LIBOR as a Keynesian Beauty Contest: A Process of Endogenous Deception

Alexis Stenfors[‡]

Abstract:

This paper uses the Keynesian Beauty Contest as a theoretical framework to analyse the London Interbank Offered Rate (LIBOR) fixing mechanism, where the actual money market rate is seen as a fundamental value towards which the LIBOR should aim. By treating the LIBOR as the outcome of a particular kind of p-beauty contest game, in which players (LIBOR banks) are guided by higher order beliefs, a process is created whereby they are not solely dependent on their own incentives and constraints. Instead, potential deception is generated endogenously though the fixing process itself, resulting in systematic deviations of the LIBOR from its fundamental value.

1 Introduction

Until around 2008, the London Interbank Offered Rate (LIBOR) was widely perceived to be a reliable reflection of the interbank money market colloquially and professionally in the economic literature. Academics treated the terms *as if* they were synonyms. Policy makers acted *as if* the LIBOR was an objective reflection of the money market rate. Corporates and households entered into LIBOR-indexed financial contacts *as if* the money market was the underlying benchmark. Recently, however, claims that the benchmark, at times, has been subject to attempts of manipulation by LIBOR panel banks, have placed this into question.

[‡] Department of Economics and Finance, Portsmouth Business School, University of Portsmouth, Richmond Building, Portland Street, Portsmouth PO1 3DE, UK. Email: alexis.stenfors@port.ac.uk. This article has benefitted greatly from discussions with Professor Costa Lapavitsas (SOAS, University of London), Professor Stergios Skaperdas (University of California), Professor Yuval Millo (University of Leicester), Professor Yanis Varoufakis (University of Texas) as well as participants at the LIBOR Games Seminar, SOAS, 7 November 2012. An earlier version of this article was made available online in October 2012 as RMF Discussion Paper No. 40 (http://www.researchonmoneyandfinance.org/index.php/publication/discussion-papers).

LIBOR-indexed derivatives portfolios and the stigma attached to signalling a relatively high funding cost to the rest of the market appears to have given some banks sufficiently strong incentives to submit 'deceptive' LIBOR quotes in order to reap monetary benefits from having the privilege to participate in the LIBOR fixing process (Financial Services Agency, 2011; Financial Services Authority, 2012; U.S. Commodity Futures Trading Commission, 2012).

The LIBOR fixing mechanism lacks binding rules requiring banks to trade at their submitted quotes, and is in fact not a market per se. Instead, the benchmark is determined by a selected group of panel banks as follows. [1] A designated calculation agent (such as Reuters) collects submitted quotes from the individual panel banks before noon. The trader or another bank person at the cash desk or treasury submits his or her quote from the bank terminal, and the other banks do the same without being able to see each others' quotes. The calculation agent audits and checks the quotes for obvious errors and then conducts the 'trimming', omitting the highest and lowest quotes (the number of which will depend on the sample size). Finally, the arithmetic mean is calculated, rounded to the specified number of decimals and published at a specific time depending on the benchmark (British Bankers Association, 2012).

The fact that LIBOR panel banks not only have the means and opportunity, but also the incentive, to submit deceptive quotes, is of course not exclusively an issue confined to legal scholars. In theory, the LIBOR should reflect current and expected future policy rates, credit and liquidity risk. The assumption, or rather false perception, that the LIBOR itself is based upon actual market transactions is in fact central to previous attempts to decompose the LIBOR and money market risk premia such as LIBOR-OIS spreads (See, for example: Bank of England, 2007; McAndrews, Sarkar, & Wang, 2008; Poskitt, 2011; Schwartz, 2010).[2] This approach assumes that the LIBOR rate is objective in the sense that it perfectly reflects where the panel banks are able to raise funds from each other, i.e. the money market rate. Problematically, the method is not robust should the LIBOR for one reason or the other not equal this money market rate. Moreover, should the by far most frequently used benchmark for the interbank money market be systematically manipulated, it would have far-reaching

[1] The LIBOR is used broadly in this article also to capture other LIBOR-equivalent benchmarks with similar fixing mechanisms, such as the Euro Interbank Offered Rate (EURIBOR), the Norwegian Interbank Offered Rate (NIBOR), the Stockholm Interbank Offered Rate (STIBOR) and the Tokyo Interbank Offered Rate (TIBOR).

[2] OIS refers to the Overnight Index Swap

consequences for financial markets and policy makers alike. Therefore, greater insight into how the LIBOR fixing mechanism works theoretically is essential in political economy.

Stenfors (2012) adopts a game-theoretical approach to illustrate how the LIBOR fixing, at a given time, can be driven by different incentives and constraints of the individual LIBOR panel banks. By constructing and solving simple 'LIBOR games', it is shown that the trimming process associated with the LIBOR fixing mechanism is not effective in ensuring a 'fair' LIBOR fixing. An endowment in the form of a LIBOR-indexed derivatives portfolio, or the stigma attached to signalling high funding costs relative to others, can act as incentives to submit LIBOR quotes deviating what could be regarded as the 'actual' money market rate. Different forms of collusion can be a possible but not exclusive reason for an 'off-market' LIBOR rate if panel banks do not know each others' endowments, but rather assume that all banks always aim to opt for the best possible strategy to use its ability to influence the LIBOR fixing. Significantly, constraints put in place to make the mechanism more 'market-like' are shown to require full transparency to be effective.

This article extends the game-theoretical analysis of the LIBOR fixing mechanism. Instead of treating it as a single-period game with equally creditworthy players, it emphasises the fact that LIBOR submissions are made daily and that the perceived creditworthiness of banks might differ. In doing so, it considers whether the deviation between the LIBOR and the rate it fundamentally should reflect can be systematic. This is important as any future modification in the way the benchmark is determined ultimately needs to consider its simple and original purpose: namely to represent the average interbank money market rate.

Keynesian Beauty Contests in general, and *p*-beauty contest games in particular, have often been used to illustrate why stock markets are volatile and how the price of a tradable asset systematically can deviate what objectively could be regarded as its fundamental value. From this perspective, we could also consider if some kind of fundamental value exists in the money market, and if and why the money market rate at times deviates from this value. The LIBOR, in this context, should be seen as a reflection of the money market rate, and not vice versa.

Using the Keynesian Beauty Contest framework, this article conceptualises the money market as a kind of fundamental value against which the LIBOR should be benchmarked. The LIBOR rate is supposed to be an objective reflection of the interbank money market rate, and more specifically the average subjectively reported funding cost of a group of banks. This reporting mechanism is viewed in terms of a LIBOR game, being played an infinite number of times, and consisting of players guided by the anticipation of what others will do

and what they anticipate others will do. By regarding the LIBOR fixing as the outcome of a peculiar form of a *p*-beauty contest game, a situation is demonstrated where the LIBOR deviates from this money market rate. In fact, a *p*-beauty contest game is precisely how we could view the LIBOR Game.[3]

The results presented in this article show that as players are guided by higher order beliefs, some LIBOR panel banks can be seen as being driven towards a behavioural pattern that is not dependent on their own incentives and constraints in the first instance, but generated endogenously though the process itself. Deception in this case does not need to result from the self-interest of an individual LIBOR submitter, but rather from the perception that others will act in such a manner that not submitting deceptive LIBOR quotes would be punished. This can result in long-lasting deviations of the LIBOR from the underlying money market. The current LIBOR fixing mechanism can be seen as a facilitator of such behaviour.

This article is structured as follows. Section 2 provides a brief overview of *p*-beauty contest games in the literature, and a discussion on how the LIBOR could conceptually fit into this context. In Section 3, a simple LIBOR *p*-beauty contest game is constructed with the aim of being as realistic as possible. Given the utility function of each player (LIBOR panel bank), possible outcomes of this game are then considered in Section 4. Section 5 draws conclusions.

2 The *p*-Beauty Contest Game: Regarding the Money Market as the 'Fundamental Value'

> Professional investment may be likened to those newspaper competitions in which the competitors have to pick out the six prettiest faces from a hundred photographs, the prize being awarded to the competitor whose choice most nearly corresponds to the average preferences of the competitors as a whole: so that each competitor has to pick, not those faces which he himself finds prettiest, but those which he thinks likeliest to catch the fancy of the other competitors, all of whom are looking at the problem from the same point of view. It is not a case of choosing those which, to the best of one's judgement, are

[3] Inspiration for the design of the LIBOR Game as *p*-beauty contest game has, in part, been drawn from numerous discussions and interviews with market participants during 2007-12. In total, individuals, representing 15 banks and 4 interdealer brokers, either directly or very closely involved in the LIBOR, TIBOR, NIBOR and STIBOR fixing process were consulted.

> really the prettiest, nor even those which average opinion genuinely thinks the prettiest. We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be. And there are some, I believe, who practise the fourth, fifth and higher degrees. (Keynes, 1936: p. 156)

This passage from Keynes has provided the basic platform for numerous and different variants of games labelled as Keynesian Beauty Contest games. In essence, we are in dealing with the phenomenon of market participants not always simply seeking a long-term fundamental value of an asset, but taking a more short-term view and incorporating what s/he believes others will do and how they believe others will do and so on.

Although some of the games modelled with this passage in mind might lack direct connotations to Keynes (Fung, 2006; Lanteri & Carabelli, 2011), we are nonetheless concerned with the observation that the price of a financial asset often deviates from the consensus view of the fundamental value of the asset in question. Moreover, the price reaction to changes in fundamentals in a beauty contest is much more sluggish than that of the consensus fundamental value (Allen, Morris & Shin, 2006). To put it differently, game-theory is used to understand and illustrate the role of higher-order beliefs in asset pricing as each market participant has the ability to affect the market price, and s/he knows that the others do as well.

A typical illustration of a *p*-beauty contest game is when a large number of players simultaneously shall choose a number from a closed interval [0,100]. The person who chooses the number closest to *p* times the mean wins a prize. In case there is a draw, the prize is divided equally amongst the winners. To explain the process in a classic *p*-beauty contest game, *p* is normally set at 2/3. Assuming the guesses are normally distributed between 0 and 100, the rational guess would there be two-thirds of 50, i.e. 33. But since others think the same, it would be 22 (two-thirds of 33), and so on. Hence, for $0 \leq p < 1$ there is only one Nash equilibrium, namely zero (See, for example: Duffy and Nagel, 1997; Ho, Camerer & Weigelt, 1998; Nagel, 1995, 1999; Nagel *et al*., 2002).

In terms of a Keynesian Beauty Contest, the LIBOR, as a benchmark, should reflect the money market – and not vice versa. Conceptually then, we could treat the money market rate (whether perfectly observable or not) as a kind of fundamental value, or a focal point, towards which the LIBOR rate should aim. More specifically, the LIBOR fixing mechanism can be viewed as a *p*-beauty contest game with more than two players where $p = 1$.

To illustrate this, let us assume that the money market rate is common knowledge and that all banks face the same funding cost. Banks in such a game would be driven by a desire to guess exactly the average of all guesses. Theoretically, we have a coordination game with infinitively many equilibrium points in which all players choose the same number (Ochs, 1995)**.** However, in a LIBOR game, we do have a natural focal point: the money market rate, which in this case is common knowledge. Therefore, the money market rate could be regarded as the fundamental value, i.e. $p = 1$.

The trimming process (the omission of the highest and lowest quotes from the calculation of the LIBOR fixing) can be seen as a mechanism put in place to ensure that players remain alert and aim for $p = 1$ in every round of the game. Therefore, as players tend to avoid extreme endpoints (Rubinstein *et al.,* 1997), and also learn from the LIBOR fixing of the previous day, outliers will increase their efforts not to be omitted the following day. Thus, the original design of the LIBOR fixing mechanism could be seen as a median-effort-game (Cachon & Camerer, 1996), where it is assumed that LIBOR panel banks harmonise their behaviour following a learning process.

However, recent investigations into the alleged LIBOR manipulation have highlighted some underlying incentives that might distort this coordination process. For instance, banks might have LIBOR-based derivatives portfolios giving them sufficiently strong incentives to submit LIBOR quotes deviating from their actual short-term funding cost. From the perspective of a *p*-beauty contest game, these portfolios could be seen as endowments automatically forming three different types of players. Players with endowments benefitting from a relatively low LIBOR are playing a game where they should guess $0 < p < 1$, whereas those benefitting from a relatively high LIBOR face a game where $p > 1$. A player with no endowment would continue to play $p = 1$. As a consequence, if some players face a game where $p \neq 1$, the probability increases that the LIBOR deviates from the actual money market rate, as players have different focal points depending on their underlying LIBOR-indexed derivatives portfolios. This game could have different outcomes depending on the distribution of the types of players.

Another incentive relates to the stigma attached to signalling a relative high short-term funding cost through the LIBOR fixing process. According to the British Bankers Association (2012), LIBOR quotes are supposed to reflect 'where the bank can fund itself in the interbank market'. Therefore, an individual quote above the average of the panel quotes might be interpreted as a signal that the bank has funding problems relative to the others. Likewise, a lower than average quote would signal that the bank is in relatively good shape –

as individually submitted LIBOR quotes are visible to the whole market, not only to the other LIBOR panel banks after the fixing has taken place. The stigma incentive, thus, rewards players submitting a below-average quote – regardless of the actual LIBOR fixing. In terms of a *p*-beauty contest game, the stigma incentive seen in isolation automatically implies that $0 < p < 1$ for all players, rather than $p = 1$.

However, despite the existence of these incentives, it is unlikely that players in the LIBOR *p*-beauty contest game (or LIBOR panel banks in reality for that matter) always aim to win the game *at any cost*. The LIBOR (in terms of a game) would not have established itself as such an important benchmark without having some kind of constraints attributed to it. For instance, the frequent use of fixed intervals in *p*-beauty contest games is not without controversy, as it could be argued that the price drift of a financial asset often lacks typical boundaries. To some degree, the same could be said about the LIBOR, which has experienced some sharp moves during times of crisis. Nonetheless, the boundaries are hardly infinite, and some kind of fixed range of numbers or a tolerated-LIBOR-range probably exists theoretically. It could, for instance, be argued that a zero-lower-bound of nominal interest rates could be applied to the LIBOR as well (although this could change should the central bank in question decide to lower the policy rate well below zero). The upper bound might be high as the LIBOR should reflect any liquidity and credit strains in the banking system. However, it still ought to correspond to some kind of worst-case-scenario where the central bank is *perceived* to be forced to step in by intervening in the money markets. After all, at some LIBOR-level, banks become insolvent and should be removed from the fixing panel in question.

Another special feature of the LIBOR fixing mechanism is the trimming process. To some degree, this process could be said to mitigate some of the distortions derived from the incentives, thereby ensuring that a sufficient majority of the players stick to $p = 1$. This, however, requires that the stigma incentive applies only to a small minority of the players, and that the endowments are perfectly offsetting and normally distributed among them.[4]

Players in a *p*-beauty contest game could also be obliged to pay a fine whose size is determined by how far the chosen number deviates from the best guess (Güth, Kocher & Sutter, 2001). In this context, we could see how the LIBOR fixing mechanism could consist of formal, or informal, reputational fines or constraints facing all players. Such a mechanism would be put in place to prevent players from submitting deceptive LIBOR quotes, and

[4] In fact, during the era of the Japan Premium, Japanese banks were consistently outliers in the LIBOR fixing process.

thereby giving them an incentive to adhere to fair play. From a bank's perspective, the constraint could be interpreted as follows: submitting a deceptive quote might, if discovered, result in less client business, legal costs of being under regulatory investigation or even the risk of being excluded from the panel altogether and being replaced by another bank. The constraint could also be interpreted as affecting only the trading desk or treasury, if they were required to commit to their quotes in reasonable-market-size, where a deceptive quote would be exploited by other LIBOR panel banks.

Another variant of the classic *p*-beauty contest game would be to rank the individual players according to how good they are perceived to be at the game (with their rankings being common knowledge). Players would then receive a fine if they, on average, manage to outwit higher ranked players (in other words, choose a number that is lower than the average of the numbers guessed by the players ranked above her/him). The aim with this constraint would be to prevent the audience from distrusting the credibility and integrity of the game. Although the outcome would be the same (in the case of $p = 2/3$), the process towards the only Nash equilibrium, namely zero, would be slower.

Whichever type of *p*-beauty contest game is modelled, within each specific game, players need to anticipate what the others will do and what they will anticipate others will do and so on. Using these particular features as our point of reference, we will now design a LIBOR *p*-beauty contest game.

3 Rules of the LIBOR *p*-Beauty Contest Game

To analyse the potential outcomes of the LIBOR *p*-Beauty Contest Game, we will first consider a hypothetical game with 16 players (LIBOR panel banks) played from t_{-1} to infinity.

The LIBOR fixing procedure is as follows. A calculation agent collects the submitted quotes from the 16 individual panel banks before noon. The individual LIBOR submissions are done simultaneously without the ability to see each others' quotes. The calculation agent then conducts the trimming process, with omission of the 4 highest and 4 lowest quotes.

Thereafter, the arithmetic mean is calculated of the eight remaining LIBOR submissions. Let us assume that all 16 banks face the same (largely known) funding cost (M) in the first round (at t_{-1}) as they are perceived to be equally creditworthy and have similar access to liquidity. Further, the banks have no LIBOR-indexed derivatives portfolios acting as incentives to distort the fixing process.

Let us also assume that each player is only allowed to adjust their quotes by increments of 10 basis points (0.10%). Furthermore, the tolerable LIBOR range is [0.00%, 2.00%]. These are not necessary conditions but useful for the sake of simplicity and clarity of argument.

From these assumptions, it is obvious that M is the clear focal point in this game and that all banks submit LIBOR quotes at, or close to, the funding cost at the time (assumed to be, say, 1.00%). In any case, outliers are omitted through the trimming process and the LIBOR fixing will end up close to 1.00% at t_{-1}. This corresponds to the p-beauty contest game where $p = 1$.

If $p = 1$ for all players, the money market rate can be seen as the natural focal point or fundamental value towards which the LIBOR should drift. However, let us now introduce some new variables that capture a more realistic scenario. To be more specific, let four significant changes take place at t_0, having an impact on the incentives structures and beliefs of the players without altering the LIBOR fixing mechanism itself.

First, some players have an endowment (E), which is private knowledge and where $E^+ > 0$, $E^0 = 0$ and $E^- < 0$. The endowment is a derivatives portfolio benchmarked against the LIBOR. For the sake of argument, let us simply assume that a player with a positive endowment (E^+) benefits from a high LIBOR, players with a negative endowment (E^-) from a low LIBOR and players with no endowment (E^0) are indifferent. Whereas the players know their own ps, they are not aware of the distribution of the ps among the others, as the endowment is private knowledge. Consequently, the payoff from the endowment in each round depends on the sign and size of the endowment, as well as the change in the LIBOR fixing (L^F):

$$\pi^{E}_{i(t)} = E_i \Delta L^F, \tag{1}$$

where $\Delta L^F = L^F_t - L^F_{t-1}$. Thus, each player has an incentive to submit a quote that maximises the expected change in value of the endowment from t_{-1} to t.

In terms of a *p*-beauty contest game, this could now be seen as a game where we have three types of players not knowing what type the others are nor the distribution among them. Player type 1 (in other words E^-) shall guess *p* times the mean where $p = 2/3$, player type 2 (E^0) shall guess *p* times the mean where $p = 1$ and player type 3 (E^+) where $p = 4/3$. The strategy of each player will simply depend on the sign of the endowment in each round.

Second, a stigma is imposed on submitting a relatively high LIBOR. This is directly caused by a credit crisis leading to a wider distribution of the perceived creditworthiness of the players (banks) by the market. Let us assume that the crisis has resulted in an increase in the average short-term bank funding cost from 1.00% to 2.00%. Specifically, we will assume that the OIS price is unchanged implying that the increase in the short-term funding cost is purely a reflection of increased credit and liquidity strains in the money market. Moreover, increased market uncertainly and volatility allows for larger day-to-day moves in LIBOR quotes (0.20% instead of 0.10%), as well as a wider tolerable LIBOR range [0.00%, 4.00%].

Despite the importance of the LIBOR as a benchmark, however, other indicators such as credit ratings or credit default swaps (CDSs) matter also. Put differently, the wider distribution of the perceived creditworthiness at t_0 calls for the introduction of an independent and objective referee as well as an internal ranking system of the players. Let us simply say that the referee is the market. The internal ranking system is market-determined in the sense that each player is allocated a place hierarchically according to how creditworthy it is perceived to be compared to its peers. The perceived creditworthiness of each individual bank is assessed by the observable 5-year credit default swap spreads in the market, which prior to t_0 were identical. Let us now assume that from t_0, the CDS spreads are unequally distributed between the 16 banks {A, B, C... P}, ranging from 100 bps to 475 bps. $Bank_A$ (CDS = 100) is perceived as the most creditworthy, $Bank_B$ slightly less (CDS = 125) and so on. $Bank_P$ is regarded as the riskiest with a CDS spread of 475 bps. Let us also assume that the CDS spreads remain constant throughout the game.

As a result, the bank funding cost is now partly dependent on the long-term funding cost (the CDS price which is public knowledge) and the short-term funding cost (which is private knowledge only but subjectively communicated through the LIBOR submission). Thus, each bank now not only wants to maximise the value of its LIBOR-indexed derivatives portfolio but also wants to minimise the stigma (σ) attached to having a relatively high funding cost.

In terms of a *p*-beauty contest game, some players now have conflicting objectives. On the one hand, they are playing a game where $p = 2/3$, $p = 1$ or $p = 4/3$ (depending on their

endowment). On the other hand, all players now simultaneously play the *same* game where $p < 0$, as they would prefer to signal to the market that their short-term funding cost is slightly lower than their peers.

The payoff from the stigma can be written as:

$$\pi_{i(t)}^{\sigma} = \left(\lambda \Delta \sigma_i^{LT} + \chi \Delta \sigma_i^{ST}\right), \tag{2}$$

where λ and χ are constants. The RHS of the equation consists of two parts: the stigma derived from the long-term funding cost, and the stigma from the short-term funding cost (the LIBOR). The long-term funding cost is exogenously determined and market-observable (proxied by the CDS spread). The payoff from this stigma (σ^{LT}) cannot be influenced by the player's actions as it is market-determined:

$$\Delta \sigma_i^{LT} = \left(CDS_{i(t)} - \frac{\sum_{j=1}^{16} CDS_{j(t)}}{16}\right) - \left(CDS_{i(t-1)} - \frac{\sum_{j=1}^{16} CDS_{j(t-1)}}{16}\right) \tag{3}$$

However, the stigma derived from the short-term funding cost (σ^{ST}) is *endogenously* derived from the LIBOR fixing mechanism which the player has influence over. Here, the individual banks can (and wish to) minimise the bank funding cost as it is perceived to be by the market:

$$\Delta \sigma_i^{ST} = \left(L_{i(t)} - \frac{\sum_{j=1}^{16} L_{j(t)}}{16}\right) - \left(L_{i(t-1)} - \frac{\sum_{j=1}^{16} L_{j(t-1)}}{16}\right) \tag{4}$$

Now, although the individual LIBOR quotes are subjective and their accuracy therefore cannot be verified, it would be unrealistic to assume that the banks perceived as the least creditworthy (judging by their long-term CDS spreads) have the ability to raise short-term funding more easily than their peers. Importantly, the market is not indifferent, and would not find it credible should the individual LIBOR quotes not correspond to at least some kind of ordering from the most creditworthy to the least creditworthy. In other words, this calls for the introduction of an credibility constraint, where each player is subject to a fine (denoted 'ω') should they signal a relatively too low funding cost, as the market (which is aware of the CDS-spreads) would not regard it as credible if a bank claimed its short-term funding cost to be lower than those with lower CDS spreads:

$$\pi_{i(t)}^{\omega} = f\left(F_i^{LT}, F_i^{ST}\right)\omega \tag{5}$$

Finally, it is likely that players in the LIBOR game are bound by some rules or constraints that relate to their reputation. This is to protect third-party actors with exposure to the LIBOR from being affected by potential incentives which individual banks might have to abuse the system and submit either too high - or too low - quotes. This reputational-constraint could take different forms: as a requirement among the banks to trade a certain amount at the submitted LIBOR quote, as a requirement by regulators to occasionally disclose underlying traders forming the judgement basis for the quote, or simply as a pre-agreed 'Gentlemen's agreement' among the panel banks to adhere to fair play. In each instance, players could be seen as being subject to a reputational fine (expressed as 'ϕ') of how much their LIBOR quotes deviate from the mean of the others:

$$\pi_{i(t)}^{\phi} = \left|L_{i(t)} - \frac{\sum_{j\neq i} L_{j(t)}}{15}\right| \phi \tag{6}$$

In sum, the new payoff function for each player can be written as follows:

$$\pi_{i(t)} = E_{i(t)}\Delta L^F - \left(\lambda\Delta\sigma_i^{LT} + \chi\Delta\sigma_i^{ST} + f\left(F_i^{LT}, F_i^{ST}\right)\omega + \left|L_{i(t)} - \frac{\sum_{j\neq i} L_{j(t)}}{15}\right| \phi\right) \tag{7}$$

4 Outcome: A Process of Endogenous Deception

Before analysing the potential outcomes of this game, let us first recap the LIBOR fixing at t_{-1}, which was 1.00%. The credit crisis then resulted in an increase in the average short-term funding cost by 1.00%. Following the new restriction of only being allowed to move in 0.20% increments in each round, the market should expect a LIBOR fixing at 1.20% at t_0, 1.40% at t_1 and finally 2.00% at t_4, as each player gradually submits a higher LIBOR quote. Since the average short-term funding cost now is 2.00%, which could be regarded as the fundamental value of M, we should theoretically expect this to be reflected in the LIBOR fixing as time progresses. However, the new game now also more closely resembles that of

the ‘real’ LIBOR fixing mechanism, and new incentives and constraints apply. This implies a totally different outcome.

First, the endowments changed the dynamics of the game. As LIBOR banks are now given incentives to submit deceptive quotes, the quotes will now be more widely dispersed. Players with small or no endowments at all ($E \approx 0$) have no incentive to submit deceptive quotes, and will therefore, on average, increase their quotes towards the expected 2.00%. However, a player with E^- would choose to submit 0.80% and a player with E^+ 1.20% in the first round. What is more, they would gradually move towards the respective extreme points of the tolerated range (0.00% and 4.00% respectively). Some quotes would naturally be omitted through the fixing process. Nonetheless, the outcome after a number of rounds have been played will depend on the distribution of the endowments, and in this case also the learning process that follows from the signalling in each round.

Second, the reputational constraint (expressed as ϕ) works as a hindrance to submit overly deceptive quotes, as the fine takes into account the size of the deviation from the average quotes. At the outset, the LIBOR should drift towards 2.00% in a few days as the average funding cost (which is public knowledge) has increased substantially. This knowledge should make players with E^+ more comfortable in raising their quotes than players with E^- in lowering their quotes. However, the reputational constraint prevents any player from adjusting her/his quote by a large increment as this could result in a reputational fine. Should the groups with E^+ and E^- be equally distributed, the LIBOR would have a tendency to move (albeit slowly) higher. Likewise, should the E/ϕ-ratio increase, players with large endowments would have the incentive to change their quote slightly *more* in their favour as the relatively small fine of being an outlier is outweighed by the possibility that others think and do the same.

Importantly, players with $E \approx 0$ cannot be safely assured that a fair quote or even a quote in a fairer direction will be left unpunished. The reputational cost occurs regardless of whether the player has an endowment or not, and imitating the crowd will consequently be necessary to avoid potential losses stemming from being an outlier. In fact, the mere expectation that players in a large sub-group (say with E^-) will shift their quotes in one direction will prompt players with E^0 to do the same, as they would (possibly unfairly) otherwise face a penalty from deviating from the mean. Thus, at this stage the game can be seen as a situation where incentives are balanced against the constraint of having to imitate the crowd.

Third, the stigma of signalling a relatively low creditworthiness prevents players from submitting high quotes. Now, since t_0, the individual bank funding costs are diverse. This in itself should imply LIBOR quotes scattered around 2.00% after a few days as the market expects the LIBOR to trend toward its fundamental value. In fact, judging by the observable CDS spreads, the market should expect some kind of ordering of the LIBOR quotes from the *best* banks' quotes well below 2% and the *worst* banks' significantly above 2%. The trimming mechanism should ensure that the extreme outliers are omitted (those hardly affected by the crisis and those facing severe trouble). From the players' perspective, however, the worsening perceived long-term, as well as the short-term, funding cost has a direct negative impact. In this game, the long-term funding cost is exogenously determined, expressed by the CDS market. However, whereas the measure for the long-term funding cost is public knowledge, the short-term funding cost lacks transparency. Instead, players are assessed according to their own assessments announced through their respective LIBOR submissions. In both instances players are rewarded (or penalised) according to how they compare against their peers. Thus, all banks now have an incentive to submit relatively low LIBOR quotes to distance themselves from the others.

Fourth, leaving the endowments aside for a moment, the credibility constraint (ω) prevents all banks apart from Bank_A to submit a relatively low quote at t_0, as they would automatically face a penalty not only from deviating from the others (the reputational constraint), but also from having submitted a non-credible quote (the credibility constraint). The market or the wider public, comparing the CDS spreads between the players, would not believe that the player's own assessment of its credit and liquidity standing is correct. If the reputational fine is small, but not non-existent, and the potential stigma payoff large, Bank_A would have an incentive to signal to the market that its short-term funding cost indeed is much lower than that of its peers (by submitting, say, 0.90%). At t_1, with the results from the previous round now taken into account within respective strategy decisions, Bank_B can safely quote 0.90%, whereby Bank_A has the opportunity to lower its quote a step further (to 0.80%) in order to distinguish itself even further from the its creditworthy peers . At t_2, it is Bank_C's turn to quote 0.90%, whereas Bank_A and Bank_B yet again opt to distance themselves further from the less creditworthy banks. Seen in isolation, this process would continue until the Nash equilibrium of 0.00% is reached. However - and here is the essence of the *p*-beauty contest game - banks *anticipate* that the others will move. Bank_B can therefore safely quote, say, 0.95% already at t_0, as s/he *knows* that the best strategy of Bank_A is to quote 0.90% (as s/he is also aware of the CDS spread of the other banks). Likewise, Bank_C anticipates that

$Bank_B$ anticipates that $Bank_A$ will quote 0.90% and can therefore also lower its quote slightly – and so on. Now, $Bank_A$, in the first place, also anticipates that others anticipate her/his initial move and therefore takes this into already with her/his first move.

The original design of the LIBOR fixing mechanism (where $p = 1$) implies that the average funding cost is 2.00% and that the LIBOR fixing should not trend lower but higher towards this fundamental value. The LIBOR *p*-beauty contest game presented here, however, illustrates that even though the LIBOR should trend towards 2.00%, this process can be very slow or not happen at all. In fact, the game shows that the opposite can occur. This game is about imitating the crowd but at the same time trying to outsmart it slightly, with the knowledge that others will do the same. The combination of different incentives and constraints, and the anticipation of what others will do, results in a slow process towards an equilibrium not necessarily equalling the expected average funding cost of the panel banks. Throughout this process, LIBOR quotes can be narrowly distributed which might not be justified by the distribution of perceived creditworthiness among the panel banks.

Banks with strong incentives from the endowment or the stigma to submit deceptive quotes can be better off doing so in this game. However, even players seemingly without such incentives get caught up in this process. For instance, players with a bank funding cost precisely equalling the average of 2% can be penalised from not only finding themselves as unexpected outliers, but being required to signal a slightly higher creditworthiness than actually assessed internally. Likewise, players with negligible or no endowments at all can become less focused on the fundamental money market rate than the anticipated LIBOR-rate. In sum, even for the seemingly average and fair player, the LIBOR *p*-beauty contest game becomes a loss-making process when *not* following the crowd. Therefore, deception can be seen as a problem not specific to the behaviour of individual players, but systematic and endogenous to the LIBOR fixing process itself.

5 Concluding Discussion

By regarding the LIBOR fixing as the outcome of a unusual form of a *p*-beauty contest game, this article has illustrated how the LIBOR can deviate systematically from what could be regarded as its fundamental value, namely the consensus view of where the average money market funding cost is. The trimming process has often been regarded as an effective prevention method against systematic manipulation. [5] This assumes either that artificially low

[5] Gyntelberg & Wooldbridge (2008), for instance, acknowledge that LIBOR panel banks, in theory, could act strategically in their fixing but that the trimming process acts as a hindering factor.

and high quotes are normally distributed, or that a LIBOR panel bank knows that a deceptive quote will be omitted from the calculation and therefore will be ineffective. However, the outcomes of the *p*-beauty contest game do not support these arguments. Moreover, a typical LIBOR panel composition is probably not heterogeneous but fairly homogenous at the outset. A common feature of all LIBOR panels is that they largely consist of universal too-big-to-fail banks that are highly active (and normally market-makers) in the money, foreign exchange and derivatives markets. As the recent global financial crisis has shown, the distribution of their asset and liabilities is not randomly distributed but fairly similar.

LIBOR-indexed derivatives portfolios can act as incentives to submit deceptive quotes. What is more, there is nothing preventing LIBOR banks from increasing or decreasing their own exposure to the benchmark they themselves can influence. Systematically favourable LIBOR fixings give the incentive to keep or increase the exposures while unfavourable fixings give incentive to reduce them.

In the LIBOR *p*-beauty contest game presented in this article, it would obviously pay for some players to collude through communication, should it be possible. For instance, a group of banks with identical endowments might want to mutually agree to opt for the same strategy to maximise the expected payoff, and consequently also share the reputational fine. Moreover, communication and signalling becomes endogenous to the LIBOR *p*-beauty contest game as it is played five business days a week and more than 200 times a year. Collusion might lead to quicker and more certain outcomes. However, a non-cooperative LIBOR game can lead to the same results; although their 'conception of the solution' is totally different (Schelling, 1980: pp. 94-95).

However, seen in isolation, the stigma attached to signalling a relatively high funding cost works against collusion as individual banks are judged individually compared to their peers. This is perhaps the single most important explanation why anecdotal evidence throughout the global financial crisis, as well as the recent investigations into the conduct of a number of LIBOR panel banks, has suggested that the LIBOR consistently has been too low. The results are therefore consistent with empirical studies suggesting underreporting of the LIBOR by panel banks (Abrantes-Metz et al., 2011; Monticini & Thornton, 2013; Snider & Youle 2009, 2010).

The LIBOR *p*-beauty contest game modelled in this article highlights another feature of the stigma: its relation to other financial indicators. If the long-term funding cost of a

particular bank is observable through some market-determined process (such as the CDS market), whereas the short-term funding cost is a kind of self-assessment (the LIBOR), the former can act as a variable that influences the LIBOR panel banks to submit deceptive quotes. This fundamental problem is highlighted through the credibility constraint in the game. It could be argued that the individual quotes by the LIBOR panel banks should be ranked according to their perceived creditworthiness in the market, for instance by their respective CDS-spreads. Even though no such ranking systems officially exist, the continuous market assessment of long-term creditworthiness, and the LIBOR banks' awareness of it, induces a process whereby banks want to look good, but not 'too' good. The credibility constraint in the LIBOR *p*-beauty contest game therefore shows that even though players at times might be ordered correctly, the distance between them depends on the other features of the game. In fact, the results show how the LIBOR can have a tendency to observe a certain 'stickiness', and how the different LIBOR quotes among the panel banks can be more narrowly distributed than would be suggested by other financial indicators.[6] As such, it might give the false impression that the money market is stable and banks have fairly similar funding costs. Finally, the reputational constraint appears as an incentive not to submit a LIBOR quote that deviates too much from the others. A possible and striking outcome of this is the inability of fair players, with small endowments or an average funding cost level, to determine the outcome of the game despite their natural desire to harmonise their quotes around the fundamental rate. Deception can become endogenous to the LIBOR fixing process, and *not* deceiving is punished in a similar way as to paying above market for a distraught asset. Consequently, as players are guided by higher order beliefs, some LIBOR panel banks can be seen as being driven towards a behavioural pattern that is not dependent on their own incentives and constraints in the first instance, but generated *endogenously* though the process itself. Deception in this case does not need to result from the self-interest of an individual LIBOR submitter, but from the perception that others will act in such a manner that *not* submitting deceptive LIBOR quotes would be punished. The privilege to be able to influence the LIBOR rests with the LIBOR panel banks. This exclusive right gives rise to significant power, which in turn becomes reinforced as 'manipulation' (whether conscious or unconscious) receives a kind of conventional status. As such, the current LIBOR fixing mechanism is characterized by a fundamental and systematic flaw.

[6] The LIBOR tends to react more slowly to unexpected rate moves, liquidity and credit shocks than the money market rate.

References

Abrantes-Metz, R.M., Villas-Boas, S. & Judge, G. (2011) Tracking the Libor Rate, *Applied Economics Letters* 18, pp. 893-899.

Allen, F., Morris, S. & Shin, H.S. (2006) Beauty Contests and Iterated Expectations in Asset Markets, *Review of Financial Studies*, 19, pp. 719-752.

Bank of England (2007) An indicative decomposition of Libor spreads, *Bank of England Quarterly Bulletin*, 47(4), pp. 498–499.

British Bankers Association (2012) *BBALIBOR explained*. Available at http://www.bbalibor.com/bbalibor-explained/the-basics (accessed 1 September, 2012).

Cachon, G.P. & Camerer, C. (1996) The Sunk Cost Fallacy, Forward Induction, and Behavior in Coordination Games, *Quarterly Journal of Economics*, 111, pp. 165-194.

Duffy, J. & Nagel, R. (1997) On the Robustness of Behaviour in Experimental Beauty Contest Games, *Economic Journal*, 107, pp. 1684-1700.

Financial Services Agency (2011) *Administrative Actions against Citibank Japan Ltd*, Press release, 16 December. Available at http://www.fsa.go.jp/en/news/2011/20111216-1.html (accessed 21 February, 2012).

Financial Services Authority (2012) *Barclays fined £59.5 million for significant failings in relation to LIBOR and EURIBOR*, Press release, 27 June. Available at http://www.fsa.gov.uk/library/communication/pr/2012/070.shtml (accessed 5 August, 2012).

Fung, M.V. (2006) Developments in Behavioural Finance and Experimental Economics and Post Keynesian Finance Theory, *Journal of Post Keynesian Economics*, 29, pp. 19-39.

Güth, W., Kocher, M. & Sutter, M. (2002) Experimental 'Beauty Contests' with Homogeneous and Heterogeneous Players and with Interior and Boundary Equilibria, *Economic Letters*, 74, pp. 219-228.

Gyntelberg, J. & Wooldridge, P. (2008) Interbank Fixings during the Recent Turmoil, *BIS Quarterly Review*, March, pp. 47-72.

Ho, T-H., Camerer, C. & Weigelt, K. (1998) Iterated Dominance and Iterated Best Response in Experimental 'p-Beauty Contests', *American Economic Review*, 88, pp. 947-969.

Keynes, J.M. (1936) *The General Theory of Interest, Employment and Money* (London: Macmillan).

Lanteri, A. & Carabelli, A. (2011) Beauty contested: how much of Keynes' remains in behavioural economics' beauty contests? *European Journal of the History of Economic Thought*, 18, pp. 269-285.

McAndrews, J., Sarkar, A. & Wang, Z. (2008) The Effect of the Term Auction Facility on the London Inter-Bank Offered Rate, *Federal Reserve Bank of New York Staff Reports*, No. 335.

Monticini, A. & Thornton, D. (2013) The Effect of Underreporting on LIBOR Rates, *Journal of Macroeconomics*, 37, pp. 345-348.

Nagel, R. (1995) Unravelling in Guessing Games: An Experimental Study, *American Economic Review*, 85, pp. 1313-1326.

Nagel, R. (1999) A Survey of Experimental Beauty Contest Games: Bounded Rationality and Learning, in: D. Budescu, I. Erev & R. Zwick (Eds) *Games and Human Behavior: Essays in Honor of Amnon Rapoport* (New Jersey: Lawrence Erlbaum).

Nagel, R., Bosch-Domènech, A., Montalvo, J.G. & Satorra, A. (2002) One, two, (three), infinity, …: Newspaper and Lab Beauty-Contest Experiments, *American Economic Review*, 92, pp. 1687-1701.

Ochs, J. (1995) Coordination Problems, in: J. Kagel & A.E. Roth (Eds) *Handbook of Experimental Economics* (Princeton. NJ: Princeton University Press).

Poskitt, R. (2011) Do liquidity or credit effects explain the behaviour of the LIBOR-OIS spread? Working Paper, University of Auckland.

Rubinstein, A., Tversky, A. & Heller, D. (1997) Naïve strategies in competitive games, in: W. Albers, W. Güth, P. Hammerstein, B. Moldovanu & E. van Damme (Eds) *Understanding Strategic Interaction: Essays in Honor of Reinhard Selten* (Heidelberg: Springer).

Schelling, T.C. (1980) *The Strategy of Conflict* (Cambridge, Mass: Harvard University Press).

Schwartz, K. (2010) Minding the Gap: Disentangling Credit and Liquidity in Risk Spreads. Working Paper, University of Pennsylvania.

Snider C. & Youle, T. (2009) Diagnosing the Libor: Strategic Manipulation Member Portfolio Positions. Working Paper. Available at http://www.econ.umn.edu/~bajari/undergradiosp10/LiborManipulation.pdf (accessed 22 November 2013(.

Snider C. & Youle, T. (2010) Does the LIBOR Reflect Banks' Borrowing Costs? Working Paper. Available at http://www.econ.umn.edu/~youle001/libor_4_01_10.pdf (accessed 22 November 2013).

Soultanaeva, A. & Strömqvist, M. (2009) The Swedish Money Market Risk Premium – Experiences from the Crisis. *Sveriges Riksbank Economic Review*, 2009:3, pp. 5-25.

Stenfors, A. (2012) LIBOR Games: Means, Opportunities and Incentives to Deceive. Research on Money and Finance Discussion Papers, No. 39, SOAS, University of London.

U.S. Commodity Futures Trading Commission (2012) *CFTC Orders Barclays to pay $200 Million Penalty for Attempted Manipulation of and False Reporting concerning LIBOR and Euribor Benchmark Interest Rates*, Press release, 27 June. Available at http://www.cftc.gov/PressRoom/PressReleases/pr6289-12 (accessed 5 August, 2012).