State-aided Price Coordination in the Dutch Mortgage Market*

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Abstract

This paper shows how price leadership bans imposed, as part of the European Commission's State aid control, on all main mortgage providers but the largest bank shifted the Dutch mortgage market from a competitive to a collusive price leadership equilibrium. In May 2009, mortgage rates in The Netherlands suddenly rose against the decreasing funding cost trend to almost a full percentage point above the Eurozone average. We derive equilibrium best-response functions, identify the price leader, and estimate response adjustments in cointegrating equations on a large data set of daily mortgage rates 2004-2012. Consistent with the full coordination equilibrium, we find structural decreases in the leader's cost pass-through and H-statistic, suggesting monopoly power, as well as much closer following of the leader's price and strongly reduced transmission of common cost changes into price followers' mortgage rates. All the structural breaks are around the Spring of 2009, when the price leadership bans were negotiated. Predicted overcharges are 125 basis points or 26% on average.

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1 Introduction

In the Spring of 2009, interest rates on mortgage loans for home purchase in The Netherlands suddenly increased against the downward trend induced by the stepwise reduced European Central Bank (ECB) policy rates to become the highest in Europe by a margin. Figure 1 displays the average mortgage rate on different maturities in the Netherlands, neighboring Germany, Belgium and France, as well as the Eurozone average.[1] Whereas the Dutch rates used to be closest to the European average before the 2007-2009 financial crisis, from May 2009 they remain structurally above.

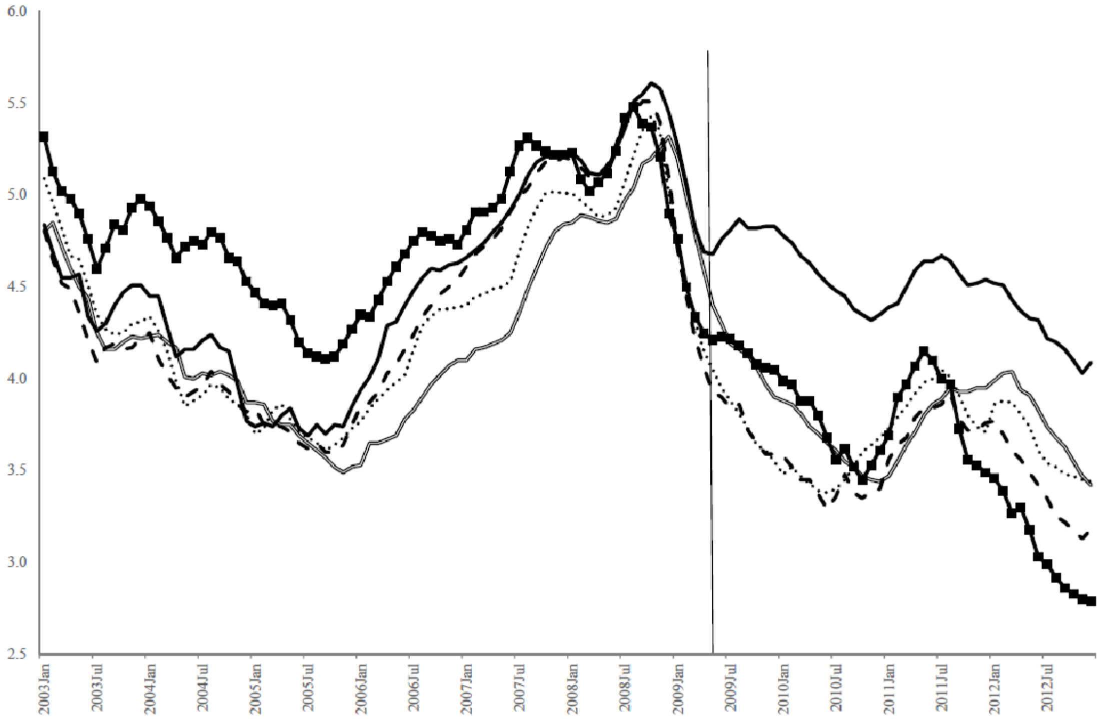

Figure 1: Average lending rate for house purchase in the Netherlands (solid line), the Euro area (long dash), Germany (blocked), France (open) and Belgium (dash).

Initially suspicious of collusion, the Netherlands Competition Authority (NMa) investigated in the Fall of 2010.[2] In May 2011, it reported to have found no evidence of cartel behavior by applying mean-variance tests.[3] The NMa was convinced that

[1]Source: ECB Statistical Data Warehouse. Rates are in percentage, monthly, each maturity is weighted monthly by its share in total outstanding mortgages.

[2]NMa, *Quick Scan Hypotheekrente*, November 2010. The pilot study was a response to concerns raised in the Dutch Parliament in early September 2010.

[3]NMa, *Sectorstudie Hypotheekmarkt: Een Onderzoek naar de Concurrentieomstandigheden op de Nederlandse Hypotheekmarkt*, May 2011, hereafter NMa (2011).

post-crisis Dutch mortgage rates could no longer be compared internationally. Steeply falling house prices had further increased the already high loan-to-value ratio's in The Netherlands, stimulated by unlimited income tax-deductability of mortgage interest payment. This would have raised the costs of attracting mortgage funding more for the Dutch providers. The agency had analyzed margins over funding costs, defined in consultation with the banking sector. Against the falling base rates (Euribor and savings deposit rates), risk premiums (CDS and RMBS spreads) had increased. In addition, the banks faced higher regulatory cost, in particular for compliance with the Basel recapitalization rules. The NMa concluded that the remaining margins on mortgages had indeed been "historically high" for a period, but returned to normal pre-crisis levels.[4]

Immediately following publication, however, mortgage margins rose again to even higher levels. Figure 2 displays the extra margin by maturity since May 2009, over and above the average margin between January 2004 and the fall of Lehman Brothers in August 2008, according to the Dutch competition authority's margin calculation method.[5] The margin turned out to have returned to pre-crisis levels only exactly for the duration of the competition authority's investigation.

Increased funding costs, nor heightened market concentration alone seemed sufficient explanation for the structural mark-ups. Changes in the money market prices affected banks elsewhere in Europe comparably.[6] The foreign mortgage providers that had contested the Dutch incumbents before the crisis always remained a small fringe. Yet where mortgage rates averaged roughly 4.5 percent before, they rose to 4.75 after the height of the crisis in 2008, while at the same time marginal funding costs had dropped by roughly 75 basis points—and the market share distribution skewed somewhat further even to the incumbent banks.[7] Why were mortgage rates suddenly about a hundred basis points high in the Low Countries?

[4]NMa (2011), page 3. The agency attributed the episode of high rates to the withdrawal of several small foreign challengers to their home markets in the crisis: the C4 and HHI had peaked in the first half of 2010—at 80 and 2000. See also Overvest and Tezel (2014).

[5]Our reconstruction of the NMa margin calculations and definition of 'extra margin' is detailed in Dijkstra and Schinkel (2013). It includes higher regulatory costs associated with the implementation of Basel III, which the NMa attributed after reopening its mortgage market investigation in ACM, *Concurrentie of the Hypotheekmarkt: Een Update van de Margeontwikkelingen sinds begin 2011*, April 2013, hereafter ACM (2013). See Dijkstra *et al.* (2014) for a detailed discussion of the funding cost explanations.

[6]The central bank DNB pointed at the so-called "Dutch funding gap" as a possible explanation for higher funding costs and thus mortgage rates in the Netherlands. See DNB, *Overview of Financial Stability Spring 2012* (20102). The theory was that the high national mortgage debt, combined with low free deposit savings—in part due to high forced pension savings institutionally invested elsewhere—would have made it expensive for the Dutch banks to obtain funding abroad. The Dutch systemic banks however turned out not to pay higher risk premiums (CDS spreads) than, for example, German mortgage providers that did not face such a gap. Nor was the Dutch housing market, with negligible default rates also throughout the crisis, perceived as particularly risky in credit ratings. See Dijkstra, Randag and Schinkel (2014) for a detailed discussion.

[7]These stylized figures are roughly consistent with descriptive statistics given in Section 4.

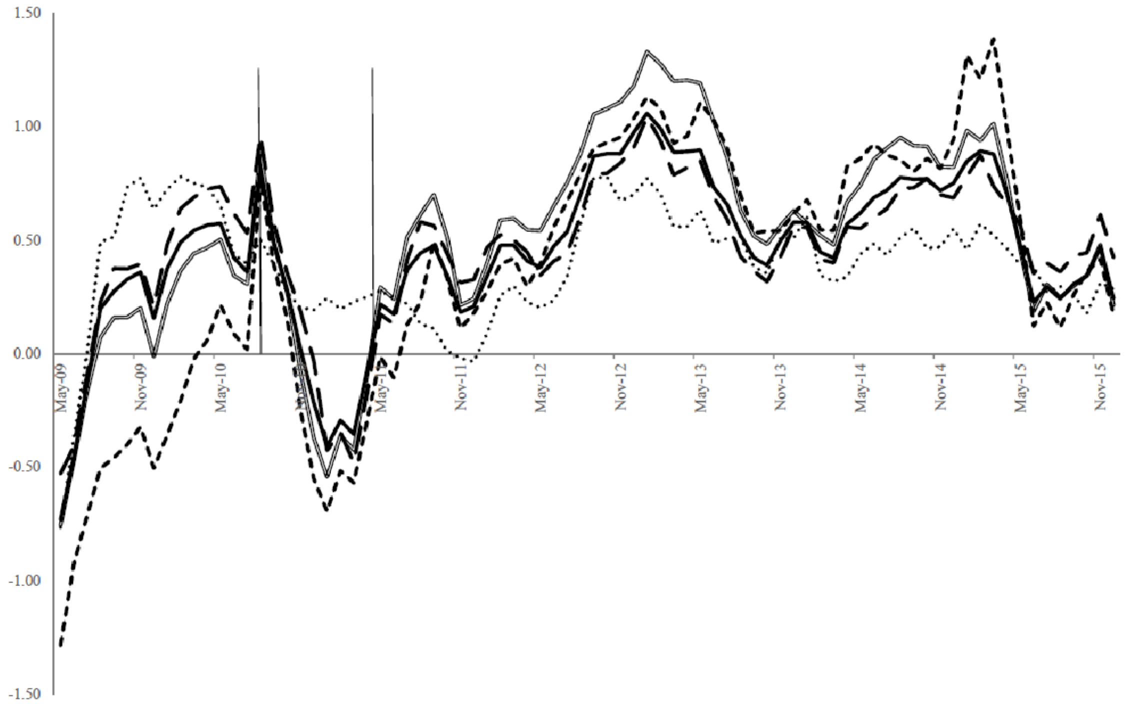

Figure 2: Extra margins on mortgage rates (percentage) since May 2009 by maturity: variable (dash), 1-5 years (long dash), 5-10 years (open), >10 years (medium dash), weighted average (solid).

In this paper we argue that price leadership bans, imposed by the European Commission as part of State aid remedies on all main mortgage providers but the price leader, shifted the Dutch mortgage market from a competitive to a fully collusive price leadership equilibrium. The Commission required these bans in the Spring of 2009, after which they acted as a coordination device. In a model based on Rotemberg and Saloner (1990) and Cooper (1997) and fitted to stylized statistics of the Dutch mortgage market at the time, we derive hypotheses on the effects of coordination by price leadership bans on the behavior of the price leader, followers under a ban and any remaining free fringe competitors.

The model predictions are tested using a large data set of daily mortgage rates between 2004 and 2012. After identifying the price leader, we estimate equilibrium best-response adjustments in cointegrating equations. Consistent with the full coordination equilibrium, we find structural decreases in the leader's cost pass-through and H-statistic, suggesting monopoly power, as well as several times closer following of the leader's price and a strong decrease of common cost pass-through into price followers' mortgage rates. Structural breaks are estimated robustly in or around the Spring of 2009, when the price leadership bans were negotiated.

The Dutch mortgage market has always been national and concentrated. Demand is stable, because mortgages are a mere necessity to (re)finance Dutch home purchases, which are expensive due to generous fiscal stimulation. Mortgage loans are somewhat differentiated (per maturity) between providers, which compete in prices. The three largest banks, household names Rabobank, ING and ABN AMRO, provided sixty to seventy percent of all mortgages, followed by SNS REAAL and AEGON with five to ten percent each.[8] Historically, Rabobank, with a steady twenty five percent market share the largest provider, is the barometric price leader. With its extensive market research department, Rabobank is looked at for predicting housing market and interest rate developments ahead of the others.[9] In a weekly cycles, Rabobank used to set its mortgage rates first, for the other providers to observe and determine their offer rates against. In competition, the threat of the followers undercutting disciplined the price leader to price close to (its nearest rival's) funding costs.[10]

At the height of the financial crisis, in the autumn of 2008, all these major banks except Rabobank had needed government support to divert the threat of bankruptcy. State aid is forbidden however by the European Treaty, albeit with exceptions.[11] The European Commission temporarily allowed the aid as "emergency measures", but under strict requirements that were to be made precise later. These State aid conditions were negotiated from the beginning of 2009. The most prominent among them were restructuring and refinancing measures. Yet further down the list, the commitments also included so-called 'price leadership bans'. Intended to prevent that a bank that had received State aid would misuse the resources to predatorily undercut banks that had not needed aid, the bans forbade the recipient to offer lower mortgage rates than its competitors.

The first formal formulation of the bans is in the Commission's State aid decision for ING, of November 18th 2009, in which the Kingdom of the Netherlands commits that:[12]

> "Without prior authorization of the Commission, ING will not offer more favorable prices on standardized ING products [including retail mortgages] than its three best priced direct competitors with respect to EU-markets in which ING has a market share of more than 5%. (...) As soon as ING

[8] NMa (2011), pages 19-25.

[9] Barometric price leadership was coined by Stigler (1947) as a form of competition in which one firm has taken on the role, for historical of institutional reasons, to pass information along to the rest of the industry. The leader is not dominant but "commands adherence of rivals to his price only because, and to the extent that, his price reflects market conditions with tolerable promptness." (*op. cit.*, page 446) Markham (1951) discusses price leadership informally as a collusive device, and Lanzilotti (1957) as competition.

[10] See De Haan and Sterken (2006, 2011).

[11] Treaty on the Functioning of the European Union (TFEU), Article 107.

[12] Commission decision 2010/608/EC of 18 November 2009 on State aid (ex N138/09) implemented by the Netherlands for ING's illiquid Assets Back-Up Facility and Restructuring Plan. Excerpts in [...] are from related parts of the decision.

> becomes aware of the fact that it [has become the price leader on a retail mortgage market within the EU], ING will as soon as possible adjust, without any undue delay, its price level which is in accordance with this commitment." (*op. cit.*, recital 84)

Shortly after, decisions with similarly formulated price leadership bans were given to Fortis-ABN AMRO (April 2010), and AEGON (August 2010), and a ban was long expected for SNS REAAL.[13] Adherence was monitored by appointed trustees. Even though the decision texts do not make remedies for infringement of the price leadership bans explicit, they clearly would have been consequential.[14] The State aid conditions applied (unrevised) for three years, or less if the aid was paid back before.

That price bans would be imposed was certain for the Dutch banks in the Spring of 2009. The conditions under which the European Commission can accept State aid are formally proposed by the aid-giving Member State. In this case, they were negotiated with the Commission by the Netherlands Ministry of Finance and the Dutch Central Bank (DNB). The Commission suggested price limitations be part of the conditions in its first Communication in 2008 and the preliminary approvals. At least for the first time on April 24th 2009, in a meeting concerning ING, European Commissioner for Competition Neelie Kroes insisted they be proposed.[15] A precedent was set on May 7, when the Commission imposed a price leadership ban on Commerzbank in Germany.[16]

All the banks benefitted from the market wide bans. In the super concentrated Dutch market, the price leadership bans became the nucleus around which market power crystallized. By disallowing four of its five largest price followers to undercut its loan rates, the European Commission effectively graduated Rabobank to must-follow price leader, allowing it to raise mortgage rates to near monopoly levels. The

[13] On 5 February 2010, the Commission extended its conditional approvals of the State aid given to ABN AMRO and Fortis by decision 2010/C95/07 with additional measures that included a price leadership ban at recital 144. Commission decision 372/2009 of 17 August 2010 concerning AEGON, recital 116. On SNS REAAL there was no official decision made on price leadership bans; Commission decision 371/2009 of 28 January 2010 concerning SNS REAAL did not contain a price leadership ban, yet the final decision not to impose such a ban was only made end of 2013 (Kamerstuk 33 532, 2013).

[14] In 2012 the Commission investigated an accusation by Mediobanca that ING had infringed its price leadership ban with ING Direct Italia, after which the Netherlands received a reprimand. The complaint also informed the revised Commission Decision on ING of 16 November 2012.

[15] Judgement of the General Court of 2 March 2012 in Cases T-29/10 and T-33/10, *Kingdom of the Netherlands and ING, supported by De Nederlandsche Bank NV v European Commission*, recital 14. Commissioner Kroes testified that Rabobank had asked for imposition of the bans on its rivals in 2009. Kamerstukken II 2011/12, 31 980, nr. 62, *Reports of Public Hearings Parlementary Inquiry Financial System*, pages 1451-1452. See also Zembla, *Your Mortgage: a Cash Cow*, which aired on 14 September 2012.

[16] Commission decision C(2009) 3708 final: State aid N 244/2009, Commerzbank, Germany, of 7 May 2009, recital 71.

risk was noted by some, including by the IMF and in a report to the Commission by Beck *et al.* (2010):

> "Banks that are prevented from trying to be a market leader just become passive followers exerting no real competitive discipline on their rivals, as though in some publicly-sponsored cartel." (*op. cit.*, page 56)

We analyze the timing and size of the State-aided price coordination effect in the Dutch mortgage market in detail. This paper is organized as follows. The next section sets our contribution to the existing literature on price leadership. Section 3 characterizes equilibrium best-responses of the leader and its followers in competition and collusion in a model of competitive barometric price leadership. Section 4 describes the data. Section 5 sets out the empirical strategy. Section 6 identifies the main mortgage providers, in particular Rabobank. Section 7 presents our empirical findings on all mortgages individual observations and 10-years daily averages respectively. Section 8 concludes. An appendix details the derivations and tests.

2 Related Literature

Our model of barometric price leadership is an extension of Rotemberg and Saloner (1990) and Cooper (1997) to n-firms, each with different marginal costs. Price leadership is sustained by asymmetric information about differentiated demand with a stochastic intercept. The most efficient bank invests in obtaining market information and uses it to set its price first. The others infer from this signal what the leader knows and price follow. In competitive equilibrium, the leader is disciplined by its followers, but still benefits from leading if it is sufficiently more efficient and information costs are not too high.

Alternative explanations offered in the literature for why a firm would take on the price leadership role in competition are consistent with the largest and most efficient firm leading, yet are somewhat less obviously fitting to this case than asymmetric market information. Deneckere and Kovenock (1992) shows for a duopoly of firms that differ in capacity, the larger firm would be willing to lead in competitive equilibrium. In Deneckere *et al.* (1992), firms differ in customer loyalty and the one with the larger loyal segment emerges as the competitive price leader. In Van Damme and Hurkens (2004) the benefit of leading is to avoid risks that come with waiting, which is largest for the low cost firm. In Pastine and Pastine (2004) there are cost of delay and the firm with the shorter reaction time or the lowest cost of delay emerges as the leader. Amir and Stepanova (2006) demonstrate in Bertrand duopoly with asymmetric costs that the low-cost firm has an advantage in leading.

The fully collusive barometric price leadership equilibrium is characterized in Rotemberg and Saloner (1990) in an infinitely repeated setting for sufficiently high discount factors. A subgroup of the firms active in a market may be sustainable as a partial cartel that price leads a competitive fringe that benefits from the umbrella effect, as in d'Aspremont *et al.* (1983). In alternative explanations, collusive price leadership facilitates monitoring. In Ishibashi (2008) the firm with largest capacity, and thus potential to serve the entire market, leads to commit not to deviate. In Mouraviev and Rey (2011) instead the least efficient firm, which has the strongest incentive to undercut the cartel, prices first, making it easier to punish it for deviations. Harrington (2017) shows how collusive price leadership may arise from little communication.

The empirical literature on price leadership uses essentially two different methods of analysis. When products are relatively homogenous and prices uniform across customers, price leadership may be inferred from price movement matching, uncontrolled. Cao *et al.* (2000) establish price leading by better informed full-service brokers during the Nasdaq preopening, analyzing ratios of sequential nonbinding quotes. Seaton and Waterson (2013) offer as a falsifiable definition of price leadership that within a predetermined short period a price change is exactly matched on the same products more often than by chance. They find many instances in the British supermarket duopoly, both up, mostly by the larger firm, and down, mostly by the smaller. Even though the upward price movements are bigger, raising the price level over time, they conclude the price leadership is competitive, because the downward movements are more quickly matched. With some more flexibility in the price matching Alé Chilet (2018) finds collusive price leadership in Chilean retail pharmacies, where upward movements are matched within a couple of days.

Price leadership in Edgeworth cycles, which are established as an equilibrium phenomenon in Maskin and Tirole (1988) and Noel (2008), has been studied extensively by direct price comparisons in gasoline markets. Eckert (2003) finds them in Canadian cities where there are also small gas stations present. Wang (2009) studies the timing of periodical pricing above competitive level. Lewis (2012) attributes Edgeworth cycles in pricing by gasoline stations in the Midwestern US to a particular retail chain in each city initiating each price restoration, using detailed analysis of the timing of price changes on the cycles. Collusive price leaders are identified by a large part of other stations matching its price increase within hours. Clark and Houde (2013) find delays in price following in a documented cartel case in gasoline in Canada, which they interpret as a transfer mechanism to sustain collusion amongst heterogeneous firms. Byrne and De Roos (2018) in Australian gasoline argue that price leadership signals focal points that coordinate market prices.

In markets in which products are more differentiated and prices contract specific, including also financial markets, combinations of vector-autoregressive (VAR) and, in case of cointegration, vector-error correction (VEC) models are used to infer Granger-causality to determine if variation in the prices set by one player can be explained by variation in the prices set by another, but not the other way around. In Canadian newsprint, a market known to be characterized by barometric leadership over a large number of producers, Booth *et al.* (1991) find only moderate mark-ups estimating the leader's response to cost changes. Based on Granger causality, Peiers (1997) identifies Deutsche Bank as the asymmetrically informed price leader in foreign exchange markets and Berck *et al.* (2008) sales promotion leadership in orange juice in U.S. groceries. In Italy, Andreoli-Versbach *et al.* (2015) establish endogenous price leadership in petrol and Bergantino *et al.* (2018) in domestic travel by air and rail using VAR estimations.

In mortgage markets, where interest rates and cost factors are commonly found to cointegrate, VEC models are used in a number of studies to assess rate responses to (mostly a single) cost proxy, including in Valadkhani (2013) for Australia, Allen and McVanel (2009) for Canada, and Cecchin (2011) for Switzerland and Francke *et al.* (2014) for the Netherlands. Our empirical approach is closest to De Haan and Sterken (2006, 2011), who conclude competitive barometric price leadership in the Dutch mortgage market during the period 1997-2003 from close following in daily mortgage rates of the interest rate on 10 year government bonds. Toolsema and Jacobs (2007) find with similar methods that rate increases are followed somewhat more closely than decreases. We use VEC regressions to estimate the response of follower banks' interest rates to the price leader's rate directly, controlling for funding cost changes.

3 Price Leadership in Mortgage Banking

Let n mortgage providers $i = 1, ..., n$ compete for the (re)financing of mortgages of the same sum and maturity, that are somewhat differentiated between them, reflecting differences in the contract terms, long-term relationships in other banking products and brand image. One bank l stands out in being the price-leader and sets its mortgage rate r_l first. It operates at marginal funding cost c_l. The other $(n-1)$ banks $i \neq l$ have marginal cost $c_{i\neq l}$., which we will assume to be somewhat higher than c_l, but for none of them a lot. They observe r_l and simultaneously set their rates $r_{i\neq l}$ optimally in response shortly after.

Demand for the mortgage offered by bank i in role $t = \{l, f\}$ depends on mortgage rate differences:

$$Q_i = a_t - br_i + d\left(\frac{1}{n}\sum_{j=1}^{n} r_j - r_i\right), \tag{1}$$

in which a_t is a stochastic intercept that differs between the leader and the followers, b a common slope and d a product differentiation parameter—the larger d, the more homogenous mortgages are. While product differentiation is symmetric, funding cost differences between the providers generate equilibrium price dispersion. Heterogeneity across providers also reflects that rate offers would in part be predicated on a provider's portfolio constitution and regulatory requirements.

All banks have full information about the structure and parameters of the model, except for the intercepts a_t. It is useful for analysis to make a distinction between a common intercept shock a that affects all firms in the same way, and an idiosyncratic shock e that affects the leader differently from the followers. Let

$$a = \frac{a_l + a_f}{2} \text{ and } e = \frac{a_l - a_f}{2},$$

so that $a_l = a + e$ and $a_f = a - e$. We assume that a and e are independently distributed over time: a with mean $\overline{a} > 0$ and variance σ_a^2, e with mean 0 and variance $\sigma_e^2 \leq \sigma_a^2$. Hence, in expectation leader and followers have the same demand intercept, their histories are not informative and $a > e$ almost always—or the followers do not participate.

The values of a and e drawn for the period can be known at a lump sum information cost I. In barometric price leadership equilibrium, one bank makes this investment, which is observable, and uses it to set its rate first. The other bank(s) follow and deduce information about the values of a and e from the leader's price. The information extraction from the leader's price signal is not perfect, however, since the followers will only be able to distill information about a_l, whereas ideally they would want to know a_f. The advertised rates would not have been fully informative also because of aspects of the mortgage marketing process here abstracted from, such as subsequent negotiations with individual borrowers to conclude the final contract rate.

Note that if $\sigma_e^2 = 0$ (or $\sigma_a^2 = 0$) the followers receive a perfect signal. Equilibrium values will depend on the combination of variances

$$s = \frac{\sigma_a^2 - \sigma_e^2}{\sigma_a^2 + \sigma_e^2},$$

which is between 0 and certainty equivalence value 1. Since the common demand shocks must be larger than the idiosyncratic, $s > 0$.

3.1 Competitive Price Leadership

In the competitive price leadership equilibrium, the leader knows that its price will be informative and matched by the followers in the second stage of the game, so that it is disciplined not to markup too high. Bank l determines its strategy by first considering the subgame perfect equilibrium under imperfect information between the followers for any optimal value of r_l, and subsequently maximize its own profits, taking the followers' optimal responses into account. The leader sets r_l^*, to which the followers respond simultaneously with $\mathbf{r}_{i \neq l}^*$.[17] Followers set a lower price and obtain a higher profit than the leader if all banks operate with the same marginal funding costs, even if $I = 0$. However, if the leader has sufficiently lower cost than the followers, it can recoup its investment I and still make a higher profit than the followers. As long as their efficiency difference to the leader is not too large, the followers undercut.

[17] The unique competitive equilibrium rates $\left(r_l^*, \mathbf{r}_{i \neq l}^*\right)$ are fully characterized in Appendix A.

Figure 3 plots equilibrium mortgage rates (left axis, lower four lines) and expected profits (right axis, upper four lines) when all followers operate at the same costs c_f, as a function of $\Delta c = c_f - c_l$.[18] The dotted lines are for $s = 0$, the solid lines for positive s. The leader's (followers') profits increase (decrease) in Δc. For lower s, the leader's profits are higher and the followers profits are lower for all cost differences—where the followers are affected most by the less informative signal.

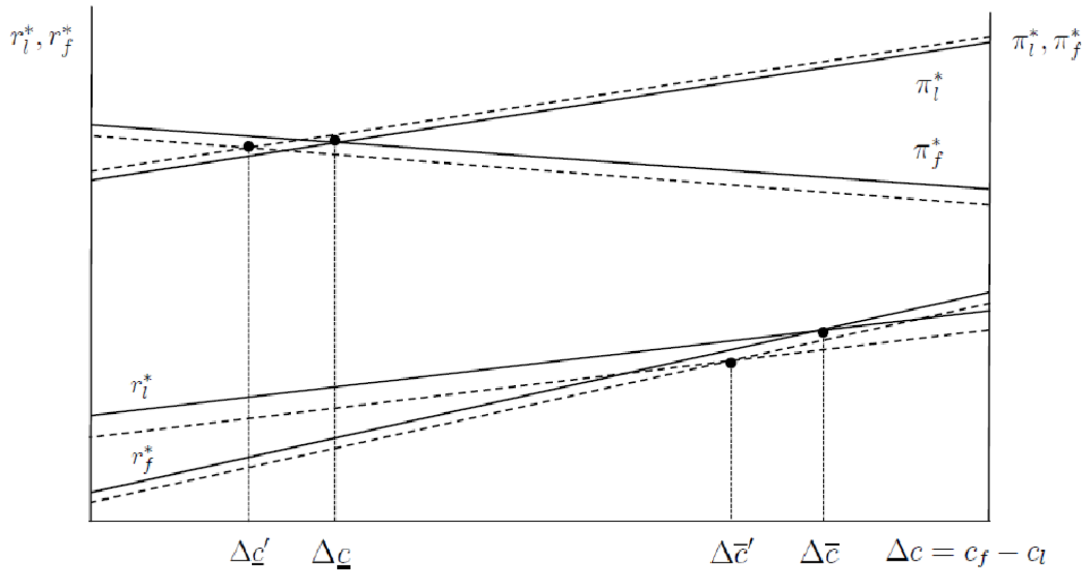

Figure 3: Equilibrium mortgage rates as a function of cost efficiency differences.

In the range $\Delta \underline{c} < \Delta c < \Delta \overline{c}$, the leader obtains a higher profit than each follower, while it is still undercut ($r_f^* < r_1^*$) in competitive equilibrium. The range depends on the parameters of demand (a, b, d) and n, and moves to the left and becomes somewhat smaller for lower values of s. In particular if mortgages are more homogeneous, can followers undercut only for smaller costs differences—that is, $\Delta \overline{c}$ moves to the left when d increases. Also the higher s, the higher is the efficiency differences until which the followers price below the leader.[19]

The barometric price leadership of the more efficient informed bank is an equilibrium for reasonable uncertainty, funding cost differences and information costs. Rates $\left(r_l^*, \mathbf{r}_{i \neq l}^*\right)$ are a competitive barometric price leadership equilibrium if the leader has

[18] The figure is based on the baseline specification given in Section 3.3.

[19] For the baseline specification, the range in which Δc can vary is between the price leader being a few percent to roughly 15% more efficient than the followers.

no incentive not to invest in information and/or not to lead, and no follower is better off also investing in I and/or also leading. This is the case for intermediate values of I, and s not too high. If I is too high, the price leader no longer invests in information yet price leads. If I is too low and s too high, (the most efficient) followers want to become fully informed by also investing in market information.[20]

Note that unilateral deviation by a bank from its role as leader or follower is less obvious. If the leader would refuse to lead, this would imply a simultaneous move price game between all the banks, with the leader either informed or uninformed, depending on I. This will generally result in lower profits for all the banks. Unilateral deviation by a follower to also lead, uninformed or informed after also investing I, would imply a duopoly simultaneous move price setting game by the two different 'leaders', taking into account the remaining $n-2$ followers' best-responses. With somewhat different information extraction, all banks again will generally have lower profits in the resulting, more competitive equilibrium.

3.2 Coordinated Price Leadership

In the barometric price leader stage game infinitely repeated, a collusive equilibrium in which the followers copy the price that the leader sets by maximizing its own profits is sustainable only for high enough discount factors.[21] In a market that is in competitive price leadership equilibrium, the imposition of price leadership bans introduces price coordination. Suppose that a bank under a price leadership ban strictly adheres to pricing not lower than it is allowed to, because the consequences of violating the State aid condition are sufficiently serious. That is, for a bank under a ban, $r_l^{PLB} \leq r_{i \neq l}^{PLB}$—hereafter PLB refers to price leadership bans. The ban thus reduce the number of followers that remains free to uncut the price leader, thereby softening competition—whether or not the followers were undercutting the leader in competitive equilibrium.

The impact of the four bans on the five largest price followers in the Dutch mortgage market depends crucially on the strength of the remaining fringe competition. If it was weak, the bans would have given the price leader a *de facto* monopoly obtaining the fully coordinated equilibrium with

$$r_l^{PLB} = \frac{a+e}{2b} + \frac{1}{2}c_l = r_{i \neq l}^{PLB}. \tag{2}$$

The last equality is by the State aid conditions provided that $r_{i \neq l}^{*}\left(r_l^{PLB}\right) \leq r_l^{PLB}$, which is the case as long as the highest $c_{i \neq l}$ is not too much higher than c_l.[22] The rate r_l^{PLB} is higher than the competitive rates r_l^{*} and $r_{i \neq l}^{*}$—as long as $c < a+e$, which is a necessary condition for the market to exist. All followers can extract again

[20] See Cooper (1996).
[21] See Rotemberg and Saloner (1990).
[22] See Appendix A.

the value of $a + e$ from observing the leader's rate—but only have use for it when they optimally price above it, which they do it cost differences are sufficiently large. The behavior of the fringe providers would have been insignificant, so that they could have freely priced to their own objectives, for example gaining market share.

If the free fringe did constitute a competitive threat, the effects of the price leadership bans can be analyzed as asymmetric duopoly competitive barometric price leadership, in which the price leader (l) sets its rate, to which the rates of its four largest followers are pegged by the bans, first, after which a representative player ff, acting as one for the smaller fringe followers together, prices second. The fringe followers benefit from an umbrella effect caused by the ban's partial coordination, but still somewhat discipline the price peloton.[23] The competitive equilibrium rates for $n = 2$ are referred to as $r_l^{PLB_{ff}}$ $(= r_{i \neq ff \neq l}^{PLB_{ff}})$ and $r_{ff}^{PLB_{ff}}$.

We note that in the Dutch mortgage market, the fringe providers together never obtained a higher market share than twenty percent against the incumbent major banks—for more they lacked brand awareness and customer trust, as well as the sales network and capacity. Since product differentiation is symmetric in demand system (1) and capacity unlimited, the duopoly model is likely to deliver stronger remaining competitive pressure than was actual in this case, so that its predictions on the effects of the bans are lower bounds. Moreover, even if the free fringe providers would have been able to contest the block of main banks, they may have realized that they were better off refraining from undercutting the price leader. Tacit full collusion may have become an equilibrium, once competition from all of the main other providers was eliminated by the bans.

3.3 Calibration to Stylized Facts

To obtain insight in the magnitudes of the effects of the bans, we calibrated the model with symmetric followers to some stylized facts about the Dutch mortgage market at the time.[24] We consider competition amongst $n = 6$ banks: the price leader plus 5 followers, of which 4 would come under a price leadership ban and the remaining one represents the smaller fringe providers jointly. With parameters $a = 6$, $b = 1$, $d = 10$ and $s = .1$, in competitive equilibrium, $r_l^* = 4.5$ slightly undercut by $r_f^* = 4.48$, for $c_l = 4.30$, $c_f = 4.32$, which are roughly consistent with the average base interest rate plus risk premium. Demand (1) is roughly consistent with weekly sales in hundreds. The price leader (each follower) has a markup over costs of 4.6% (3.8%) on a share of total mortgages sold of 48% (10%). The leader makes a mere ten percent higher operational profit than its followers, enough to cover substantial information costs. While the three largest providers have a joint market share of almost 70%, as Rabobank, ING and ABN AMRO had together, due to the model symmetry the market share of the next largest competitors is somewhat higher in equilibrium than

[23] See D'Aspremont *et al.* (1983).

[24] Detailed descriptive statistics are given in Section 4.

actual (SNS REAAL and AEGON served roughly 5% of the market), and that of the rest somewhat lower.

Under the price leadership bans, despite about 75 basis points lower funding costs ($c_l = 3.5$, c_f can be less lower) $r_l^{PLB} = 4.75$ ($= r_f^{PLB}$) in full coordination. The bans are binding the followers, since the cost difference is comfortably small enough for them to want to price below r_l^{PLB}.[25] Market shares hardly change: at equal prices, the leader serves exactly half of the market. Competitive rates but-for the price leadership bans also depend on the funding cost level of the followers in the post-crisis period. They remain well below four percent, however, even if c_f decreased considerably less than c_l. All providers benefit greatly from the bans: the leader's markup increases to over one third, that of the followers to only little less. Overcharges are almost 100 basis points, or over 25 percent.

In the duopoly coordinated regime with remaining fringe competition (PLB_f), an average equilibrium mortgage rate at 4.75% ($r_l^{PLB_f} = 4.65$, $r_{ff}^{PLB_f} = 4.85$) only obtains for higher cost levels, since margins are lower. The leader and ban-pegged followers need to operate jointly at $c_l = 4$, and $c_{ff} = 4.8$. That relatively high funding costs are required is partly due to the fact that remaining competition is stronger than actual in the symmetric model. The fringe follower (ff) maintains a fitting market share in duopoly equilibrium of just below 10% and barely breaks even, while the leader has a good 15% overcharge. The average margin increase is 33 basis points and the overcharge 7.6%. We note that the absolute funding cost and rate levels are less relevant for our empirical analysis of the effects of the bans, which focusses on changes in best-responses in the following.

3.4 Equilibrium Best-Responses

3.4.1 Competitive Price Leadership

The competitive price-leadership equilibrium response of follower i's mortgage rate $r_{i\neq l}^*$ to the leader's equilibrium rate r_l^* is a linear function with fixed parameters in r_l, c_l (as the followers learn from r_l), and the individual costs of $c_{i\neq l}$ and all other followers:

$$r_{i\neq l}^* = B_{i\neq l,0} + B_{i\neq l,1} r_l^* + B_{i\neq l,21} c_{i\neq l} + B_{i\neq l,22} c_l + B_{i\neq l,23} \sum_{k\neq i\neq l}^{n-2} c_k, \qquad (3)$$

in which the constituted parameters are all functions of n, b, d, σ_a^2 and σ_e^2.[26] Knowing its followers' equilibrium responses, the price leader bases its rate entirely on their and its own costs.

[25] For the specification, $r_{i\neq l}^* \left(r_l^{PLB}\right) \leq r_l^{PLB}$ for $c_f \leq 0.59 c_l + 2.48$.

[26] Equations (25) and (26) in Appendix A provide full equilibrium specifications.

To changes in the leader r_l^*, despite possible costs differences, each follower's response is the same

$$\frac{dr_{i\neq l}^*}{dr_l^*} = B_{i\neq l,1} = \frac{d + (2bn + 2d(n-1))s}{(2b+d)n + 2d(n-1)s}, \tag{4}$$

which decreases in n and increases in s and d between 0 (for $d \to 0$, $s = 0$) and 1 $(n = 1)$.

Figure 4, left-hand panel plots $B_{i\neq l,1}$ as a function of s for different numbers of banks. Its value is small but positive for values of s around zero, that is when the variances of the common and idiosyncratic demand shock are similar, so that the leader's rate is not a very informative signal. It remains below three quarters also when s goes to its upper bound. Higher values of n and d respectively push the lines parallel down and up somewhat. For the baseline specification, $B_{i\neq l,1} \approx .26$, rising to .71 when $s = 1$.

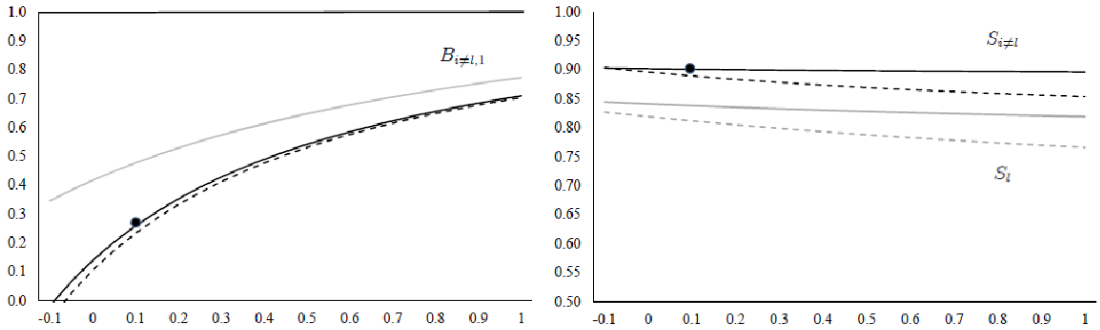

Figure 4: As a function of s for $n = 2$ (grey, fringe) and $n = 6$ (black, baseline): left-hand panel $B_{i\neq l,1}$ and right-hand panel $S_{i\neq l}$ (solid) and S_l (dotted).

The price leader sets the following competitive equilibrium price

$$r_l^* = B_{l,0} + B_{l,21}c_l + B_{l,22}\sum_{i\neq l}^{n-1} c_i, \tag{5}$$

in which the constituted parameters are all functions of n, b, d, σ_a^2 and σ_e^2. The leader's response to a common cost shock is the sum of cost coefficients

$$S_l = B_{l,21} + (n-1)B_{l,22}, \tag{6}$$

which increases in n and d between $\frac{1}{2}$ (for $d \to 0$) and 1 (for $d \to \infty$). Figure 4, right-hand panel shows that S_l decreases in s but remains in the upper quartile. In the competitive baseline, $S_l \approx .47 + 5 \times .08 = .89$.

Each follower's equilibrium rate $r^*_{i\neq l}$ increases, including through the leader's response to cost changes primarily in its own cost $c_{i\neq l}$ by

$$\frac{dr^*_{i\neq l}}{dc_{i\neq l}} = B_{i\neq l,1}B_{l,22} + B_{i\neq l,21},$$

which is around half (.53 in the baseline). Only little are the effects of changes in the leader's cost c_l,

$$\frac{dr^*_{i\neq l}}{dc_l} = B_{i\neq l,1}B_{l,21} + B_{i\neq l,22},$$

which is has an upper limit at $\frac{1}{2}$ $(d \to \infty,\ n = 1)$ but remains close to zero for all reasonable parameter values (.065 in the baseline), as well as in the cost of one of the other followers $c_{k\neq i\neq l}$ (.054 each in the baseline).

The total effect on $r^*_{i\neq l}$ of a common cost shock for the followers is the sum of cost coefficients, with $\frac{dr^*_{i\neq l}}{dc_{k\neq i\neq l}}$ premultiplied by $n-2$, or rewritten

$$S_{i\neq l} = B_{i\neq l,21} + B_{i\neq l,22} + (n-2)\, B_{i\neq l,23} + B_{i\neq l,1}S_l, \tag{7}$$

in which the last component is the indirect effect through the leader's rate. The direct cost pass-through of each follower, that is $S^d_{i\neq l} = B_{i\neq l,21} + B_{i\neq l,22} + (n-2)\, B_{i\neq l,23}$, also increases in competition (n and d), between $\frac{1}{2}(1-s)$ and $\frac{n-1}{n+2s(n-1)}$, or .45 and $\frac{2}{3}$ in the baseline. The combined effect $S_{i\neq l}$ is between $\frac{1}{2}$ $(d \to 0)$ and 1 $(d \to \infty)$. For the baseline, $S_{i\neq l} \approx .67 + .26 \times .89 = .90$. In the right-hand panel of Figure 4, the values of $S_{i\neq l}$ remain close to 1 for lower values of s, in particular for higher n.

3.4.2 Coordinated Price Leadership

As long as the funding costs for followers under a price leadership ban are not too much higher than those of the leader, so that the incentive remains to undercut, the followers' responses to changes in the leader's rate are instantaneous and complete: downwards, because the followers prefer to price below, and upwards as not to violate the State aid conditions. Hence,

$$\frac{dr^{PLB}_{i\neq l}}{dr^{PLB}_{l}} = 1,$$

for all banks under a ban, irrespective of any remaining fringe competition. The responsiveness of the follower banks increases by close to four-fold for followers under a ban, from the competitive market situation ($\frac{dr^*_{i\neq l}}{dr^*_l} \approx .26$).

In the case of remaining fringe competition, in duopoly the representative competitor bank ff responds in the baseline specification by $B_{ff1}|_{n=2}$, so that

$$\frac{dr^{PLB_f}_{ff}}{dr^{PLB_f}_{l}} \approx .48,$$

which increases in s to maximally .77 when $s = 1$. Hence, the responsiveness of mortgage providers not under a ban is expected to increase as well, but only about half as strong as that of the banks bound by a ban.

The price leader's rate response to cost changes will also be markedly different after the bans. In competitive equilibrium, the leader sets its price as a function first and foremost of its own marginal funding costs ($\frac{dr_l^*}{dc_l} \approx .47$) and only somewhat also takes its followers' costs somewhat into account ($\frac{dr_l^*}{dc_{i\neq l}} \approx .08$). While the leader responds to changes in its own cost almost the same in competitive and coordinated equilibrium (by roughly $\frac{1}{2}$), its responsiveness to a common cost shock (S_l) decreases by 44 percent in the baseline: from .89 in competition to $\frac{dr_l^{PLB}}{dc_l} = \frac{1}{2} = \frac{dr_{i\neq l}^{PLB}}{dc_l}$ in the fully coordinated regime—in which the followers' costs are irrelevant. More competition prior to the bans increases the size of this change, to maximally 50 percent in perfect competition. With remaining fringe competition, S_l decreases by a mere 10% ($S_l|_{n=2} = .81$), as the leader remains responsive to the fringe followers' costs. Hence, a strong decrease in S_l is indicative of a weak competitive fringe.

The bans essentially reverse the effects of cost changes on the rates of the followers under a ban: through the leader's responses, each follower responds much stronger than in competition to changes in the leader's cost (from near zero to (near) one half) and no longer to changes in their own costs (from near one half to zero). Combined, responsiveness of follower banks under a ban to a common cost shocks falls close to half of that in competitive equilibrium, largely irrespective of whether there remains a competitive fringe or not ($S_{i\neq l}$). The direct effect ($S_{i\neq l}^d$) is a decrease by a quarter. For any remaining fringe competition, the common cost chock response (S_{ff}) does not decrease noticeably with the imposition of bans, although its direct effect would by a third.[27] The fringe may as well have priced with the leader, or be less responsive: not following prices upwards in order to establish a position in the market as a perceived price fighter, and not downward because of higher costs.

4 Data and Descriptive Statistics

Our data set contains all new and renewed mortgage contracts of various maturities signed daily on workdays between January 1st 2004 and December 12th 2012 under a Netherlands government mortgage guarantee program (Nationale Hypotheek Garantie, NHG), which insures commercial mortgage providers against residual mortgage debt in case of foreclosure.[28] NHG-backed mortgages present a low credit risk to the mortgage provider, which would allow them to offer lower interest rates. The sample to NHG-backed mortgages is relatively homogeneous in terms of both risk

[27] The changes in equilibrium responsiveness predicted by the baseline specification are detailed in Appendix B and summarized in Tables 7.3 and 7.4.

[28] The data sources and cleaning are detailed in Appendix C.

profile and house size, because the loan provider is insured against default and limits are imposed on the size of the mortgage.[29]

The data set includes observations on 974864 rates as included in the mortgage contract. Each observation contains information on the contract date, the (anonymized) mortgage provider, the loan duration, the loan amount, loan type (duration of the fixed interest rate) and the effective interest rate.[30] The mortgage provider of each contract is anonymous in the sample. We have labeled them alphabetically by share of total mortgages sold. Of the total number of mortgage contracts, close to twenty percent (178406) were supplied by bank A—followed by the next largest provider at a mere ten percent. Of all mortgages, more than half had a 10-year maturity. The average mortgage was for 170548 euro.

Data on the costs of obtaining funding for mortgages in the money and capital markets include various interest and swap rates. Obtained from the Dutch Central Bank (DNB) are data on interest rates on deposits (monthly), interbank swap rate as base rate (daily, differentiated by maturity), the overnight Eonia rate (daily) and the quarterly ratio of Tier1-capital to risk-weighted assets as an average for all Dutch banks. Credit Default Swaps (CDS, daily, differentiated by maturity) were obtained for the biggest five Dutch mortgage providers from Thomson Datastream, and Residential Mortgage Backed Securities (RMBS, daily, differentiated by maturity) from Markit. The monthly HHI was calculated from the NHG mortgages data set on a monthly basis over all maturities.

Table 4.1 summarizes some of the information in the data set for the eight banks with the largest market share, over the entire period as well as before and after May 1st 2009 as the approximate date at which the price leadership bans may have taken effect.

[29] The NHG is administered by the WEW, a fund that is financed through nominal entrance fees paid by qualifying mortgage takers. Strict upper-bounds apply to income and only houses up to a set price ceiling are eligible for an NHG. This ceiling was 265K euro for most of our sample period, with an exception for the period 2009-2011 when it was raised to 350K euro to stimulate housing demand in the wake of the financial crisis. This limits the sample to mortgages on houses with a below average price on the Dutch market, which are typically fully mortgage financed.

[30] Mortgage rates were registered on contract dates, whereas typically some time passes between quotation and contract signing—with limited space for price negotiations. The period that a rate offer remains valid differs per provider, between two to seven months. Using the contract date may therefore not fully capture the exact timing of the interest rate responses. The WEW supplied us with additional information on offer dates, which we were able to connect to the contract dates. The contract rates correlate highly with the window rates. Findings using the offer dates are less pronounced, in part reflecting matching issues.

Table 4.1: Sample statistics

		before		after		full sample				
	N	mean	std dev	mean	std dev	mean	std dev	median	min	max
var	100558	4.39	1.15	4.68	.62	4.63	.76	4.80	1.00	6.78
1-5	33127	3.94	1.28	4.62	.81	4.20	1.17	4.30	1.00	7.80
5	61240	4.45	.93	4.10	.53	4.25	.75	4.05	1.00	8.14
5-10	100367	3.99	.54	4.54	.55	4.02	.55	4.00	.88	8.98
10	420242	4.53	.60	4.74	.40	4.65	.51	4.70	.50	10.38
>10	259330	4.68	.55	5.17	.54	4.84	.60	4.80	.70	13.50
all	974864	4.45	.71	4.76	.40	4.65	.51	4.70	.50	13.50
r_{base}		3.98	.70	2.44	1.11	3.27	3.52	1.20	.07	5.36
r_{Eonia}		2.78	.89	.52	.31	1.73	2.02	1.32	.07	4.60
$r_{deposit}$		2.62	.35	2.18	.22	2.42	2.40	.30	1.96	3.19
$CDS_{Rabobank}$		.28	.39	.93	.40	.58	.43	.51	.00	2.13
CDS_{ING}		.33	.40	1.37	.69	.81	.64	.75	.01	2.92
CDS_{ABN}		.32	.36	1.17	.26	.72	.77	.53	.01	2.13
CDS_{AEGON}		.73	1.05	2.00	.72	1.32	1.14	1.11	.02	6.74
CDS_{SNS}		.68	1.27	2.83	1.02	1.67	1.43	1.58	.02	8.25
$RMBS$		1.39	2.02	2.00	1.19	1.81	1.52	1.39	.08	8.44
$Tier1$		9.71	.41	11.85	.35	10.70	9.47	1.14	9.00	12.40
HHI		.0785	.0124	.1100	.0137	.0931	.0947	.0204	.0574	.2793

Notes: maturity in years; rates in %; break at May 1st 2009.

Average rates for almost all maturities are structurally higher in the after-period, while their standard deviations decreased. The mean-to-variance ratio for all maturities increased, close to doubling for most, which is consistent with coordination. The base rate, Eonia and deposit rates fell steeply after May 1st 2009, due to monetary policy interventions. At the same time did CDS spreads increase as a combined result of increased risk, enhanced risk pricing, and higher risk aversion of investors in the wake of the financial crisis—in part regulation induced. The higher and more increased risk premiums paid by AEGON and SNS REAAL compared to Rabobank, ING and ABN AMRO, reflecting the implicit State aid from their status as systemic bank.

Table 4.2 provides some insight in demand developments. It gives the number of mortgages closed per week before and after May 1st 2009. In the last column, mortgages over 265K euro are excluded, as in July the NHG upper-bound was extended to 350K euro in an attempt to stimulate demand. Corrected for the new category of higher end mortgages, sales are relatively stable. In combination with the mortgage rates increasing slightly, this suggests relatively stable market demand—including price-inelastic refinanced mortgages of which the fixed interest rate period had expired. Demand did shift somewhat from the smaller and fringe providers to the larger ones.

Table 4.2: Mortgages sold per week

bank	before	after	corr.
A	321	459	271
B	170	317	186
C	100	219	130
D	96	214	125
E	111	168	102
F	135	131	81
G	102	118	73
H	114	91	58
total (excl. fringe)	1149	1718	1028
total (incl. fringe)	1854	2356	1423

Notes: break at May 1st 2009.

We note two strong and relevant patterns in the sales of mortgages by the largest banks A and B that are in the sample. First, bank A supplied almost no variable rate NHG-backed mortgages in any year: between 5-18 each year out of approximately twenty thousand mortgages sold, or less than .1%. Second, from 2008/2009 onwards, bank B started to aggressively supply variable mortgages, and reduced its sales of the maturities it had been selling more before. While in 2004-2007 bank B closed 48 mortgages with a variable rate annually on average, in 2008 it sold 4250, growing steeply to 8100 in 2009 and 20330 in 2010. Over the same years, bank B's sales of NHG-backed mortgages with a 10 year maturity dropped to 86 in 2009 and 118 in 2010, whereas it closed on average of about 3250 10-year mortgages per year in 2004-2007. Bank B seems to have decided to go out of the 10-year maturity market in 2008, when it sold 1200. This divergence complicates the analysis of the relationship between the interest rates of bank A and B in years where the two banks have few observations with the same maturity.

5 Empirical Strategy

The predicted differences in the equilibrium responses of followers between competitive and coordinated price leadership in the model are pronounced. To test empirically whether there is evidence of a shift from a competitive to a collusive price leadership equilibrium in the Dutch mortgage market around the time the European Commission imposed price leadership bans, we follow a three step procedure.

First we conjecture the identities of the main banks in the anonymous data set from descriptive statistics. In particular do we determine the price leader, bank A, by estimating which bank is most likely to Granger-cause the interest rate of the other banks. That this bank is Rabobank is corroborated by other evidence. Note that this suffices for the main analysis—even though we are pretty sure about several followers' names as well. It is not necessary to know the identity of individual follower banks, since we expect them to behave similarly once they are under a price leadership ban. Subsequently response lags in the data are established as week days.

In the second step, we test whether and when the responsiveness of bank A to cost changes breaks structurally over time over all maturities, using a Quandt-Andrews test. A structural model with a number of funding cost factors is fitted before and after all days in 2008-2009 as potential candidate single break dates. In addition, a monthly Herfindahl-Hirschman-index (HHI) is included to control for market concentration. The date with the highest combined significance level of the two regressions, *i.e.* the highest F-statistic, is reported as the most likely date at which the price leadership bans took effect.

Bank A's rate is regressed according to the leader's equilibrium pricing rule, with a dummy that interacts with a constant and all controls after the estimated break date. Theory predicts that the cost factors will be structurally less important in explaining the interest rates after the bans. Breaking the HHI is the best alternative to recalculating its values in the after period by treating all the banks under a ban as one against the remaining fringe competitors—which we cannot do without full provider identification. The maturity fixed effects proxy for a yield curve effect where mortgages with longer term maturities may command a higher mortgage rate. While the exact shape of the yield curve may change over time, this is due to outsider factors, including the financial crisis, not to the imposition the price leadership bans.[31]

Third, we regress the rates of each of the seven follower mortgage providers with the largest market shares on a cointegrating equation, which has the structure of its equilibrium best-response function. A cointegrating approach is appropriate, since all interest rate series display unit roots in levels (not in first differences) and pairwise cointegration between the rates of the leader and the followers.[32] It is essential to control for any cost changes, or the followers' rate responses are likely to be overestimated.[33] Also for each follower separately is the break date determined using the Quandt-Andrews test and an almost fully interacted dummy variable model estimated before and after. It brings out any changes in the price followers' responses to the price leader with the imposition of the bans.

Subsequently, response adjustments are analyzed by estimating short-run deviations from the cointegrating relations, as is common is common in the VEC approach, given the break dates. Even though the two-stage price leadership model does not offer guidance on magnitudes, signs and significance of the short-run estimation parameters, it can give further support to the conjectured regime shift. Fast adjustment, ideally within the weekly cycle, gives further support to the equilibrium model predictions.

The costs for the banks to obtain the funds for supplying mortgages consist of various components that enter into a complex and unknown cost function. They are

[31] This (almost) fully interacted dummy variable approach is (nearly) equivalent to regressing the time series before and after the break moment separately, *i.e.* the forecasting approach. Consistently do we obtain almost identical estimation results to the analyses in sections 7 and 8.

[32] Non-stationarity and cointegration test results are given in Appendix D.

[33] See Appendix E.

a mix of base and deposit rates, premiums and regulatory costs, none of which are necessarily matched with maturities. In addition, most cost factors on which data is available are common to all banks, such as the policy rate, or averaged over all banks, such as deposit rates. The exception is information on CDS spreads for the large Dutch banks Rabobank, ING, ABN AMRO, AEGON and SNS REAAL, which we are, however, not able to identify with certainty. It is therefore not possible to distinguish empirically between the costs of the leader and the follower banks, so that the stark predictions on changes in their roles the banks pricing rules cannot be tested. Instead, we include the same nine relevant cost factors, besides the HHI, as inputs for all the regressions simultaneously. This gives the model the most freedom of estimation and is in line with the theory that all costs in principle (indirectly) matter for all equilibrium rates.

Since the cost factors in our data set are all affected similarly and simultaneously by underlying fundamentals in financial markets, they are highly collinear, so that the cost coefficients cannot be interpreted individually.[34] The consequences of this for our analysis are limited. We are primarily interested in the effects of the interest rate of the price leader (r_A) on the interest rates of the other mortgage providers, for which only multicollinearity with r_A would be a concern. Only the RMBS spread is highly correlated with r_A. Moreover, variance inflation factors show that multicollinearity in regressions (11) mostly takes place between the different cost factors, while the variance inflation factor on the interest rate of the price leader remains below 10 for all.

For theses reasons, we excluded the RMBS spread from the estimations, even though it can proxy directly for the riskiness of the Dutch housing market.[35] Since the series started only in 2006, including it would also have meant excluding 2 years of data, which is more than half of the data before the financial crisis.[36] Moreover, we analyze the cost coefficients jointly as common cost changes, for which we introduced S_l, $S_{i \neq l}$ and S_{ff}. These summations are exact, since the individual cost coefficients implicitly estimate the weights of the cost component in the cost functions of all individual banks.[37] Also, any shifts in the funding composition over time would level out in the summation. Nevertheless, we note that the summation of a larger number of coefficients can accumulate beyond its theoretical upper-bound of unity, as the cost coefficients will pick up the effect of a cost function that is more complex than linear, as may inevitably omit variables, despite a proper fit.

[34] The correlation table is given in Appendix F.

[35] For the same reason were no additional interest rates included, such as the rate on government bonds.

[36] The relevant results from estimating the model including the RMBS spreads were qualitatively similar, but less robust due to the shorter time series.

[37] The identity is shows in Appendix G.

6 Bank Identification

The identities of the eight mortgage providers that are largest in terms of the total number of mortgages sold over the entire sample period, banks A to H, can be conjectured with reasonable certainty.[38] A first source of identification is the annual report that the NHG publishes. From 2006 onwards, for each year it provides the names of the biggest (5 in 2006-2010 and 10 in 2011-2012) suppliers of NHG-backed mortgages and the number of NHG mortgages that each sold. These identified market shares are nearly identical to those obtained from our sample: bank A correlates (ρ) closely with Rabobank (.97), bank B with ING (.95), bank C with AEGON (.94), and bank D with ABN AMRO (.97). Bank A selling little or no mortgages with a variable rate is furthermore consistent with Rabobank's policy not to be active in this market segment.

The remaining banks cannot be unambiguously distinguished in this manner. However, bank H is likely to be Argenta, a Belgian insurer. The NHG reports on Argenta show a large presence of this bank, with similar quantities in the market in the periods 2006-2007 and 2011-2012, but not in the first years of the financial crisis, a pattern also in our data. Indeed did Argenta withdraw from the Dutch market in the crisis period to focus on its home market. More speculative is our suspicion that bank G is likely Obvion, a price-fighter subsidiary of Rabobank. Banks E and F could either be SNS REAAL or Fortis—although one of them may be a subsidiary of ABN AMRO as well.

In order to test whether bank A is indeed the price leader, we perform Granger causality tests on daily averages of mortgage rates with a 10-year maturity per provider over the full sample period.[39] Mortgage rates are commonly set once per week, by each provider on a different day of the business week, typically on a bank-specific fixed day.[40] The following VAR model is estimated for each bank pair (i, j)

[38] In total, bank A sold (in thousands) 178 (18%), bank B 109 (11%), followed by four providers with between 60 and 70 (6-7%) mortgage contract closed each. Banks G and H each closed around 50 (5%) mortgages. The other providers were considerably smaller, with the next largest provider supplying 35 (3.5%).

[39] The mortgage rates time series being non-stationary may suggest to test for Granger causality in first differences. Toda and Yamamoto (1995) however establish that Granger causality can be inferred from non-stationary data that features cointegration on levels. Applied to first differences, results are less pronounced, but still point at bank A as the price leader.

[40] This is confirmed in interviews with bankers: interest rates are set roughly once a week (weekday may differ). De Haan and Sterken (2011) also find that the price leading bank in the Dutch mortgage market (also anonymized to bank A) adjusts prices always on the same weekday. This pattern is consistent with our data, as daily first differences appear to jump on given days and change less for the rest of the week—Bank A changing its mortgage rates mostly on a Friday.

between banks A to H

$$\begin{pmatrix} r_{i,t} \\ r_{j,t} \end{pmatrix} = \begin{pmatrix} \alpha_{0,i} \\ \alpha_{0,j} \end{pmatrix} + \begin{pmatrix} \alpha_{i,1,11} & \alpha_{i,1,12} \\ \alpha_{j,1,21} & \alpha_{j,1,22} \end{pmatrix} \begin{pmatrix} r_{i,t-1} \\ r_{j,t-1} \end{pmatrix} + \dots$$
$$+ \begin{pmatrix} \alpha_{i,\tau,11} & \alpha_{i,\tau,12} \\ \alpha_{j,\tau,21} & \alpha_{j,\tau,22} \end{pmatrix} \begin{pmatrix} r_{i,t-\tau} \\ r_{j,t-\tau} \end{pmatrix} + \begin{pmatrix} \epsilon_{i,t} \\ \epsilon_{j,t} \end{pmatrix}, \quad (8)$$

where τ is the number of lags 1-5.

Table 6.1 shows Chi-squared values of the null hypothesis that the interest rate in a certain row does not Granger-cause the interest rate in the column. For example the value in the first row, second column (38.31) represents the Chi-squared value on the test that r_A does not Granger-cause r_B, which is rejected. Bank A Granger-causes the interest rate set by bank B.

Table 6.1: Granger causality test pairwise VAR models, daily interest rates

	r_A	r_B	r_C	r_D	r_E	r_F	r_G	r_H
r_A	×	38.31***	43.44***	59.77***	47.54***	32.03***	55.50***	30.08***
r_B	6.15	×	16.71***	34.12***	23.67***	5.62	23.56***	28.08***
r_C	8.92	19.86***	×	20.30***	24.38***	20.14***	43.40***	15.65***
r_D	13.60**	51.81***	56.20***	×	47.11***	32.08***	75.98***	22.04***
r_E	19.26***	21.48***	46.96***	74.40***	×	34.46**	37.26***	31.30***
r_F	6.70	13.54**	24.92***	28.04***	35.27***	×	33.43***	14.45**
r_G	4.94	16.77***	34.22***	20.94***	23.85***	18.99***	×	16.83***
r_H	12.53**	32.89***	17.67***	47.52***	32.54***	10.27*	28.95***	×

Notes: Chi-squared values; *,** ,*** indicating significance at the 10, 5 and 1% level respectively.

Most interest rates Granger-cause one another, which is not surprising given that each of the interest rates comoves and responds to underlying cost factors. However, bank A is the only bank that consistently Granger-causes the interest rates of all the other banks, whereas it is Granger-caused by the fewest of all other banks. Furthermore, the Chi-squared value associated with Granger causation from bank A to other banks is always higher than the other way around, which is not the case for any of the other mortgage providers.[41] We therefore conclude that bank A is most likely the price leader. Note from Table 5.1 that the CDS spread is lowest for Rabobank already before May 1st, in particular compared to its nearest competitors ING and ABN AMRO, suggesting lower costs of funding, which is consistent with the theory of a price leader with a cost advantage.

The pairwise VAR models also allow inference of the lags by which the price followers respond to the price leader. The lag τ in $\alpha_{A,\tau,22}$ that is most significant implies that bank C responds after 1 day to bank A's rate, bank G after 2 days,

[41] Qualitatively similar results obtain including cost controls and determining the number of lags endogeneously using the Schwartz Information Criterion.

banks B, D and E after 3 days, and banks F and H after 5 days, *i.e.* a full business week.

Rabobank (bank A) had not needed State aid and hence remained free to act as price leader. Banks B (ING), bank C (AEGON), bank D (ABN AMRO) and banks E and F (SNS REAAL, Fortis or ABN AMRO subsidiary) were all given State aid conditions that included price leadership bans that forbade them, in mortgage products, to price lower than their nearest competitors. Indeed do almost all the banks price more often higher than bank A after May 2009: for banks B to G on average (against Rabobank's minimum rate on the day) 54% (92%) of all business days after, against 44% (86%) before.

That these differences are not more pronounced can have several causes. The formulation of the commitment to the European Commission provided for occasional undercutting, as long as no structural price fighter role was taken by the bank under a ban. Variances in the rate averages are large—see Table 5.1. Also adherence to the bans would have been monitored primarily on the advertised rates, whereas the rates compared are the final contract rates. The aided banks would have been able to discount more from the offer rates in individual negotiations with mortgage borrowers. Complaints of infringement would have been hard to substantiate. In addition, some incidental undercutting may have been due to some heterogeneity in Rabobank's window rates, resulting from the fact that the cooperative allowed its local branches some discretion in determining their own individualized rate offers. In practice there was central guidance from headquarters, however, and (local) competitors would have known Rabobank's relevant rate.

Price following behavior is expected to increase markedly, and the responsiveness of follower banks to common cost changes to decrease. Bank H (Argenta) was most likely not under a ban and is therefore expected to respond to the bans differently from the other providers in the sample. It priced significantly below bank A before and after May 2009. If bank H was a formidable fringe follower, the change in S_l would be relatively small. In that case, bank H is expected to also respond more to bank A's rate and less to common costs, but considerably less strongly so than the other followers. If bank H did not constitute much of a competitive threat to the incumbent banks, its responsiveness may also have decreased.

The distribution of the market shares changed only somewhat before and after May 2009, skewing it further towards the incumbent banks. The largest providers each gained share in the number of mortgages sold: bank A from 17% to 20%, bank B from 9% to 14%, banks C and D from 5% to 9%. Together, the largest five providers increased their share from about 55% to almost 70%, at the expense of the remaining fringe competition.

Finally, we note that, having identified bank A as the unconstrained price leader, bank B's observed switch from 10-year to variable rate mortgages may itself be induced by the price leadership bans: with bank A traditionally not supplying the market for variable rate contracts, bank B would have had more freedom to determine variable rates. Alternatively, bank B may have reduced its sales in 10-year maturity in an aim to deleverage its balance sheet in order to meet tighter regulatory requirements.

7 Price Leadership Regime Shift

To determine whether the nature of the price leadership has changed with the imposition of the price leadership bans, we test whether mortgage rates are set structurally differently before and after the period within which the bans were introduced. In Section 7.1, we first consider the pricing behavior of price leader bank A—including in the log-linear specification, which is the Panzar-Rosse test.

In Section 7.2, the responses of the seven largest price follower banks are estimated as pairwise cointegrating relationships between the rate of bank A and their rates. In Section 7.3, we analyze short-run first differences to obtain a sense of the speed of adjustment and convergence to the equilibrium response functions. Section 7.4 reports the rates that the estimations suggest would have been if the market had continued in competitive leadership.

In the baseline estimation, the unit of observation is individual mortgages across all maturities, so that the largest possible number of independent observations in the NHG data set is exploited. The shares of mortgages by maturity included in the regressions are: variable .5%, 1-9 years 18.4%, 10 years 55.5%, 11-19 years 10.1%, 20 years 10.1% and over 20 years 5.3%. The markets for different mortgage types may however differ—for example in product differentiation, price elasticity and number of active providers. Section 7.5 reports our findings on only the 10-year maturity market, which is the most sold mortgage product by far.

7.1 Price Leadership

Bank A's rate is expected to be determined by a linear combination of cost factors that include its own costs and that of its followers

$$r_{A,j,m,t} = \beta_{A,m,0} + \boldsymbol{\beta}_{A,2}\mathbf{C}_{m,t} + \left(\beta_{A,0}^{PLB} + \boldsymbol{\beta}_{A,2}^{PLB}\mathbf{C}_{m,t}\right) D_{A,t}^{PLB} + \epsilon_{A,j,m,t}, \qquad (9)$$

where $r_{A,j,m,t}$ is the interest rate set by bank A on individual mortgage j, with maturity m at day t. Constant $\beta_{A,m,0}$ contains maturity fixed effects to deal with the unobserved variation in the demand shifters (a and e).

Vector $\mathbf{C}_{m,t}$ contains ten explanatory variables per maturity m. These include nine cost controls: CDS spreads for the biggest five mortgage providers in the Netherlands (matched by maturity), two base rates (Eonia and the interbank swap rate with maturity matched to the mortgage), the rate on Dutch deposits, and the amount of Tier 1 equity capital to the value risk-weighted assets. The latter is included to control for possible costs of capital requirements in compliance with Basel III, which was relevant in anticipation from 2010. In addition, market concentration is controlled for using a monthly HHI (between 0 and 1), based on the total volume of NHG mortgages sold per provider in a given month. The moment of the dummy $D^{PLB}_{A,t}$, which interacts with a constant and all controls, is determined by a Quandt-Andrews test.

Table 7.1 gives the relevant regression results of model (9) in the left-hand column.[42]

Table 7.1. Regression results bank A's rate to costs, individual observations

	Price leader response		Panzar-Rosse	
break date	01-03-2009 (495.3461)		01-07-2009 (404.3552)	
	before	after ($\times D^{PLB}_{A,t}$)	before	after ($\times D^{PLB}_{A,t}$)
S_l	1.8462*** (.0166)	−.9873*** (.0267)	×	×
HHI	.0311*** (.0020)	−.0216** (.0021)	.0399*** (.0038)	−.0089* (.0048)
H_A	×	×	.8980*** (.0151)	−.5222*** (.0214)
N	176442		176442	
R^2	.6262		.6536	

Notes: Break date with F-statistic. Robust standard errors in parentheses; *,** ,*** indicating significance at the 10, 5 and 1% level respectively.

Bank A's pricing behavior changed structurally around the Spring of 2009.[43] The common cost effect sum S_l, in which almost all individual cost coefficients are significant, has a low accumulated standard error. Its absolute value is larger than one, reflecting colinearity as discussed. However, the decrease in S_l after the bans took effect is highly significant, consistent with coordinated price leadership by bank A, and in size (53%) as predicted for the full coordination model. This suggests that little fringe competition remained on the Dutch mortgage market after the crisis, favoring the full coordination model. Note that the effect of the HHI becomes even less important after the break date—even though its average value increases from .078 to .11 (see Table 5.1). The maturity fixed effects are small, significant, and do not form a discernible pattern. The relevant results are robust to their exclusion.

Bank A obtains substantial market power. The right-hand column in Table 7.1 provides the result of estimating a loglinearized version of model (9)

$$\ln r_{A,j,m,t} = \beta_{A,m,0} + \boldsymbol{\beta}_{A,2} \ln \mathbf{C}_{m,t} + \left(\beta^{PLB}_{A,0} + \boldsymbol{\beta}^{PLB}_{A,2} \ln \mathbf{C}_{m,t}\right) D^{PLB}_{A,t} + \epsilon_{A,j,m,t}, \quad (10)$$

[42] For the full table of regression results, see Appendix H.

[43] The F-values to all estimated break dates reported in the following far surpass the critical F-test values at the numbers of observations we analyze. Also, all the relevant results are nearly identical taking May 1st 2009 as a fixed dummy moment.

which is the Panzar-Rosse test for estimating (lack of) competition. It estimates elasticities of price to cost factors on the theory that in perfect competition marginal cost changes are passed-through in full, so that the sum of cost elasticities (the H-statistic) equals 1, while lower values are indicative of market power. July 1st 2009 is found to be the most likely break in cost pass-through by bank A. Consistent with coordinated price leadership of bank A upon the imposition of the bans, the H-statistic decreases from close to unity (.90), which is consistent with the Dutch mortgage market being competitive before the financial crisis, to .38, a value that suggests a dominant position for Rabobank with little remaining fringe competition.

7.2 Follower Responses

The equilibrium best-response of each of the seven largest price following banks (B to H) to the mortgage rate set by price leader bank A is pair-wise estimated as

$$\begin{aligned} r_{f,j,m,t} &= \beta_{f,m,0} + \beta_{f,1} r_{A,m,t-\tau} + \boldsymbol{\beta}_{f,2} \mathbf{C}_{m,t} \\ &+ \left(\beta_{f,0}^{PLB} + \beta_{f,1}^{PLB} r_{A,m,t-\tau} + \boldsymbol{\beta}_{f,2}^{PLB} \mathbf{C}_{m,t} \right) D_{f,t}^{PLB} + \epsilon_{f,j,m,t}, \end{aligned} \tag{11}$$

where $r_{f,j,m,t}$ is the mortgage rate set on mortgage j of follower bank $f = B, \ldots, H$ with maturity m at day t, and $r_{A,m,t-\tau}$ is the average rate set by the price leader bank A on the matching maturity at day $t - \tau$. Hence, τ represents the number of days that it takes the price-following bank to respond (1-5 days), which were identified in Section 6.

Any maturity fixed effects are captured in $\beta_{f,m,0}$. The coefficients on the interest rate set by bank A, β_1 and β_1^{PLB} are not expected to differ between maturities, which allows for obtaining a single estimate for the behavior of follower banks to bank A's interest rate. The followers almost surely include all banks under an explicit price leadership ban, as well as at least one smaller free fringe follower bank—most likely bank H—but failure to include all mortgage providers active in the market has no bearing on the pairwise results. $\mathbf{C}_{m,t}$ is a 10×7 matrix of the ten control variables specified in Section 7.1, for each of the seven price-following banks included in the regression. Cost factors were matched by maturity of the mortgage where possible, *i.e.* for CDS spreads and the interbank swap rates.[44]

The moment of the follower-specific dummy $D_{f,t}^{PLB}$ is expected to be in or around the Spring 2009. The main coefficient of interest is $\beta_{f,1}^{PLB}$, which measures the difference in response of the price follower f to the interest set by the price leader A before and after imposition of the price leadership ban. We expect these coefficients to be positive and significantly different from zero for all price-following banks, as the theory predicts that the interest rates of the followers respond more to the price leader's rate in a coordinated than in a competitive market. More specifically do we

[44]The overnight Eonia, deposit and Tier1/RWA rates do not differ by maturity. Matching the HHI left too few datapoints for certain infrequent maturities in certain months.

expect $\beta_{f,1} + \beta_{f,1}^{PLB}$ to be close to 1, and $\beta_{f,1}$ relatively small. Any free fringe follower (bank H) would follow bank A's interest rate much less closely—with the smaller the bank, the least it will follow. To a common cost shock, we expect all the followers' responses (S_f) to decrease—the competitive fringe less so.

The relevant results of regression (11) are in Table 7.2.[45]

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Table 7.2: Interest best-response results follower banks' to bank A's rate and costs, individual observations

The pricing behavior of all followers structurally changes in the Spring of 2009, between mid February and mid June, consistent with the price leadership bans coordinating mortgage rates.[46] In the period before the price leadership bans, the effect of bank A's rate ($\beta_{f,1}$) is positive for all followers, and significant for all but bank C, ranging from close to zero to .206. After the bans became effective, $\beta_{f,1}^{PLB}$ is significantly positive at 1%-level for all followers—except as expected bank H that had not come under a ban. It is small for bank B, which may reflect that its business focus had shifted to variable rate mortgages, which bank A did not sell. All signs of the cost coefficients are in the expected direction and statistically significant. The common cost effects S_f^d are all larger than one in absolute value. HHI is a significant but small explanatory variable, the effect of which becomes smaller for all banks but bank C after the bans. The variance inflation factors confirm multicollinearity between the different cost factors—yet on the interest rate of the price leader the VIF remains below 10 for all regressions.[47]

Table 7.3 summarizes the three main predictions on follower behavior from theory and compares them to the findings on followers B to E (F and G are similar).

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Table 7.3: Predicted and realized best-response results follower banks' to bank A's rate and costs, individual observations

The interest rate of bank A became much more important to the price following banks under a ban, with the sums of the coefficients increasing over twofold, as predicted by theory, to even four-fold, to .53 for bank C (now a close follower) and even

[45] For the full table of regression results, see Appendix H.

[46] The results are robust to slight changes in the break dates in and around Spring 2009. We also performed a robustness test with the break date for all banks set at March 1st 2009, the day on which the price-leadership was found to have changed in model (9). This gave similar results for the follower responses.

[47] See Appendix E.

Table 7.2: Interest best-response results follower banks' to bank A's rate and costs, individual observations

	$r_{B,j,m,t}$	$r_{C,j,m,t}$	$r_{D,j,m,t}$	$r_{E,j,m,t}$	$r_{F,j,m,t}$	$r_{G,j,m,t}$	$r_{H,j,m,t}$
response time	3	1	3	3	5	2	5
break date	16-06-09	13-02-09	04-03-09	03-03-09	27-05-09	01-03-09	01-03-09
	(686.990)	(581.596)	(243.678)	(310.731)	(75.591)	(153.646)	(507.252)
$r_{A,m,t-\tau}$	.095***	.024	.206***	.116***	.133***	.161***	.119***
	(.018)	(.016)	(.022)	(.010)	(.009)	(.011)	(.007)
$r_{A,m,t-\tau} \times D^{PLB}_{f,t}$	.231***	.504***	.635***	.472***	.391***	.370***	−.329***
	(.056)	(.017)	(.023)	(.013)	(.019)	(.016)	(.030)
$\mathbf{C}_{m,t}$ (combined)	1.970***	1.883***	1.654***	1.663***	1.620***	1.684***	1.389***
	(0.060)	(0.037)	(0.051)	(0.029)	(0.028)	(0.031)	(0.093)
$\mathbf{C}_{m,t} \times D^{PLB}_{f,t}$	−2.994***	−1.852***	−1.504***	−1.777***	−.844***	−1.653***	−.976***
	(.148)	(.044)	(.060)	(.042)	(.073)	(.057)	(.244)
HHI	.092***	.039***	.057***	.036***	.050***	.007*	.110***
	(.004)	(.003)	(.004)	(.003)	(.002)	(.003)	(.003)
$HHI \times D^{PLB}_{f,t}$	−.101***	.030***	−.040***	−.029***	−.021***	−.008*	−.115***
	(.005)	(.006)	(.005)	(.003)	(.005)	(.003)	(.003)
maturity FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	56088	59767	62540	55230	57255	46485	32939
R^2	.4551	.6835	.5591	.6807	.6514	.6213	.6818

Notes: Response time in days. Break date with F-statistic. Robust standard errors in parentheses; *,**,*** indicating significance at the 10, 5 and 1% level respectively.

Table 7.3: Predicted and realized best-response results follower banks' to bank A's rate and costs, individual observations

	prediction			$r_{B,j,m,t}$			$r_{C,j,m,t}$			$r_{D,j,m,t}$			$r_{E,j,m,t}$		
	before	after	$\frac{\text{after-before}}{\text{before}}$	before	after	$\frac{\text{after}-\text{before}}{\text{before}}$	before	after	$\frac{\text{after}-\text{before}}{\text{before}}$	before	after	$\frac{\text{after}-\text{before}}{\text{before}}$	before	after	$\frac{\text{after}-\text{before}}{\text{before}}$
$B_{f,1}$	.26	1	2.85	.095	.326	2.43	.024	.528	21	.206	.841	3.08	.116	.588	4.07
S_f^d	.67	.5	−.25	1.97	−1.024	−1.52	1.88	.031	−.98	1.654	.15	−.91	1.663	−.114	−1.07
S_f	.89	.5	−.44	2.15	−.74	−1.34	1.93	.49	−0.74	2.04	.88	−.57	1.88	.40	−.79

.84 (bank D) for most price followers. While bank B has a somewhat lower combined coefficient of .326, the influence of bank A's rates on all mortgages (but bank H) more than doubled—despite bank B quite aggressively obtaining more market share in variable mortgages after the Spring of 2009. For all follower banks do both S_f^d and S_f decrease significantly, indicating that the importance of cost changes to price under the bans is reduced as expected. Both absolute values and relative changes are much larger than predicted by the linear model. For some banks (B and E) S_f^d even becomes slightly negative. Note also that while $S_f > S_f^d$, as predicted, the relative change in S_f is somewhat smaller. The pattern of change is consistent with the price leadership bans fully coordinating prices.

Table 7.4 compares predictions and findings for bank H. As expected, it behaves markedly different from the banks under a ban. In fact, bank H's responsiveness to the leader's rate in fact *de*creases with the introduction of the bans, whereas the theory only predicts a much lower increase in responsiveness, relative to the other followers, in case bank H constituted a serious competitive threat. Bank H does change its responsiveness to common cost changes in the expected direction and less pronounced than the other banks. Its somewhat maverick behavior, undercutting the other banks with less regards to cost and Rabobank's pricing, while gaining little market share, seems consistent with bank H being perceived as only a weak competitor—which also the findings on S_l suggest.

Table 7.4: Predicted and realized best-response results fringe follower bank H to bank A's rate and costs, individual observations

	prediction			$r_{H,j,m,t}$		
	before	after	$\frac{\text{after}-\text{before}}{\text{before}}$	before	after	$\frac{\text{after}-\text{before}}{\text{before}}$
$B_{ff,1}$	.26	.48	.85	.119	$-.21$	-2.76
S_{ff}^d	.67	.45	$-.33$	1.389	.413	$-.70$
S_{ff}	.89	.84	$-.06$	1.61	.23	$-.86$

The main results are not sensitive to the selection of the response period.[48] Qualitatively comparable results also obtain if the offer date instead of the date of closure of a mortgage is used at the relevant rate setting moment.[49] The same is true for regressing model (11) on all mortgages of all providers (but bank A) combined, thus including all of any remaining fringe competition.[50]

[48] Setting $\tau = 0$, we estimated regressions (11) with a same-day response time. The changes in responsiveness to bank A are comparable to the main analysis, also in significance, except for bank B, which has a weaker increase at only 10% level.

[49] Using additional WEW information on offer date and household ID, we were able to identify the offer date of 146455 observations for the price following banks, or approximately 9 loans made per bank per day—however the information appeared to contain many errors, which were excluded.

[50] For this case, sums of parameters (all signifcant at 1%-level) $\beta_{f,1} + \beta_{f,1}^{PLB}$ also increase strongly, by .38 to .42 from .15 to .27. The sum of cost parameters decreases across the board, from the range of 1.46 to 1.75 to the range of $-.08$ to .10, consistent with the model prediction that remaining fringe competition mitigates the coordinating effect of the bans.

Panzar-Rosse tests on the followers also indicate that the price leadership bans largely eliminated competition in the Dutch mortgage market in the Spring of 2009. We regressed model (10) for each price follower instead of bank A before and after a per-bank estimated break date. The H-statistics are significant before and after the estimated break dates and decrease steeply for all follower banks from the $.8-.9$ (competition) to $.3-.5$ (monopoly) range, consistent with market power for bank A (Rabobank), combined with tighter following by the banks under a ban.[51]

7.3 Response Adjustment

The long-run cointegration equations capture the equilibrium best-response theory and allow for estimating short-run adjustments to equilibrium. We take the first differences from equation (11) for each of the banks $f \neq A$ responding to bank A's adjustment of its rate $\Delta r_{A,m,t-T}$, that is

$$\begin{aligned} \Delta r_{f,j,m,t} &= \gamma_{f,m,0} + \gamma_{f,1} \Delta r_{A,m,t-T} + \boldsymbol{\gamma}_{f,2} \Delta \mathbf{C}_{m,t} \\ &\quad + \left(\gamma_{f,0}^{PLB} + \gamma_{f,1}^{PLB} \Delta r_{A,m,t-T} + \boldsymbol{\gamma}_{f,2}^{PLB} \Delta \mathbf{C}_{t,j} \right) D_{f,t}^{PLB} \\ &\quad + \theta_f \epsilon_{f,m,t-5} + \varepsilon_{f,j,m,t}, \end{aligned} \tag{12}$$

in which the one business week differences error term $\epsilon_{f,m,t-5}$ from the estimation results from cointegrating equation (11) is used.[52] Maturity fixed effects are captured in $\gamma_{f,m,0}$. For each provider, $\Delta r_{f,j,m,t} = r_{f,j,m,t} - \overline{r}_{f,m,t-5}$ so that each mortgage j with maturity m is compared to the average interest rate on mortgages with maturity m sold by that provider in the week before ($\overline{r}_{f,m,t-5}$). Cost factors are similarly expressed as weekly differences, interacting together with the dummy.

The main coefficient of interest is $\gamma_{f,1}^{PLB}$, which is an indication of how much closer bank A is followed after the imposition of the price leadership bans. They are expected to be positive for all banks, except H. The coefficient θ_f can be interpreted as the speed of adjustment (in weeks) towards the long-run equilibrium, which should have a value between zero and -1 (full return to equilibrium within a week)—with for example $-.7$ implying return within two weeks.

The relevant results of regression (12) are in Table 7.5.[53]

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Table 7.5: Response adjustment results follower banks' rate to bank A's rate and costs, individual observations

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[51] The full table of Panzar-Rosse test results is given in Appendix I.

[52] This lag is appropriate, since each bank tends to adjust its rate on a given day of the business week, so that price variance over the days between is little. By comparing each day's interest rate to last week's interest rate, the intended changes will be measured most often, even if the actual response time were misspecified by even a few days.

[53] For the full table of regression results, see Appendix H.

Table 7.6: Response adjustment results follower banks' rate to bank A's rate and costs, individual observations

	$\Delta r_{B,j,m,t}$	$\Delta r_{C,j,m,t}$	$\Delta r_{D,j,m,t}$	$\Delta r_{E,j,m,t}$	$\Delta r_{F,j,m,t}$	$\Delta r_{G,j,m,t}$	$\Delta r_{H,j,m,t}$
response time	3	1	3	3	5	2	5
break date	16-06-09	13-02-09	04-03-09	03-03-09	27-05-09	01-03-09	01-03-09
$\Delta r_{A,j,m,t-\tau}$	.0485***	.0152	.0637***	.0469***	.0292***	.0527***	.0270***
	(.0185)	(.0114)	(.0269)	(.0102)	(.0093)	(.0095)	(.0054)
$\Delta r_{A,j,m,t-\tau} \times D_{f,t}^{PLB}$	.0310	.0823***	.2005***	.0966***	.1458***	.0915***	−.0675
	(.0295)	(.0130)	(.0326)	(.0196)	(.0366)	(.0247)	(.0765)
$\epsilon_{f,j,m,t-5}$	−.6321***	−.4340***	−.6736***	−.6117***	−.6946***	−.7433***	−.5798***
	(.0185)	(.0192)	(.0177)	(.0120)	(.0124)	(.0129)	(.0227)
$\Delta\mathbf{C}_{m,t}$ (combined)	.9179***	.4975***	.5024***	.4872***	.4411***	.5698***	.4235**
	(.1986)	().0941	(.1313)	(.0976)	(.0669)	(.1134)	(.1770)
$\Delta\mathbf{C}_{m,t} \times D_{f,t}^{PLB}$	.1897	−.5095***	−.8701***	−.7791***	−.4370***	−1.0980***	−.1023
	(.7504)	(.1069)	(.1604)	(.1285)	(.0871)	(.1862)	(.9822)
other controls	ΔHHI	ΔHHI	ΔHHI	ΔHHI	ΔHHI	ΔHHI	ΔHHI
maturity FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	47035	48810	52366	45028	59785	37921	27797
R^2	.1433	.1047	.1475	.1322	.0985	.1903	.1120

Notes: Robust standard errors in parentheses; *,** ,*** indicating significance at the 10, 5 and 1% level respectively.

The coefficient $\gamma_{f,1}^{PLB}$ is overall positive, significantly different from zero and sizable compared to γ_1, indicating that the interest rate differences of bank A play a larger role in determining the interest rate of the price-following banks after the price leadership ban is in place. Banks B and H are again exceptions. For bank B, the coefficient is insignificant, most likely caused by a lack of matching mortgage maturities in the later period. For bank H the coefficient is negative, which is consistent with it not being constrained by a price leadership ban. That the estimates of $\gamma_{f,1}^{PLB}$ are larger than for $\gamma_{f,1}$ for all banks C to G substantiates that the bans affected pricing.

The values of θ_f lie between $-.4340$ and $-.7433$, suggesting that the adjustment to the long-run relation is fast, between two and three weeks. While longer than the weekly mortgage rate cycle, this is relatively fast adjustment. We separately tested for asymmetry between up- and downward price movements, but found no significant difference, which also should not be expected on the basis of the theory. Adjustment to common cost shock differences all decrease—except for bank B and H, for which the changes are not significant. The effects of ΔHHI are significant but small. We conclude that the response adjustment results support the equilibrium findings.

7.4 But-for Mortgage Rates

The regressions results allow some insight into what may have been the mortgage rates, but for the imposition of the price leadership bans. Setting $D_{A,t}^{PLB} = 0$ in (9), from March 1th 2009 forward the daily mortgages rates that Rabobank would have set in competitive price leadership can be calculated from the estimated parameters and values of the explanatory variables. Using this rate and the parameters found for each follower bank to (11), with $D_{f,t}^{PLB} = 0$ from the later bank-specific break dates onwards, we can predict what would have been that bank's competitive offers in response.

Table 7.6 summarizes the estimated average but-for mortgage rate and overcharge per type.[54] The but-for rates are consistent with the calibrated model. The overcharges found suggest full coordination. Across all mortgage types and banks, the average overcharge is 125 basis points on average, or 26%. Bank H's overcharge is even larger. Nearly identical overcharges result from comparing estimated, rather than observed, actual rates to the but-for rates.

[54] The underlying estimates per follower bank are provided in Appedix J.

Table 7.6: Predictions of but-for mortgage rates

	bank A			average B to G			overall average		
	but-for	overcharge		but-for	overcharge		but-for	overcharge	
		bp.	%		bp.	%		bp.	%
var	2.85	79.93	19.69	2.77	90.93	26.28	2.78	89.36	25.34
1-5	2.86	87.68	23.22	3.16	95.94	22.26	3.12	94.76	22.40
5	2.93	124.06	29.44	3.34	82.11	20.87	3.28	88.11	22.10
5-10	3.30	114.49	25.46	3.43	113.48	24.46	3.41	113.62	24.60
10	3.42	136.43	28.41	3.50	125.58	27.31	3.49	127.13	27.47
>10	3.65	142.70	27.64	3.66	138.03	26.86	3.66	138.70	26.97
all	3.44	136.25	28.17	3.48	123.10	25.62	3.47	124.97	25.99

Notes: Overcharges are expressed as percentage of actual rate.

These values are only indicative, as a number of caveats apply. The linear model may not capture all the complexities of actual bank funding. The full vector of cost components was included in each regression as controls, rather than to approximate actual total marginal funding costs, while RMBS was excluded yet a relevant premium. Also, the funding portfolio constitutions were likely changed after the financial crisis, possibly also structurally. In particular may refinancing risks have increased after the crisis, when the banks may have been tempted to use more short-term over longer-term term funding, as especially short-term rates were kept low by monetary policy with an uncertain time horizon. To the extent that the banks did not fully maturity match or hedge their longer term mortgage contracts, they would have priced in the perceived risk of refinancing costs rising during the mortgage period. In hindsight, funding costs may have stayed lower longer than expected at the time. Projecting but-for rates without taking such relevant expectations, for which we have no proxy available, fully into account can overestimate overcharges by a chance factor that partly is a risk reward. Consistent with this concern, the overcharges found are higher for the longer maturities, which represented higher refinancing risks.

7.5 10-year Maturity

We find confirmation of the theory of coordinated price leadership under the bans combining all observations. However, as mortgages are product differentiated by their maturity, it is reasonable to expect differently sloped best-response functions per type. Moreover, the full data set is thin in places, which may have affected the robustness of the results. In particular did Bank A not offer variable rate mortgages, whereas it was the largest seller of 10-year contracts. We would therefore expect a stronger effect from the change in its price leadership role for this product in isolation.

In this section, we consider only new contracts closed with a 10-year maturity, which is the mortgage type most sold in the period (55.5% of the full sample). In order also to focus on variance in time, we eliminate unwanted within panel variance by considering daily average rates. In particular, as noted, during the sample period January 2004 to December 2012, bank B hardly sold 10-year mortgages in parts of the years 2009-2010. Market concentration in 10-year mortgages is somewhat larger than average, which may have left stronger fringe competition to mitigate the effects of the price leadership bans. The HHI was .08 and .11 on average before and after March 1th 2009.

For bank A, regressing model (9) on 10-year maturity daily averages establishes a structural break on February 28th 2009 ($F = 312.4729$), after which S_l decreases from 2.116*** (.040) by 1.300*** (.073). This indicates weak fringe competition. The Panzar-Rosse test breaks earlier, November 25th 2008, with the H-statistic decreasing from 1.167*** (.044) by .869*** (.053).

For the followers, Table 7.7 present the results of the interest response estimation of model (11), dropping j, m.[55]

PLACE TABLE HERE

Table 7.7: Interest best-response results follower banks' to bank A's rate and costs, 10-years daily average

All follower banks except bank H change structurally to responding much stronger to the rate of bank A in the period early January to end of May 2009. The estimates of $B_{f,1}$ are positive, significantly different from zero and substantially larger for all banks under a ban in 10-year maturity than across all contracts. In particular is bank B's following behavior strongly affected in this product, in which it rivalled directly with bank A. The responsiveness of most follower banks to bank A's interest rate close to tripled. For all banks in the sample (except H), the coefficients $\beta_{f,1}$ are small in competition and increase to close to one, in accordance with the theory. The common cost shock responses are again large in absolute value, but all decreasing roughly according to theory. Bank H again behaves independently without constituting much as competitive threat.[56]

Estimation results for the short-run adjustment to equilibrium in the 10-year maturity specification of model (12) are given in Table 7.8.

PLACE TABLE HERE

Table 7.8: Response adjustment results follower banks' rate to bank A's rate and costs, 10-years daily average

[55] For the full table of regression results, see Appendix H.

[56] Repeating the 10-year maturity type estimations with individual mortgages as the unit of measurement gave comparable results, which are somewhat in between those presented in Table 7.2 (all mortgage types, individual observations) and Table 7.7 (10-year maturity, daily average rates). Except does bank B's responsiveness to bank A's rate no longer increase significantly different from zero, which may again be explained by bank B in the after period moving out of 10-year mortgages and into variable mortgages instead, which bank A did not sell.

Table 7.7: Interest best-response results follower banks' to bank A's rate and costs, 10-years daily average

	$r_{B,t}$	$r_{C,t}$	$r_{D,t}$	$r_{E,t}$	$r_{F,t}$	$r_{G,t}$	$r_{H,t}$
response time	3	1	3	3	5	2	5
break date	13-01-09	26-01-09	04-03-09	24-2-09	27-05-09	06-01-09	14-01-08
	(31.514)	(27.858)	(61.707)	(72.984)	(70.824)	(17.182)	(18.439)
$r_{A,t-\tau}$ ($\beta_{f,1}$)	.385***	.386***	.422***	.245***	.238***	.278***	.260***
	(.045)	(.060)	(.041)	(.038)	(.028)	(.061)	(.033)
$r_{A,t-\tau} \times D_{f,t}^{PLB}$	.187***	.418***	.585***	.629***	.633***	.529***	−.224**
	(.110)	(.069)	(.058)	(.058)	(.059)	(.074)	(.144)
$\mathbf{C}_t$ (σ_f^d)	1.109***	1.295***	1.518***	1.373***	1.575***	1.757***	1.228***
	(.142)	(.158)	(.102)	(.095)	(.075)	(.156)	(.328)
$\mathbf{C}_t \times D_{f,t}^{PLB}$	−1.615***	−1.616***	−1.569***	−1.502***	−1.043***	−1.594***	−.786
	(.278)	(.170)	(.119)	(.128)	(.141)	(.177)	(.448)
HHI	.018***	−.009**	.015***	.030***	.006***	−.009***	.038***
	(.004)	(.004)	(.003)	(.003)	(.002)	(.003)	(.004)
$HHI \times D_{f,t}^{PLB}$	−.038***	−.024***	−.033***	−.053***	−.025***	−.006	−.042***
	(.006)	(.005)	(.004)	(.004)	(.003)	(.004)	(.008)
N	1657	1957	2205	2162	2217	2125	1626
R^2	.8020	.8157	.8723	.8763	.8742	.7448	.5003

Notes: Break date with F-statistic. Robust standard errors in parentheses; *,** ,*** indicating significance at the 10, 5 and 1% level respectively.

Table 7.9: Response adjustment results follower banks' rate to bank A's rate and costs, 10-years daily average

	$\Delta r_{B,t}$	$\Delta r_{C,t}$	$\Delta r_{D,t}$	$\Delta r_{E,t}$	$\Delta r_{F,t}$	$\Delta r_{G,t}$	$\Delta r_{H,t}$
response time	3	1	3	3	5	2	5
break date	13-01-09	26-01-09	04-03-09	24-02-09	27-05-09	06-01-09	14-01-08
$\Delta r_{A,t-\tau}$ ($\gamma_{f,1}$)	.146***	.273***	.180***	.131***	.133***	.137*	.124***
	(.037)	(.064)	(.035)	(.029)	(.028)	(.073)	(.039)
$\Delta r_{A,t-\tau} \times D^{PLB}_{f,t}$	.114**	.064	.287***	.302***	.423***	.168*	−.436
	(.078)	(.080)	(.066)	(.063)	(.087)	(.110)	(.226)
$\epsilon_{f,t-5}$ (θ_f)	−.790***	−.870***	−.753***	−.699***	−.819***	−.899***	−.922***
	(.038)	(.033)	(.029)	(.034)	(.033)	(.032)	(.071)
$\Delta \mathbf{C}_t$ (combined)	.266	.521	.441*	.394*	.694**	.880***	.801
	(.447)	(.480)	(.271)	(.207)	(.276)	(.264)	(.493)
$\Delta \mathbf{C}_t \times D^{PLB}_{f,t}$	−.208	−.658	−.499	−.337	−.739*	−1.262***	−1.050
	(.765)	(.493)	(.324)	(.294)	(.372)	(.403)	(.965)
other controls	ΔHHI	ΔHHI	ΔHHI	ΔHHI	ΔHHI	ΔHHI	ΔHHI
N	1472	1724	2125	2056	2168	1980	1335
R^2	.3988	.4521	.3921	.3592	.4151	.3602	.4584

Notes: Robust standard errors in parentheses; *,**,*** indicating significance at the 10, 5 and 1% level respectively.

Whereas all followers respond weakly to bank A's rate before in competition, the price leader is followed several times more closely after imposition of the price leadership bans. The increase in $\gamma_{f,1}$ is significant. The estimates of θ_f suggest a swift return to equilibrium within a week or two. Obviously the regression results on 10-year mortgages alone have less power than those for all maturities (Table 7.2), since the number of observations in each regression is now only some ten percent. The parameter changes are, however, even more pronounced in support of the theory. Also the H-statistics for the follower banks decrease significantly for the 10-year maturity mortgages, from the $.9 - 1$ (competition) to $.0 - .6$ (monopoly) range.[57]

In the 10-years maturity estimated in isolation, but-for rates are lower (2.77 to 3.46) and overcharges substantially higher (134 to 200 basis points, 28 to 42 percent) than in the baseline model, which is consistent with the concern that but-for estimations for longer term fixed-rate contracts should be corrected for refinancing risks as perceived and priced in at the time, or the overcharges may be overestimated by a materialized risk reward.

8 Concluding Remarks

We find significant evidence that price leadership bans imposed by the European Commission on all main mortgage providers but the price leader in the Spring of 2009 shifted the market from a competitive to a collusive barometric price leadership equilibrium. Before the bans, Rabobank would set its rate close to funding costs under the competitive pressure of its main rivals undercutting. After the bans, all providers but an insignificant free fringe followed the lead rate of Rabobank closely up, while funding costs ceased to be important.

The empirical findings are all consistent, both in sign and magnitude, with the model equilibrium predictions for a change from imperfect competition to full coordination. The baseline specification is a fitting calibration. Not rising risk premiums funding cost, but stalled banking competition explains the sudden high mortgage rates in the Low Countries. Withdrawal from the market of several foreign challengers only had a fringe effect. Instead it was the price leadership bans that locked the market. Indicative estimates of but-for mortgage rates and overcharges are substantial and fitting to the model.

The must-follow price leader role of Rabobank may also explain the brief period of low margins during the NMa's initial investigation. By not following up with its mortgage rates the rising funding costs at the time, Rabobank could force reduced margins, even losses, on all banks banned from pricing above it. Interestingly, only the margins on mortgages with a variable mortgage rate, which is the only mortgage type that Rabobank did not carry, remained high during the 'NMa study-dip'.

All structural breaks in pricing behavior are estimated robustly around the Spring

[57] See Appendix I.

of 2009, when the price leadership bans were negotiated—and almost a year after the fall of Lehman Brothers. We note that the bans were not strictly legally binding until after the formal decisions were published, in November 2009 and early 2010. During the preceding months, undercutting would not yet have been directly punishable as a State aid violation.[58] Such a time lapse is normal, however, for internal processing and signing of a formal Commission decision. The aided banks would not have wanted to poach Rabobank's market share aggressively during it, since this was exactly the Commission's concern and doing so would likely have further tightened restructuring and divestiture requirements. The price leadership bans had been anticipated, lobbied for in fact, and the commitment was policed by the Ministry of Finance. Rabobank may even have threatened no longer to lead if its rate were not immediately followed upwards, which would have exposed the banks under a ban to the risk of unintentionally violating their State aid conditions.[59]

Remarkably, also after the bans were (partially and sequentially) lifted, several years later, did mortgage rates in the Netherlands stay relatively high compared to other EMU countries.[60] Tighter regulation and stricter market access requirements from the Dutch Central Bank in response to the crisis created a significant barrier to entry.[61] The incumbents may well have been able to maintain a level of coordination in the mean time, as unprecedented low interest rate levels (effectively zero for financial institutions) imply discount factors above a critical level for sustainability of collusion. In fact, as the steep policy rate fall happened simultaneously, the price leadership bans may have simply been a cartel catalyst.[62] The surplus margins on mortgages in Figure 2 however did fade from the Summer of 2015, when entry started to occur.

[58]NMa (2011) and ACM (2013) dismissed the bans as a possible explanation for the mortgage rates rise on the argument that the price rise occured before the State aid decisions were formally given. Remarkably, in October 2009 the NMa had warned the Commission that the concentrated Dutch market would be "locked" with a price ban for ING, and later possibly also ABN AMRO. See Dijkstra *et al.* (2014) for a detailed account.

[59]Theoretically it is possible that Rabobank would have been better off in a simultaneous move uninformed equilibrium, in which the other banks were handicapped by the price leadership bans. The bans would then have forced Rabobank's competitors to price precautiously high, in order to avoid undercutting any of their rivals in equilibrium—in breach of their bans. Rabobank would set a high price, pushing up its followers' prices. Its unlikely however that Rabobank would have benefited from giving up its superior market research department. Moreover, all tests indicate that bank A remained in the lead throughout. See Section 6.

[60]AEGON's ban was no longer under a ban from June 15th 2011, when it had repaid the aid. ING's price leadership ban was lifted for the Netherlands in a revised Commission Decision of 16 November 2012, State Aid SA.33305 (2012/C) and SA.29832 (2012/C) implemented by Netherlands for ING, recital 112. For SNS REAAL coming under a ban remained a possibility until end of 2013. ABN AMRO was under bans until April 2014.

[61]See KPMG Financial Services, *Barriers to entry, growth and exit in the retail banking market in the Netherlands*, June 2014. The study was commissioned and subscribed to by ACM.

[62]In a formal analysis of cartel stability conditions, the critical discount factor to surpass is highly dependent on the punishment strategy, on which we have no information. In Rotemberg and Saloner (1990), Nash reversion is to simultaneous price setting, which however is not obvious in our setting.

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A Solutions to the Model

In Section $A1.1$, the competitive equilibrium with $n-1$ followers is characterized. In Subsection $A1.1.1$, the model is first fully solved for all followers being identical. In Subsection $A1.1.2$, the best-response functions for the case of heterogenous follower banks that are used in the main text are derived by analogy. Section $A1.3$ identifies the conditions under which the leader-follower roles are stable in equilibrium. Section $A1.4$ characterizes the equilibrium with a price-leadership ban.

A.1 Competitive Equilibrium

Without loss of generality, let $l = 1$ with costs c_l, and let each follower have its own individual costs c_i, for $i = 2, ..., n$, which are common knowledge. Let $\mathbf{c}_{i \neq l} = (c_2, ..., c_n)$. The profits of firm i with type $t = \{l, f\}$ are

$$\pi_i = (r_i - c_i)\, V \left(a_t - br_i + d \left(\frac{1}{n} \sum_{j=1}^{n} r_j - r_i \right) \right),$$

in which the value of $a_l = a + e$ is known to the leader, who invested in obtaining this information, but the followers can only form expectations about their $a_f = a - e$. V is the monetary value of the mortgage type, depending on the interest and the financed sum and the length of the fixed interest rate-period (maturity). Without loss of generality, we set $V = 1$.

The leader sets it price optimally first at r_l^*, to be analyzed later. Since apart from the value of a en e, the games is common knowledge, the followers can extract the value of $a + e$ from observing r_l^* and (knowing $\overline{a}$) form conditional expectations

$$E[a - \overline{a} | a - \overline{a} + e] = \frac{(a - \overline{a} + e)\sigma_a^2}{\sigma_a^2 + \sigma_e^2} \text{ and } E[e | a - \overline{a} + e] = \frac{(a - \overline{a} + e)\sigma_e^2}{\sigma_a^2 + \sigma_e^2},$$

from which follows that their

$$\begin{aligned} E\left[a_f | a + e\right] &= E\left[a - e | a - \overline{a} + e\right] = E\left[a | a - \overline{a} + e\right] - E\left[e | a - \overline{a} + e\right] \\ &= E[a - \overline{a} | a - \overline{a} + e] + \overline{a} - E[e | a - \overline{a} + e] \\ &= \overline{a} + (a - \overline{a} + e)s \text{ in which } s = \frac{\sigma_a^2 - \sigma_e^2}{\sigma_a^2 + \sigma_e^2}. \end{aligned}$$

As it turns out, the equilibrium price of the leader is linear in the following components

$$r_l^* = \frac{a+e}{A} - \frac{B}{A} f\left(\mathbf{c}_{i\neq l}\right) - \frac{C}{A} c_l - \frac{D}{A}, \tag{13}$$

in which $f\left(\mathbf{c}_{i\neq l}\right)$ is a function and A, B, C and D are constants made precise below. Hence, the followers can distill that

$$a - \overline{a} + e = Ar_l^* + Bf\left(\mathbf{c}_{i\neq l}\right) + Cc_l + D - \overline{a}$$

and the signal r_l^* is interpreted as

$$\begin{aligned} E\left[a_f | a+e\right] &= \overline{a} + (a - \overline{a} + e)s \\ &= \overline{a} + \left(Ar_l^* + Bf\left(\mathbf{c}_{i\neq l}\right) + Cc_l + D - \overline{a}\right)s. \end{aligned}$$

Then

$$\begin{aligned} E\left[a_f | a+e\right] &= \left(Ar_l^* + Bf\left(\mathbf{c}_{i\neq l}\right) + Cc_l\right)s + (1-s)\,\overline{a} + Ds \\ &= Asr_l^* + Bsf\left(\mathbf{c}_{i\neq l}\right) + Csc_l + E \text{ in which } E = (1-s)\,\overline{a} + Ds. \end{aligned}$$

Given this expectation, the followers move simultaneously after bank l, so we first consider the equilibrium prices between the followers for any value of r_l. Follower $i \neq l$ maximizes expected profits, after observing r_l, that is

$$\max_{r_{i\neq l}} E\left[\pi_{i\neq l}\right] = \left(r_{i\neq l} - c_{i\neq l}\right)\left(Asr_l + Bsf\left(\mathbf{c}_{i\neq l}\right) + Csc_l + E - br_{i\neq l} + d\left(\frac{1}{n}\sum_{j=1}^{n} r_j - r_{i\neq l}\right)\right).$$

This provides $n-1$ first-order conditions, one for each follower $i \neq l$:

$$\frac{d\pi_{i\neq l}}{dr_{i\neq l}} = Asr_l + Bsf\left(\mathbf{c}_{i\neq l}\right) + Csc_l + E - 2br_{i\neq l} + \frac{d}{n}\left(\sum_{j=1}^{n} r_j + r_{i\neq l}\right) - 2dr_{i\neq l} + c_{i\neq l}\left(b + \frac{n-1}{n}d\right) = 0. \tag{14}$$

which solve as a subgame perfect equilibrium amongst the followers.

A.1.1 Symmetric Followers

In case all followers have the same costs c_f, $f(\mathbf{c}_{i\neq l}) = c_f$ and the followers subgame has a symmetric equilibrium at price r_f. The system (14) simplifies to

$$Asr_l + Bsc_f + Csc_l + E - 2br_f + \frac{d}{n}\left(\sum_{i=1}^{n} r_j + r_f\right) - 2dr_f + c_f\left(b + \frac{n-1}{n}d\right) = 0 \tag{15}$$

or, since by switching the isolated r_f with r_l in the summation

$$\frac{1}{n}\left(\sum_{i=1}^{n} r_j + r_f\right) = \frac{1}{n}nr_f + \frac{1}{n}r_l = r_f + \frac{r_l}{n},$$

$$E - (2b+d)\,r_f + \left(\frac{d}{n} + As\right)r_l + c_f\left(b + \frac{n-1}{n}d + Bs\right) + Csc_l = 0.$$

This solves as

$$r_f^* = \frac{E + \left(\frac{d}{n} + As\right)r_l + c_f\left(b + \frac{n-1}{n}d + Bs\right) + Csc_l}{2b+d}. \tag{16}$$

The leader bank l sets its rate r_l, knowing the values of a and e, and taking the followers equilibrium responses into account, that is by maximizing profit

$$\begin{aligned}\pi_l &= (r_l - c_l)\left(a + e - br_l + d\left(\frac{n-1}{n}r_f + \frac{1-n}{n}r_l\right)\right) = \frac{r_l - c_l}{n}\left((a+e)\,n + (n-1)\,dr_f + (d - (b+d)\,n)\,r_l\right)\\ &= (r_l - c_l)\left(a + e - br_l + d\left(\frac{n-1}{n}\left(\frac{E + \left(\frac{d}{n} + As\right)r_l + c_f\left(b + \frac{n-1}{n}d + Bs\right) + Csc_l}{2b+d}\right) + \frac{1-n}{n}r_l\right)\right),\end{aligned}$$

to r_l. From setting the derivative

$$\begin{aligned}\frac{d\pi_l}{dr_l} &= a + e - 2br_l + d\left(\frac{n-1}{n}\left(\frac{E + 2\left(\frac{d}{n} + As\right)r_l + c_f\left(b + \frac{n-1}{n}d + Bs\right) + Csc_l}{2b+d}\right) + 2\frac{1-n}{n}r_l\right)\\ &\quad + c_l b - c_l d\frac{(n-1)\left(\frac{d}{n} + As\right)}{n\,(2b+d)} - c_l d\frac{1-n}{n}\end{aligned} \tag{17}$$

equal to zero follows

$$\begin{aligned} r_l^* = {} & (a+e)\frac{n^2(2b+d)}{2(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn)} \\ & +\frac{dn(n-1)E}{2(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn)} \\ & +\frac{2b^2n^2-2d^2n+d^2n^2+d^2+3bdn^2-2bdn-Adn^2s+Cdn^2s+Adns-Cdns}{2(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn)}c_l \\ & +\frac{d(n-1)(bn-d+dn+Bns)}{2(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn)}c_f. \end{aligned} \tag{18}$$

As alluded to, the structure of the leader's best-response function is indeed the linear form (13) which identified conditional expectations. Therefore, implicit definitions of A, B, C and D are obtained from equating (18) and (13) as:

$$\begin{aligned} A &= \frac{2(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn)}{n^2(2b+d)} \\ B &= -\frac{d(n-1)(bn-d+dn+Bns)A}{2(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn)} \\ C &= -\frac{(2b^2n^2-2d^2n+d^2n^2+d^2+3bdn^2-2bdn-Adn^2s+Cdn^2s+Adns-Cdns)A}{2(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn)} \\ D &= -\frac{dn(n-1)EA}{2(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn)} \end{aligned}$$

These solve, using the definition $E = (1-s)\,\overline{a} + Ds$, as:

$$\begin{aligned}
A &= \frac{-4d^2n + 4b^2n^2 + 2d^2n^2 + 2d^2 + 6bdn^2 - 4bdn}{2bn^2 + dn^2 + 2dn^2s - 2dns} \\
B &= -\frac{-2d^2n + d^2n^2 + d^2 + bdn^2 - bdn}{2bn^2 + dn^2 + dn^2s - dns} = -\frac{(n-1)\,((n-1)\,d + bn)\,d}{n\,(2bn + dn - ds + dns)} \\
C &= -\frac{(2b+d)\left(-2d^2n + 2b^2n^2 + d^2n^2 + d^2 + 3bdn^2 - 2bdn\right)}{(2bn + dn - ds + dns)\,(2bn + dn - 2ds + 2dns)} \\
D &= \frac{\overline{a}\,(d - dn - ds + dns)}{2bn + dn - ds + dns} = \frac{\overline{a}d\,(1-n)\,(1-s)}{(2b+d)\,n - d\,(1-n)\,s} \\
E &= \frac{(2b+d)\,(1-s)\,\overline{a}n}{2bn + dn - ds + dns}
\end{aligned} \tag{19}$$

These allow for making the best-response function explicit as

$$\begin{aligned}
r_f^* &= \frac{\frac{(2b+d)(1-s)\overline{a}n}{2bn+dn-ds+dns} + \left(\frac{d}{n} + \frac{-4d^2n+4b^2n^2+2d^2n^2+2d^2+6bdn^2-4bdn}{2bn^2+dn^2+2dn^2s-2dns}s\right)r_l + c_f\left(b + \frac{n-1}{n}d - \frac{-2d^2n+d^2n^2+d^2+bdn^2-bdn}{2bn^2+dn^2+dn^2s-dns}s\right)}{2b+d} \\
&\quad - \frac{\frac{(2b+d)\left(-2d^2n+2b^2n^2+d^2n^2+d^2+3bdn^2-2bdn\right)}{(2bn+dn-ds+dns)(2bn+dn-2ds+2dns)}sc_l}{2b+d},
\end{aligned}$$

which beautifies into

$$r_f^* = \frac{n\overline{a}\,(1-s)}{(2b+d)\,n + d\,(n-1)\,s} + \frac{d + (2bn + 2d\,(n-1))\,s}{(2b+d)\,n + 2d\,(n-1)\,s}r_l + \frac{bn + (n-1)\,d}{(2b+d)\,n + d\,(n-1)\,s}c_f - \frac{\left(2b^2n^2 + 3bdn^2 - 2bdn + d^2n^2 - 2d^2n + d^2\right)s}{((2b+d)\,n + d\,(n-1)\,s)\,((2b+d)\,n + 2d\,(n-1)\,s)}c_l. \tag{20}$$

Then

$$r_l^* = \frac{(a+e)\,n^2\,(2b+d) + dn\,(n-1)\,E + \left(2b^2n^2 - 2d^2n + d^2n^2 + d^2 + 3bdn^2 - 2bdn - Adn^2s + Cdn^2s + Adns - Cdns\right)c_l + d\,(n-1)\,(bn - d + dn + Bns)\,c_f}{2\left(2b^2n^2 + 3bdn^2 - 2bdn + d^2n^2 - 2d^2n + d^2 - Asdn^2 + Asdn\right)},$$

from which it follows that

$$r_l^* = \frac{n\,(2bn + dn + 2dns - 2ds)}{4b^2n^2 + 6bdn^2 - 4bdn + 2d^2n^2 - 4d^2n + 2d^2}\left(a + e - \frac{\overline{a}d\,(n-1)\,(s-1)}{2bn + dn - ds + dns} + \frac{(2b+d)\left(4b^2n^2 + 6bdn^2 - 4bdn + 2d^2n^2 - 4d^2n + 2d^2\right)}{2\,(2bn + dn - ds + dns)\,(2bn + dn - 2ds + 2dns)}c_l + \frac{d\,(n-1)\,(bn + d\,(n-1))}{2bn^2 + dn^2 + dn^2s - dns}c_f\right). \tag{21}$$

The combination (21) and (20) with $r_l = r_l^*$ in (20) indeed satisfies the two first-order conditions (15) plus (17), and so $\left(r_l^*, r_f^*\right)$ constitute the unique Nash equilibrium of this game.

A.1.2 Asymmetric Followers

In case each follower have its own individual costs c_i, for $i = 2, ..., n$, the followers subgame is asymmetric and the solution of $n-1$ equations, for each $i \neq l$, the first order condition is:

$$Asr_l + Bsf\left(\mathbf{c}_{i\neq l}\right) + Csc_l + E - 2br_{i\neq l} + \frac{d}{n}\left(\sum_{j=1}^{n} r_j + r_{i\neq l}\right) - 2dr_{i\neq l} + c_{i\neq l}\left(b + \frac{n-1}{n}d\right) = 0,$$

so that

$$r_{i\neq l} = \frac{Asr_l + E + \left(b + \frac{n-1}{n}d\right) c_{i\neq l} + Bsf\left(\mathbf{c}_{i\neq l}\right) + Csc_l + \frac{d}{n}\sum_{j\neq i}^{n} r_j}{2\left(b + \frac{n-1}{n}d\right)},$$

which can be rewritten as

$$2\left(b + \frac{n-1}{n}d\right) r_{i\neq l} - \frac{d}{n}\sum_{j\neq i\neq l}^{n} r_j = E + \left(\frac{d}{n} + As\right) r_l + Csc_l + \left(b + \frac{n-1}{n}d\right) c_{i\neq l} + Bsf\left(\mathbf{c}_{i\neq l}\right) \text{ for } i = 2, ..., n$$

in which $\sum_{j\neq i\neq l}^{n} r_j$ is the sum of all mortgage rates except that of bank l and follower bank i considered.

We can write this system of $n-1$ first-order conditions in matrix notation as

$$\begin{bmatrix} 2\left(b+\frac{n-1}{n}d\right) & -\frac{d}{n} & -\frac{d}{n} & -\frac{d}{n} & -\frac{d}{n} \\ -\frac{d}{n} & 2\left(b+\frac{n-1}{n}d\right) & -\frac{d}{n} & -\frac{d}{n} & -\frac{d}{n} \\ -\frac{d}{n} & -\frac{d}{n} & \dots & -\frac{d}{n} & -\frac{d}{n} \\ -\frac{d}{n} & -\frac{d}{n} & -\frac{d}{n} & 2\left(b+\frac{n-1}{n}d\right) & -\frac{d}{n} \\ -\frac{d}{n} & -\frac{d}{n} & -\frac{d}{n} & -\frac{d}{n} & 2\left(b+\frac{n-1}{n}d\right) \end{bmatrix} \begin{bmatrix} r_2 \\ r_3 \\ \dots \\ r_{n-1} \\ r_n \end{bmatrix} = \begin{bmatrix} E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_2 + Bsf\left(\mathbf{c}_{i\neq l}\right) \\ E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_3 + Bsf\left(\mathbf{c}_{i\neq l}\right) \\ \dots \\ E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_{n-1} + Bsf\left(\mathbf{c}_{i\neq l}\right) \\ E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_n + Bsf\left(\mathbf{c}_{i\neq l}\right) \end{bmatrix}.$$

So

$$\begin{bmatrix} r_2^* \\ r_3^* \\ \dots \\ r_{n-1}^* \\ r_n^* \end{bmatrix} = \begin{bmatrix} 2\left(b+\frac{n-1}{n}d\right) & -\frac{d}{n} & -\frac{d}{n} & -\frac{d}{n} & -\frac{d}{n} \\ -\frac{d}{n} & 2\left(b+\frac{n-1}{n}d\right) & -\frac{d}{n} & -\frac{d}{n} & -\frac{d}{n} \\ -\frac{d}{n} & -\frac{d}{n} & \dots & -\frac{d}{n} & -\frac{d}{n} \\ -\frac{d}{n} & -\frac{d}{n} & -\frac{d}{n} & 2\left(b+\frac{n-1}{n}d\right) & -\frac{d}{n} \\ -\frac{d}{n} & -\frac{d}{n} & -\frac{d}{n} & -\frac{d}{n} & 2\left(b+\frac{n-1}{n}d\right) \end{bmatrix}^{-1} \begin{bmatrix} E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_2 + Bsf\left(\mathbf{c}_{i\neq l}\right) \\ E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_3 + Bsf\left(\mathbf{c}_{i\neq l}\right) \\ \dots \\ E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_{n-1} + Bsf\left(\mathbf{c}_{i\neq l}\right) \\ E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_n + Bsf\left(\mathbf{c}_{i\neq l}\right) \end{bmatrix}$$

$$= \frac{1}{(2b+d)(2bn-d+2dn)} \begin{bmatrix} d+2bn+dn & d & d & d & d \\ d & d+2bn+dn & d & d & d \\ d & d & \dots & d & d \\ d & d & d & d+2bn+dn & d \\ d & d & d & d & d+2bn+dn \end{bmatrix} \begin{bmatrix} E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_2 + Bsf\left(\mathbf{c}_{i\neq l}\right) \\ E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_3 + Bsf\left(\mathbf{c}_{i\neq l}\right) \\ \dots \\ E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_{n-1} + Bsf\left(\mathbf{c}_{i\neq l}\right) \\ E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_n + Bsf\left(\mathbf{c}_{i\neq l}\right) \end{bmatrix}.$$

Hence, for example

$$r_2^* = \frac{(d+2bn+dn)\left(E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_2 + Bsf\left(\mathbf{c}_{i\neq l}\right)\right) + d\left(E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_3 + Bsf\left(\mathbf{c}_{i\neq l}\right) + \dots\right)}{(2b+d)(2bn-d+2dn)},$$

which generalizes by analogy to the symmetric case to

$$r_{i\neq l}^* = \frac{(d+2bn+dn)\left(E + \left(\frac{d}{n}+As\right) r_l + Csc_l\right) + (d+2bn+dn)\left(b+\frac{n-1}{n}d\right) c_{i\neq l} + (d+2bn+dn)\, Bsf\left(\mathbf{c}_{i\neq l}\right) + d\,(n-2)\, Bsf\left(\mathbf{c}_{i\neq l}\right) + d\sum_{k\neq i\neq l}^{n}\left(E + \left(\frac{d}{n}+As\right) r_l + Csc_l + \left(b+\frac{n-1}{n}d\right) c_k\right)}{(2b+d)(2bn-d+2dn)},$$

which, since

$$\sum_{k\neq i\neq l}^{n}\left(E+\left(\frac{d}{n}+As\right)r_l+Csc_l+\left(b+\frac{n-1}{n}d\right)c_k\right)=(n-2)\left(E+\left(\frac{d}{n}+As\right)r_l+Csc_l\right)+\left(b+\frac{n-1}{n}d\right)\sum_{k\neq i\neq l}^{n}c_k,$$

and

$$(d+2bn+dn)\,Bsf\left(\mathbf{c}_{i\neq l}\right)+d\,(n-2)\,Bsf\left(\mathbf{c}_{i\neq l}\right)=(2bn-d+2dn)\,Bsf\left(\mathbf{c}_{i\neq l}\right)$$

can be written as

$$\begin{aligned} r^*_{i\neq l} &= \frac{(2bn+2dn-d)\left(E+\left(\frac{d}{n}+As\right)r_l+Csc_l\right)+(d+2bn+dn)\left(b+\frac{n-1}{n}d\right)c_{i\neq l}+(2bn-d+2dn)\,Bsf\left(\mathbf{c}_{i\neq l}\right)+d\left(b+\frac{n-1}{n}d\right)\sum_{k\neq i\neq l}^{n}c_k}{(2b+d)\,(2bn-d+2dn)} \\ &= \frac{E+\left(\frac{d}{n}+As\right)r_l+Csc_l+\frac{b+\frac{n-1}{n}d}{2bn-d+2dn}\left((d+2bn+dn)\,c_{i\neq l}+d\sum_{k\neq i\neq l}^{n}c_k\right)+Bsf\left(\mathbf{c}_{i\neq l}\right)}{2b+d} \end{aligned} \qquad (22)$$

Note indeed that if all followers have the same costs $c_f=f\left(\mathbf{c}_{i\neq l}\right)$ we get (16):

$$r^*_{i\neq l}=\frac{E+\left(\frac{d}{n}+As\right)r_l+Csc_l+\left(b+\frac{n-1}{n}d+Bs\right)c_f}{2b+d}=r^*_f.$$

Next, to find the constant values A, B, C, D and E, consider that leader bank l sets its rate r_l, knowing the values of a and e, and taking the followers equilibrium responses into account—that is by maximizing profit

$$\begin{aligned} \pi_l &= (r_l-c_l)\left(a+e-br_l+d\left(\frac{1}{n}\sum_{j\neq l}^{n}r_j+\frac{1-n}{n}r_l\right)\right) \\ &= (r_l-c_l)\left(a+e+\left(\frac{1-n}{n}d-b\right)r_l+\frac{d}{n}\sum_{j\neq l}^{n}\frac{E+\left(\frac{d}{n}+As\right)r_l+Csc_l+\frac{b+\frac{n-1}{n}d}{2bn-d+2dn}\left((d+2bn+dn)\,c_{j\neq l}+d\sum_{k\neq j\neq l}^{n}c_k\right)+Bsf\left(\mathbf{c}_{i\neq l}\right)}{2b+d}\right) \\ &= (r_l-c_l)\left(a+e-\left(b-d\frac{1-n}{n}-d\frac{n-1}{n}\frac{\left(\frac{d}{n}+As\right)}{2b+d}\right)r_l+d\frac{n-1}{n}\frac{E}{2b+d}+d\frac{n-1}{n}\frac{Cs}{2b+d}c_l+d\frac{n-1}{n}\frac{Bsf\left(\mathbf{c}_{i\neq l}\right)}{2b+d}+\frac{d\,(bn-d+dn)}{n^2\,(2b+d)\,(2bn-d+2dn)}\sum_{j\neq l}^{n}\left((d+2bn+dn)\,c_j+d\sum_{k\neq j\neq l}^{n}c_k\right)\right) \end{aligned}$$

which again reduces to the symmetric case for all followers' costs equal to c_f.

Setting the derivative

$$\begin{aligned} \frac{d\pi_l}{dr_l} &= a+e-2\left(b-d\frac{1-n}{n}-d\frac{n-1}{n}\frac{\left(\frac{d}{n}+As\right)}{2b+d}\right)r_l+d\frac{n-1}{n}\frac{E}{2b+d}+d\frac{n-1}{n}\frac{Bsf\left(\mathbf{c}_{i\neq l}\right)}{2b+d} \\ &\quad+\frac{d\,(bn-d+dn)}{n^2\,(2b+d)\,(2bn-d+2dn)}\sum_{j\neq l}^{n}\left((d+2bn+dn)\,c_j+d\sum_{k\neq j\neq l}^{n}c_k\right)+c_l\left(d\frac{n-1}{n}\frac{Cs}{2b+d}+b-d\frac{(n-1)\left(\frac{d}{n}+As\right)}{n\,(2b+d)}-d\frac{1-n}{n}\right) \end{aligned}$$

equal to zero obtains

$$\begin{aligned}\left(2b-2d\frac{1-n}{n}-d\frac{n-1}{n}\frac{2\left(\frac{d}{n}+As\right)}{2b+d}\right)r_l &= a+e+d\frac{n-1}{n}\frac{E}{2b+d}+d\frac{n-1}{n}\frac{Bsf\left(\mathbf{c}_{i\neq l}\right)}{2b+d}\\ &+c_l\left(d\frac{n-1}{n2}\frac{Cs}{2b+d}+b-d\frac{(n-1)\left(\frac{d}{n}+As\right)}{n\left(2b+d\right)}-d\frac{1-n}{n}\right)\\ &+\frac{d\left(bn-d+dn\right)}{n^2\left(2b+d\right)\left(2bn-d+2dn\right)}\sum_{j\neq l}^{n}\left(\left(d+2bn+dn\right)c_j+d\sum_{k\neq j\neq l}^{n}c_k\right)\end{aligned}$$

so that

$$\begin{aligned}r_l^* &= (a+e)\frac{n^2\left(2b+d\right)}{2\left(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn\right)}+\frac{dn\left(n-1\right)E}{2\left(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn\right)}\\ &+\frac{dn\left(n-1\right)Bsf\left(\mathbf{c}_{i\neq l}\right)}{2\left(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn\right)}+\frac{2b^2n^2-2d^2n+d^2n^2+d^2+3bdn^2-2bdn-Adn^2s+Cdn^2s+Adns-Cdns}{2\left(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn\right)}c_l\\ &+\frac{d\left(bn-d+dn\right)}{2\left(2bn-d+2dn\right)\left(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn\right)}\sum_{j\neq l}^{n}\left(\left(d+2bn+dn\right)c_j+d\sum_{k\neq j\neq l}^{n}c_k\right)\end{aligned} \tag{23}$$

which is the same equilibrium structure and identical to (18) if all followers operated under c_f.

Note that

$$\begin{aligned}\sum_{j\neq l}^{n}\left(\left(d+2bn+dn\right)c_j+d\sum_{k\neq j\neq l}^{n}c_k\right) &= \left(d+2bn+dn\right)\sum_{j\neq l}^{n}c_j+d\sum_{j\neq l}^{n}\left(j-2\right)c_j\\ &= \sum_{j\neq l}^{n}\left(\left(d+2bn+dn\right)c_j+d\left(j-2\right)c_j\right)\\ &= \sum_{j\neq l}^{n}\left(2bn+dn+\left(j-1\right)d\right)c_j,\end{aligned}$$

which makes the case exactly the same as the symmetric case by taking "$j=n$":

$$\sum_{j\neq l}^{n}\left(2bn+dn+\left(j-1\right)d\right)c_f=\left(n-1\right)\left(2bn+dn+\left(n-1\right)d\right)c_f=\left(n-1\right)\left(2bn-d+2dn\right)c_f.$$

Take

$$f\left(\mathbf{c}_{i\neq l}\right)=\frac{\sum_{j\neq l}^{n}\left(2bn+dn+\left(j-1\right)d\right)c_j}{\left(n-1\right)\left(2bn-d+2dn\right)}\ \text{ or }\ \sum_{j\neq l}^{n}\left(2bn+dn+\left(j-1\right)d\right)c_j=\left(n-1\right)\left(2bn-d+2dn\right)f\left(\mathbf{c}_{i\neq l}\right),$$

so that indeed $f\left(\mathbf{c}_{i\neq l}\right)=c_f$ if all banks have the same cost c_f.

$$\begin{aligned}r_l^* &= (a+e)\frac{n^2\left(2b+d\right)}{2\left(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn\right)}+\frac{\left(bn-d+dn+Bns\right)d\left(n-1\right)}{2\left(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn\right)}f\left(\mathbf{c}_{i\neq l}\right)\\ &+\frac{2b^2n^2-2d^2n+d^2n^2+d^2+3bdn^2-2bdn-Adn^2s+Cdn^2s+Adns-Cdns}{2\left(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn\right)}c_l+\frac{dn\left(n-1\right)E}{2\left(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2-Asdn^2+Asdn\right)}\end{aligned}$$

From the structure (13) follow implicit definitions of A, B, C and D that resolve as the same expressions as in (19) for the symmetric case above. Substituting these into (22) obtains

$$
\begin{aligned}
r^*_{i\neq l} &= \frac{\frac{(2b+d)(1-s)\overline{a}n}{2bn+dn-ds+dns} + \left(\frac{d}{n} + \left(\frac{-4d^2n+4b^2n^2+2d^2n^2+2d^2+6bdn^2-4bdn}{2bn^2+dn^2+2dn^2s-2dns}\right)s\right)r_l - \frac{(2b+d)\left(-2d^2n+2b^2n^2+d^2n^2+d^2+3bdn^2-2bdn\right)}{(2bn+dn-ds+dns)(2bn+dn-2ds+2dns)}sc_l}{2b+d} \\
&+ \frac{\frac{b+\frac{n-1}{n}d}{2bn-d+2dn}\left((d+2bn+dn)\,c_{i\neq l} + d\sum_{k\neq i\neq l}^{n} c_k\right) - \frac{-2d^2n+d^2n^2+d^2+bdn^2-bdn}{2bn^2+dn^2+dn^2s-dns}s\frac{\sum_{j\neq l}^{n}\left((d+2bn+dn)c_j + d\sum_{k\neq j\neq l}^{n} c_k\right)}{(n-1)(2bn-d+2dn)}}{2b+d} \\
&= \frac{(1-s)\,n\overline{a}}{2bn+dn-ds+dns} + \frac{d+(2bn+2d\,(n-1))\,s}{(2b+d)\,n+2d\,(n-1)\,s}r_l - \frac{\left(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2\right)s}{(2bn+dn-ds+dns)\,(2bn+dn-2ds+2dns)}c_l \\
&+ \frac{b+\frac{n-1}{n}d}{(2bn-d+2dn)\,(2b+d)}\left((d+2bn+dn)\,c_{i\neq l} + d\sum_{k\neq i\neq l}^{n} c_k - \frac{ds}{2bn+dn-ds+dns}\sum_{j\neq l}^{n}\left((d+2bn+dn)\,c_j + d\sum_{k\neq j\neq l}^{n} c_k\right)\right)
\end{aligned}
\tag{24}
$$

Note that

$$\sum_{j\neq l}^{n}\left((d+2bn+dn)\,c_j + d\sum_{k\neq i\neq l}^{n} c_k\right) = (2n\,(b+d)-d)\left(c_{i\neq l} + \sum_{k\neq i\neq l}^{n} c_k\right)$$

so that the last component in (24) simplifies as follows:

$$
\begin{aligned}
& \frac{b+\frac{n-1}{n}d}{(2bn-d+2dn)\,(2b+d)}\left((d+2bn+dn)\,c_{i\neq l} + d\sum_{k\neq j\neq l}^{n} c_k - \frac{ds}{(2bn+dn-ds+dns)}\sum_{j\neq l}^{n}\left((d+2bn+dn)\,c_j + d\sum_{k\neq j\neq l}^{n} c_k\right)\right) \\
=\; & \frac{b+\frac{n-1}{n}d}{(2bn-d+2dn)\,(2b+d)}\left((d+2bn+dn)\,c_{i\neq l} + d\sum_{k\neq j\neq l}^{n} c_k - \frac{ds}{(2bn+dn-ds+dns)}\left((2n\,(b+d)-d)\left(c_{i\neq l} + \sum_{k\neq i\neq l}^{n} c_k\right)\right)\right) \\
& \frac{b+\frac{n-1}{n}d}{(2bn-d+2dn)\,(2b+d)}\left(\left((d+2bn+dn) - \frac{ds\,(2n\,(b+d)-d)}{(2bn+dn-ds+dns)}\right)c_{i\neq l} + \left(d - \frac{ds\,(2n\,(b+d)-d)}{(2bn+dn-ds+dns)}\right)\sum_{k\neq i\neq l}^{n} c_k\right) \\
=\; & \frac{(bn-d+dn)\,(d+2bn+dn-2ds+dns)}{(2bn-d+2dn)\,(2bn+dn-ds+dns)}c_{i\neq l} + \frac{d\,(1-s)\,(bn-d+dn)}{(2bn-d+2dn)\,(2bn+dn-ds+dns)}\sum_{k\neq i\neq l}^{n} c_k.
\end{aligned}
$$

Replacing this latter part in (24), the full expression given in the main text is obtained:

$$
\begin{aligned}
r^*_{i\neq l} &= \frac{(1-s)\,n\overline{a}}{2bn+dn-ds+dns} + \frac{d+(2bn+2d\,(n-1))\,s}{(2b+d)\,n+2d\,(n-1)\,s}r_l - \frac{(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2)\,s}{(2bn+dn-ds+dns)\,(2bn+dn-2ds+2dns)}c_l \\
&+ \frac{(bn-d+dn)\,(d+2bn+dn-2ds+dns)}{(2bn-d+2dn)\,(2bn+dn-ds+dns)}c_{i\neq l} + \frac{d\,(1-s)\,(bn-d+dn)}{(2bn-d+2dn)\,(2bn+dn-ds+dns)}\sum_{k\neq i\neq l}^{n} c_k,
\end{aligned}
\tag{25}
$$

which again reduces to (20) for the symmetric followers cost c_f case.

From (13) and using that

$$f\left(\mathbf{c}_{i\neq l}\right)=\frac{c_{i\neq l}+\sum_{k\neq i\neq l}^{n}c_k}{n-1}=\frac{\sum_{i\neq l}^{n}c_i}{n-1},$$

we construct

$$\begin{aligned} r_l^* &= \frac{n\left(a+e\right)\left(2bn+dn-2ds+2dns\right)}{4b^2n^2+6bdn^2-4bdn+2d^2n^2-4d^2n+2d^2}-\frac{\bar{a}dn\left(n-1\right)\left(s-1\right)\left(2bn+dn-2ds+2dns\right)}{\left(2bn+dn-ds+dns\right)\left(4b^2n^2+6bdn^2-4bdn+2d^2n^2-4d^2n+2d^2\right)} \\ &\quad +\frac{2bn+dn}{4bn+2dn-2ds+2dns}c_l+\frac{d\left(bn-d+dn\right)\left(2bn+dn-2ds+2dns\right)}{\left(2bn+dn-ds+dns\right)\left(4b^2n^2+6bdn^2-4bdn+2d^2n^2-4d^2n+2d^2\right)}\sum_{i\neq l}^{n}c_i, \end{aligned} \tag{26}$$

which if all followers have the same costs $c_f=f\left(\mathbf{c}_{i\neq l}\right)$ reduces to (21).

Hence, in the Nash equilibrium

$$\begin{aligned} r_{i\neq l}^* &= \frac{\left(1-s\right)n\bar{a}}{2bn+dn-ds+dns}+\frac{d+\left(2bn+2d\left(n-1\right)\right)s}{\left(2b+d\right)n+2d\left(n-1\right)s} \\ &\quad\times\left(\begin{array}{c}\frac{n(a+e)(2bn+dn-2ds+2dns)}{4b^2n^2+6bdn^2-4bdn+2d^2n^2-4d^2n+2d^2}-\frac{\bar{a}dn(n-1)(s-1)(2bn+dn-2ds+2dns)}{(2bn+dn-ds+dns)\left(4b^2n^2+6bdn^2-4bdn+2d^2n^2-4d^2n+2d^2\right)} \\ +\frac{2bn+dn}{4bn+2dn-2ds+2dns}c_l+\frac{d(bn-d+dn)(2bn+dn-2ds+2dns)}{(2bn+dn-ds+dns)\left(4b^2n^2+6bdn^2-4bdn+2d^2n^2-4d^2n+2d^2\right)}\sum_{i\neq l}^{n}c_i\end{array}\right) \\ &\quad -\frac{\left(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2\right)s}{\left(2bn+dn-ds+dns\right)\left(2bn+dn-2ds+2dns\right)}c_l+\frac{\left(bn-d+dn\right)\left(d+2bn+dn-2ds+dns\right)}{\left(2bn-d+2dn\right)\left(2bn+dn-ds+dns\right)}c_{i\neq l} \\ &\quad +\frac{d\left(1-s\right)\left(bn-d+dn\right)}{\left(2bn-d+2dn\right)\left(2bn+dn-ds+dns\right)}\sum_{k\neq i\neq l}^{n}c_k, \end{aligned} \tag{27}$$

so that the parameters of interest are:

$$\begin{aligned}
B_{l,21} &= \frac{2bn+dn}{4bn+2dn-2ds+2dns} \\
B_{l,22} &= \frac{d\,(bn-d+dn)\,(2bn+dn-2ds+2dns)}{(2bn+dn-ds+dns)\,(4b^2n^2+6bdn^2-4bdn+2d^2n^2-4d^2n+2d^2)} \\
B_{i\neq l,1} &= \frac{d+(2bn+2d\,(n-1))\,s}{(2b+d)\,n+2d\,(n-1)\,s} \\
B_{i\neq l,21} &= \frac{((b+d)\,n-d)\,((2b+d)\,n+d\,(n-2)\,s+d)}{(2n\,(b+d)-d)\,((2b+d)\,n+d\,(n-1)\,s)} \\
B_{i\neq l,22} &= -\frac{(2b^2n^2+3bdn^2-2bdn+d^2n^2-2d^2n+d^2)\,s}{(2bn+dn-ds+dns)\,(2bn+dn-2ds+2dns)} \\
B_{i\neq l,23} &= \frac{d\,(n\,(b+d)-d)\,(1-s)}{(2n\,(b+d)-d)\,((2b+d)\,n+d\,(n-1)\,s)}.
\end{aligned}$$

A.2 Fully Coordinated PLB Equilibrium

Fully coordinated monopoly pricing by the leader is an equilibrium if $r^*_{i\neq l}\left(r_l^{PLB}\right) \leq r_l^{PLB}$, which holds for a wide range relevant values of Δc. Since bank l knows that $r_{i\neq l} = r_l$ for all followers, it determines its optimal rate simply by

$$\max_{r_l} \pi_l^{PLB} = (r_l - c_l)(a + e - br_l).$$

From

$$\frac{d\pi_l^{PLB}}{dr_l} = a + e - 2br_l + c_l b = 0$$

it follows that

$$r_l^{PLB} = \frac{a+e}{2b} + \frac{1}{2}c_l = r_{i\neq l}^{PLB} \gg \max\left(r_l^*, r_{i\neq l}^*\right) \text{ for } c < a+e, \text{ for all } i \neq l.$$

The condition that $c < a + e$ is always obviously the case, or the mortgage market does not exist.

B Predictions of the Baseline Specification

The symmetric model is calibrated to some stylized facts about the Dutch mortgage market at the time. Let $e = 0$ and $b = 1$, so that the competitive equilibrium rates are:

$$\begin{aligned}
r_l^* &= \frac{n(2n + dn + 2dns - 2ds)}{4n^2 + 6dn^2 - 4dn + 2d^2n^2 - 4d^2n + 2d^2} \\
&\times \left(a - \frac{ad(n-1)(s-1)}{2n + dn - ds + dns} + \frac{(2+d)\left(4n^2 + 6dn^2 - 4dn + 2d^2n^2 - 4d^2n + 2d^2\right)}{2(2n + dn - ds + dns)(2n + dn - 2ds + 2dns)}c_l + \frac{d(n-1)(n + d(n-1))}{2n^2 + dn^2 + dn^2s - dns}c_f\right) \\
r_f^* &= \frac{na(1-s)}{(2+d)n + d(n-1)s} + \frac{d + (2n + 2d(n-1))s}{(2+d)n + 2d(n-1)s}r_l^* + \frac{n + (n-1)d}{(2+d)n + d(n-1)s}c_f \\
&- \frac{\left(2n^2 + 3dn^2 - 2dn + d^2n^2 - 2d^2n + d^2\right)s}{((2+d)n + d(n-1)s)((2+d)n + 2d(n-1)s)}c_l,
\end{aligned}$$

while

$$r_l^{PLB} = \frac{a}{2} + \frac{1}{2}c_l = r_{i\neq l}^{PLB}.$$

Mortgage rates averaged roughly at 4.5 percent before and 4.75 percent after 1 May 2009, while the funding costs dropped 75 basis point from roughly 4.25 percent. Fixing also $a = \overline{a} = 6$ and $c_l = 3.50$, $r_l^{PLB} = r_{i\neq l}^{PLB} = 4.75$ under a fully coordinating price leadership ban. With further $d = 10$ and $s = .1$ and a somewhat higher funding cost for the followers at $c_f = 4.32$ in the period before, mortgage rates in the competitive price leadership equilibrium for $n = 6$ (the leader plus 5 identical followers) are $r_l^* = 4.50$ and $r_f^* = 4.48$.

In case the bans did not fully coordinate prices and instead the one follower not under a price ban acts as a (representative) free fringe firm, insights can be obtained from the model with $n = 2$. Maintaining $a = \overline{a} = 6$, $d = 10$ and $s = .1$, an average mortgage rate of 4.75 obtains for post-ban costs $c_l = 4.02$, $c_f = 4.80$. Higher costs are required to replicate the observed market rate of 4.75 on average ($r_l^{PLB_f} = 4.65$ and $r_f^{PLB_f} = 4.84$), because the remaining competition allows only slim margins. With weaker competition than the symmetric product differentiation model allows for, funding cost can be lower, and so closer to observed values.

Market share in number of mortgages sold for the follower(s together) for any price combination (r_f, r_f) is

$$s_f = \frac{a - r_f + d\left(\frac{r_l - r_f}{n}\right)}{\left(a - r_l + d\left(\frac{n-1}{n} r_f + \frac{1-n}{n} r_l\right)\right) + \left(a - r_f + d\left(\frac{r_l - r_f}{n}\right)\right)},$$

which is in the competitive regime 10.5% (leader 47%), 10% under a fully coordinating ban (leader 50%) and 9% in the fringe competition model (leader plus the four ban-pegged followers together 81%).

Table B.1 below summarizes the changes in equilibrium values expected from the baseline specification. The upper two parts, first 5 columns, of the table compare the case of competitive leadership (column 'comp') to the fully coordinated regime (column 'PLB'). The 'ban foll.' are the banks under a price leadership ban. The right two columns and the lower part of the table compare comp to the regime with fringe competition ($n = 2$).

Table B.1 Predicted comparative statics from the baseline specification

	parameters	comp	PLB	$\frac{\text{post-prePLB}}{\text{prePLB}}$	PLB	$\frac{\text{post-prePLB}}{\text{prePLB}}$
leader:			no fringe		fringe	($n = 2$)
$\frac{dr_l^*}{dc_l}$	$B_{l,21}$	.47	$\frac{1}{2}$		.48	
$\frac{dr_l^*}{dc_{i \neq l}}$	$B_{l,22}$	.08	0		.33	
S_l	$B_{l,21} + (n-1) B_{l,22}$	**.89**	$\frac{1}{2}$	$-.44$	**.81**	$-.09$
ban foll.:						
$\frac{dr_{i \neq l}^*}{dr_l^*}$	$B_{i \neq l,1}$	**.26**	**1**	2.85	**1**	2.85
$\frac{dr_{i \neq l}^*}{dc_{i \neq l}}$	$B_{i \neq l,1} B_{l,22} + B_{i \neq l,21}$	.53	0		0	
$\frac{dr_{i \neq l}^*}{dc_l}$	$B_{i \neq l,1} B_{l,21} + B_{i \neq l,22}$	.065	$\frac{1}{2}$		.48	
$\frac{dr_{i \neq l}^*}{dc_{k \neq i}}$	$B_{i \neq l,1} B_{l,22} + B_{i \neq l,23}$	.032	0		0	
$S_{i \neq l}^d$	$B_{i \neq l,21} + B_{i \neq l,22} + (n-2) B_{i \neq l,23}$	.67	$\frac{1}{2}$	$-.25$		
$S_{i \neq l}$	$B_{i \neq l,1} (B_{l,21} + (n-1) B_{l,22}) + S_{i \neq l}^d$	**.90**	$\frac{1}{2}$	$-.44$	**.48**	$-.47$
free fringe:						
$\frac{dr_{ff}^{PLB_f}}{dr_l}$	$B_{ff,1}$	**.26**	$\times$		**.48**	.85
$\frac{dr_{ff}^{PLB_f}}{dc_{ff}}$	$B_{ff,1} B_{l,22} + B_{ff,21}$	.53			.64	
$\frac{dr_{ff}^{PLB_f}}{dc_l}$	$B_{ff,1} B_{l,21} + B_{ff,22}$	.065			.20	
S_{ff}^d	$B_{ff,21} + B_{ff,22}$	.67			.45	$-.33$
S_{ff}	$B_{ff,1} (B_{l,21} + (n-1) B_{l,22}) + S_{ff}^d$	**.90**	$\times$		**.84**	$-.07$

The three most pronounced and promising changes to test for are, all three irrespective of remaining fringe competition (value): $\frac{dr_{i\neq l}}{dr_l}$ increasing fourfold from .26 to 1 (1), $S_{i\neq l}$ decreasing from .90 to $\frac{1}{2}$ (.48), and S_l decreasing from .89 to $\frac{1}{2}$ (.81). The switch in roles for $c_{i\neq l}$ and c_l in explaining $r_{i\neq l}$ (from zero to one half and vice versa) is distinct, but not independently testable due to multicollinearity in the cost data. The same if true for the strong increase in $\frac{dr_l}{dc_{i\neq l}}$ in case some fringe competition remains (from .08 to .33), compared to when bank A obtains full monopoly power (from .08 to 0).

The change in S_l is much less pronounced in the regime with fringe competition than in the fully coordinated regime (from .89 to .81 instead of to $\frac{1}{2}$). Also, the increase in the responsiveness of any free fringe banks to changes in the rate of bank A, $\frac{dr_{ff}^{PLB_f}}{dr_l}$, is considerably less than in the full coordination model (from .26 to .48 instead of to 1). This reflects that the symmetric product differentiation model does not capture well that a relatively remote fringe competition in reality constrains pricing little. The reason the combined effect is higher in the fringe competition model namely is that the fringe weighs in in the common cost shock, even though the costs of the other big banks do not matter for the leader's rate. The leader responds to these costs by a factor .33. Without it, the prediction is that the followers respond less to a common cost shock under the price leadership bans than in competition. More responsiveness in competition (that is, higher values of B_1 and B_{21} in particular) make the change more pronounced. These are associated with lower values of s in Figure 4.

If S_l is significantly lower in price leadership ban equilibrium than in competitive equilibrium, this is indication of a strong reduction of competition due to the bans, favoring the full coordination model over the fringe competition model. In addition, the weaker the fringe, the more would all follower banks respond to r_l after the bans. That is, if $\frac{dr_{ff}^{PLB_f}}{dr_l}$ for free fringe banks would increase more significantly than doubling, the full coordination model is favored. The same is true if for a free fringe follower, there is a significant decrease in S_{ff}.

C Data Sources

The raw data set of NHG-backed mortgage transactions contained 978704 observations and was cleaned by correcting obvious errors. Removed were all observations where the interest rate was zero or missing (15 observations), which had a negative or missing maturity (2903 observations), and with a maturity over 100 years (919 observations). Obvious typos were repaired (10), or removed (3) when it was not clear what was meant—for example a 10 was corrected into .10 (10%), but a 24 would be taken out if it could not be determine with certainty whether 2.4% or 24% would have been the actual observation. The clean data set consists of 974864 rate observations.

There were only 5 cases of interest rates lower than 1%, which may also include typos. Excluding them did not change the results.

Data on base interest rates was taken from the Dutch Central Bank's online statistical data (Table 1.3.1). This data set presents the nominal interest rate term structure that is used to calculate liabilities for pension funds, which itself is based on interbank interest rates. Rates are presented at different maturities with one-year maturity intervals, and have a monthly frequency. Base rate maturities were matched with mortgage maturities.

Data on the Eonia interest rate for overnight maturity was obtained from the ECB statistical data warehouse. The rate is weighted by the ECB and calculated from data collected on unsecured overnight lending in the euro area as provided by banks belonging to the Eonia panel. The data series has a daily frequency and is not differentiated by maturity.

Data on deposit rates was taken from the Dutch Central Bank's online statistical data (Table 5.2.7). It is the rate on deposits that are redeemable at notice with a period of notice less than 3 months. As banks are known to base the financing of part of their mortgage loans on deposits, this series proxies for part of the costs of attracting funding. The data on deposit rates has a monthly frequency and is not differentiated by maturity.

Data on CDS spreads (only senior debt) was obtained from Thomson Datastream, available for maturities at 1, 4, 5, 7 and 10 years for all 5 main mortgage providers (Rabobank, ING, ABN AMRO, AEGON and SNS REAAL). These CDS spreads were matched by maturity a much as possible—for example were mortgages with a maturity of 3 years matched with 4-year CDS spreads and mortgages with a maturity over 10 years with 10-year CDS spreads. The data series on CDS spreads has a daily frequency.

Data on the Tier1 ratio was taken from the Dutch Central Bank's online statistical data (Table 10.1). It contains the average amount of Tier1 capital over risk-weighted assets that is a proxy for the costs of equity and adhering to capital regulation (Basel II and/or III) for the Dutch banks. The data on the Tier1 ratio has a quarterly frequency and is not differentiated by maturity.

Data on the HHI was calculated from the NHG data set directly, by calculating the shares in the total number of NHG mortgages of all maturities together over the providers per month, and taking the sum of these market shares squared. Differentiation by maturity led to high outlier values (regularly exactly 1) where there were only few mortgages supplied for several mortgage types in certain months. The 10-year maturity category of mortgages did have enough observations to create a meaningful HHI series, which was used for the analysis of 10-year mortgages (daily averages) alone.

D Non-stationarity and Cointegration Test Results

This appendix contains the results of unit root tests and tests for cointegration on the NHG-backed mortgage rate data. Table D.1 presents the Dickey-Fuller test statistics for non-stationarity in the interest rate data (10 year maturity, daily averages by provider). The table results are based on 5 autoregressive terms, selected to align the unit root tests to the VAR tests that were used to determine Granger causality. Similar results were obtained when the number of autoregressive terms was selected based off the Schwartz Information Criterion, which found 5 to 10 autoregressive terms, depending on the data series. The table shows that all series display unit roots in levels, but not in first differences.

Table D.1: Dickey-Fuller test statistics for interest rates

	Levels		First differences	
	t-value	probability	t-value	probability
$r_{A,t}$	−.783	.377	−29.989	.000
$r_{B,t}$	−.663	.430	−25.017	.000
$r_{C,t}$	.334	.782	−24.634	.000
$r_{D,t}$	−.558	.476	−31.011	.000
$r_{E,t}$	−.824	.359	−27.870	.000
$r_{F,t}$	−.385	.795	−31.931	.000
$r_{G,t}$	.856	.895	−32.534	.000
$r_{H,t}$	.240	.756	−16.597	.000

Notes: no trend or constant included.

Table D.2 presents the Johansen trace statistic for cointegration between the interest rate of bank A and the other banks. Again five autoregressive terms were chosen to conform to the VAR model used for the Granger causality tests in Section 6. The table shows that one cointegrating relationship exists between each interest rate of banks B to H paired with the interest rate set by bank A.

Table D.2: Johansen trace tests for pairwise cointegration with $r_{A,t}$

	No cointegrating eq.		At most one cointegrating eq.	
	trace statistic	p-value	trace statistic	p-value
$r_{B,t}$	26.451	.000	1.228	.313
$r_{C,t}$	17.567	.006	.601	.499
$r_{D,t}$	47.949	.000	1.312	.295
$r_{E,t}$	50.022	.000	.975	.375
$r_{F,t}$	16.770	.009	.153	.747
$r_{G,t}$	26.491	.000	.125	.771
$r_{H,t}$	22.478	.001	.065	.835

Notes: no trend or constant assumed, five autoregressive terms.

As a second test for cointegration, Table D.3 shows the results for Engle-Granger tests for pairwise cointegration between $r_{A,t}$ and each of the price followers' interest rates. The procedure first estimates a linear relationship between $r_{A,t}$ and a price follower's interest rate, after which the residuals from that regression are tested for stationarity. The table shows the Dickey-Fuller test statistics on the residuals of these regressions.

Table D3: Engle-Granger tests for pairwise cointegration with $r_{A,t}$

	t-value	p-value
$r_{B,t}$	-5.081	.000
$r_{C,t}$	-3.553	.000
$r_{D,t}$	-6.690	.000
$r_{E,t}$	-7.020	.000
$r_{F,t}$	-4.022	.000
$r_{G,t}$	-5.003	.000
$r_{H,t}$	-3.814	.000

Notes: no trend or constant assumed; 5 autoregressive terms.

The results show that the residuals from the linear regressions do not display unit roots, suggesting that the interest rates of the price followers are cointegrated with the interest rate set by the price leader.

E Controlling for Cost Changes

Controlling in cointegration equation (11) for changes in the cost is essential to obtain proper estimates. Figure 5 pictures the equilibrium best-response of a follower to the leader's interest rate. From equilibrium A, suppose an increase in r_l is accompanied by an increase in the costs of the follower—which is typically correlated to a cost increase for the leader, which may be the source of Δr_l. The cost increase shifts the equilibrium best-response curve upwards, so that the new equilibrium interest rate is in point B. If the relationship between r_l and $r_{i \neq l}$ were empirically measured from observations A and B without controlling for the cost change, the response would be overestimated compared to the actual value of the slope of the best-response function. The overestimation can make it impossible to distinguish between competitive and coordinated price leadership, in which the response is expected to be unity.

To see the effects of (partially) controlling for cost changes, we have estimated the cointegration equation (11) with different combinations of cost factors included for the third largest bank C.[63] We conjecture bank C to be AEGON, for which the price

[63] Bank C was chosen for lack of data on the main 10-years mortgage rate category for bank B.

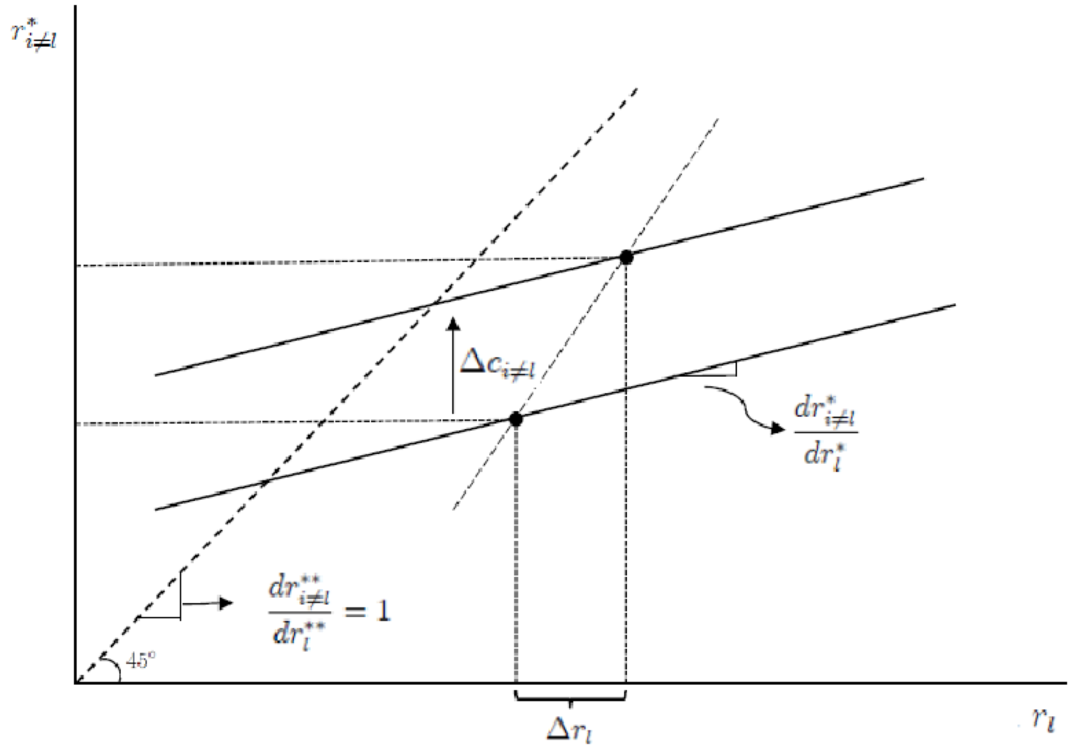

Figure 5: Follower banks equilibrium price best-responses to price leader's rate.

leadership ban became effective March 2nd 2009. Table E.1. collects the relevant results.

Table E.1 shows how the coefficients change when costs are not controlled for versus when they are partially or fully.

Table E.1: Results cointegrating equation for bank C with varying cost controls

	$r_{C,t}$	$r_{C,t}$	$r_{C,t}$	$r_{C,t}$	$r_{C,t}$
break date	13-02-09	13-02-09	13-02-09	13-02-09	13-02-09
$r_{A,t-1}$	.6866***	.1631***	.2598***	.0245	.0948**
	(.0088)	(.0169)	(.0191)	(.0162)	(.0480)
$r_{A,t-1} \times D_t^{PLB}$	−.0166*	.4574***	.3350***	.5043***	.4707***
	(.0099)	(.0176)	(.0202)	(.0166)	(.0512)
D_t^{PLB}	.00175***	.0180***	.0229***	.0107***	−.0001
	(.0005)	(.0004)	(.0011)	(.0011)	(.0022)
cost factors	no	deposits	all	all	all plus RMBS
maturity FE	no	no	no	yes	yes
N	59876	59767	59767	59767	25369
R^2	.4472	.5281	.5793	.6835	.5945

Notes: Robust standard errors in parentheses; *,**,*** indicating significance at the 10, 5 and 1% level respectively.

The results in the first column are without accounting for costs. The coefficient on $r_{A,t-T}$ is overestimated in the competitive regime and not affected by the price leadership bans: the (negative) coefficient on $r_{A,t-T} \times D_t^{PLB}$ cannot be distinguished from zero and is insignificant. By only including the deposit rate, in the second column, the coefficients take on values that are in line with the results in the main text and theory. The deposit rate is relevant, because on average during the 2004-2012 period about 45% of the liabilities of the Dutch banks was funded through deposits.[64] The coefficient on $r_{deposit,t}$ is close to 1 and the coefficient on $r_{deposit,t} \times D_t^{PLB}$ is close to -1, yet by a Wald test the hypothesis that they add up to zero is rejected at the 1% significance level. The results are somewhat more pronounced when including the other cost components as in the main text (third column). The final column shows that also including RMBS spreads and/or fixed effects does not critically alter the main findings, so that leaving it out as we do in the main text is not problematic.

F Multicollinearity

Table F.1 presents correlations between the relevant variables. In particular does the RMBS spread correlate with r_A, which was therefore excluded from the analyses in the text, in order to avoid potential multicollinearity concerns.

PLACE TABLE HERE
Table F.1: Correlation Table

Table F.2 presents variance inflation factors (VIF) for a regression that is similar to (11) in Section 7.2 but is estimated separately before and after the estimated break date to assess any variance inflation created by the interaction terms themselves. Multicollinearity concerns arise for VIF values are over 10 (sometimes 5), which mostly are on the CDS spreads that strongly comove. For this reason, we do not interpret the coefficients on the CDS spreads in the text separately. Table F.2 also reveals that the VIF of r_A mostly stay under 5, and always under 10, so that there is no concern for multicollinearity between our main explanatory variable r_A and all other factors, validating our approach.

PLACE TABLE HERE
Table F.2: Variance Inflation Factors

[64] Source: DNB statistics, table 5.2.

Table F.1: Correlation Table

	r_A	CDS_{ABN}	CDS_{AEGON}	CDS_{ING}	$CDS_{Rabobank}$	CDS_{SNS}	r_{base}	$r_{deposit}$	$Tier1$	r_{Eonia}	HHI	$RMBS$
r_A	1	×	×	×	×	×	×	×	×	×	×	×
CDS_{ABN}	.44	1	×	×	×	×	×	×	×	×	×	×
CDS_{AEGON}	.42	.82	1	×	×	×	×	×	×	×	×	×
CDS_{ING}	.29	.86	.87	1	×	×	×	×	×	×	×	×
$CDS_{Rabobank}$	.41	.87	.95	.94	1	×	×	×	×	×	×	×
CDS_{SNS}	.33	.81	.94	.89	.94	1	×	×	×	×	×	×
r_{base}	.36	−.34	−.30	−.37	−.31	−.48	1	×	×	×	×	×
$r_{deposit}$	.19	−.45	−.10	−.31	−.19	−.24	.55	1	×	×	×	×
$Tier1$	.19	.81	.61	.72	.68	.73	−.66	−.70	1	×	×	×
r_{Eonia}	−.01	−.62	−.50	−.56	−.57	−.64	.71	.72	−.86	1	×	×
HHI	.33	.79	.69	.74	.73	.77	−.51	−.44	.78	−.63	1	×
$RMBS$	.48	.37	.52	.14	.43	.51	.24	.11	.31	−.42	.28	1

Table F.2: Variance Inflation Factors

	$r_{B,j,m,t}$		$r_{C,j,m,t}$		$r_{D,j,m,t}$		$r_{E,j,m,t}$		$r_{F,j,m,t}$		$r_{G,j,m,t}$		$r_{H,j,m,t}$	
response time	3		1		3		3		5		2		5	
break date	16-06-09		13-02-09		04-03-09		03-03-09		27-05-09		01-03-09		01-03-09	
	before	after	before	after	before	after	before	after	before	after	before	after	before	after
r_A	3.93	3.89	5.76	2.08	6.36	2.91	4.73	2.79	5.02	3.73	3.78	3.26	3.21	2.35
CDS_{ABN}	56.25	11.81	24.41	5.40	33.81	4.14	28.93	4.34	29.27	6.76	41.18	3.52	29.06	8.45
CDS_{AEGON}	24.02	9.14	10.28	8.51	11.13	8.40	16.50	9.46	12.62	6.58	12.38	6.92	12.65	13.11
CDS_{ING}	61.44	18.87	45.92	8.30	68.84	10.54	58.82	9.22	50.31	14.40	60.06	8.33	42.99	20.74
$CDS_{Rabobank}$	36.11	25.31	38.30	21.37	42.13	20.32	66.21	22.15	60.60	13.99	43.95	17.30	35.15	33.86
CDS_{SNS}	9.64	10.69	22.10	10.55	24.49	11.46	41.91	11.58	24.44	10.06	18.55	7.73	13.46	15.14
r_{base}	4.77	8.91	3.98	4.22	4.45	4.86	4.49	4.14	5.45	3.78	3.26	5.83	3.59	4.10
$r_{deposit}$	2.70	4.45	8.50	10.43	8.11	6.78	7.72	8.98	4.38	6.37	6.17	6.24	3.17	8.72
$Tier1$	1.52	3.72	1.50	2.41	1.25	1.72	1.34	2.02	1.50	1.30	1.48	2.22	1.93	3.59
r_{Eonia}	3.09	4.80	4.13	2.42	3.43	2.55	3.92	2.41	3.77	2.26	3.38	3.38	2.60	4.13
HHI	2.05	1.23	2.94	2.25	3.26	1.74	3.82	1.57	2.21	2.23	2.21	1.28	1.85	1.38

G Common Cost Shocks

Due to multicollinearity in the funding cost factors, the absolute value of the cost coefficient estimates cannot be meaningfully interpreted individually. Instead, we consider predictions about the sum of cost coefficients. In this section, we make precise how this comparison relates to the theory.

The model in the text considers a single 'total' marginal cost c_i per bank, which differ as either c_l for the leader, $c_{i\neq l}$ for follower $i \neq l$ and c_k for all other followers. Suppose instead that a bank i's total marginal costs consists of several (C_i) components that add up linearly, each with weight $w_{l,i}$, so that

$$c_i = \sum_{j=1}^{C_i} w_{i,j} c_{i,j}.$$

We do not have (sufficiently precise) information about the size of these weights.[65]

First consider the price leader bank, which sets its rate at

$$r_l^* = B_{l,0} + B_{l,21} c_l + B_{l,22} \sum_{i\neq l}^{n-1} c_i,$$

from which we can derive hypotheses for the effect of all cost components changing by the same amount (a 'common cost shock'), that is about

$$S_l = B_{l,21} + (n-1)\, B_{l,22}.$$

Given that total marginal costs consists of several components, the marginal change in the mortgage rate in response to a common cost shock really is

$$S_l' = B_{l,21} \sum_{j=1}^{C_l} w_{l,j} + (n-1)\, B_{l,22} \sum_{j=1}^{C_{i\neq l}} w_{i\neq l,j}.$$

The regression for the leader bank is done on all cost components, that is on model (9) in Section 7.1, in which $\mathbf{C}_{m,t}$ consists of nine cost controls: CDS spreads for the biggest five mortgage providers in the Netherlands (matched by maturity), two base rates (Eonia and the interbank swap rate with maturity matched to the mortgage), the rate on Dutch deposits, and the amount of Tier1 equity capital to risk-weighted assets. That is, stylized for one maturity and no lags (*i.e.* dropping j, m and t), without the HHI, and setting $D_{i,t}^{PLB} = 0$, we regress (in competition):

$$r_A = \beta_{A,0} + \sum_{j=1}^{9} \beta_{A,j,2} c_j + \epsilon_A,$$

[65] An indication can obtained from ACM (2013), in which the funding costs for mortgages are determined by a base rate (Euribor) plus roughly (the weights fluctuate monthly) for .3 each by CDS, RMBS and deposit rates, .1 by capital costs and an additional 80 basis points for fixed costs.

which can be rewritten as

$$r_A = \beta_{A,0} + \sum_{j=1}^{9} \left(\overbrace{\beta_{l,21} w_{l,j} + (n-1)\,\beta_{l,22} w_{i\neq l,j}}^{\beta_{A.j,2}} \right) c_j + \epsilon_A,$$

since of each cost factor its combined effect via all banks (the leader and all followers, including bank $i \neq l$ itself) is estimated at once, including the weights which that cost factor has in all the banks total marginal costs. In other words, the parameters $\beta_{A,j,2}$ estimates the total effect of a change in cost factor c_j through all the banks in the model.

Therefore the sum of estimated coefficients, which implicitly includes estimations of the weights, is

$$\begin{aligned} \widehat{S}_l' &= \sum_{j=1}^{9} \widehat{\beta}_{A,j,2} = \sum_{j=1}^{9} \left(\widehat{\beta}_{l,21} \widehat{w}_{l,j} + (n-1)\,\widehat{\beta}_{l,22} \widehat{w}_{i\neq l,j} \right) \\ &= \widehat{\beta}_{l,21} \sum_{j=1}^{9} \widehat{w}_{l,j} + (n-1)\,\widehat{\beta}_{l,22} \sum_{j=1}^{9} \widehat{w}_{i\neq l,j}, \end{aligned}$$

which is the proper estimation of S_l' if it is assumed that $C_l = 8$, for leader and followers the same.

Next consider the followers. From the equilibrium best-reponse

$$r_{i\neq l}^* = B_{i\neq l,0} + B_{i\neq l,1} r_l^* + B_{i\neq l,21} c_{i\neq l} + B_{i\neq l,22} c_l + B_{i\neq l,23} \sum_{k\neq i\neq l}^{n-2} c_k,$$

we can derive hypotheses for the effect of all cost components changing by the same amount (a 'common cost shock') that consists of direct and indirect equilibrium effects.

With several cost components, The direct effect in the mortgage rate in response to a common cost shock is

$$S_{i\neq l}^d = B_{i\neq l,21} + B_{i\neq l,22} + (n-2)\,B_{i\neq l,23},$$

or with several components

$$S_{i\neq l}^{d\prime} = B_{i\neq l,21} \sum_{j=1}^{C_{i\neq l}} w_{i\neq l,j} + B_{i\neq l,22} \sum_{j=1}^{C_l} w_{l,j} + (n-2)\,B_{i\neq l,23} \sum_{j=1}^{C_{k\neq i\neq l}} w_{k\neq i\neq l,j}.$$

The regressions for each follower bank are performed on all cost components, that is on model (11) in Section 7.2, in which $\mathbf{C}_{m,t}$ consists of the same nine cost controls for all follower banks: CDS spreads for the biggest five mortgage providers in the

Netherlands (matched by maturity), two base rates (Eonia and the interbank swap rate with maturity matched to the mortgage), the rate on Dutch deposits, and the amount of Tier 1 equity capital to risk-weighted assets. That is, stylized for one maturity and no lags (*i.e.* dropping j, m and t), without the HHI, and setting $D_{i,t}^{PLB} = 0$, we obtain the following expression for the regression in competition:

$$r_{i \neq l} = \beta_{i \neq l,0} + \beta_{i \neq l,1} r_l + \sum_{j=1}^{9} \beta_{i \neq l,j,2} c_j + \epsilon_{i \neq l},$$

which can be rewritten as

$$r_{i \neq l} = \beta_{i \neq l,0} + \beta_{i \neq l,1} r_l + \sum_{j=1}^{9} \left(\overbrace{\beta_{i \neq l,21} w_{i \neq l,j} + \beta_{i \neq l,22} w_{l,j} + (n-2) \beta_{i \neq l,23} w_{k \neq i \neq l,j}}^{\beta_{i \neq l,j,2}} \right) c_j + \epsilon_{i \neq l},$$

since of each cost factor its combined direct effect via all banks (the leader and all followers, including bank $i \neq l$ itself) is estimated at once, including the weights which that cost factor has in all these banks total marginal costs. In other words, the parameters $\beta_{i \neq l,j,2}$ estimates the total *direct* effect of a change in cost factor c_j through all the banks in the model.

Therefore the sum of estimated coefficients, which implicitly includes estimations of the weights, is

$$\begin{aligned} \widehat{S}_{i \neq l}^{d\prime} &= \sum_{j=1}^{9} \widehat{\beta}_{i \neq l,j,2} = \sum_{j=1}^{9} \left(\widehat{\beta}_{i \neq l,21} \widehat{w}_{i \neq l,j} + \widehat{\beta}_{i \neq l,22} \widehat{w}_{l,j} + (n-2) \widehat{\beta}_{i \neq l,23} \widehat{w}_{k \neq i \neq l,j} \right) \\ &= \widehat{\beta}_{i \neq l,21} \sum_{j=1}^{9} \widehat{w}_{i \neq l,j} + \widehat{\beta}_{i \neq l,22} \sum_{j=1}^{9} \widehat{w}_{l,j} + (n-2) \widehat{\beta}_{i \neq l,23} \sum_{j=1}^{9} \widehat{w}_{k \neq i \neq l,j}. \end{aligned}$$

which is the proper estimation of $S_{i \neq l}^{d\prime}$ if it is assumed that $C_i = 8$, for leader and followers the same. Note that in theory, if a bank's total marginal costs are determined by fewer than the 9 cost components (for example only its own CDS spread), this would be reflected in a zero weight w_{ij} on that cost factor. By including in the regressions more cost controls (9) than there are banks (8), we should have an outer set of determinants. Yet theoretically $\widehat{S}_{i \neq l}^{d\prime}$ would be an underestimation of $S_{i \neq l}^{d\prime}$ in case more cost factors influence to pricing decisions of some of the banks considered—for example the CDS spreads of a remote fringe.

Finally, note that since r_l is included separately in the regression (11), the *indirect* effect of the common cost shock on $r_{i \neq l}$, through its effect on r_l^* is not included in the joint cost effect. We can combine the estimated elements to make predictions about the the full common cost shock effect on a followers equilibrium rate derived in the text, which is

$$\begin{aligned} S_{i\neq l} &= S^d_{i\neq l} + B_{i\neq l,1} S_l. \\ &= B_{i\neq l,21} + B_{i\neq l,22} + (n-2) B_{i\neq l,23} + B_{i\neq l,1} S_l \\ &= B_{i\neq l,21} + B_{i\neq l,22} + (n-2) B_{i\neq l,23} + B_{i\neq l,1} \left(B_{l,21} + (n-1) B_{l,22}\right). \end{aligned}$$

H Estimation Results

The tables below present the raw estimation results for individual observations (equilibrium and short-run response) and 10 year daily averages (equilibrium response only).

Table H.1. Regression results bank A's rate to costs, individual observations

	Price leader response		Panzar-Rosse	
break date	01-03-2009 (495.3461)		01-07-2009 (404.3552)	
	before	after ($\times D^{PLB}_{A,t}$)	before	after ($\times D^{PLB}_{A,t}$)
CDS_{ABN}	.1564*** (.0232)	−.2601*** (.0282)	.0625*** (.0030)	−.0054 (.0063)
CDS_{AEGON}	.0190*** (.0059)	−.0055 (.0080)	−.0143*** (.0027)	.0881*** (.0042)
CDS_{ING}	.04817* (.0278)	−.1097*** (.0284)	−.0188*** (.0042)	−.0568*** (.0054)
$CDS_{Rabobank}$	−.3936*** (.0306)	.7170*** (.0348)	−.0325*** (.0031)	.0858*** (.0051)
CDS_{SNS}	−.0333*** (.0076)	−.1561*** (.0084)	.0133*** (.0014)	−.1003*** (.0039)
$r_{deposit}$	2.082*** (.0183)	−1.289*** (.0232)	.9679*** (.0109)	−.4539*** (.0139)
r_{base}	.2879*** (.0061)	.0181*** (.0061)	.2264*** (.0048)	−.0752*** (.0048)
r_{eonia}	−.1119*** (.0027)	−.0147** (.0069)	−.0820*** (.0012)	.0582*** (.0015)
$Tier1$	−.1018*** (.0041)	.1128*** (.0061)	−.2244*** (.0096)	−.0627*** (.0159)
HHI	.0311*** (.0020)	−.0216** (.0021)	.0399*** (.0038)	−.0089* (.0048)
S_l	1.8462*** (.0166)	−.9873*** (.0267)	×	×
H_A	×	×	.8980*** (.0151)	−.5222*** (.0214)
N	176442		176442	
R^2	.6262		.6536	

Notes: Break date with F-statistic. Robust standard errors in parentheses; *,** ,*** indicating significance at the 10, 5 and 1% level respectively.

Table H.2: Results interest best-response follower banks' to bank A's rate, cost factors, HHI and maturity fixed-effects, individual observations

	$r_{B,j,m,t}$	$r_{C,j,m,t}$	$r_{D,j,m,t}$	$r_{E,j,m,t}$	$r_{F,j,m,t}$	$r_{G,j,m,t}$	$r_{H,j,m,t}$
time to response	3 days	1 day	3 days	3 days	5 days	2 days	5 days
break date	16-06-09	13-02-09	04-03-09	03-03-09	27-05-09	01-03-09	01-03-09
	(686.990)	(581.596)	(243.678)	(310.731)	(75.591)	(153.646)	(507.252)
$r_{A,m,t-\tau}$	.095***	.024	.206***	.116***	.133***	.161***	.119***
	(.018)	(.016)	(.022)	(.010)	(.009)	(.011)	(.007)
$r_{A,m,t-\tau} \times D^{PLB}_{f,t}$	.231***	.504***	.635***	.472***	.391***	.370***	−.329***
	(.0564)	(.017)	(.023)	(.013)	(.019)	(.016)	(.030)
$CDS_{ABNAMRO}$	−.434***	.313***	.087***	.268***	−.061*	.173***	−.416***
	(.066)	(.021)	(.033)	(.027)	(.037)	(.029)	(.117)
$CDS_{ABN} \times D^{PLB}_{f,t}$	.738***	−.477***	.005	−.406***	.448***	−.328***	.747***
	(.140)	(.030)	(041)	(.035)	(.060)	(.045)	(.188)
CDS_{Aegon}	.017	.029***	−.067***	.006	−.012*	.049***	.072
	(.025)	(.005)	(.005)	(.007)	(.007)	(.008)	(.054)
$CDS_{Aegon} \times D^{PLB}_{f,t}$	−.104***	−.010	.140***	.131***	.090***	.032**	.037
	(.029)	(.007)	(.009)	(.010)	(.021)	(.013)	(.062)
CDS_{ING}	.351***	−.057**	−.240***	−.287***	.179***	−.056*	.219
	(.088)	(.024)	(.038)	(.030)	(.042)	(.032)	(.142)
$CDS_{ING} \times D^{PLB}_{f,t}$	−.630***	−.108***	.089**	−.063**	−.145***	−.094***	−.247
	(.090)	(.026)	(.039)	(.031)	(.048)	(.034)	(.151)
$CDS_{Rabobank}$	.425***	−.483***	.220***	.143***	.075	−.115***	.142
	(.097)	(.029)	(.030)	(.036)	(.047)	(041)	(.191)
$CDS_{Rabobank} \times D^{PLB}_{f,t}$	.045	.737***	−.428***	−.024	−.554***	.069	−.185
	(.102)	(.035)	(.038)	(.043)	(.069)	(.050)	(.207)
CDS_{SNS}	−.342***	−.120***	−.110***	−.030***	.001	−.083***	−.280***
	(.025)	(.007)	(.007)	(.006)	(.011)	(.010)	(.046)
$CDS_{SNS} \times D^{PLB}_{f,t}$	.395***	.097***	.190***	.006	.037**	.071***	.176***
	(.028)	(.008)	(.009)	(.010)	(.018)	(.012)	(.059)
$r_{deposit}$	2.311***	2.523***	1.998***	1.550***	1.309***	1.850***	1.715***
	(.056)	(.041)	(.056)	(.031)	(.027)	(.035)	(.035)
$r_{deposit} \times D^{PLB}_{f,t}$	−4.046***	−2.288***	−1.798***	−1.450***	−.644***	−1.605***	−1.415***
	(.077)	(.043)	(.057)	(.037)	(.057)	(.045)	(.112)
r_{base}	.054***	−.132***	−.065***	.146***	.161***	.008	.153***
	(.013)	(.011)	(.014)	(.009)	(.008)	(.010)	(.008)
$r_{base} \times D^{PLB}_{f,t}$	.574***	.149***	.025	−.250***	−.256***	−.091***	−.115***
	(.031)	(.013)	(.016)	(.011)	(.014)	(.013)	(.028)
r_{Eonia}	−.225***	−.110***	−.016**	−.022***	.011**	−.113***	−.106***
	(.005)	(.006)	(.006)	(.005)	(.005)	(.006)	(.004)
$r_{Eonia} \times D^{PLB}_{f,t}$	.166***	−.112***	−.034***	.037***	.001	.167***	.051
	(.034)	(.011)	(.011)	(.011)	(.016)	(.013)	(.059)
$Tier1$	−.188***	−.080***	−.154***	−.113***	−.043***	−.027***	−.110***
	(.008)	(.006)	(.008)	(.004)	(.005)	(.005)	(.010)
$Tier1 \times D^{PLB}_{f,t}$	−.131**	.161***	.310***	.233***	.183***	.125***	−.024
	(.051)	(.007)	(.010)	(.008)	(.013)	(.013)	(.070)
HHI	.092***	.039***	.057***	.036***	.050***	.007*	.110***
	(.004)	(.003)	(.004)	(.003)	(.002)	(.003)	(.003)
$HHI \times D^{PLB}_{f,t}$	−.101***	.030***	−.040***	−.029***	−.021***	−.008*	−.115***
	(.005)	(.006)	(.005)	(.003)	(.005)	(.003)	(.003)
$D^{PLB}_{f,t}$	.094***	.011***	−.016***	.007***	−.008***	.017***	.069***
	(.006)	(.001)	(.001)	(.001)	(.002)	(.002)	(.010)
maturity FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	56088	59767	62540	55230	57255	46485	32939
R^2	.4551	.6835	.5591	.6807	.6514	.6213	.6818

Table H.3: Results response adjustment follower banks' rate to bank A's rate changes, cost factors, HHI and maturity fixed-effects, individual observations

	$\Delta r_{B,j,m,t}$	$\Delta r_{C,j,m,t}$	$\Delta r_{D,j,m,t}$	$\Delta r_{E,j,m,t}$	$\Delta r_{F,j,m,t}$	$\Delta r_{G,j,m,t}$	$\Delta r_{H,j,m,t}$
time to response	3 days	1 day	3 days	3 days	5 days	2 days	5 days
break date	16-06-09	13-02-09	04-03-09	03-03-09	27-05-09	01-03-09	01-03-09
$\Delta r_{A,m,t-\tau}$	.0485***	.0152	.0637**	.0469***	.0292***	.0527***	.0270***
	(.0185)	(.0114)	(.0269)	(.0102)	(.0093)	(.0095)	(.0054)
$\Delta r_{A,m,t-\tau} \times D^{PLB}_{f,t}$	.0310	.0823***	.2005***	.0966***	.1458***	.0915***	−.0675
	(.0295)	(.0130)	(.0326)	(.0196)	(.0366)	(.0247)	(.0765)
$\varepsilon_{f,j,m,t-5}$	−.6321***	−.4340***	−.6736***	−.6117***	−.6946***	−.7433***	−.5798***
	(.0185)	(.0192)	(.0177)	(.0120)	(.0124)	(.0129)	(.0227)
$\Delta CDS_{ABNAMRO}$	−.0853	.0391*	−.0475	.0406	−.0396	.0556*	−.0769
	(.0674)	(.0204)	(.0358)	(.0291)	(.0407)	(.0296)	(.1400)
$\Delta CDS_{ABN} \times D^{PLB}_{f,t}$	1.4864**	.0481*	.0962*	−.0484	.1143	.0110	.5811
	(.7232)	(.0266)	(.0559)	(.0400)	(.0964)	(.1052)	(.9619)
ΔCDS_{Aegon}	−.1005***	−.0025	−.0244***	−.0065	−.0095	.0117	.0522
	(.0269)	(.0059)	(.0046)	(.0060)	(.0067)	(.0075)	(.0424)
$\Delta CDS_{Aegon} \times D^{PLB}_{f,t}$	.1493***	−.0047	.0273***	.0166*	.0185	−.0299***	−.0537
	(.0291)	(.0073)	(.0085)	(.0086)	(.0204)	(.0116)	(.0505)
ΔCDS_{ING}	.3175***	−.0763**	.1102**	−.0188	.1210**	−.0261	−.0221
	(.0940)	(.0282)	(.0437)	(.0317)	(.474)	(.0370)	(.1599)
$\Delta CDS_{ING} \times D^{PLB}_{f,t}$	−.3923***	.0730***	−.1053**	.0181	−.1456***	.0365	.0567
	(.0957)	(.0284)	(.0175)	(.0322)	(.0509)	(.0388)	(.1698)
$\Delta CDS_{Rabobank}$	−.0069	−.0326*	−.0548***	−.0158	−.0537***	.0027	.1154
	(.0329)	(.0172)	(.0175)	(.0154)	(.0189)	(.0154)	(.0828)
$\Delta CDS_{Rabobank} \times D^{PLB}_{f,t}$	.1746***	.0195	.0002	−.0177	.0340	−.0397*	−.1681
	(.0397)	(.0191)	(.0219)	(.0206)	(.0344)	(.0237)	(.1131)
ΔCDS_{SNS}	−.0775**	.0165***	.0159***	.0080	−.0054	−.0081	−.0709
	(.0340)	(.0055)	(.0060)	(.0061)	(.0082)	(.0089)	(.0440)
$\Delta CDS_{SNS} \times D^{PLB}_{f,t}$	.1232***	−.0079	.0021	.0003	.0217	.0160	.0800
	(.0347)	(.0066)	(.0079)	(.0077)	(.0159)	(.0098)	(.0492)
$\Delta r_{deposit}$	1.0137***	.6263***	.6429***	.5791***	.3017***	.5736***	.4534***
	(.1900)	(.0892)	(.1209)	(.0870)	(.1086)	(.1125)	(.1220)
$\Delta r_{deposit} \times D^{PLB}_{f,t}$	−1.9286***	−.6789***	−.8546***	−.7184***	.1207	−.9831***	−.2287
	(.2221)	(.0995)	(.1431)	(.1124)	(.1942)	(.1501)	(.2473)
Δr_{base}	.0346	−.0198	−.0516*	−.0819***	−.0235	−.0436**	.0087
	(.0297)	(.0259)	(.0309)	(.0266)	(.0240)	(.0219)	(.0155)
$\Delta r_{base} \times D^{PLB}_{f,t}$	.3650***	−.0339	−.1031***	−.0807***	−.1957***	−.0747**	−.1480
	(.0462)	(.0297)	(.0344)	(.0314)	(.0424)	(.0315)	(.1188)
Δr_{Eonia}	−.0842***	−.0012	.0311	.0070	−.0090	−.0030	−.0037
	(.0199)	(.0140)	(.0193)	(.0124)	(.0129)	(.0138)	(.0153)
$\Delta r_{Eonia} \times D^{PLB}_{f,t}$	.1631***	−.0380**	−.0445**	.0106	.0250	.0141	−.1352*
	(.0373)	(.0163)	(.0216)	(.0160)	(.0204)	(.0193)	(.0762)
$\Delta Tier1$	−.0935***	−.0520***	−.1194***	−.0243*	−.0247*	.0071	−.0326*
	(.0150)	(.0119)	(.0184)	(.0122)	(.0137)	(.0123)	(.0186)
$\Delta Tier1 \times D^{PLB}_{f,t}$	.0489	.1134***	.1117***	.0405**	.0352	−.0481	−.0864
	(.0636)	(.0152)	(.0242)	(.0190)	(.375)	(.0313)	(.1332)
ΔHHI	.0384***	.0104	.0064	−.0105	.0355***	.0153	.0580***
	(.0121)	(.0090)	(.0124)	(.0094)	(.0102)	(.0126)	(.0059)
$\Delta HHI \times D^{PLB}_{f,t}$	−.0344***	.0293***	.0252*	.0300***	−.0030	−.0163	−.0616***
	(.0124)	(.0103)	(.0133)	(.0103)	(.0141)	(.0126)	(.0061)
$D^{PLB}_{f,t}$	−.0018***	.0000	−.0005***	−.0004***	−.0004	.0000	−.0005
	(.0001)	(.0001)	(.0001)	(.0001)	(.0003)	(.0001)	(.0006)
maturity FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	47035	48810	52366	45028	49785	37921	27797
R^2	.1433	.1047	.1475	.1322	.0985	.1903	.1120

Table H.4. Regression results bank A's rate to costs, 10-year maturity daily average

	Price leader response		Panzar-Rosse	
break date	28-02-2009 (312.4729)		25-11-2009 (404.3552)	
	before	after ($\times D^{PLB}_{A,t}$)	before	after ($\times D^{PLB}_{A,t}$)
CDS_{ABN}	.2550***	.0038	.0217***	.0544***
	(.0596)	(.0770)	(.0099)	(.0132)
CDS_{AEGON}	−.0262***	.0455***	.0046	.0471***
	(.0094)	(.0163)	(.0061)	(.0081)
CDS_{ING}	−.1872***	.0616	.0384***	−.0553***
	(.0703)	(.0726)	(.0125)	(.0138)
$CDS_{Rabobank}$	−.2922***	.2638***	−.0681***	.0300**
	(.0634)	(.0785)	(.0084)	(.0122)
CDS_{SNS}	−.0119	−.2451***	−.0175***	−.1799***
	(.0164)	(.0200)	(.0041)	(.0078)
$r_{deposit}$	2.5076***	−1.3094***	1.3599***	−.7460***
	(.0502)	(.0744)	(.0285)	(.0358)
r_{base}	.1945***	−.1963***	.1675***	−.1611***
	(.0153)	(.0214)	(.0139)	(.0163)
r_{eonia}	−.0761***	−.0270	−.0673***	.0499***
	(.0072)	(.0222)	(.0048)	(.0052)
$Tier1$	−.1478***	.1030***	−.2721***	.0916**
	(.0117)	(.0173)	(.0274)	(.0377)
HHI	−.0005	−.0223**	.0319***	−.1023***
	(.0026)	(.0030)	(.0109)	(.0123)
$Cons$	−.0109***	.0495***	1.4395***	−3.1215***
	(.0014)	(.0025)	(.1156)	(.1453)
S_l	2.216***	−.9873***	×	×
	(.0404)	(.0267)		
H_A	×	×	1.1673***	−.8695***
			(.0437)	(.0532)
N	2253		2253	
R^2	.9091		.9149	

Notes: Break date with F-statistic. Robust standard errors in parentheses; *,** ,*** indicating significance at the 10, 5 and 1% level respectively.

Table H.5: Results interest best-response follower banks' to bank A's rate, 10-year maturity daily average

	$r_{B,j,m,t}$	$r_{C,j,m,t}$	$r_{D,j,m,t}$	$r_{E,j,m,t}$	$r_{F,j,m,t}$	$r_{G,j,m,t}$	$r_{H,j,m,t}$
time to response	3 days	1 day	3 days	3 days	5 days	2 days	5 days
break date	13-01-09	26-01-09	04-03-09	24-02-09	27-05-09	06-01-09	14-01-08
	(31.514)	(27.858)	(61.707)	(72.984)	(70.824)	(17.182)	(18.439)
$r_{A,m,t-\tau}$	.3854***	.3855***	.4220***	.2452***	.2382***	.2776***	.2596***
	(.0445)	(.0604)	(.0414)	(.0377)	(.0282)	(.0611)	(.0329)
$r_{A,m,t-\tau} \times D_{f,t}^{PLB}$	.1868**	.4178***	.5846***	.6291***	.6333***	.5290***	−.2242
	(.1099)	(.0690)	(.0577)	(.0582)	(.0593)	(.0742)	(.1441)
$CDS_{ABNAMRO}$	−.2553*	.1086	−.1181*	.0284	−.02103***	.4765***	−.7232***
	(.1324)	(.0926)	(.0685)	(.0599)	(.0657)	(.0892)	(.2550)
$CDS_{ABNAMRO} \times D_{f,t}^{PLB}$	−.0382	−.0189	.3683***	.1857**	.8645***	−.3452***	.9080***
	(.2296)	(.0176)	(.0862)	(.0887)	(.1111)	(.01127)	(.3064)
CDS_{Aegon}	.0620	.0043	−.1395***	−.0292***	−.0601***	.0513***	.3176**
	(.0398)	(.0138)	(.0119)	(.0107)	(.0128)	(.0138)	(.1457)
$CDS_{Aegon} \times D_{f,t}^{PLB}$	−.1129**	−.0189	.1409***	.1021***	.0788**	−.0794***	−.1645
	(.0572)	(.0176)	(.0226)	(.0197)	(.0345)	(.0261)	(.1591)
CDS_{ING}	.2699**	−.1456**	−.0527	−.0839	.2520***	−.3841***	−.4781
	(.1337)	(.1018)	(.0873)	(.0704)	(.0678)	(.1007)	(.3670)
$CDS_{ING} \times D_{f,t}^{PLB}$	−.4978***	−.0655	−.1365	−.2072***	−.3595***	.2673***	.4356
	(.1424)	(.1031)	(.0904)	(.0745)	(.0791)	(.1038)	(.3806)
$CDS_{Rabobank}$	−.1539	−.0435	.4169***	.2845***	.3276***	−.2454**	1.0060**
	(.2211)	(.1050)	(.0753)	(.0790)	(.0850)	(.0968)	(.5026)
$CDS_{Rabobank} \times D_{f,t}^{PLB}$	.2331	.1091	−.6735***	−.4494***	−.6730***	.2378**	−1.3597**
	(.2522)	(.1163)	(.0952)	(.1029)	(.1229)	(.1191)	(.5673)
CDS_{SNS}	−.1746***	−.0425	−.1060***	−.0965***	−.0176	−.0692***	−.8724***
	(.0529)	(.0261)	(.0166)	(.0151)	(.0189)	(.0224)	(.1533)
$CDS_{SNS} \times D_{f,t}^{PLB}$	.3262***	.0761**	.2577***	.1851***	.2470***	.1396***	.8354***
	(.0629)	(.0302)	(.0247)	(.0251)	(.0337)	(.0294)	(.1638)
$r_{deposit}$	1.5752***	1.5029***	1.7098***	1.3954***	1.2052***	2.1939***	2.0980***
	(.1521)	(.1877)	(.1267)	(.1078)	(.0904)	(.1966)	(.1185)
$r_{deposit} \times D_{f,t}^{PLB}$	−1.9607***	−1.5960***	−1.7646***	−1.5151***	−1.2245***	−2.1800***	−1.5919***
	(.2181)	(.1985)	(.1425)	(.1311)	(.1362)	(.2114)	(.3043)
r_{base}	.0761***	−.0018	−.0346*	.0109	.0577***	−.1086***	.1008***
	(.0236)	(.0369)	(.0198)	(.0234)	(.0166)	(.0352)	(.0213)
$r_{base} \times D_{f,t}^{PLB}$	.0008	−.1697***	−.0822***	−.0986***	−.1642***	.0964**	−.1452*
	(.0636)	(.0393)	(.0242)	(.0279)	(.0257)	(.0380)	(.0812)
r_{eonia}	−.1439***	−.0340**	−.0179	.0038	.0516***	−.1163***	−.1228***
	(.0161)	(.0141)	(.0109)	(.0101)	(.0096)	(.0163)	(.0160)
$r_{eonia} \times D_{f,t}^{PLB}$	.3258***	−.0201	.0453*	.0390	−.0195	.1292***	.1065
	(.0636)	(.0231)	(.0244)	(.0265)	(.0311)	(.0301)	(.0737)
$Tier1$	−.1461***	−.0531**	−.1399***	−.1404***	−.0324***	−.0407**	−.0984***
	(.0161)	(.0227)	(.0154)	(.0129)	(.0108)	(.0187)	(.0232)
$Tier1 \times D_{f,t}^{PLB}$	.1081**	.0612**	.2761***	.2559***	.2076***	.1400***	.1901***
	(.0530)	(.0251)	(.0208)	(.0190)	(.0231)	(.0259)	(.0718)
HHI	.0179***	−.0090**	.0148***	.0302***	.0064***	−.0093***	.0380***
	(.0035)	(.0043)	(.0030)	(.0029)	(.0020)	(.0032)	(.0040)
$HHI \times D_{f,t}^{PLB}$	−.0375***	−.0240***	−.0330***	−.0528***	−.0252***	−.0056	−.0420***
	(.0056)	(.0046)	(.0035)	(.0036)	(.0034)	(.0038)	(.0077)
$Constant$	.0005	−.0035	−.0039**	.0063***	−.0007	.0110***	−.0172***
	(.0016)	(.0024)	(.0016)	(.0016)	(.0011)	(.0023)	(.0031)
$D_{f,t}^{PLB}$	−.0375***	.0284***	−.0062*	−.0046	−.0163***	.0117***	.0408***
	(.0086)	(.0033)	(.0034)	(.035)	(.0044)	(.0042)	(.0129)
N	1657	1957	2205	2162	2217	2125	1626
R^2	.8020	.8157	.8723	.8763	.8742	.7448	.5003

I Panzar-Rosse Tests on Followers

Table I.1 presents the Panzar-Rosse test results from estimating the log-specification on the full sample.

$$\ln r_{f,j,m,t} = \beta_{f,m,0} + \boldsymbol{\beta}_{f,2} \ln \mathbf{C}_{m,t} + \left(\beta_{f,0}^{PLB} + \beta_{f,1}^{PLB} r_{A,m,t-\tau} + \boldsymbol{\beta}_{f,2}^{PLB} \ln \mathbf{C}_{m,t}\right) D_{f,t}^{PLB} + \epsilon_{f,j,m,t}, \quad (28)$$

per follower.

PLACE TABLE HERE

Table I.1: H-statistics for price-follower banks, individual observations

The break dates are again as expected and the H-statistic decreases significantly for each follower. Consistent with competition before the bans were imposed, the values of all followers are close to one. The lower values after are consistent with market power, which reflects the *de facto* must-follow price leadership position of Rabobank. Again findings on banks B and H are outliers for reasons explained: bank B traded little in part of of the after period, bank H behaved largely independently.

The pattern of changes in the H-statistic for the follower banks is even more pronounced for 10-year maturity in Table I.2

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Table I.2: H-statistics for price-follower banks, 10-years daily average

J But-for Estimations

Table I.1 details the but-for mortgages rates estimations per follower bank behind the averages Table 7.6 in the main text.

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Table J.1: Predictions of but-for mortgage rates per bank

Table 7.5: H-statistics for price-follower banks

	$r_{B,j,m,t}$		$r_{C,j,m,t}$		$r_{D,j,m,t}$		$r_{E,j,m,t}$	
break date	28-02-09 (917.079)		9-09-08 (493.132)		01-07-09 (288.853)		23-01-09 (551.645)	
	before	after $(\times D^{PLB}_{A,t})$	before	after $(\times D^{PLB}_{A,t})$	before	after $(\times D^{PLB}_{A,t})$	before	after $(\times D^{PLB}_{A,t})$
H_f	.969***	−1.595***	.959***	−.641***	1.156***	−.419***	.883***	−.538***
	(.025)	(.035)	(.026)	(.030)	(.031)	(.021)	(.015)	(.023)
N	107729		70165		67569		63375	
R^2	.4603		.6073		.5369		.7686	

Notes: Break date with F-statistic. Robust standard errors in parentheses; *,**,*** indicating significance at the 10, 5 and 1% level respectively.

	$r_{F,j,m,t}$		$r_{G,j,m,t}$		$r_{H,j,m,t}$	
break date	30-05-09 (100.925)		24-07-09 (395.329)		03-01-09 (1255.428)	
	before	after $(\times D^{PLB}_{A,t})$	before	after $(\times D^{PLB}_{A,t})$	before	after $(\times D^{PLB}_{A,t})$
H_f	.912***	−.022	.911***	−.342***	.862***	−1.365***
	(.021)	(.046)	(.015)	(.039)	(.020)	(.051)
N	62636		51353		49455	
R^2	.6628		.7260		.7183	

Notes: Break date with F-statistic. Robust standard errors in parentheses; *,**,*** indicating significance at the 10, 5 and 1% level respectively.

Table I.2: H-statistics for price-follower banks, 10-years daily average

	$r_{B,j,m,t}$		$r_{C,j,m,t}$		$r_{D,j,m,t}$		$r_{E,j,m,t}$	
break date	1-08-08 (140.807)		20-01-09 (131.109)		04-03-09 (181.988)		28-02-09 (173.004)	
	before	after	before	after	before	after	before	after
H_f	1.289***	−1.172***	1.090***	−1.095***	1.080***	−.639***	.783***	−.460***
	(.054)	(.123)	(.068)	(.080)	(.051)	(.071)	(.042)	(.066)
N	1674		1977		2229		2186	
R^2	.8003		.8018		.8369		.8518	

Notes: Break date with F-statistic. Robust standard errors in parentheses; *,**,*** indicating significance at the 10, 5 and 1% level respectively.

	$r_{F,j,m,t}$		$r_{G,j,m,t}$		$r_{H,j,m,t}$	
break date	30-05-09 (148.740)		2-12-08 (98.523)		12-04-08 (41.357)	
	before	after	before	after	before	after
H_f	1.012***	−.291***	1.202***	−.854***	1.431***	−1.084***
	(.038)	(.084)	(.071)	(.085)	(.080)	(.266)
N	2239		2149		1642	
R^2	.8581		.7606		.5448	

Notes: Break date with F-statistic. Robust standard errors in parentheses; *,**,*** indicating significance at the 10, 5 and 1% level respectively.

Table J.1: Predictions of but-for mortgage rates per bank

	bank *A*			bank *B*			bank *C*			bank *D*		
	but-for	overcharge bp.	overcharge %	but-for	overcharge bp.	overcharge %	but-for	overcharge bp.	overcharge %	but-for	overcharge bp.	overcharge %
var	2.85	79.93	19.69	4.03	73.10	14.85	4.44	−5.26	−3.04	2.55	85.76	25.22
1-5	2.86	87.68	23.22	3.13	189.91	35.58	4.54	−3.07	−2.10	3.37	53.34	12.91
5	2.93	124.06	29.44	3.65	11.31	2.60	4.29	40.83	8.39	2.96	111.10	27.21
5-10	3.30	114.49	25.46	3.13	107.93	25.07	3.65	125.51	25.49	3.02	143.02	31.18
10	3.42	136.43	28.41	3.61	99.29	21.32	3.54	136.12	27.71	3.05	165.78	42.02
>10	3.65	142.70	27.64	3.44	121.73	25.25	3.63	162.14	30.90	3.16	183.37	36.34
all	3.44	136.25	28.17	3.63	81.59	17.46	3.60	144.44	28.49	3.06	161.93	34.32

Notes: Overcharges are expressed as percentage of actual rate.

	bank *E*			bank *F*			bank *G*			bank *H*		
	but-for	overcharge bp.	overcharge %	but-for	overcharge bp.	overcharge %	but-for	overcharge bp.	overcharge %	but-for	overcharge bp.	overcharge %
var	1.71	149.98	46.93	2.21	104.88	32.39	1.67	137.10	41.35	2.70	182.69	40.26
1-5	2.19	112.98	33.75	2.52	134.30	32.60	3.22	88.19	20.82	2.66	176.93	39.73
5	3.01	122.94	28.96	3.07	108.73	24.61	3.07	97.77	33.47	2.22	181.01	44.52
5-10	3.60	101.17	21.94	3.56	100.16	21.19	3.59	103.06	21.86	2.91	161.84	33.94
10	3.44	127.88	26.95	3.69	108.23	21.94	3.66	116.16	23.91	2.73	174.84	38.93
>10	3.72	128.05	25.16	4.11	108.61	19.87	3.88	124.30	23.61	2.87	101.64	22.32
all	3.42	127.19	26.99	3.54	108.41	22.62	3.63	115.01	23.86	2.71	172.82	38.59

Notes: Overcharges are expressed as percentage of actual rate.