Impact of Non-cooperative Oligopoly of the Banking System on Its Pro-cyclicality in the Czech Republic

Vliv nekooperativního oligopolu bankovního sektoru na jeho procyklikalitu v České republice

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Abstract

Irrational behavior of banks in the form of excessive credit expansions or contractions, as appropriate, in the course of an economic cycle, together with the subsequent intoxication of bank assets, has become the subject of many controversial regulatory measures since the 1990s. The study simulates this phenomenon using the Bayesian game, which models environment of a conflict situation with incomplete information based on historical data of the past decade in the Czech Republic. The results imply that the dominant banking strategy is – irrespectively of the behavior of other players – the strategy with inadequate risk aversion, with excessive (inadequate) optimistic or pessimistic expectations, as appropriate, depending on the economic cycle stage. The reason for this behavior that contradicts the Pareto efficiency principle is the lack of information about the portfolio strategy of other players and their mutual rivalry in terms of market share increase. The conclusions of the study bring a solution in the form of open bank cartels (cooperative oligopoly) aimed at the coordination of their strategy. The objective of this measure would be the self-regulation of the banking sector credit policy, with acceptable profits and risks for banks and tolerable terms for debtors, reflecting the given economic cycle stage.

Keywords

credit (loan) portfolio, pro-cyclical behavior, oligopoly, Bayesian game, Bayesian Nash equilibrium, mixed strategies

JEL Codes

D43, D81, G11, G21

Abstrakt

Neracionální jednání bank v době ekonomického ochlazení ve formě nezdravé redukce úvěrů pro reálnou ekonomiku se stalo v poslední době diskutovaným tématem. Podle dostupných studií může být toto jednání následkem předešlých nadměrných úvěrových expanzí v době ekonomické prosperity. Navazující úvěrová kontrakce prodlužuje ekonomickou depresi se zpětnými negativními efekty do úvěrových portfolií bank. Studie popisuje tento fenomén pomocí několika modelů teorií her, z nichž ústřední je Bayesovská hra, která modeluje prostředí konfliktní situace s nedokonalými informacemi. Výsledek implikuje, že dominantní bankovní strategií, bez ohledu na jed-

nání ostatních hráčů, je právě agresivní strategie s nízkou averzí k riziku a tedy volba rizikovějšího, nicméně potenciálně výnosnějšího, portfolia v době ekonomické prosperity. Příčinou tohoto nepareto-optimálního jednání je neznalost informací o portfoliové strategii ostatních hráčů a jejich vzájemná rivalita v navýšení tržního podílu. Tedy vedle již známých příčin procyklikality, vstupuje do hry taktéž rivalita oligopolistů. Závěr práce nabízí východisko v podobě otevřených bankovních kartelů (kooperujícího oligopolu) za účelem koordinace strategie. Cílem by mohla být volba vhodné úvěrové expanze celého bankovního sektoru (vice versa úvěrové restrikce) s přijatelným ziskem a rizikem pro banky a únosnými podmínkami pro dlužníky vhodné pro daný ekonomický cyklus.

Klíčová slova
úvěrové portfolio, procyklické chování, oligopol, Baeysovská hra, Nashova-Bayesova rovnováha, smíšené strategie

Introduction

The objective of the game theory models is to examine the behavior of an intelligent player (rational entity) in conflict situations and to seek a balanced solution, which does not always have to comply with the Pareto efficiency principle. Nevertheless, a bank – as a key player in developed markets – appears not to act rationally in terms of pro-cyclical behavior, destabilizing economy and, by return, intoxicating bank assets. The real and optimal shares of individual loan categories within the portfolio of Czech banks were examined in the study of Podpiera and Weill (2010), which discovered remarkable deviations from an optimal, where the banking sector could have generated higher returns by maintaining the risk level (in the period of 2005-2008). The data about returns and risks of the aforementioned aggregated credit (loan) portfolios became the basis for the applied game theory simulation models presented in this study.

The pro-cyclical behavior[1] of the banking sector during the period of economic prosperity is characterized by excessive credit expansion within the real economy. It seems that such support of consumption and investments positively extends economic growth; however, it also finances ineffective investments and inadequate capital structure, which is subsequently corrected during the period of economic depression, with the need to discontinue a lot of the production capacities (Rothbard 1975, Holman, Ševčík et al. 2005). Economic shocks are usually followed by the aforementioned credit shocks, manifested by intense reduction of loans for the real sector, which – according to available studies – may unhealthily intensify the crisis and prolong the recovery process (Geršl, Jakubík 2010, p. 108).

1 *The pro-cyclicality of the banking sector refers to its ability to amplify the cyclical fluctuations of economic activity via the provision of loans and other activities of financial institutions, resulting from the feedback between the macroeconomic development and the financial system (Frait, Komárková 2011, p. 98).*

The effectiveness of traditional transmission channels of the central authority's monetary policy appears to be very weak in such critical situations (Komárek, Komárková 2012). The limited impact of existing macro-prudential instruments[2] on banking portfolio excesses is viewed similarly (Frait, Komárková 2011, p. 105). In terms of game theory, a bank basically selects a new dominant strategy in the period of economic uncertainties, which consists in a sharp reduction of the credit portfolio – irrespectively of the behavior of other market players – which further deepens the credit assets intoxication within the banking sector via macroeconomic destabilization and increasing systemic risks (Geršl, Seidler 2012, p. 97).

The aim of this work is to verify the hypothesis that is the adverse effect of the banks' rivalry on pro-cyclical behavior under prevailing oligopolistic market structure, manifested in the form of inadequate risk aversion in terms of credit policy. Therefore, it is intuitively possible to arrive at a conclusion that cooperative banking oligopoly, which coordinates its strategies in terms of the output volume and interest rate level[3], may be beneficial for the credit market and health of the financial system. In such case, the price of banking services may ultimately be higher; however, with the compensation of a healthy financial system and shorter economic depressions.

The application part of this study tries to simulate the portfolio strategy of banking oligopolists with the use of game theory models, specifically with the use of conflict situation model of banking duopoly, which best illustrates the situation within an oligopolistic market. The first two presented models simulate theoretical knowledge of the opponent's risk aversion as well as the resulting optimal credit portfolio. Next is the Bayesian game model (Harsanyi 1968), which simulates more rigorously the real situation with incomplete information about the competitors' strategies. The resulting equilibrium situation (Nash equilibrium – see Chapter 4) differs from the Pareto-optimal equilibrium via the preference of aggressive credit strategy with low risk aversion. This implies the benefits of banking cooperation within an oligopolistic market in setting a credit portfolio strategy as well as the harmful nature of rivalry that may promote the banking sector pro-cyclicality.

In the first part, the study addresses available literature in the area of banking sector market structures, pro-cyclical behavior, interest revenue, and game theory models. The application part comprises presentation of all three simulation models and the process of acquiring the input data from the banking sector in the Czech Republic.

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2 It is based on the central bank's macro-prudential policy, which is aimed at preventing the occurrence and spreading of systemic risks of the financial sector, thereby reducing the probability of emerging financial crises with significant losses for the economy as a whole in terms of its real output (during such crises, GDP is declining, on an average basis, for the period of about two years, not returning to its original trend for about four years) (Frait, Komárková 2011, p. 97).

3 Analogically, the coordination is beneficial to natural (network) monopoly, without which the effective management of energy networks would not work (Hon 2008).

1 Specificity of Market Structures and the Structure of the Banking Market in the Czech Republic

Can open cooperation of banks reduce the pro-cyclical behavior of the banking sector? It intuitively seems like valid hypothesis, since an open cartel or cooperative oligopoly, if you will, prefers long-term profits, market stability, and smooth supply to ensure than consumers do not look for substitutes. It is possible to find analogy to this in a key international open cartel OPEC[4], the long-term strategy of which is to ensure stable supply of oil to the world at a fair price, without fluctuations in deliveries with potential adverse effects on the economy of consuming nations (OPEC Statute, Chapter 1, Article 2).

In reality, perfect competition markets only exist in theory, while real markets tend to show attributes of imperfect competition, which changes its market structure based on circumstances. High number of sellers is not sustainable in the long run, always converging to clustering – i.e. combination of companies into individual cartels that compete with one another under a concentrated structure similar to oligopoly (Aumann 2000). The banking market is characterized by virtually all known characteristics of imperfect competition, with oligopolistic or monopolistic structure, as appropriate, mainly given by barriers to market entry (e.g. registered capital, central authority's permission), economies of scale for branch network, as well as by legal regulation and qualification requirements or product differentiation (given by, for example, credit standards on the basis of risk tolerance). Strategic decision-making of oligopolists is interconnected, since each of such entities may affect the market price through its output. Therefore, oligopolists are the price makers, unlike the perfect competition market entities, which are the price takers, without the ability to affect the price through its production (Hořejší, Soukupová et al. 2010).

The standard approach relating to the benefits of competition for consumers may be incorrect when it comes to the credit (loan) market. In general, efforts aimed at establishing a perfect competition environment result in the restriction of consumer choice (differentiated products) and limited development of innovations, which are the precondition to economic growth (Heissler, Valenčík et al. 2010). Some studies mention information externalities, i.e. increased costs of monitoring the clients' financial standing in case of a high number of banks operating within the market (Cotorreli, Peretto 2000); in terms of game theory, it concerns the concept of the free rider model[5]. This may result in an emergence of a segment of clients selected on the basis of first-rate monitoring or, as appropriate, a segment of clients, who did not undergo the monitoring process and were selected randomly. Consequently, the well-known risk accumulation takes place as a result of increasing probability of credit defaults upon emerging cyclical recession.

According to a study published in the Financial Stability Report of the Czech National Bank (Podpiera, A. 2007), the Czech market was characterized by a sharp decline in the market

4 *According to the declaration of an OPEC official (Yamani 1973), the reason for such approach may seem prosaic – i.e. that developed are not encouraged, through instability of deliveries and unbearable prices, to look for ways of doing without this commodity altogether.*

5 *Small banks use shared bank client databases about their financial standing – i.e. they eliminate costs of client screening; it is an information externality (Cotorreli, Peretto 2000).*

concentration during the 1990s, with many banks operating in the market, and its subsequent increase until the end of the period under review in 2005. The monopolistic competition was a sign of low market concentration, which converged to gradual oligopolization. This trend was associated with the banking sector stabilization, privatization of key banks in the country, and fixation of their respective market shares. The new decade, with the entry of internet banks and lower barriers to market entry (no need to develop a branch network), could lead to the monopolistic competition trend once again. The theory of contestable markets (Baumol 1982), where oligopolists are not interested in significant price increases not to attract other participants to the sector and start a price war, promotes the cooperative oligopoly and its long-term stability and benefits for some types of markets. The natural barriers to entry to the banking sector – particularly the branch network development – are currently becoming less significant due to internet-based banking, whereas oligopolistic banks act as if operating in a competitive market in this regard.

2 Reasons and Implications of the Pro-cyclical Behavior of the Banking Sector (not only) in the Czech Republic

The literature identifies five key factors for the banks' pro-cyclicality: herd behavior, information asymmetry, expectations, fluctuations in banks' balance sheet items, and financial innovations (Geršl, Jakubík 2010, p. 105). The first three causes fall within the study of behavior of economic entities and have previously been subject to a game theory analysis (Akerlof 1970, 1985, Geenwald and Stiglitz 1990, Bickchandani and Sharma 2001).

In case an increase in the market interest rates leads to lower profitability of banks (e.g. due to higher increase in reference rate or due to increasing risk premium as a result of regulatory measures), bank may react to this by increasing the supply of loans, with a view to maintain the profitability by expanding the banking portfolio (Geršl, Jakubík 2010 p. 106). This results in an increasing share of external funds of financial and nonfinancial institutions, leading to accumulation of systemic risks. During the economic recession stage, this is associated with sharp acceleration in the risk level and interconnected implications for the financial and nonfinancial sector in the period of insufficient financial reserves (Geršl, Jakubík 2010 p. 106). Banks react via interest rate restrictions, which may have adverse effects on the credit portfolio quality. Credit standards restriction is mainly manifested by increasing requirements for one's own funds for project financing or by imposing stricter requirements for loan security. This dynamically increases implied costs of investors in the form of higher costs of "expensive" equity (Kislingerová 2009). This actually results in the well-known adverse selection effect (Akerlof 1970, Geenwald and Stiglitz 1990), where risker projects, which can cover the interest rate through their expected returns, drive out more stable and less risky projects that generate lower returns and, consequently, cannot bear the interest burden, again with self-strengthening effects on systemic and credit risks[6]. This also postpones the natural economic recovery process.

Empirical data relating to the pro-cyclical behavior of Czech banks during the conjuncture are shown in the 2007 Financial Stability Report (Czech National Bank, FSR, pp. 47-59).

6 Systemic risk is given by the characteristics of national economy that may be reduced by the portfolio diversification on the international level. Credit risk is the risk of a loan default.

Loans increased by 42% for nonfinancial enterprises and 37.5% for households. The total volume of client loans amounted to CZK 1.78 billion. The year-to-year growth rate of 26.4% was mainly recorded in the business segment. Defaulted loans amounted to 3.1% of business loans, i.e. higher than in case of households (2.7%). The Report also stated that housing loans had become the top component of the credit portfolio.

The results of stress tests for 2007 indicate that in case of the implementation of scenario A – safe approach – the rate of default would amount to 7.9% for business and 3.1% for households. Therefore, it would be much higher within the business sector, which is more sensitive to economic fluctuations due to the riskier nature of its projects.

3 Determinants of Clients' Interest Income and the Credit Portfolios in the Czech Republic

Clients' interest income is affected by internal and external factors (Černohorský, Teplý 2011, p. 110). Internal factors mainly include costs of a bank, client's risk assessment, loan maturity and security, etc. In addition to the macroeconomic environment of the given country and government bond returns, external factors also include the competition environment level. Therefore, generally speaking, higher competition pressures lead to lower interest rates on loans and higher interest rates on deposits. A bank's credit portfolio is used to diversify the risks for the sectors of businesses, households, and government, becoming the bank's key loan strategy. The publication of Podpiera and Weill (2010) evaluated the excessive risk of credit portfolios in relation to the revenues of the Czech banking sector as a whole in the period of January 2005 – February 2008 for the sector of businesses and households. The ascertained average excessive risk of 33% in the period under review meant that one third of the non-optimal risk could have been reduced while retaining the same revenue. The excessive risk was analyzed by comparing the optimal portfolio with real portfolio (Table 1). The share of business loans – i.e. operating, export and import loans – was 1% higher than the optimal share. This means that their reduction would have contributed to better risk position with the same revenue of the portfolio. Similarly, reduction of loans for acquisition of financial instruments by 1.5% and of consumer loans by 1.8% would have led to the overall portfolio risk reduction. Finally, an increase in real-estate loans (particularly housing loans) by 4% would have resulted in the reduction of excessive risk. The analysis documented some trends of pro-cyclical behavior of the banking sector and irrational behavior of banks during the period of economic growth, with the preference of riskier loans. It is interesting that the highest differences between the optimal and the real share of individual loan categories within the portfolio were identified for operating business loans and loans for acquisition of financial instruments – up to 23% and 28% of the specific bank's portfolio, respectively. Such cases indicate aggressive portfolio strategies.

Table 1: Analysis of banking loan strategies for the sector of businesses and households in the period of 2005-08 in the Czech Republic

	Businesses		Households	
Loan category:	Income (%)	Risk (%)	Income (%)	Risk (%)
1) Operating, export/import loans	4.3	0.51		
2) Real-estate loans	5.5	0.41	5.7	0.31
3) Loans for acquisition of financial instruments	5.76	0.94		
4) Consumer loans	5.8	1.35	6.9	0.74
Average:	**5.3**	**0.80**	**6.3**	**0.52**
Credit portfolio components	Businesses		Households	
	Shares (real)	Shares (optimal)	Shares (real)	Shares (optimal)
1) Operating, export/import loans	14.23	13.33		
2) Real-estate loans	17.18	19.12	30.8	33.06
3) Loans for acquisition of financial instruments	14.32	12.81		
4) Consumer loans	3.71	3.36	19.79	18.54
Total:	**49.44**	**48.62**	**50.59**	**51.60**

Note: Aggregated % income (weighted average of interest rate for individual loan categories) and risk position (standard deviation of incomes).
Source: Data were aggregated for individual sectors by the author based on the data obtained from the study (Podpiera and Weill 2010).

4 Strategic Decisions of Banking Institutions from the Perspective of Game Theory

Unlike single-round or limited-time game situations, the repeated game system that is similar to reality gradually leads to the cooperation of players (Aumann 2000). Intelligent players look for the Nash equilibrium solution[7], such solution that guarantees the highest winnings irrespectively of the strategy selected by other players - i.e. identification of the so-called dominant strategy (Nash 1951, Dlouhý and Fiala 2009). The banking market is forced, through regulation, to non-cooperative behavior and selection of dominant strategies, irrespectively of their Pareto-optimality. A cooperative strategy on the banking market is only possible if it brings higher guaranteed profits than noncooperation, at the expense of hidden cartels on the basis of collusion agreements, which significantly increase the costs of cooperation. Such cartels are unstable and their members tend to violate the collusion agreements, since no institutional framework for the enforcement thereof exists (Hořejší, Soukupová et al. 2010). Secretive cartel (collusion) agreements, by

7 *A situation, where no player may improve his situation by changing the selected strategy; at the same time, it is a solution concept of a non-cooperative game involving two or more players. It was named after John Nash, who proved that each finite game has at least one such solution.*

nature aimed at short-term profits, naturally promote irrational behavior of banks and the pro-cyclicality of the entire sector.

The original model situations of game theory were based on interactions of two entities that pursue conflicting goals, with a set of strategies at their disposals to be used in order to attain their goals (Morgenstern and Neumann 1944, Dlouhý and Fiala 2009). In a normal form, a game represents a situation, where players have complete information – e.g. about the payoff matrix, which represents the overview of information about the payoffs of all players (utilities, preferences). Naturally, each player knows their own payoff function; however, he/she is unlikely to know the payoff functions of other players (e.g. a company does not know the cost functions of its competitors, an investor does not know the risk aversion of other investors, etc.).

The Cournot duopoly model (Cournot 1838), which is a special case of oligopoly, strived for equilibrium in finding the optimal product while maximizing profit, de facto becoming the first general concept of the Nash equilibrium solution. Analogically, it is the same as finding the optimal product of a bank in the form of optimal credit expansion while maximizing client interest rate adjusted for credit risk. The publication includes a model situation of non-cooperative oligopoly, expanded by the unfamiliarity with the competitor's risk aversion. This situation represents analogy to the category of games with incomplete information, such games being characterized by the unfamiliarity with private (proprietary) information. These games are also called Bayesian games in theory (Dlouhý and Fiala 2009).

The modelling of conflict situations with incomplete information was further developed by J. C. Harsanyi (1967-8) by introducing a prior move of an imaginary player (Nature), determining the type of each player. The player types, and consequently their preferences, result from the random variable selected by Nature. It simulates a situation, where players do not know the type of player to be selected. This lack of information is modelled with the same probability for the selection of type of each player.

Bayesian game is defined by:

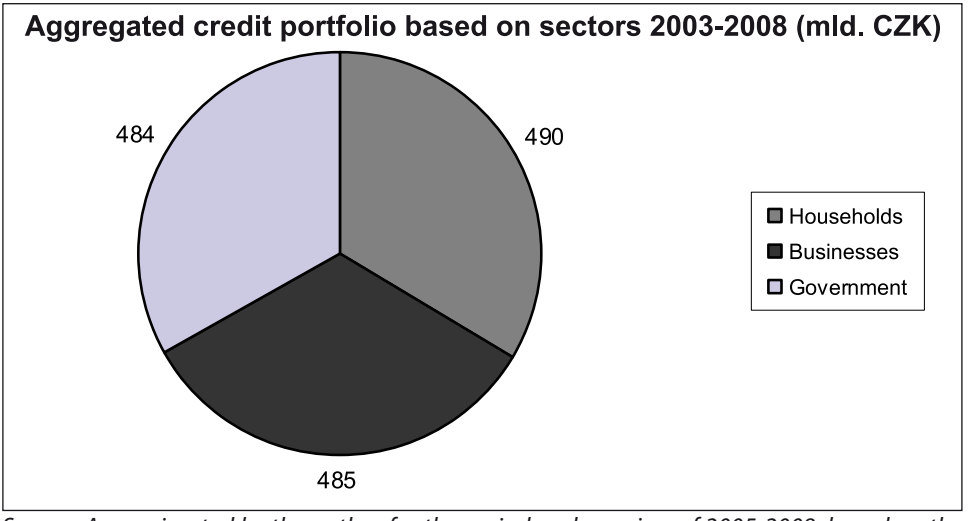
1. Set of players: {1,2….N}
2. Set of strategy profiles: {X1,X2….,XN}; specific strategies are described as (x1,x2…,xN);
3. Set of player types: {T1,T2….,TN}. Type ti→Ti corresponds to certain payoff function, which can be utilized by player i. The player i know his type, but he does not know the types of other players.
4. Set of players' views: {p1,p2….,pN}. The view ppi represents the view of player i relating to the types of other players. The view of a player is captured in the model via a subject probability function.
5. Set of payoff functions: {f1 (x1,x2…,xN , t1,t2…tN),….,fN (x1,x2…,xN , t1,t2…tN)}. Payoff function is a two-place function of strategy profiles and player types; it depends not only on the specific player's decision, but also on the decisions of other players.

5 Data Base for Compiling the Model of the Banking Oligopoly in the Czech Republic

The case study deals with a version of non-cooperative banking oligopoly. The basis for the strategic decisions of oligopoly is the optimal portfolio distribution in terms of income and risks of individual loan categories. In order to simply the model, the credit portfolio asset structure was aggregated from the macroeconomic perspective under three main sectors of the economy, specifically: households, businesses, and government. In this study, the impact of the foreign sector was excluded for the time being.

Acquisition of government bonds by a bank does not represent a conventional financial loan; however, the income from such transactions represents a benchmark of risk-free income for conservative credit strategies. In case of an adjustment of interest rates for households and businesses, it is possible to compare the risk-free income of these sectors with the government bond returns (see Table 2).

Figure 1: Aggregated banking credit portfolio according to individual sectors of the Czech economy



Source: Approximated by the author for the period under review of 2005-2008, based on the data from monetary and financial statistics of the Czech National Bank.

Surprisingly, domestic banks contributed, on an approximated basis, similar share to the government debt in the period under review. Therefore, the three-sector model of credit portfolio of financial institutions in the Czech Republic model is symmetrical (Figure 1).

Table 2 includes interest rates, which serve as the basis for determining the payoff function for individual sectors of bank's portfolio under a standard-form game. The interest rate is

adjusted for discount or premium, as appropriate, relating to transaction costs[8] of loan categories, showing some costs inefficiency for servicing individual sectors. This adjustment did not relate to the government sector due to its neutrality in terms of transaction costs. The last interest rate adjustment is the so-called risk-free income based on the "two sigma" quantitative rule for normal distribution of probability based on statistical analysis. In this case, it applies under normal distribution of the variable under review (i.e. loan income) that 95% of all values are within the interval of twice the standard deviation from the median. Consequently, it is possible to say – with 95% probability – that the income will not be less than 4.26% for the household sector and 4.7% for the business sector. However, the aforementioned income levels are still higher than the government bond income in the period under review and, consequently, banks prefer to finance projects of real sector and of households during the period of cyclical prosperity.

Table 2: Analysis of interest income from banking portfolios according to individual sectors in the period of 2004-08 in the Czech Republic

	Businesses	Households	Government
Approximated market interest rate on loans	5.3%	6.3%	3.5%
Transaction costs discount / premium	Plus 1%	Minus 1%	0%
Approximated interest rate after adjustment	6.3%	5.3%	3.5%
Risk – standard deviation	1.6%	1.04%	0%
Risk-free interest rate (interest rate adjusted for risk)	4.7%	4.26%	3.50%

Source: Approximated interest rate and standard deviation from the data of the study for the period of 2005-2008 (Podpiera and Weill 2010); model discount or premium, as appropriate, estimated by the author.

6 Construction of the Banking Duopoly Model

The market interest rates of individual economic sectors adjusted for transaction costs represent the basis for the game model of banking duopoly for the period under review in the Czech Republic. Higher number of enterprises (banks) within the industry does not change the principle of a duopoly model and is, under the given preconditions, also relevant in other cases of oligopoly (Dlouhý and Fiala 2009, Hořejší, Soukupová et al. 2010). In this case, the banking oligopoly is represented by a duopoly model with two banks, where one of the banks represents the remaining banking sector. This approach is based on the precondition that the behavior of one bank in the area of credit portfolio strategy is affected by the entire market and that neither bank has information about the strategy selected by the other bank.

8 *Transaction costs represent any and all costs associated with arranging (ensuring) the given transaction – i.e. costs of the entire loan relation process in this specific case. Banks generate costs savings (economies of scale) for business loans, as the volume of individual loans tends to be higher compared to household loans. The impact of transaction costs is apparent by preference of corporate loans before household loans despite the lower interest rate and higher risk as is clear from the data shown in Table 1. The amount of the discount / premium model is established precisely to compensate for the gap between interest income and the risk of business loans and household loans.*

An intelligent player represents a player with complete information about the game and his behavior is aimed at maximizing the payoff function value. Non-antagonistic conflict distinguishes two situations, where players may / may not reach agreements on their choices prior to making such choices; based on this criterion, we distinguish a cooperative or non-cooperative game, as appropriate. We will find the optimal strategy of players in the game using the Nash equilibrium. The Nash equilibrium is attained by identifying the saddle point of a matrix[9]. Publicly known information is available to all players (e.g. competitor's client interest rate). In addition to the publicly known information, games with incomplete information also feature private/proprietary information, which is only available to some players (e.g. risk aversion). This initial private/proprietary information determines the so-called player type in the game – i.e. with aggressive or conservative strategy, as appropriate, in our case (Dlouhý and Fiala 2009).

The model is constructed under the following conditions: it comprises two economic entities: Bank 1 (representing the remaining banking sector) and Bank 2. The optimal portfolio strategy of Bank 2 is sought, whereas Bank 2 does not have the private information concerning the risk aversion level of Bank 1 (conservativeness or aggressiveness).

The model base of the credit market structure – i.e. of the entire banking sector portfolio – relies on the empirical data for the period under review 2005-2008 and it is divided into thirds with the corresponding share of loans in individual sectors: 1/3 businesses (B), 1/3 households (H), and 1/3 government (G) – see Figure 1.

Another determinant of the banking duopoly model is the elasticity of interest rate or payoff function, as appropriate, in case of banks' higher output – i.e. supply of loans in individual sectors – compared to the demand after such output under the given credit terms (interest rate, credit standards). The reaction is the output price reduction (i.e. reduction of interest rate) or increase in interest rate in case of lower money supply compared to the demand of individual sector.

The first two models (Model 1 and Model 2) foresee a simple matrix game in standard form, where players are familiar with the game structure – i.e. potential types of aggressive or conservative portfolios (as appropriate) of an opponent in our case but not with their final chosen portfolio. In other words, the players are familiar with their opponent's risk aversion.

The first banking duopoly model comprises to types of aggressive portfolio of Bank 1 in case of its aggressive strategy (according to the game theory terminology, it concerns the so-called Bank 1 type 1):

1) BBH – 1/3 businesses, 1/3 businesses, 1/3 households = 2/3 businesses and 1/3 households
2) BHH – 1/3 businesses, 1/3 households, 1/3 households = 1/3 businesses and 2/3 households

9 *A saddle point is an element of the matrix which is both the largest element in its column and the smallest element in its row.*

Both portfolio selected in the model have lower risk aversion, focusing on more profitable sectors of businesses and households and doing without the so-called risk-free investments in government bonds. The first alternative of the portfolio, BBH, is more aggressive, with predominant share of more profitable, though riskier, business loans. The second alternative, BHH, shows dominant share of household loans with lower income, but – logically – with lower risks.

Bank 2 has three different portfolio strategies at its disposal, which will be subjected to testing under game model as follows:

1) BHG – 1/3 businesses, 1/3 households, 1/3 government – purely diversified portfolio
2) BBH – 1/3 businesses, 1/3 businesses, 1/3 households = 2/3 businesses and 1/3 households
3) BHH – 1/3 businesses, 1/3 households, 1/3 households = 1/3 businesses and 2/3 households

The first portfolio is purely diversified. The second portfolio, BBH, is aggressive (see Bank 1 type 1), whereas the third portfolio, BHH, is less aggressive, with focus on the household sector.

Model 1: The game matrix (normal form) in case of aggressive strategies of Bank 1 (Bank 1 type 1) and selected mix of portfolio strategies of Bank 2.

		Aggressive strategies of Bank 1 (Bank 1 type 1)			
		BBH		BHH	
Bank 2	BHG	(5.03)	[5.30]	(5.03)	4.97
	BBH	4.97	[4.97]	4.97	4.63
	BHH	4.63	[4.97]	4.63	4.63

Note: Input data from the monetary and financial statistics of the Czech National Bank and from the underlying study (Podpiera and Weill 2010). Source of final values: Own calculation.

The maximum values in each column for Bank 2 are shown in parentheses, whereas the maximum values in each row for Bank 1 are shown in brackets. The saddle point comprises two values shown in parentheses/brackets. Bank 2 identifies the dominant strategy of Bank 1, BBH, as it is familiar with the game structure – i.e. with potential types of aggressive portfolios, and selects its strategy accordingly – i.e. BHG. Moreover, this is the dominant strategy of Bank 2, meaning it would select it irrespectively of the Bank 1 strategy. The Nash equilibrium solution with dominant strategy applies in this case, where Bank 2 may only worsen its position by selecting another strategy (in this case BBH or BHH – the so-called dominated). The payoff function of 5.03 generated in case of the dominant strategy for Bank 2 is the same as the payoff function for the equilibrium in all sectors (5.03). This solution is also Pareto-optimal, i.e. neither of the players may improve their situation without one of the players being worse off. At the same time, zero-value of information exists in this game – Bank 2 would not change its strategy even if the strategy of Bank 1 is disclosed.

Model 2 foresees two conservative portfolios for Bank 1 in case of its cautious strategy (according to the game theory terminology, it concerns the so-called Bank 1 type 2):
BHG – 1/3 businesses, 1/3 households, 1/3 government – purely diversified portfolio
HHG – 1/3 households, 1/3 households, 1/3 government = 2/3 households, 1/3 government

The first portfolio, BHG, represents a purely diversified portfolio of assets distributed evenly among the three main economic sectors. The second portfolio, HHG, represents a super-conservative portfolio, with elimination of the riskiest component – i.e. business loans – in favor of the less risky household sector, with one share of risk-free investments in the form of government bonds. Once again, Bank 2 has a mix of three portfolio strategies at its disposal, similarly as in the first model.

Model 2: The game matrix (standard form) in case of conservative strategies of Bank 1 (Bank 1 type 2) and selected mix of portfolio strategies of Bank 2.

		Conservative strategies of Bank 1 (Bank 1 type 1)			
		BHG		HHG	
Bank 2	BHG	5.03	[5.03]	5.03	4.03
	BBH	(5.30)	[5.03]	(5.63)	4.37
	BHH	4.97	[5.03]	4.97	4.03

Note: Input data from the monetary and financial statistics of the Czech National Bank and from the underlying study (Podpiera and Weill 2010).Source of final values: Own calculation.

Once again, the saddle point comprises two values shown in parentheses/brackets. Again, Bank 2 identifies the dominant strategy of Bank 1 on the basis of the known game structure, selecting its optimal strategy (BBH) accordingly - this being the most aggressive strategy. The saddle point represents the Nash equilibrium solution with dominant strategy, where Bank 2 generates above-average income of 5.3 or 5.63 (as appropriate), if Bank 1 diverts from its dominant strategy BHG. In this case, the Nash solution is also the Pareto-optimal solution for the banks' incomes – as in the previous case.

In the next case, the risk aversion of Bank 1 (i.e. its type) represents unknown information for Bank 2; i.e. Bank 2 does not know, which portfolio strategy will be selected by Bank 1 out of its set of available strategies. We say that Bank 2 does not have the private (proprietary) information about the type of Bank 1, unless we consider insider-trading or cooperative strategies. In practice, this means that the bank does not know the prevailing portfolio strategy within the banking sector. It is a typical game with incomplete information, because Bank 2 does not know whether Bank 1 prefers aggressive or conservative banking portfolio, while Bank 1 obviously has this proprietary information. We will convert the two-player game with incomplete information to a three-player game with imperfect information, involving Bank 2, Bank 1 type 1 (prefers aggressive portfolio), and Bank 1 type 2 (prefers conservative portfolio). Both banks know the probability of distribution of types (P = 0.5) prior to the Nature's move; however, only Bank 1 will find out the results of lottery that determines its type at the beginning of the game. Since Bank 2 does not know the current type of Bank 1, it must estimate the optimal actions of both types of Bank 1.

The strategy (BBH, BHG) will describe a situation, where Bank 1 type 1 selects portfolio BBH and Bank 1 type 2 selects portfolio BHG. The strategy (BBH, HHG) means that type 1 opts for BBH, while type 2 chooses HHG, and accordingly for other combinations between the strategies of Bank 1 type 1 / type 2 from Models 1 and 2. In this manner, we create the payoff matrix of three players, where the first value represents the payoff for Bank 2, the second value represents the payoff for Bank 1 type 1, and the third value represents the payoff for Bank 1 type 2. The payoff for Bank 2 for strategy BHG against the pair of strategies of Bank 1 (BBH, BHG) will be calculated as follows: 0.5 x 5.03 + 0.5 x 5.03 = 5.03. The payoff for Bank 1 type 1 is determined as the combination of strategies (BHG, BBH) from the first matrix, i.e. 5,03. The payoff for Bank 1 type 2 is determined as the combination of strategies (BHG, BHG) from the second matrix, i.e. 5. The remaining elements of the matrix will be determined accordingly – see Model 3.

Model 3: The game matrix (normal form) in case of mixed strategy of Bank 1 (Bank 1 type 1 and Bank 1 type 2) and selected mix of portfolio strategies of Bank 2.

Mixed strategy of Bank 1 (probability of application of aggressive or conservative strategy is 50%)

		BBH,BHG			BBH,HHG			BHH,BHG			BHH,HHG		
Bank 2	BHG	5.03	[5.30]	[5.03]	5.03	[5.30]	4.03	5.03	4.97	[5.03]	5.03	4.97	4.03
	BBH	(5.13)	[4.97]	[5.03]	(5.30)	[4.97]	4.37	(5.13)	4.63	[5.03]	(5.30)	4.63	4.37
	BHH	4.80	[4.97]	[5.03]	4.80	[4.97]	4.03	4.80	4.63	[5.03]	4.80	4.63	4.03

Source of final values: Own calculation.

We will find balanced (equilibrium) actions for all players as follows: Bank 2 seeks maximums of the first values in each column; Bank 1 type 1 seeks maximum of the second values in each row; and Bank 1 type 2 seeks maximum of the third values in each row.

In case we identify a trio shown in parentheses/brackets, it is the Bayesian-Nash equilibrium in pure strategies. The banking duopoly game with incomplete information has its equilibrium in the pure strategies {BBH (BBH, BHG)}. Bank 2 will select strategy BBH, i.e. the most aggressive credit portfolio focusing on the business sector, and waits for the strategy selected by Bank 1. In case Bank 1 opts for more aggressive strategies, Bank 2 gets lower returns than if Bank 1 chooses more conservative portfolio. However, Bank 2 generates above-average returns in all three cases, with 5.13 and 5.3, respectively, whereas Bank 1 only generates below-average returns ranging from 4.37 to 5.03. In case Bank 2 diverts from the dominant strategy, it will get less (see the Nash equilibrium solution). However, such solution is not Pareto-optimal – highlighted in grey. In case Bank 2 selects the dominated strategy BHG, both banks receive more compared to the Bayesian-Nash equilibrium with dominant strategy. The payoff function of Bank 2 could amount up to 5.19 (see Table 3), so that Bank 1 is still motivated to redistribute the income more. (Budinský, Valenčík 2009) Model no. 3 represents the Pareto-optimal solution for cooperation, to which repeated games of non-cooperative oligopoly widely converge. Table 3 compares adjusted incomes of Bank 2 in individual games with the risk-free income from government bonds. Bank 2 generates the second highest risk-free income with diversified strategy under the structure of aggressive type of Bank 1 (see Model 1). The mixed strategy leads to the lowest difference – specifically for the non-cooperative mixed strategy pursuant to Model 3,

on the contrary, the cooperative strategy leads to the highest risk-free income. This means that banks' rivalry aimed at achieving dominant position in more profitable segments is associated with negative effects typical of pro-cyclicality during the period of economic growth, i.e. reduction of interest rates (or risk premiums, as appropriate) and easing of credit standards, with consequent accumulation of credit risks (see the stress tests for the period under review in the 2007 FSR of the CNB mentioned in Chapter 3 of this Article).

Table 3: Income of Bank 2 for individual equilibria shown in Models 1 through 3 and subsequent risk-free income.

	Market interest rate of the portfolio	Portfolio risk	Risk-free interest rate of the portfolio	Excess income of the portfolio over the government bond income
Bank 2 in duopoly with information about the opponent's aggressive strategy	5.03 %	0.88 %	4.15 %	0.65 %
Bank 2 in duopoly with information about the opponent's conservative strategy	5.3 %	1.4 %	3.9 %	0.4 %
Bank 2 in non-cooperative duopoly with mixed strategy	5.13 %	1.4 %	3.73 %	0.23 %
Bank 2 in cooperative duopoly with mixed strategy	5.19 %	0.88 %	4.31 %	0.81 %

Source of final values: Author's own calculation based on the input data from Models 1-3 and Table 2.

Conclusions

The study indicates that rivalry of banks during favorable economic cycles promotes pro-cyclicality of the banking system (ceteris paribus based on the data used from the period of 2005-2008). In case private (proprietary) information about the banks' portfolio strategies is not disclosed, solutions may be selected that are not Pareto-optimal. This means that dominant strategies prefer more aggressive portfolio aimed at increasing the market share within the most profitable segments, particularly in the business segment followed by the household segment (and vice versa, the dominant strategy during recession may be the abandoning of risky sectors and dominating of conservative sectors, particularly within the government bond market). Repeated non-cooperative games converge to cooperative behavior (Aumann 2000; Dlouhý a Fiala 2009) – i.e. to various collusion agreements and formation of hidden cartels in case of oligopolistic markets, which are generally unstable. Available publications document (Hořejší, Soukupová aj. 2010; Dlouhý a Fiala 2009) that the dominant strategy of a secret cartelist is the output tampering, short-term profits, and adherence to agreements only in case of one-sided benefits, which may further promote pro-cyclicality. It is thus possible to deduce on the basis of a model that open cooperative oligopoly on a credit market could lead to a Pareto-optimal solution at the expense of higher, yet bearable interest rates and credit standards – i.e. optimal solution for banks as well as the market as a whole or, consequently, for the financial system without counter-effects on credit and systemic risks (accumulation of risks during the period of positive expectations), with causal excessive prolongation of cyclical recession.

Cooperation of banks could fittingly supplement the efforts of central authorities aimed at smoothing economic cycles, in addition to increasingly less effective transmission channels and controversial unconventional instruments of central banks' monetary policy.

Higher price of banking services, as the consequence of the proposed limitation of rivalry in case of the banks' cooperation, could become the compensation of the taxpayers' expenses associated with financial crises (government guarantees to banks for banking liabilities, capital injections to institutions at risk, etc.). Utilization of public funds for the recovery of the banking system's assets has become the implication of the last financial and, currently, debt crisis in Europe and in the United States. Sharing of information and coordination of credit strategies could create desired self-regulation of forefront banks, with immediate impact on the real economy – unlike external regulation by a central bank with the use of conventional and unconventional instruments, with varying effective date and effectiveness depending on hardly predicated changes in factors (Komárek, Komárková 2012).

The provision of information about the optimal output (product) may be ensured by a central bank, based on its expert analyses (share of loans in GDP and deviation from normal, gaps in asset prices and returns, etc.). Accordingly, the central authority may recommend the application of individual regulatory instruments, which are subject to macro-prudential policy (Frait, Komárková 2011), in addition to effects of monetary policy instruments that do not prevent rivalry, price wars, and collusion agreements in the banking market. Therefore, self-regulation – i.e. a type of banking self-administration within the industry – would operate in parallel to the supervision authority. Similarly as in case of the cartel of petroleum exporting countries – homogeneous commodity, essential for economy – credit facilities, which are an inevitable source of economic development, should be perceived in the same manner.

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