_0 : \hat{H}_t = 1)^c$	.020	.000	.000	.255	.003	.438	.325	.002	.003	.004	.003

$^{***}p < 0.01$, $^{**}p < 0.05$, $^{*}p < 0.10$.

[a] Probability of F-test with H_0 : all RHS variables are jointly zero.

[b] One-tailed tests for monopoly ($H_a : 0 < \hat{H}_t$)

[c] One-tailed tests for perfect competition ($H_a : \hat{H}_t < 1$).

Notes:

TI, Total Income; FR, Funding Rate; CPA, Cost of Personnel A; CER, Capital Expenditure Ratio; CR, Capital Ratio; FS, Financing Structure; ORB, Other Role of Banks; BDR, Bad Debt Ratio; TA, Total Assets.

All varariables are dimensionless, except from TI, TA (both in thousands of euro) and CPA (in thousands of euro per employee).

Newey-West standard errors between brackets.

The summary with the rolling H_t estimates can be found in Table 12 in Appendix E. From this Table and from Figure 2, it can be seen that one H_t point estimate that is larger than one, H_{13}. Although this is clearly not an acceptable H_t-statistic in the PR model, it is due to statistical error (the fact that this observation has the largest standard error of all estimates confirms this view). Of all the 41 estimated rolling H_ts, only this one has a value that is out of the $[-1\,;\,1]$ range. Many studies in fact show that finding a small fraction of H-statistics to be out of the $[-1\,;\,1]$ range is normal if many Hs are estimated[27]. To be on the safe side, we leave out this H_t for the estimation of the second-stage equation. As a robustness check, we also estimate this equation with $H_{13} = 1$, and the impact is inappreciable.

As announced above (see Section 9), we also estimate equation 7 with the Cost of Personnel B, defined as $\frac{\text{Personnel Expenses}}{\text{Total Assets}}$, and report the results in Table 13 in Appendix F. The H_t-statistics show a very similar evolution, confirming the robustness of our main results.

We now attempt to explain the evolution of the H_t-statistic over the different years. It is important to note that the point estimates of H_t only serve as an indication, since their standard errors show that the estimation can be adjusted downwards or upwards. We thus focus on their evolution. In Figure 2, we see a strong increase in competition in the period 2001-2002[28], and a subsequent decline in 2003. Much of this evolution can possibly be attributed to the introduction of the euro in January 2002. The 2001-2002 course of the graph seems to confirm the intuition that the euro increased banking competition as it facilitates stronger international competition. Anticipating this, banks may have behaved more competitively around this period to fend off potential competitors. However, when the unified banking market in the euro area turned out to be more illusionary than realistic, financial institutions might have dropped this competitive attitude and reverted again to their normal practices. Bikker and Spierdijk (2008) find similar results.

In 2006, the economic boom was at its peak and industry profit was at an all-time high of €9.67 billion[29] (Febelfin, 2007). The competition decline in that year might be attributable to the fact that banks were performing admirably, and they did not see the need for strong competition in a flourishing market. In addition, the largest banks were assured of a considerable and growing revenue stream from merchant banking activities, and were increasingly focused on foreign markets, distracting their attention from the traditional banking activities on their home market. In 2007, their profits declined, which might explain the increased competition in that year.

The decline of the H_t-statistic in 2008 and 2009 is likely attributable to the financial crisis. Banks came under increased pressure when the first signs of subprime ABS losses became apparent (see Section 2 for an elaboration on ABSs). All of Belgium's large banks reported losses due to ABS writedowns. Since the interbank lending market severely tightened, they could not settle

[27] See for example Nathan and Neave (1989), Coccorese (2004) and Bikker *et al.* (2006).

[28] As explained above, the result in 2002 is conceptually wrong. As we only attempt to explain the evolution, the 2002 results has no impact on this discussion.

[29] This is assessed by comparing different Annual Reports of Febelfin, the Belgian federation of financial institutions.

their consequent liquidity needs and state aid, their last resort, was inevitable. Most banks were focusing on their survival and not on their market share, hence probably the decreased competition level.

Whether this change in competition over the period 2008-2009 is attributable to state aid or not, is the object of the research presented in Section 10.

9.3 The long-term equilibrium test

As described above in Section 7, the PR model assumes that the analyzed banks are in a state of long-term equilibrium[30]. Shaffer (1982) developed an empirical test for long-run equilibrium, which uses the natural logarithm of the return on assets (ratio of net pre-tax profits to total assets) as the left-hand side (LHS) variable in the reduced form revenue equation under the assumption that, in long-run equilibrium, the rates of return across banks in a competitive market are equalized (Coccorese, 2004). The natural logarithm of the ratio of net profits before tax to equity can also be used as the dependent variable (Nathan and Neave, 1989), although $\ln(ROA)$ is the standard LHS. If the banks in the sample are in long-term equilibrium, the return on assets should not be statistically correlated with the factor prices. If they are correlated, strong market entry or exit movements will occur, and the industry is considered to be in transition towards a new equilibrium. Therefore, the sum of the elasticities of the factor prices in long-run equilibrium must equal zero. In the sum of factor price elasticities H of this alternative equation, which we name H_{ROA}, we find a test statistic that proves a disequilibrium if H_0: $H_{ROA} = 0$ does not hold, with H_A: $H_{ROA} < 0$ (Claessens and Laeven, 2004).

Whilst this test has been applied to numerous studies, not much attention has been given to its fundamentals. Bikker *et al.* (2009) reassess the long-term equilibrium test and conclude that $H_{ROA} < 0$ could imply various competitive cases: monopoly, oligopoly or short-run equilibrium. They reposition it to a joint test of structural equilibrium and competitive pricing. Further, they note that $H_{ROA} < 0$ where $H > 0$ is consistent with largely competitive conduct, although some structural disequilibrium exists, be it not enough to reverse the $H > 0$ finding.

While Shaffer (1982) asserts that the banks analyzed are in disequilibrium if ROA is not independent of the factor prices, this is estimated by a one-tailed test where H_A: $H_{ROA} < 0$, in which case firms are either unable to charge an increase in input prices to their customers, forcing some firms to leave the market, or succeed in keeping prices nondecreasing when factor prices decrease, suggesting market entry. However, when $H_{ROA} > 0$, firms increase their ROA when factor prices rise, inducing entry, or their ROA falls when factor prices fall, leading to exit. Therefore, we find a two-tailed test more plausible, as it is troublesome to assume that the market is in equilibrium if $H_{ROA} > 0$.

It should be clear from the above paragraph that more research into the Shaffer long-term equilibrium test is needed, and its results should be treated with caution. We perform the test with the first-differenced $\ln(ROA)$ as LHS variable, and, as a robustness check, also with the

[30] This assumption does not need to hold in the monopoly case.

first-differenced ln(ROE). Applying the needed caution, we only omit observations from being used in the second-stage equation (see Section 10) if the two-tailed test with H_0: $H_{ROA,t} = 0$ and H_A: $H_{ROA,t} \neq 0$ rejects H_0 at the 1% level. As can be seen in Table 14 in Appendix G, this is not the case for any of the estimated H_ts[31]. The regression with the first-differenced ln(ROE) as LHS variable, also reported in Table 14 in Appendix G, confirms these results.

10 The second-stage equation

In this Section, we investigate the effect of state aid on competition in the Belgian banking sector by a regression on the H_t-statistics we estimate with the first-stage equation. We first present the model employed, before describing the results.

Since we are interested in the particular effect of state aid in the Belgian banking sector, it is necessary to clearly define the kind of government support that is considered and modeled further in this section. We define five sector-specific state aid measuring variables. All of them are used in regressions on the rolling H_t-statistics (which are estimated by means of the first-stage equation), with each time only one state aid measuring variable used, since the correlation between them approximates 1. We test for different measurement methods of the government support since measuring the given state aid is complex.

The first state aid measuring variable is the sum of the direct capital injections (which include recapitalization and liquidity support), CI, given by the Belgian governments to Belgian banks. The variable is constructed as the average over four quarters of the quarterly sum of direct capital injections. The quarterly sum measures the state aid capital injections to that date, meaning that, for example, the Q1 2009 quarterly sum is the sum of all direct capital injections to that date (as the first direct capital injection took place in Q4 2008, the Q1 2009 quarterly sum equals the direct capital injections given in Q4 2008 plus those given in Q1 2009). An overview of the different direct capital injections by the Belgian governments can be found in Table 6.

The four other state aid measuring variables are all time dummies, $SAD1$ through $SAD4$. Since the dummy variable can only equal zero (no government support has been given yet) or one (government support has been given), it measures *all* different state aids (specified in Section 3). The first quarter in which state aid has been given is quarter 40 (October-December 2008), since the first state aid operation occurred on September 29, 2008. Clearly, this only has a marginal impact on quarter 39, and therefore we see quarter 40 as the first quarter in which state aid has been given. The time dummies differ from each other in which four-quarterly period they start equaling 1. The four different state aid dummies are set up as it is interesting to test for different starts of the state aid dummy, given that we work with rolling H_t-statistics. In Table 7, the values for the different state aid measuring variables are given.

Other sorts of government support to the banking sector, such as state guarantees for funding and state guarantees for losses on mortgage-backed security portfolios, are not analyzed as separate variables such as capital injections is, for they are difficult to model, as they are only partially used by the banks.

[31] This also holds for the one-tailed test where H_A: $H_{ROA,t} < 0$.

Table 6: The various capital injections by Belgian governments to Belgian banks in 2008-2009

Date	*Capital Injection*	*Description*
September 29th 2008	€6.5 billion	Buy-in / Capital raise
September 30th 2008	€2 billion	Capital raise
October 5th 2008	€4.7 billion	Takeover
October 5th 2008	€2.5 billion	Buy-in in CDO vehicle
October 27th 2008	€3.5 billion	Subordinate loan (Core Tier 1)
January 22nd 2009	€2 billion	Perpetual subordinate loan (Core Tier 1)
May 14th 2009	€1.5 billion	Raise of perpetual subordinate loan (Core Tier 1)

Table 7: The observation values of the various state aid measuring variables used in the second-stage equation.

Period	Year	t	CI[a]	SAD1	SAD2	SAD3	SAD4
Q1-Q4	1999	1	0	0	0	0	0
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.
Q33-Q36	2007	33	0	0	0	0	0
Q34-Q37		34	0	0	0	0	0
Q35-Q38		35	0	0	0	0	0
Q36-Q39		36	0	0	0	0	0
Q37-Q40	2008	37	4,775,000	1	0	0	0
Q38-Q41		38	10,050,000	1	1	0	0
Q39-Q42		39	15,700,000	1	1	1	0
Q40-Q43		40	21,350,000	1	1	1	1
Q41-Q44	2009	41	22,225,000	1	1	1	1

[a] In thousands of euro.

Notes:
Period: quarters of data used to estimate the model.
Year: indicates the year in which four subsequent quarters are located.
t: number specifying the first of four quarters of data used to estimate a rolling H_t.
CI, Capital Injections: rolling four-quarterly average of sum of direct capital injections given by the Belgian governments to Belgian banks.
SAD1, SAD2, SAD3, SAD4: State Aid Dummy 1 to 4.

10.1 Methodology

After calculating rolling H_t-statistics, we investigate the effect state aid has on the competitive environment, measured by a part of the changes in these rolling H_ts.

We construct a second-stage equation, a time-based regression on H_t, in order to explain the yearly H_t-statistics exhaustively using a number of competition impacting variables. Given our data from January 1999 to December 2009 and the controlling constraints, the general time-based regression of the 40 rolling H_ts (which can be found in Table 12 in Appendix E) is:

$$H_t = \kappa + \sum_{l=1}^{w} \lambda_l C_{l,t} + \lambda_{w+1} STM_t + \lambda_{w+2} SIM_t + \lambda_{w+3} SA_t + \varepsilon_t \tag{8}$$

for $t = 1, ..., 41$ (with $t = 13$ excluded[32])

with H_t the rolling estimates calculated by the first-stage equation (t indicates the first of the four quarters used to estimate H_t), κ a constant , $C_{l,t}$ w Crisis Variables, STM_t a Market Structure variable, SIM_t a Market Size variable, SA_t a State Aid variable and ϵ_t the error term.

Claessens and Laeven (2004) were the first to employ such a second-stage equation, by regressing H on a number of cross-country determinants of competition. In their search for factors that explain the competition over countries, Claessens and Laeven (2004) use a large amount of variables as a measurement of various concepts and categories[33]. We aim to explain H_t exhaustively by a number of concepts and categories. We are most interested in the state aid measuring variables' coefficient and significance, the other variables are only control variables to ensure that the state aid coefficient only measures the effect of state aid. Many of the categories tested by Claessens and Laeven (2004) are not applicable to our study as it is limited to a single country. This leaves us with equation 8. More details on the selection of the categories can be found in Appendix H.

After choosing variables to measure the effect of the respective categories (for more details on the selection, see Appendix H), we regress the following equation (all variables are four-quarterly):

$$H_t = \kappa + \lambda_1 \ln IL_t + \lambda_2 CR5_t + \lambda_3 \ln D_t + \lambda_4 SA_t + \varepsilon_t \tag{9}$$

for $t = 1, ..., 41$ (with $t = 13$ excluded[34])

Again, H_t are the rolling estimates calculated by the first-stage equation (t indicates the first of the four quarters used to estimate H_t), κ is a constant and ϵ_t is the error term. As a proxy for the financial crisis impact, the natural logarithm of the sector average of Interbank Loans $\ln IL_t$ is used. $CR5_t$ is the 5-bank Concentration Ratio[35], a proxy for the market structure. Then, to control for the market size, the natural logarithm of the sum of sector Deposits $\ln D_t$ is chosen. Finally, SA_t is one of the five state aid measuring variables (see above). More information on

[32]Because $H_{13} > 1$. See Section 9 above for more details.
[33]Such as market structure, market size, barriers to entry, protection to property rights, GDP per capita, etc.
[34]We also run the regression with H_{13} reset to 1 as a robustness check, and the results are very similar.
[35]Calculated as the four-quarterly average of $\frac{\text{Total assets of the five largest banks}}{\text{Total assets of the industry}}$.

how those variables are calculated can be found in Appendix H. This equation is regressed six times in various forms: for five different specifications of SA_t, and once without SA_t. Their values for the various rolling four-quarterly observations can be found in Table 7 above. The descriptive statistics of the used variables can be found in Table 17 in Appendix H.

10.2 Results

In this Subsection, we present the results of regressing equation 9. More details on the statistical characteristics of the regression can be found in Appendix H. The regression results can be found in Table 8. We perform, next to regular OLS regressions, weighted OLS regressions to account for the standard errors of H_t. The used weights, $1/se(H_t)$, cause the more precise H_ts to assert more influence on the estimations. Both regression methods provide very similar results.

All of the state aid measuring variables' coefficients are positive, with the variables consistently significant over all estimations at the 10% level, in a regression with jointly significant and individually significant variables. This means that, based on the assumptions of the Panzar-Rosse model, the state aid given in 2008-2009 *increased* competition, rather than the intuitively expected decrease. The positive effect is strong, with the impact of state aid on H_t ranging from 0.215 to 0.311[36], ceteris paribus, depending on the state aid measuring variable used. A further indication of the significance of state aid can be found in the higher adjusted R^2 of the estimations with a State Aid variable, and in the fact that the F-test's null hypothesis that the variables are jointly insignificant cannot be rejected in estimation (f).

We identify three possible reasons for this competition increasing effect. Firstly, state aid is not free: the banks that received it have to pay fees that are related to the size of the state aid injection, or have to allow an equity dilution for the existing shareholders. These results show that the prices which the various Belgian governments charged were at least high enough to offset any possible negative competition effects.

Secondly, as mentioned in Section 3, state aid can have a positive impact on other firms in the banking sector, as possible distress becomes less likely and any fear of losing interbank debt is allayed.

Thirdly, the banks that did not receive state aid may have gotten an impetus to compete more fiercely as the state aid banks' operations are damaged. Direct Belgian governments' state aid was only given to three of the largest Belgian banks, who are now under increased government pressure, and their trustworthy reputation is also damaged. On these two grounds, the state aid banks now have an incentive to make lesser use of their dominant position, as doing so might upset the public and the state, and any future government rescue would be compromised. Also, this could have a signaling effect on customers, who in turn might decide to spread their financial services use over more banks or completely churn to banks they perceive as being safer, banks that did not receive state aid, both spreading business more evenly in the market, inducing stronger competition. This effect is partially attributable to the financial distress these banks find themselves in, but also partially to the state aid as this sends a signal to consumers that these problems are more dangerous than previously thought.

[36]The effect of CI varies between 0.23 and 0.26.

Table 8: OLS estimates of the four-quarterly rolling Panzar and Rosse measure of competition H_t for the various state aid measuring variables, regular vs. weighted by $1/\text{se}(H_t)$.

	Measuring var. 1		Measuring var. 2		Measuring var. 3		Measuring var. 4		Measuring var. 5		No state aid var.	
H_t	*regular*	*weighted*	*regular*	*weighted*	*regular*	*weighted*	*regular*	*weighted*	*regular*	*weighted*	*regular*	*weighted*
ln(IL[a])	.421**	.426**	.401**	.413**	.536**	.516**	.434*	.439**	.395*	.414**	.196	.258
	(.20)	(.17)	(.20)	(.17)	(.23)	(.20)	(.23)	(.18)	(.22)	(.18)	(.20)	(.17)
CR5	5.330**	4.656**	5.248**	4.590**	5.426***	4.817**	4.517**	4.078*	4.167**	3.820*	3.407*	3.103
	(2.12)	(2.15)	(2.12)	(2.14)	(1.90)	(2.00)	(1.96)	(2.05)	(1.89)	(1.99)	(1.73)	(1.85)
ln(D[a])	−.880***	−.805***	−.853***	−.785***	−.994***	−.905***	−.790**	−.743***	−.713**	−.689***	−.445*	−.464**
	(.28)	(.25)	(.28)	(.25)	(.26)	(.24)	(.29)	(.26)	(.27)	(.24)	(.22)	(.21)
ln(CI[a])	.015*	.013*										
	(.01)	(.01)										
SAD1			.233*	.198*								
			(.13)	(.11)								
SAD2					.311***	.276***						
					(.10)	(.08)						
SAD3							.215*	.196*				
							(.12)	(.10)				
SAD4									.215*	.201**		
									(.11)	(.10)		
Constant	4.347*	3.544*	4.264*	3.474*	4.376**	3.679**	3.306	2.797	2.909	2.497	2.170	1.758
	(2.46)	(2.05)	(2.45)	(2.04)	(2.13)	(1.80)	(2.06)	(1.73)	(1.89)	(1.61)	(1.67)	(1.42)
F for joint significance	4.0	3.7	3.8	3.6	5.4	4.5	3.6	3.8	2.9	3.3	1.8	1.9
$p(F\text{-test})$[b]	.009	.013	.012	.015	.002	.005	.014	.011	.035	.022	.165	.152
R^2[c]	.241	.228	.237	.225	.272	.261	.209	.204	.202	.198	.169	.165
R^2-adj	.154	.140	.150	.136	.189	.177	.119	.113	.110	.106	.099	.096

***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

[a] In thousands of euro. H_t and CR5 are dimensionless; all State Aid Dummies are 0/1.

[b] Probability of F-test with H_0 : all RHS variables are jointly zero.

[c] Calculated with the ordinary OLS standard errors of each model.

Notes:

Newey-West standard errors between brackets.

regular: regular OLS estimation without weights; *weighted*: OLS estimation weighted by $1/\text{se}(H_t)$, calculated from the first-stage equation.

H_t: the estimated H_t-statistic from the first-stage equation.

IL, Interbank Loans avg.: rolling four-quarterly sector averages.

CR5, 5-bank Concentration Ratio (based on Total Assets). D, Total Deposits average: rolling four-quarterly average of the sum of sector deposits.

CI, Capital Injections: rolling four-quarterly average of sum of direct capital injections given by the Belgian governments to Belgian banks; SAD1-SAD4: State Aid Dummy 1 to 4.

To sum up, the larger banks might make less use of their dominant position and will have to surrender part of their dominance because of churning customers anyways. Adding to the positive competition effect, the non-state aid banks may now compete more strongly to capture a substantive share of the moving customers. Evidence to support this theory is found in the asset transfer of household depositors from state aid banks to non-state aid banks over the course of 2008-2009[37].

Whether one of these reasons, or a mix, can explain the positive competition effect of state aid, is an interesting suggestion for future research.

It is important to note that the EC competition authorities force banks that have received state aid to take compensationary measures, such as downsizing and bans on being price leader in the relevant market, which come into force from January 2010 on. These can have a further positive impact on competition, however, they are not taken into account as reasons for the competition effect in 2008 and 2009, as the timing of those measures is outside of our sample period. For an overview of how the EC relaxed its state aid rules during the financial crisis, see Drijber and Burmester (2009).

Without going into detail, we also look at the signs of the control variables, which are also consistently positive or negative over all estimations. The coefficient sign of Interbank Loans is positive. Therefore, when in the financial crisis banks lended less to each other, competition decreased ceteris paribus. The coefficient sign of $CR5$ is positive. This seems counterintuitive, as it means that higher concentration implies more competition, ceteris paribus. However, academics do no longer see concentration as the main indicator, and this result again confirms the appropriateness of this evolution. Claessens and Laeven (2004) also find a positive coefficient for $CR5$. The coefficient sign of Total Deposits, finally, is negative. Thus, when the industry grows, competition declines, ceteris paribus. This result is in accordance with the notion that when the pie is larger, each bank's slice is large enough not to fight extensively for the slice of another bank.

We perform a number of robustness checks, both with OLS and weighted OLS estimations. Firstly, we regress an equation that is similar to equation 9, but uses two crisis variables. The regressions are performed on equation 10 in Appendix H, and the results can be found in Table 18 in that same Appendix. The first two tested state aid measuring variables, CI and $SAD1$ are only significant at a 12% level, but the other state aid measuring variables remain significant at a 10% level or lower. The coefficients remain positive and the sign of the coefficients of all control variables remains the same as well. The lower significance of CI and $SAD1$ can be explained by their high correlation with BCB (see Table 16 in Appendix H for the correlation matrix), suggesting that the state aid impact is not purely measured by CI and $SAD1$ alone anymore. In fact, it has been suggested that the extremely low ECB borrowing rate during the financial crisis (Reinhart and Felton, 2008) is a form of universal state aid, and it might thus take up part of the positive competition response of the other state aid variables. The remaining significance of $SAD2$, $SAD3$ and $SAD4$ may indicate that the effect of state aid is stronger in 2009 than it

[37] This assertion is based on deposit comparisons between the different banks in our data set, and is confirmed by various market players.

is in the fourth quarter of 2008. This is in accordance with intuition, as a combined effect of all state aid is likely, and part of the state aid was granted in 2009. Overall, it can be stated that these robustness check regressions confirm our earlier results.

Secondly, we estimate these regressions with the Cost of Personnel B as the proxy for the factor price of personnel. The results are similar, as it makes most state aid variables more significant, whilst the coefficients stay positive. However, the joint significance of the variables goes down.

11 Policy implications

Our results disprove the intuition that state aid has a negative impact on competition, showing that it is a trying exercise to assess the competition impact of state aid beforehand. This complexity also affects the choices that governments face when granting state aid in a crisis situation. They have to act fast to protect their economy, whilst the competition authorities (for Belgium, the EC) only rule on the specifics of the government aid months later. In the 2008-2009 financial crisis, governments were allowed by the EC to provide state aid to financial institutions, as it was seen as a remedy to a serious disturbance in their economy (EU, 2008). The EC's approval is subject to a number of stipulations (for an overview, see Beck *et al.* (2010)) that are imposed to minimize the competitive distortions of the given aid. From these stipulations result a number of choices governments have to make, such as which price to charge for the state aid, before executing their support.

One of the stipulations is that the price of any government support should be close to the prices the market would charge for it. With the financial sector in severe distress in 2008-2009, the market prices were in doubt, and governments were left with some freedom in determining the price for their aid. Judging from our results, the Belgian government priced their granted state aid at least fairly, if not too high (as explained above, the competition increase might also be partially attributable to other reasons). This indicates that measures a priori (i.e., those included in the state aid agreement between the administration and the bank) can have a stronger than previously anticipated mitigating influence on any possible competition disrupting effects of state aid, even before those start to take place. As reasoned above, possible signaling effects of the government support to consumers, competitors and the state aid banks themselves cannot be ignored as mitigating influences either.

The above indicates that policy responses, both from governments and competition authorities, to state aid could be more complex than previously thought, suggesting an investigation into the mitigating effects that a priori state aid conditions, imposed by governments, can have on the possible competition distorting impact of that aid. In future crises, a larger role can be given to a priori conditions, as they are preferred to ex post measures from an industry stability point of view. A broad framework for these a priori measures should be constructed, in order to ensure an effective and efficient state aid policy, and, in the EU case, to avoid a subsidy race between Member States.

12 Conclusion

By linking the Panzar-Rosse competition indicator, calculated in a first stage, with state aid and a number of controlling competition impacting factors in a second stage, we find evidence that the Belgian state aid to financial institutions during the global financial crisis of 2008-2009 has a significantly positive impact on competition. We measure the effect of state aid with several variables, and their coefficients are consistently large, suggesting that state aid has played a strong role in the competitive landscape of 2008 and 2009.

These positive effects can be attributed to a number of factors. Firstly, state aid to one bank can have positive effects for other banks as well, since financial turbulence and interbank loan defaults are avoided.

Secondly, the given state aid is not free, banks have to pay fees or allow equity dilution of the existing shareholders in order to receive state aid. Therefore, it is possible that the pricing of this state aid is in line with or higher than the market prices would be, inducing a high cost for the state aid banks.

Thirdly, the three banks that received direct government support are three of the largest banks in Belgium. They are now under increased government pressure and their trustworthy reputation is damaged. This inevitably makes them less inclined to use their dominant position in the market, focusing more on survival and restructuring. This could have a signaling effect on customers, who decide to spread their financial services use over more banks or churn to banks they perceive as being safer, banks that did not receive state aid, both spreading market share more evenly over all players, inducing stronger competition. This effect is partially attributable to the financial distress these banks find themselves in, but also partially to the state aid, as it sends a signal to consumers that their bank's problems are more dangerous than imagined. As the larger banks now lose part of their dominant position due to churning customers, and they are already inclined to reduce the use of this position, smaller, non-state aid banks now have an opportunity to seize. These non-state aid banks may now compete more strongly to capture a substantive share of the moving customers. Evidence to support this theory is found in the asset transfer of household depositors from state aid banks to non-state aid banks over the course of 2008-2009[38].

These results are based on a number of assumptions, explained above. To test for the validity of those assumptions and thus of our results, we perform a number of robustness checks. These confirm our results, adding weight to our conclusions.

Our findings indicate that state aid policy could be more complex than previously thought. The conditions that governments impose, such as pricing, before agreeing to provide state aid, could well have a stronger than previously anticipated mitigating influence on the competition disrupting effects of state aid. From a market stability point of view, these a priori conditions are preferred over ex post measures of competition authorities. Therefore, giving more weight

[38]This assertion is based on deposit comparisons between the different banks in our data set, and is confirmed by various market players.

to the a priori conditions could improve social welfare in state aid cases.

Our study is the first to examine the effects of state aid on competition using quantitative models. It is also the first time that the specific characteristics of state aid in the financial sector are researched empirically. We also present a number of theoretical novelties.

Firstly, we show that a regression on the Panzar and Rosse competitive indicator H_t can be used to assess the competitive consequences of events and actions of market players. This opens the door for a number of analyses by examining coefficients of changing competition indicators in a regression on H_t. The impact of a merger on market-wide competition, for example, could be examined by the changes in H_t over time and by the coefficients of an industry concentration ratio or a merger dummy.

Secondly, we reason for the alteration of the widely used long-term equilibrium test for the Panzar and Rosse model, developed by Shaffer (1982) from a one-tailed to a two-tailed test.

Thirdly, we show that calculating an H-statistic over a large number of years, as most studies do, is troublesome in a dynamic industry such as the banking sector, and we are the first to analyze H_t-statistics on a four-quarter basis.

Finally, we add to the discussion in Bikker *et al.* (2006) and Bikker *et al.* (2009), who condemn the problematic but widespread use of the natural logarithm of scale variables as bank-specific control variables in the reduced form revenue equation. We assert that using scale variables without taking their natural logarithm is not problematic, which provides us with the correct alternative to control for scale of banks. Also, we note that taking natural logarithms of bank-specific variables is troublesome in itself, and recommend bank-specific variables to be included in the reduced form revenue equation without transformations, an approach that has not yet been used in the literature.

We suggest further research into the competition implications of state aid in order to get a more complete view on state aid dynamics. This research could be done in different sectors, over various time periods, investigating a number of state aid measures. To prepare policymakers for any future crises, the competitive impact of 2008-2009 banking state aid needs to be assessed in other countries, so as to get a clear overview of what might impact these competition implications, and how they interact with country characteristics. Another interesting research question is whether banks made a conduct change in the run-up to the financial crisis with the aim of becoming too big to fail (see Cheng and Van Cayseele (2009)). Theoretically, more research on the Shaffer long-term equilibrium test is needed. Also, further examination on which time period the H_t-statistics should be estimated to best reflect the changing competitive situation is of interest. Finally, we call for an investigation into current competition policy for the financial sector, as our results indicate that providing correct policy responses might be more complicated than previously thought.

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Appendix

A Data adjustments

In this Appendix Section we look into the adjustments that are made to our original data. We make these adjustments to ensure that the data are conceptually correct and do not contain any wrong observations, and they are used to achieve the results below. Very strict criterions are used to identify these incorrect observations and outliers, in order to ensure that no relevant data are omitted from the data set.

A.1 Conceptual Corrections

Corrections related to the estimation equation Observations with any of the following features are omitted from the data set, as their natural logarithms are N/A and can thus not be used in equation 3:

- *Total Income* ≤ 0
- *Any of the ultimately chosen factor prices*[39] ≤ 0
- *Denominators of the ultimately chosen factor prices* $= 0$
- Any of the variables needed for estimating our chosen PR reduced form revenue equation[40] that were missing

Corrections to incorrect observations Observations with any of the following features are omitted from the data set, as they are incorrect and would skew the estimation:

- *Equity* ≤ 0. These observations are concentrated in a small number of banks.
- Observations that are in-between many negative equity observations and are undoubtedly incorrect. This is only done for five observations of one bank, as these five observations are also among the eight lowest values for equity in our data set.

Corrections for extreme accounting A number of observations are omitted as they represent extreme outliers that are clearly attributable to accounting interventions[41].

Bank corrections One bank is completely omitted from our data set, as too many of its observations are missing to provide reasonable estimates[42].

[39] We retain three factor prices: the Funding Rate, the Price of Personnel A and the Capital Expenditure. See Section 9 and Appendix B for more details on the selection.

[40] See equation 6 in Section 9 for the specified reduced form revenue equation.

[41] For example, in one observation the property expenses increased ninefold, subsequently most of this rise was canceled by a strongly negative property expenses, only for the property expenses to return to its normal pattern the observation after.

[42] Observations for many of the bank-specific variables were not available for any period for this bank.

A.2 Corrections because of estimation[43]

For the calculation of the first possible proxy for the Factor Price of Personnel, the Cost of Personnel A ($\frac{\text{Personnel Expenses}}{\text{Number of Payroll employees}}$; see Table 9 in Appendix B), the number of payroll employees is needed. We have quarterly payroll employment numbers from Q4 2002 until Q4 2009 for almost all banks in our data set. However, the survey that collects these numbers only started at the end of 2002, and therefore no quarterly payroll employment data are available before Q4 2002.[44] We do, however, have yearly payroll employment numbers available for the period 1998-2009, thus we can estimate the quarterly numbers by applying the linearly interpolated growth rate of the yearly data to the last available quarterly number of payroll employees. This method requires that certain checks are carried out in order to ensure the validity of these estimations. The following changes were made to our data set:

- For one observation, the Cost of Personnel A shows that the estimate for the number of payroll employees is too high[45]. As no other fair estimate offered a plausible alternative, this observation and the previous one[46] are omitted. Another observation of another bank is omitted because the Cost of Personnel A shows that the estimate for the number of payroll employees is too low[47].

- For three cases, a large difference between the two yearly estimates that were used brought about a wrong Cost of Personnel A. Clearly, the change in number of payroll employees had taken place earlier or later in that year, and using the Cost of Personnel A we were able to locate the time of the drastic change and adjust the estimations accordingly.

- A number of banks in our sample only existed before Q4 2002, and there are thus no quarterly payroll employment numbers available for these banks. In this case, the linearly interpolated growth rate is applied to the first yearly observation. Since these numbers are fragile (we can, for example, not compare the yearly employment numbers with the quarterly numbers for consistency for the years where both are available), we apply an extra test to them: we omit all the estimations of a bank if one or more estimated number of payroll employees causes the Cost of Personnel A to exit a plausible range[48]. Through this criterion, two banks, representing only ten observations, are omitted from our sample.

A.3 Corrections for extreme outliers

We only want to omit outliers that incorrectly disrupt our estimation, as some observations that are simply normal for a certain bank (e.g., some banks have a consistently higher Cost of

[43]For the regression with the second possible proxy for the Factor Price of Personnel ($\frac{\text{Personnel Expenses}}{\text{Total Assets}}$), these corrections are not applied.

[44]For five banks, no quarterly payroll employment data were available for 2009, and we used the same method to estimate those observations.

[45]Though only at June 1999, the Cost of Personnel A that used this estimate was significantly higher than any other Cost of Personnel A in later periods, increased threefold from the period before, and then halved again in the next period.

[46]As that observation is an outlier for that bank and is estimated by applying the inverse yearly growth rate to the incorrect following one.

[47]Five times lower than the observation before and the observation after.

[48]We define a plausible range as $[Q_1 - 3 * IQR; Q_3 + 3 * IQR]$, with Q_1 the 25^{th} percentile, Q_3 the 75^{th} percentile, and IQR the interquartile range $(Q_3 - Q_1)$.

Personnel than the mean) could otherwise be omitted, and the H-statistic would be skewed by leaving those out. To ensure this goal, we only make adjustments if strict, clear-cut conditions are fulfilled. We omit the following observations:

- *Sample outliers* Observations for which both of the following conditions are fulfilled: for the observation, one (or more) of the ultimately chosen factor prices is in the 1^{st} percentile and the 99^{th} percentile of the whole sample, and that factor price is also out of the aforementioned plausible range of all the factor prices of the specific bank. An exception to this rule is made if there is a macroeconomic reason for these outliers, since in that case they represent a correct observation. We applied this exception once, when we noticed that the 1^{st} percentile of observations for the Factor Price of Funding consisted for over 85% of observations in 2009. This is attributable to the fact the European Central Bank provided liquidity at near zero cost[49], driving the Factor Price of Funding down. Of these observations, we only omit those that are not in the plausible range of the Funding Rate for *all* banks in 2009.

- *Bank outliers* Even after the above correction, some bank specific outliers remain, but these are rare (we only leave out seven) and consist of observations that are outliers of one (or more) factor price proxies[50] in a certain sequence[51] for a certain bank. The criterion used is that the bank Factor Price of that period must be at least 2.5 times as high as the bank Factor Price of the period before and after, and that the observation is extraordinary when comparing it to all other observations of this factor Price of the bank.

B Choice of first-stage equation variables

In determining how to specify the reduced form revenue equation, we investigate which variables, both for a number of factor prices and a number of bank-specific variables, are most consistently significant in the rolling H_ts we estimate. The possible variables we test for are summarized in Table 9 for the factor price variables and in Table 10 for the bank-specific variables, which control for differences between banks.

Gischer and Stiele (2009) add a proxy for the price of equity, namely $\frac{\text{Operating Results}}{\text{Equity}}$. We decide not to include it since we see it as a very noisy proxy for the price of equity, as operating results do not necessarily deliver the required return on equity. Especially in our study many banks suffer from low or even negative operating results during the financial crisis, and with the proxy of Gischer and Stiele (2009) the real price of equity would be underestimated grossly during this period.

Apart from that, Gischer and Stiele (2009) find that the price of equity only has a minimal impact on the H-statistic, which might not reflect reality. From finance theory, we see the use of a market model, such as the Capital Asset Pricing Model (CAPM), as preferential in estimating the price of equity. Whilst it would be an interesting exercise to include a proxy for the price of

[49] See Reinhart and Felton (2008).

[50] These corrections are not applied to Capital Expenditure Ratio, as large fluctuations are inherent to it.

[51] Meaning that the outlier seems to be most probably inconsistent in a certain sequence of observations, but is not necessarily the highest or lowest observation for that factor price for that bank, but definitely among the outer observations.

Table 9: Possible Factor Price proxies

Label	*Name*	*Proxy for the Factor Price of ...*	*Formula*
FR	Funding Rate	Funding	$\frac{\text{Interest Expenses}}{\text{Total Liabilities} - (\text{Equity+Reserves})}$
CPA	Cost of Personnel A	Personnel	$\frac{\text{Personnel Expenses}}{\text{Total Number of Payroll Employees}}$
CPB	Cost of Personnel B	Personnel	$\frac{\text{Personnel Expenses}}{\text{Total Assets}}$
CER	Capital Expenditure Ratio	Fixed Assets	$\frac{\text{Property Expenses}}{\text{Fixed Assets}}$

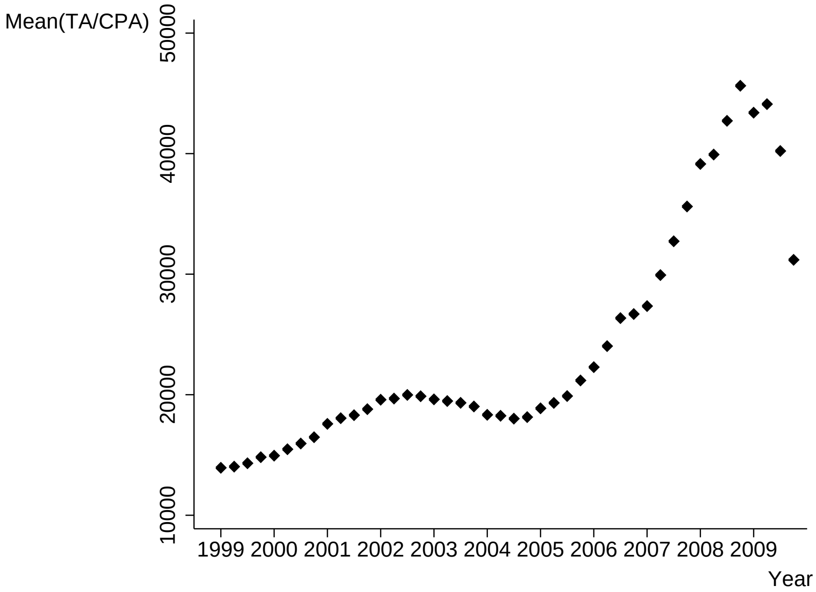
Table 10: Possible Bank-Specific Variables

Label	*Name*	*Formula*
CR	Capital Ratio	$\frac{\text{Equity}}{\text{Total Assets}}$
FS	Financing Structure	$\frac{\text{Interbank Deposits}}{\text{Interbank Deposits + Non-bank Deposits}}$
CRI	Credit Risk	$\frac{\text{Loans to non-banks}}{\text{Total Assets}}$
MLP	Maturity of Loan Portfolio	$\frac{\text{Loans with Maturity of up to 1 Year}}{\text{Loans to Non-bank Clients}}$
HLR	Household Loan Ratio	$\frac{\text{Loans to Households}}{\text{Loans to Non-bank Clients}}$
PLR	Public Operator Loans Ratio	$\frac{\text{Loans to Public Operators}}{\text{Loans to Non-bank Clients}}$
ORB	Other Role of Banks	$\frac{\text{Other Income}}{\text{Interest Income}}$
BDR	Bad Debt Ratio	$\frac{\text{Bad and Doubtful Debt}}{(\text{Cash to Central Banks + Interbank Loans +Loans to Non-banks})}$
TA	Total Assets	Total Assets

equity based on the CAPM, most of the banks in our sample are not listed on the stock exchange and therefore we cannot include it in our study.[52]

[52]We tested the rate of return on a 25 year government bond (called OLO for the Belgian case) as a partial

Figure 3: The quarterly evolution of the mean of Total Assets to Cost of Personnel A



We identify two possible proxies for the Price of Personnel (see Table 10):

- $\text{Cost of Personnel A} = \frac{\text{Personnel Expenses}}{\text{Total Number of Payroll Employees}}$

- $\text{Cost of Personnel B} = \frac{\text{Personnel Expenses}}{\text{Total Assets}}$

The Cost of Personnel A is conceptually superior as it is a closer proxy for the Price of Personnel. However, most studies applying the Panzar-Rosse model to the banking industry have used Cost of Personnel B, as they do not have employment numbers at their disposal. Since we do, we work with the superior Cost of Personnel A, but do run the regression with the Cost of Personnel B to check and to see what the possible estimation disruption of using the Cost of Personnel B might cause (we come back to this regression below).

The Cost of Personnel B is a troublesome proxy for the price of personnel as total assets and number of employees are not necessarily related. If they were related, the ratio $\frac{\text{Total Assets}}{\text{Number of Employees}}$ would be roughly fixed. We check this for our sample and whilst this ratio is fixed for certain periods, overall that is not the case, as can be seen in Figure 3 below. This figure also affirms the intuition that total assets fluctuates more than the number of payroll employees, an observation that is, not surprisingly, the most apparent in 2009.

Two important variable choices have to be made: the factor prices and the bank-specific variables.

proxy for the price of equity, since it represents the risk-free part of the CAPM. However, this led to a drastic rise of the standard errors of the H_ts, and the sign of its coefficient was inconsistent, as it alternated with large absolute numbers.

We decide to retain the three possible factor prices, since they represent the most important inputs and have become standard in the literature.

Four bank-specific variables, Maturity of Loan Portfolio, Household Loans Ratio, Public Operator Loans Ratio and Credit Risk, are virtually never significant and enlarge the standard error of the H_t estimates, thereby severely compromising the reliability of the results. Therefore, we do not further consider them. This leaves us with five, and to choose among them we test every plausible combination, using the criterion that the sum of the standard errors of the H_ts should be minimized. The model that includes all performs the best on this criterion and we thus retain all five.

C Choice of panel data analysis method

The data set at our disposal is a panel data set, consisting of 52 banks (61 before data adjustments) over 44 quarters (Q1 1999 - Q4 2009). In this Section we explain our reasoning behind the choice of our panel estimation method.

A first element of determination of the estimation method hinges on whether a bank-specific effect needs to be estimated. If the unobserved bank-specific effects α_i are significant, which is clearly the case for our sample[53], it should be taken into account. As a result, pooled OLS, which assumes equal α_is among all banks, is not an option anymore. Note that this assumption is natural: unobserved bank-specific factors do affect the earned total income per bank.

The estimation methods at our disposal are thus Fixed Effects (FE) models, Random Effects (RE) models and pooled OLS models that are estimated with differenced data[54]. In the banking competition literature, the latter estimation method is not even considered while one of the first two is chosen depending on the outcome of the Hausman specification test[55].

However, we want to know whether heteroskedasticity and autocorrelation are present in our data set and base our choice on the characteristics of the data. Especially since we employ quarterly data, the need for serial correlation corrections might be stringent. Indeed, based on Woolridge's test for serial correlation in panel data (Wooldridge, 2002), the H_0 that the model exhibits no serial correlation is significantly rejected[56]. Even though most PR employing studies work with yearly data, it is still surprising to see that none of them report corrections for autocorrelation, as serial correlation is a natural characteristic in this model.

Given the autocorrelation and the fact that the fixed effects model is a generalization of random effects (Wooldridge, 2002), we consider five alternative estimates of the Panzar and Rosse measure of competition H and compare the $se(\hat{H})$. The results are presented in Table 11.

The first estimation method (a) is a fixed effects model with an AR(1) disturbance term, which cannot correct for heteroskedasticity. Next to these results, pooled OLS estimations of first-differenced variables are presented with different standard error adjustments. Note that

[53] The H_0 of the Breusch-Pagan LM test for random group effects is always rejected (*P-value* < 0.001). Also, the F-test for joint significance of individual effects consistently rejects (*P-value* < 0.001) its H_0.

[54] Note that the pooled OLS estimation *without* first-differencing is eliminated already.

[55] If one cannot reject this test's H_0, the random effects model is preferred (more efficient)

[56] The P-values of the F-test ($F(1, 51)$) are consistently smaller than 0.001.

Table 11: Five alternative estimates of the Panzar and Rosse measure of competition H. Heteroskedasticity is tested by comparing $se(\hat{H})$. For simplicity, we use the whole data set.

	FE with AR(1)[a]	Pooled OLS, differenced data with:			
	(ordinary se)	(ordinary se)	(robust se)	(r. and i. se)[b]	(Newey-West se)
	(a)	(b)	(c)	(d)	(e)
dep. var.:	*ln(TI)*	Δ*ln(TI)*	Δ*ln(TI)*	Δ*ln(TI)*	Δ*ln(TI)*
ln FR	.102**				
	(.037)				
ln CPA	.445***				
	(.042)				
ln CER	–.071***				
	(.018)				
CR	–1.509**				
	(.520)				
FS	1.206***				
	(.188)				
ORB	.440***				
	(.050)				
BDR	–2.895				
	(3.140)				
TA	.000				
	(.000)				
Δln(FR)		.488***	.488***	.488***	.488***
		(.035)	(.063)	(.101)	(.083)
Δln(CPA)		.124***	.124*	.124	.124*
		(.035)	(.058)	(.077)	(.061)
Δln(CER)		–.003	–.003	–.003	–.003
		(.015)	(.026)	(.033)	(.029)
ΔCR		–1.256**	–1.256	–1.256*	–1.256
		(.416)	(.947)	(.542)	(.910)
ΔFS		.517***	.517**	.517*	.517**
		(.156)	(.161)	(.210)	(.198)
ΔORB		.412***	.412***	.412***	.412***
		(.038)	(.048)	(.058)	(.071)
ΔBDR		–1.216	–1.216	–1.216	–1.216
		(2.799)	(1.481)	(1.475)	(1.445)
ΔTA		.000	.000	.000	.000
		(.000)	(.000)	(.000)	(.000)
Constant	9.497***				
	(.038)				
$\hat{H}$	.476	.611	.611	.611	.611
$se(\hat{H})$	(.060)	(.049)	(.089)	(.137)	(.105)
$\hat{\rho}$[c]	.83	1.00	1.00	1.00	1.00
Observations[d]	1436	1385	1385	1385	1385

***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

[a] Estimations of $y_{it} = \alpha_i + x'_{it}\beta + u_{it}$ with AR(1) error $u_{it} = \rho u_{i,t-1} + \epsilon_{it}$.

[b] Standard error adjusted for heteroskedasticity and intragroup correlation.

[c] Estimated autocorrelation coefficient, which is assumed to equal one in (b), (c), (d) and (e).

[d] Differencing is sometimes not possible due to N/A values, hence the difference in observations.

Notes:

TI, Total Income; FR, Funding Rate; CPA, Cost of Personnel A; CER, Capital Expenditure Ratio; CR, Capital Ratio; FS, Financing Structure; ORB, Other Role of Banks; BDR, Bad Debt Ratio; TA, Total Assets.

All varariables are dimensionless, except from TA (in thousands of euro) and CPA (in thousands of euro/employee).

first-differencing is a proper alternative to adjust for autocorrelation since it imposes an AR(1) structure. Also, no intercept is estimated[57]. The pooled OLS estimations are presented with ordinary standard errors (b), with robust standard errors adjusting for heteroskedasticity (c), with standard errors that are adjusted for both heteroskedasticity and intragroup serial correlation (d) and with Newey-West standard errors (e). The last adjustment means that the error structure is assumed to be heteroskedastic and possibly autocorrelated up to some specified lag[58].

The comparison makes sense because estimation method (a) and (b) have the same assumptions: both have ordinary standard errors, the bank-specific effect is ruled out and they control for autocorrelation of almost the same level. Since (c), (d) and (e) are only robust versions of model (b), and model (a) and (b) are similar, their estimated standard error of $\hat{H}$ can be compared to $se(\hat{H})$ of (a) to examine the necessity of adjusting for heteroskedasticity. Since the $se(\hat{H})$ of (a) and (b) are quite similar and the $se(\hat{H})$ of (c), (d) and (e) are considerably higher, evidence of the need to adjust the $se(\hat{H})$ for heteroskedasticity is found. Still, the standard error of (c) is not adjusted for higher order autocorrelation, hence the standard error difference with (d) and (e). Model (d)'s assumptions are too strict as it assumes that there is always autocorrelation, whereas in model (e), the structure is only possibly autocorrelated and only corrected for if necessary. Therefore, we will use pooled OLS, after first-differencing the variables, with Newey-West standard errors.

D A note on the non-additive separability of H

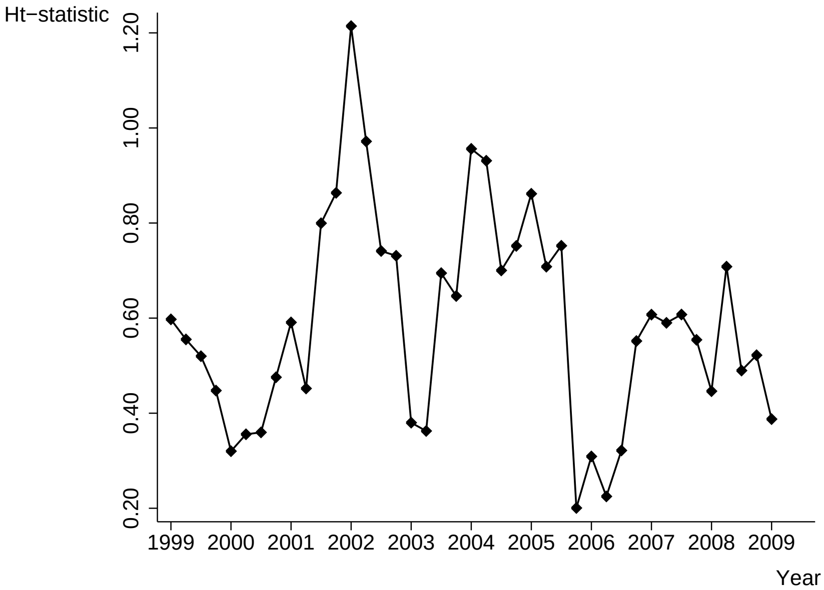
In this Appendix Section, we reason that an H-statistic calculated over a number of years is not an average of the H_t-statistics of the individual years.

Indeed, since OLS coefficients are by definition estimated by using least squares, they are in se not additively separable. In other words, the coefficients of an OLS regression performed with one data set cannot be a function of the coefficients of various regressions that each use part of the data set. Moreover, since H is a linear combination of coefficients, this non-additive separability holds for estimates of H with OLS. Note that fixed and random effects models are also estimated with pooled OLS, the former using time-demeaned and the latter quasi-demeaned data(Wooldridge, 2006). Therefore, if H is estimated over a large time period using pooled OLS, it cannot be a function, let alone the arithmetic average, of the H_t-statistics estimated per individual period. Since H is always estimated with a panel data method, this note generalizes to the whole PR literature. Whatever estimation method is used, the non-additive separability will prevent H-statistics that are estimated by using data over a large period of time from being the arithmetic average of the H_ts of subperiods.

[57] Leaving a constant after differencing, $\zeta = \zeta t - \zeta(t-1)$, would imply a time trend in the original model.

[58] The maximum lag order of autocorrelation is $m(T) - 1 = floor[4(\frac{T}{100})^{\frac{2}{9}}] - 1 = floor[4(\frac{44}{100})^{\frac{2}{9}}] - 1 = 2$. First-differenced data account already for one lag of autocorrelation.

Figure 4: The rolling four-quarterly H-statistics



E Rolling H_t-statistic estimates

In Figure 4, the graph of the rolling four-quarterly H_t-statistic estimates can be found. In the Table 12 below, the four-quarterly rolling H_t-statistic estimates are given.

F Robustness check for H_t estimates

As a robustness check for our model, we also regress equation 7 in Section 9 with the Cost of Personnel B as a proxy for the prices of personnel. The results can be found in Table 13. The similar evolution confirms the correctness of our earlier results.

G Long-term equilibrium tests

In Table 14 below, the outcome of the long-term equilibrium tests for our estimated H_t-statistics is shown.

H Choice of second-stage equation variables and regression characteristics

H.1 Category selection

As already mentioned in Section 10, many of the concepts and categories Claessens and Laeven (2004) use are irrelevant for our study as it only researches competition in a single country. All relevant categories are represented in equation 8, except for barriers to entry. Barriers to entry,

Table 12: Pooled OLS estimates of the rolling four-quarterly Panzar and Rosse measure of competition H_t, first-differenced data.

Period	Year	t	$\hat{H}_t$	se($\hat{H}_t$)	Δln(FR)	Δln(CPA)	Δln(CER)
Q1-Q4	1999	1	0.597	(0.193)	0.424	0.166	0.008
Q2-Q5		2	0.555	(0.168)	0.343	0.206	0.006
Q3-Q6		3	0.520	(0.166)	0.315	0.211	-0.006
Q4-Q7		4	0.448	(0.174)	0.276	0.177	-0.005
Q5-Q8	2000	5	0.320	(0.166)	0.242	0.108	-0.029
Q6-Q9		6	0.356	(0.114)	0.274	0.111	-0.029
Q7-Q10		7	0.360	(0.123)	0.320	0.058	-0.018
Q8-Q11		8	0.476	(0.117)	0.475	0.045	-0.044
Q9-Q12	2001	9	0.591	(0.093)	0.717	-0.092	-0.035
Q10-Q13		10	0.452	(0.238)	0.834	-0.233	-0.149
Q11-Q14		11	0.800	(0.315)	0.926	0.046	-0.173
Q12-Q15		12	0.864	(0.237)	0.921	0.099	-0.156
Q13-Q16	2002	13	1.214	(0.325)	1.111	0.302	-0.198
Q14-Q17		14	0.972	(0.333)	0.810	0.309	-0.148
Q15-Q18		15	0.741	(0.224)	0.695	0.103	-0.057
Q16-Q19		16	0.731	(0.205)	0.797	-0.039	-0.027
Q17-Q20	2003	17	0.380	(0.226)	0.477	-0.070	-0.028
Q18-Q21		18	0.363	(0.195)	0.383	-0.004	-0.016
Q19-Q22		19	0.695	(0.330)	0.438	0.181	0.075
Q20-Q23		20	0.646	(0.359)	0.345	0.248	0.053
Q21-Q24	2004	21	0.956	(0.282)	0.658	0.257	0.041
Q22-Q25		22	0.931	(0.247)	0.556	0.359	0.016
Q23-Q26		23	0.700	(0.230)	0.530	0.149	0.022
Q24-S27		24	0.752	(0.281)	0.496	0.207	0.049
Q25-Q28	2005	25	0.862	(0.305)	0.503	0.329	0.030
Q26-Q29		26	0.708	(0.336)	0.346	0.302	0.060
Q27-Q30		27	0.752	(0.223)	0.487	0.222	0.043
Q28-Q31		28	0.201	(0.237)	0.078	0.104	0.018
Q29-Q32	2006	29	0.309	(0.236)	0.254	0.055	0.000
Q30-Q33		30	0.225	(0.170)	0.286	-0.044	-0.017
Q31-Q34		31	0.322	(0.236)	0.406	-0.066	-0.018
Q32-Q35		32	0.552	(0.108)	0.613	-0.095	0.034
Q33-Q36	2007	33	0.607	(0.143)	0.580	0.019	0.008
Q34-Q37		34	0.590	(0.121)	0.520	0.115	-0.044
Q35-Q38		35	0.608	(0.139)	0.514	0.085	0.008
Q36-Q39		36	0.554	(0.196)	0.440	0.098	0.016
Q37-Q40	2008	37	0.446	(0.207)	0.249	-0.089	0.286
Q38-Q41		38	0.708	(0.217)	0.464	-0.088	0.332
Q39-Q42		39	0.490	(0.240)	0.470	-0.283	0.302
Q40-Q43		40	0.568	(0.262)	0.362	-0.118	0.323
Q41-Q44	2009	41	0.435	(0.188)	0.351	-0.004	0.087

Notes:
Dependent variable: Δln(TI), with TI being Total Income.
Period: quarters of data used to estimate the model.
Year: the year in which four subsequent quarters are located.
t: number specifying the first of four quarters of data used to estimate a rolling H_t.
$\hat{H}_t$: the rolling four-quarterly H_t-statistic.
se($\hat{H}_t$): Newey-West adjusted standard error of H_t.
FR, Funding Rate; CPA, Cost of Personnel A; CER, Capital Expenditure Ratio.
All variables are dimensionless, except from TI (in thousands of euro) and CPA (in thousands of euro per employee).

Table 13: Pooled OLS estimates of the rolling four-quarterly Panzar and Rosse measure of competition H_t, first-differenced data. Instead of CPA, we use CPB as the factor price of personnel.

Period	Year	t	$\hat{H}_t$	se($\hat{H}_t$)	Δln(FR)	Δln(CPB)	Δln(CER)
Q1-Q4	1999	1	0.500	(0.173)	0.423	0.068	0.008
Q2-Q5		2	0.413	(0.152)	0.352	0.056	0.004
Q3-Q6		3	0.364	(0.142)	0.318	0.051	-0.006
Q4-Q7		4	0.235	(0.149)	0.284	-0.047	-0.002
Q5-Q8	2000	5	0.125	(0.137)	0.255	-0.103	-0.027
Q6-Q9		6	0.299	(0.121)	0.290	0.038	-0.029
Q7-Q10		7	0.306	(0.133)	0.352	-0.029	-0.016
Q8-Q11		8	0.435	(0.123)	0.523	-0.049	-0.039
Q9-Q12	2001	9	0.571	(0.069)	0.738	-0.136	-0.031
Q10-Q13		10	0.385	(0.185)	0.821	-0.288	-0.148
Q11-Q14		11	0.571	(0.273)	0.903	-0.156	-0.176
Q12-Q15		12	0.655	(0.232)	0.903	-0.088	-0.160
Q13-Q16	2002	13	0.957	(0.383)	1.075	0.073	-0.191
Q14-Q17		14	0.826	(0.341)	0.783	0.176	-0.133
Q15-Q18		15	0.667	(0.230)	0.684	0.027	-0.044
Q16-Q19		16	0.672	(0.200)	0.816	-0.138	-0.006
Q17-Q20	2003	17	0.320	(0.236)	0.508	-0.168	-0.021
Q18-Q21		18	0.277	(0.200)	0.408	-0.115	-0.017
Q19-Q22		19	0.649	(0.423)	0.507	0.063	0.079
Q20-Q23		20	0.640	(0.455)	0.423	0.162	0.055
Q21-Q24	2004	21	0.949	(0.374)	0.732	0.162	0.056
Q22-Q25		22	0.875	(0.390)	0.653	0.142	0.081
Q23-Q26		23	0.550	(0.198)	0.555	-0.037	0.032
Q24-S27		24	0.606	(0.238)	0.496	0.052	0.058
Q25-Q28	2005	25	0.695	(0.274)	0.496	0.168	0.031
Q26-Q29		26	0.595	(0.307)	0.355	0.180	0.059
Q27-Q30		27	0.665	(0.201)	0.502	0.122	0.042
Q28-Q31		28	0.114	(0.224)	0.105	-0.012	0.021
Q29-Q32	2006	29	0.266	(0.229)	0.285	-0.022	0.002
Q30-Q33		30	0.191	(0.159)	0.366	-0.174	0.000
Q31-Q34		31	0.257	(0.190)	0.485	-0.232	0.004
Q32-Q35		32	0.494	(0.097)	0.644	-0.191	0.040
Q33-Q36	2007	33	0.500	(0.130)	0.600	-0.114	0.014
Q34-Q37		34	0.489	(0.117)	0.519	0.008	-0.038
Q35-Q38		35	0.533	(0.132)	0.528	-0.007	0.012
Q36-Q39		36	0.478	(0.180)	0.472	-0.015	0.021
Q37-Q40	2008	37	0.466	(0.173)	0.316	-0.141	0.292
Q38-Q41		38	0.669	(0.193)	0.494	-0.154	0.329
Q39-Q42		39	0.546	(0.215)	0.522	-0.275	0.298
Q40-Q43		40	0.553	(0.237)	0.367	-0.143	0.328
Q41-Q44	2009	41	0.392	(0.139)	0.344	-0.044	0.092

Notes:
Dependent variable: Δln(TI), with TI being Total Income.
Period: quarters of data used to estimate the model.
Year: indicates the year in which four subsequent quarters are located.
t: number specifying the first of four quarters of data used to estimate a rolling H_t.
$\hat{H}_t$: the rolling four-quarterly H_t-statistic; se($\hat{H}_t$): Newey-West adjusted standard error of H_t.
FR, Funding Rate; CPB, Cost of Personnel B; CER, Capital Expenditure Ratio.
All variables are dimensionless, except from TI (in thousands of euro).

Table 14: Results of two tests for long-term equilibrium, with Δln(ROA) and Δln(ROE) as LHS using pooled OLS, first-differenced data.

Period	Year	$\hat{H}_{ROA,t}$	se($\hat{H}_{ROA,t}$)	$p(\hat{H}_{ROA,t}=0)^a$	$\hat{H}_{ROE,t}$	se($\hat{H}_{ROE,t}$)	$p(\hat{H}_{ROE,t}=0)^a$
Q1-Q4	1999	0.002	(0.003)	0.410	-0.023	(0.224)	0.919
Q2-Q5		0.001	(0.002)	0.637	0.362	(0.331)	0.277
Q3-Q6		0.001	(0.002)	0.614	0.483	(0.435)	0.269
Q4-Q7		0.000	(0.002)	0.991	0.393	(0.428)	0.360
Q5-Q8	2000	-0.002	(0.002)	0.228	0.207	(0.458)	0.652
Q6-Q9		-0.002	(0.002)	0.223	-0.288	(0.270)	0.288
Q7-Q10		-0.002	(0.002)	0.259	-0.294	(0.283)	0.301
Q8-Q11		0.000	(0.002)	0.924	-0.280	(0.281)	0.322
Q9-Q12	2001	-0.004	(0.003)	0.211	-0.140	(0.175)	0.424
Q10-Q13		-0.009	(0.005)	0.090	0.067	(0.195)	0.731
Q11-Q14		-0.011	(0.005)	0.021	0.022	(0.181)	0.904
Q12-Q15		-0.008	(0.005)	0.139	0.042	(0.162)	0.797
Q13-Q16	2002	0.000	(0.005)	0.998	0.276	(0.208)	0.188
Q14-Q17		-0.001	(0.005)	0.81	-0.142	(0.179)	0.430
Q15-Q18		0.000	(0.006)	0.999	-0.084	(0.182)	0.644
Q16-Q19		0.001	(0.004)	0.831	-0.003	(0.154)	0.982
Q17-Q20	2003	-0.002	(0.004)	0.550	-0.096	(0.135)	0.480
Q18-Q21		-0.002	(0.002)	0.431	0.017	(0.080)	0.832
Q19-Q22		0.000	(0.003)	0.989	0.065	(0.066)	0.328
Q20-Q23		-0.001	(0.002)	0.743	-0.042	(0.072)	0.565
Q21-Q24	2004	-0.001	(0.002)	0.827	-0.156	(0.117)	0.185
Q22-Q25		-0.003	(0.002)	0.144	-0.241	(0.154)	0.120
Q23-Q26		-0.005	(0.002)	0.055	-0.212	(0.168)	0.210
Q24-S27		-0.005	(0.002)	0.029	-0.183	(0.126)	0.150
Q25-Q28	2005	-0.003	(0.002)	0.113	-0.053	(0.070)	0.452
Q26-Q29		-0.003	(0.002)	0.190	-0.035	(0.053)	0.508
Q27-Q30		-0.002	(0.003)	0.445	-0.115	(0.138)	0.406
Q28-Q31		-0.001	(0.005)	0.828	-0.123	(0.163)	0.453
Q29-Q32	2006	-0.002	(0.003)	0.508	-0.215	(0.161)	0.185
Q30-Q33		-0.005	(0.003)	0.077	-0.214	(0.134)	0.113
Q31-Q34		-0.004	(0.002)	0.047	-0.086	(0.050)	0.084
Q32-Q35		-0.003	(0.002)	0.088	-0.069	(0.047)	0.143
Q33-Q36	2007	0.000	(0.002)	0.925	-0.032	(0.045)	0.475
Q34-Q37		0.001	(0.002)	0.414	-0.105	(0.072)	0.152
Q35-Q38		0.002	(0.002)	0.315	-0.114	(0.078)	0.148
Q36-Q39		-0.005	(0.006)	0.427	-0.369	(0.175)	0.037
Q37-Q40	2008	-0.006	(0.006)	0.315	-0.290	(0.160)	0.072
Q38-Q41		-0.012	(0.006)	0.047	-0.406	(0.192)	0.037
Q39-Q42		-0.013	(0.005)	0.021	-0.446	(0.175)	0.012
Q40-Q43		-0.007	(0.004)	0.071	-0.289	(0.141)	0.042
Q41-Q44	2009	-0.003	(0.003)	0.271	-0.200	(0.099)	0.046

[a] The probability of the two-tailed test that $\hat{H}_{ROA,t}$ and $\hat{H}_{ROE,t}$, respectively, are equal to zero.

Notes:

ROA, Return on Assets: Net Income before Taxes to Total Assets.

ROE, Return on Equity: Net Income before Taxes to Total Equity.

Period: quarters of data used to estimate the model.

Year: the year in which four subsequent quarters are located in the same year.

$\hat{H}_{ROA,t}$ and $\hat{H}_{ROE,t}$: the estimated value of the $H_{ROA,t}$- and $H_{ROE,t}$-statistic of the long-term equilibrium test.

se($\hat{H}_{ROA,t}$), se($\hat{H}_{ROE,t}$): the Newey-West adjusted standard error of, respectively, $H_{ROA,t}$ and $H_{ROE,t}$.

though, is a broad concept for which a specific variable is not readily available. We use number of banks as a proxy for barriers to entry, as it can be assumed that the lower the barriers to entry, the more banks are active in the industry, and vice versa. However, we find, not surprisingly, that this variable is strongly correlated with CR5[59], the variable that is used for the category market structure (see Table 16 below), and cannot be used together with CR5 as it renders both variables strongly insignificant. We prefer to use CR5 as structure is the more important factor, number of banks is a troublesome proxy for barriers to entry, and the joint significance of the models with CR5 are higher.

We choose four competition impacting categories (crisis, state aid, structure of market, size of market) in order to ensure that the state aid measurement variable only estimates the state aid effect. All the other variables are control variables, used to neutralize their influence to ensure pure measurement of state aid by the state aid variable. In Table 15, the tested variables are given per category. The ultimately analyzed models are the most significant ones.

It is important to note that variables that remain constant throughout the time span of our data set, are irrelevant in the regression of equation 8, as they will only affect the intercept if not included. No major new legislation regarding entry requirements for banks was introduced during the time span of our study[60], thus the legal barriers to entry are constant and therefore irrelevant. There is also no apparent reason to assume that the economic barriers to entry changed significantly. Therefore we can conclude that even if there is an influence of the barriers to entry, it would be small. Our competition impacting categories are thus at least close to exhaustive.

H.2 The variables: calculation and selection

In Table 15, the possible specification variables for the different categories are given.

Since the H_ts are rolling four-quarterly estimates, the crisis variables are calculated as the rolling four-quarterly sector averages, except for the Euribor and the ECB Marginal Lending Facility Rate variables. The Euribor is calculated as the four quarter mean, whilst the ECB Marginal Lending Facility Rate variable is the mean of the end of quarter rates. The CR5 average, then, is the mean of the CR5 of the four quarters. The Total Assets and Total Deposits sum variables are the four-quarterly mean of the quarterly sums of Total Assets and Total Deposits, respectively.

[59] Calculated as the four-quarterly average of $\frac{\text{Total assets of the five largest banks}}{\text{Total assets of the industry}}$.

[60] Major new legislation after the financial crisis was not yet adopted by the end of 2009.

Table 15: Possible specific variables for each of the competition impacting categories

C_t	STM_t	SIM_t	SA_t
• Borrowings from Central Banks average • Interbank Borrowing Rate Euribor average • Interbank Deposits average • Interbank Loans average • ECB Marginal Lending Facility Rate average	• CR5 average	• Total Assets sum • Total Deposits sum	• CI: Sum of Direct Capital Injections in Belgian Banks by the Belgian Governments • SAD1, SAD2, SAD3, SAD4: State Aid Dummy (four different specifications)

The aim of our regression is to explain the H_t-statistic as well as possible. In order to do so, we look at the F-test for joint significance of all variables, at the R^2 and the Adjusted R^2, and at the significance level of the individual variables. Given that we work with specific categories, it is important that the used variables show low inter-category correlation, especially since state aid and the financial crisis occur with only a short in-between lag. If the inter-category correlation is high, the correlated variables might measure effects of a category they do not represent. Especially for the state aid measurement variables, this criterion is relevant. The correlation matrix for the ultimately used variables can be found in Table 16. Besides these statistical criteria, it it also important that the regression equation exhibits economic significance, meaning that the variables put together make sense. Also, as already mentioned, at least one variable of each category should be included.

We test all different state aid measurement variables, thus, as can be seen in Table 15, we have to select the crisis variables and the market size variables. The market size variables Total Assets and Total Deposits have a correlation of 1, thus we only retain one. Total Deposits is used since Total Assets harms the joint significance of the variables. Total Deposits as it yields the best estimations. Table 15 includes only conceptually relevant Crisis variables, thereby excluding a number of possible but conceptually problematic variables[61]. The ECB Marginal Lending Facility Rate and the Euribor have no explanatory power, making the F-test insignificant. We therefore exclude them. The Interbank Deposits and Interbank Loans variables have a correlation of 0.99, thus only one can be retained. Interbank Deposits is omitted, as it does not have any explanatory power, it is never significant and severely decreases the joint significance of the variables. This leaves us with two crisis category variables: Interbank Loans and Borrowings from Central Banks. In Section 10, the various regressions with Interbank Loans as crisis variable are discussed. The Ramsey Reset test shows no omitted variables in these regressions. As a robustness check, we also perform regressions with both Interbank Loans and Borrowings from Central Banks as crisis variables (the results are summarized in Subsection H.5). Broadly, they confirm the results of the main regressions.

H.3 Descriptive statistics

The descriptive statistics of the chosen variables can be found in Table 17 below.

H.4 Estimation method choice

We perform several tests to ensure validity of the model, and thus of the results:

- The model does not seem to lack omitted variables, as the P-values of the Ramsey Reset test are always between 0.70 and 0.90 for all models in Table 8.
- The H_0 of no heteroskedasticity is rejected at a 10% level. Indeed, the P-value for the Breusch-Pagan / Cook-Weisberg is often around 0.03, and exceptionally it is 0.08.

[61] Such as the Tier I ratio, which is too strongly correlated with the capital injections aimed at increasing the Tier I ratio.

Table 16: Correlation matrix of second-stage equation variables

Variables	H_t	ln(IL[a])	ln(BCB[a])	CR5	ln(D[a])	ln(CI[a])	SA1	SA2	SA3
ln(IL[a])	0.03	1.00							
	(0.87)								
ln(BCB[a])	-0.00	0.83	1.00						
	(0.99)	(0.00)							
CR5	0.24	0.79	0.54	1.00					
	(0.14)	(0.00)	(0.00)						
ln(D[a])	-0.03	0.96	0.87	0.76	1.00				
	(0.85)	(0.00)	(0.00)	(0.00)					
ln(CI[a])	-0.09	0.25	0.47	-0.10	0.37	1.00			
	(0.56)	(0.13)	(0.00)	(0.54)	(0.02)				
SA1	-0.09	0.25	0.47	-0.09	0.38	1.00	1.00		
	(0.56)	(0.12)	(0.00)	(0.56)	(0.02)	(0.00)			
SA2	-0.05	0.16	0.39	-0.14	0.30	0.90	0.88	1.00	
	(0.77)	(0.33)	(0.01)	(0.39)	(0.06)	(0.00)	(0.00)		
SA3	-0.12	0.08	0.28	-0.18	0.23	0.77	0.75	0.85	1.00
	(0.47)	(0.63)	(0.08)	(0.28)	(0.15)	(0.00)	(0.00)	(0.00)	
SA4	-0.09	0.01	0.15	-0.18	0.16	0.63	0.61	0.69	0.81
	(0.58)	(0.93)	(0.35)	(0.26)	(0.33)	(0.00)	(0.00)	(0.00)	(0.00)

[a] In thousands of euro.
H_t and CR5 are dimensionless; all State Aid Dummies are 0/1.

Notes:
H_t: the estimated H_t-statistic from the first-stage equation.
IL, Interbank Loans avg.; BCB, Borrowings from Central Banks avg.: rolling four-quarterly sector averages.
CR5, 5-bank Concentration Ratio (based on Total Assets).
D, Total Deposits average: rolling four-quarterly average of the sum of sector deposits.
CI, Capital Injections: rolling four-quarterly average of sum of direct capital injections given by the Belgian governments to Belgian banks.
SAD1, SAD2, SAD3, SAD4: State Aid Dummy 1 to 4.
P-values between brackets below correlation coefficients.

Table 17: Descriptive statistics of second-stage equation variables. Subdivision by dependent variable (top), crisis, market structure and size control variables (middle) and state aid measuring variables (bottom).

	Mean	StDev	5th Percentile	95th Percentile
H_t	.579	.200	.267	.944
ln(IL[a])	15.620	.372	15.136	16.170
ln(BCB[a])	9.149	1.460	7.005	11.540
CR5	.821	.034	.768	.859
ln(D[a])	16.750	.367	16.193	17.241
ln(CI[a])	2.047	5.488	.000	16.723
SAD1	.125	.335	.000	1.000
SAD2	.100	.304	.000	1.000
SAD3	.075	.267	.000	1.000
SAD4	.050	.221	.000	.500

[a] In thousands of euro.
H_t and CR5 are dimensionless; all State Aid Dummies are 0/1.

Notes:
H_t, the estimated H_t-statistic from the first-stage equation.
IL, Interbank Loans avg.; BCB, Borrowings from Central Banks avg.: rolling four-quarterly sector averages.
CR5, 5-bank Concentration Ratio (based on Total Assets).
D, Total Deposits average: rolling four-quarterly average of the sum of sector deposits.
CI, Capital Injections: rolling four-quarterly average of sum of direct capital injections given by the Belgian governments to Belgian banks.
SAD1, SAD2, SAD3, SAD4: State Aid Dummy 1 to 4.

- The H_0 of no autocorrelation is rejected at a 5% level. The Breusch-Godfrey LM test for autocorrelation, finds on average 20 lags of autocorrelation at a 5% level. Moreover, Durbin's alternative test for autocorrelation also points towards autocorrelation.

We can correct for these last two issues by estimating OLS with Newey-West adjusted standard errors[62]. Doing so, the statistical validity of our results is ensured.

H.5 Results of regression with two crisis variables

In this section, we regress the following equation:

$$H_t = \kappa + \lambda_1 \ln IL_t + \lambda_2 \ln BCB_t + \lambda_3 CR5_t + \lambda_4 \ln D_t + \lambda_5 SA_t + \varepsilon_t \tag{10}$$

for $t = 1, ..., 41$ (with $t = 13$ excluded[63])

with H_t the rolling estimates calculated by the first-stage equation (t indicates the first of the four quarters used to estimate H_t), κ a constant, $\ln IL_t$ the natural logarithm of the sector average of Interbank Loans, $\ln BCB_t$ the natural logarithm of the sector average of Borrowings from Central Banks, $CR5_t$ the 5-bank Concentration Ratio[64], $\ln D_t$ the natural logarithm of the sum of sector Deposits, SA_t a State Aid measuring variable and ϵ_t the error term. This equation is similar to equation 10, but has two crisis variables. We again estimate equation 10 with the five different alternatives for SA_t and one model without SA_t.

In Table 18, the results of the regressions of equation 10 can be found.

[62]We choose the maximum lag order of autocorrelation for Newey-West in accordance with the following standard formula: $m(T) = floor[4(\frac{T}{100})^{\frac{2}{9}}] = floor[4(\frac{40}{100})^{\frac{2}{9}}] = 3$.

[63]We also run the regression with H_{13} reset to 1 as a robustness check, and the results are very similar.

[64]Calculated as the four-quarterly average of $\frac{\text{Total assets of the five largest banks}}{\text{Total assets of the industry}}$.

Table 18: OLS estimates of the four-quarterly rolling Panzar and Rosse measure of competition H_t, using two crisis control variables, for the various state aid measuring variables, regular vs. weighted by 1/se(H_t).

	Measuring var. 1		Measuring var. 2		Measuring var. 3		Measuring var. 4		Measuring var. 5		No state aid var.	
H_t	*regular*	*weighted*	*regular*	*weighted*	*regular*	*weighted*	*regular*	*weighted*	*regular*	*weighted*	*regular*	*weighted*
ln(IL[a])	.384*	.375**	.365*	.362**	.502**	.467**	.421*	.397**	.423**	.400**	.177	.228
	(.07)	(.04)	(.08)	(.05)	(.03)	(.03)	(.07)	(.04)	(.05)	(.03)	(.40)	(.18)
ln(BCB[a])	.052*	.049	.052*	.049	.054*	.048	.064**	.060**	.075**	.069**	.062**	.064**
	(.09)	(.12)	(.09)	(.11)	(.08)	(.12)	(.03)	(.04)	(.01)	(.02)	(.05)	(.03)
CR5	5.833***	4.881**	5.743***	4.815**	6.020***	5.114**	5.379***	4.603**	5.332***	4.590**	4.208**	3.741**
	(.01)	(.02)	(.01)	(.02)	(.00)	(.01)	(.00)	(.02)	(.00)	(.01)	(.02)	(.04)
ln(D[a])	−1.054***	−.928***	−1.025***	−.910***	−1.185***	−1.036***	−1.061***	−.945***	−1.087***	−.971***	−.697***	−.701***
	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.00)	(.01)	(.00)
ln(CI[a])	.014	.010										
	(.11)	(.16)										
SAD1			.211	.163								
			(.14)	(.18)								
SAD2					.295***	.247***						
					(.00)	(.01)						
SAD3							.222*	.181*				
							(.06)	(.07)				
SAD4									.270***	.224***		
									(.00)	(.00)		
Constant	6.925**	5.776**	6.827**	5.719**	7.126**	5.973**	6.744***	5.844***	7.086***	6.169***	5.467**	5.082**
	(.02)	(.02)	(.02)	(.02)	(.01)	(.02)	(.01)	(.01)	(.00)	(.00)	(.02)	(.01)
F for joint significance	4.3	4.6	3.9	4.4	8.0	7.3	4.8	5.3	6.5	6.3	2.5	3.6
p(F-test)[b]	.004	.003	.007	.004	.000	.000	.002	.001	.000	.000	.059	.015
R^2[c]	.271	.255	.267	.251	.305	.287	.255	.247	.263	.254	.212	.214
R^2-adj	.164	.145	.159	.141	.202	.183	.146	.136	.154	.144	.122	.124

***$p < 0.01$, **$p < 0.05$, *$p < 0.10$.

[a] In thousands of euro. H_t and CR5 are dimensionless; all State Aid Dummies are 0/1.

[b] Probability of F-test with H_0 : all RHS variables are jointly zero.

[c] Calculated with the ordinary OLS standard errors of each model.

Notes:

Newey-West standard errors between brackets.

regular: regular OLS estimation without weights; *weighted*: OLS estimation weighted by 1/se(H_t), calculated from the first-stage equation.

H_t: the estimated H_t-statistic from the first-stage equation.

IL, Interbank Loans avg.; BCB, Borrowings from Central Banks avg.: rolling four-quarterly sector averages.

CR5, 5-bank Concentration Ratio (based on Total Assets). D, Total Deposits average: rolling four-quarterly average of the sum of sector deposits.

CI, Capital Injections: rolling four-quarterly average of sum of direct capital injections given by the Belgian governments to Belgian banks; SAD1-SAD4: State Aid Dummy 1 to 4.