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

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Abstract

This paper uses the Keynesian Beauty Contest as a theoretical framework to analyse the LIBOR fixing mechanism. The 'true' money market rate can be seen as a fundamental value, or focal point, towards which the LIBOR should aim. By treating the LIBOR as the outcome of a particular and unusual kind of *p*-beauty contest game, where the behaviour of the 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 can be seen as being generated endogenously though the fixing process itself. Simply the anticipation of possible attempts by others to submit deceptive LIBOR quotes will prompt neutral players to play 'dishonestly'. As a result, it is demonstrated that deviations of the LIBOR from what could be regarded as its 'fundamental value' (the underlying money market), are not temporary, but long-lasting and systematic.

1. Introduction

Up until around 2008, the London Interbank Offered Rate (LIBOR) was widely perceived to be a reliable reflection of the interbank money market. Recently, however, claims that the benchmark, at times, has been subject to attempts of manipulation by LIBOR panel banks, have put this into question. (Financial Services Agency (2011abc); Financial Services Authority (2012); U.S. Commodity Futures Trading Commission (2012))

The LIBOR, and its equivalent benchmarks in other financial centres, is determined by a selected group of panel banks as follows. A designated calculation agent (such as Reuters) collects submitted quotes from the individual panel banks before noon. The trader or other 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. Then, the calculation agent audits and checks the quotes for obvious errors and then conducts the 'trimming', the omission the highest and lowest quotes (the number which depends on the sample size). Finally, the arithmetic mean is calculated, rounded to the specified number of decimals and published at a certain time mid-day depending on the benchmark (British Bankers Association, 2012).

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 be 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 'true' 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. Importantly, constraints put in place to make the mechanism more 'market-like', are shown to require full transparency to be effective. This paper extends the game-theoretical analysis by shifting the focus towards the discrepancy between the LIBOR, and the rate it *fundamentally* should reflect, namely the 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 fundamental value. The LIBOR, in this context, should be seen as a reflection of the money market rate, and not *vice versa*.

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. Using the Keynesian Beauty Contest framework, this paper conceptualises the money market as a kind of fundamental value against which the LIBOR should be benchmarked. This 'LIBOR game', being played an infinite number of times, consists 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.

Importantly, as players are also guided by the anticipation of what others will do and what they anticipate others will do, some LIBOR panel banks can also 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. As the LIBOR fixing mechanism facilitates such behaviour, it is characterized by a fundamental and systematic flaw.

The paper proceeds 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 LIBOR *p*-beauty contest game is constructed with the aim of being as realistic as possible. Given the utility function of each player (a LIBOR panel bank), possible outcomes of this game are then considered in Section 4. Finally, in Section 5, conclusions are drawn.

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 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)

The passage by Keynes above 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 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 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 instance Duffy & Nagel, 1997; Ho, Camerer & Weigelt, 1998; Nagel, 1995, 1999; Nagel et al., 2002).

There are many variants of this game in the literature. For instance, the game might consist of a group of players that are supposed to guess the average number of the group, where either $p = 1$, 0 <

p < 1 or *p* > 1. We could also have a situation where players know their own *p*s, but not that of the others (i.e. *p* only being private knowledge). Suppose we have a game with many players where there are 3 types of players, each simultaneously selecting a number [0,100]. Player type 1 shall guess *p* times the mean where $p = 2/3$, player type 2 where $p = 1$ and player type 3 where $p = 4/3$. No player knows the other's *p*, neither the distribution of the *p*s among the players. Furthermore, players could be obliged to pay a 'fine' whose size is determined by how far the chosen number deviates from the best guess[2]. Thus, 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.

In theory, the LIBOR should reflect current and expected future policy rates, credit and liquidity risk. The assumption that the LIBOR itself is based upon actual market transactions is in fact central to previous attempt to decompose the LIBOR and money market risk premia such as LIBOR-OIS spreads[3]. 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 fundamentally flawed should the LIBOR for one reason or the other not equal this money market rate.

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 game with more than two players where p=1 in a *p*-beauty contest game.

Let us assume that the money market rate is common knowledge and 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 (see Ochs, 1995). However, in a LIBOR game, we do have a natural focal point: the money market rate. Therefore, the money market rate could be regarded as the fundamental value and also p=1. The trimming process (with the highest and lowest quotes being omitted from the process) is a mechanism put in place to ensure that players remain alert and aim for p=1 in every round of the game.

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

[2] For a *p*-beauty contest designed with 'fines', see Güth, Kocher & Sutter (2001).
[3] See for instance Bank of England, 2007; McAndrews, Sarkar & Wang, 2008; Poskitt, 2011; Schwartz, 2010.

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 game is the fixing mechanism, where outliers are omitted through a trimming process. However, as players tends to avoid extreme endpoints (see Rubinstein, Tversky & Heller, 1997), and also learn from the LIBOR fixing of the previous day, outliers will increase their efforts not to be omitted the next day. Thus, the original design of the LIBOR fixing mechanism could be seen as a median-effort-game (see Cachon & Camerer, 1996), where it is assumed that LIBOR panel banks harmonise their behaviour following a learning process. However, players in the LIBOR game may have different incentives or constraints in the form of endowments, reputation and stigma distorting this coordination process. Moreover, players might not know the optimal strategy of the other players (Stenfors, 2012).

In the context of a *p*-beauty contest game, we could therefore consider a new variant with the following basic setup: 16 players choose a number between [0,100] and aim to guess closest to the mean times p = 2/3. However, in contrast to the classic *p*-beauty contest game, in terms of calculation of the mean, only the 8 middle quotes are considered (after the 4 highest and 4 lowest are omitted).

Players in a LIBOR game could also be assigned endowments, that are either positive, zero or negative, and that are private knowledge. The endowment (denoted E) could, for instance, be a LIBOR-indexed derivatives portfolio that gives players the incentive to play a certain way. We could see this as a game where player type 1 shall guess p times the mean (between [0,100]) where p = 2/3 (in other words E^-), player type 2 where p = 1 (E^0) and player type 3 where p = 4/3 (E^+). If $p \neq 1$ we immediately get a situation where the LIBOR becomes more likely to deviate from the 'true' money market rate, as players are allocated different focal points depending on their underlying LIBOR-indexed derivatives portfolios.

Another feature of this game could be that each player is ranked individually from 1 to 16 by an 'independent referee', according to how good they are perceived to be at this game, with their rankings being common knowledge. Furthermore, the rules in this game could also state two distinct possibilities of receiving a fine. First, a reputational fine is paid according to how far they deviate from the 'correct' guess. Players are thus given the incentive to take the game seriously. Second, players receive an additional 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 him). This is to prevent the audience from distrusting the integrity of the game, as well as the judgement of the independent referee.

Using these particular features as our point of reference, let us now turn to designing a LIBOR *p*-beauty contest game.

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

Consider a hypothetical LIBOR game with 16 players (LIBOR panel banks). 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. Then, the calculation agent conducts the 'trimming', the omission the 4 highest and 4 lowest quotes. Thereafter, the arithmetic mean is calculated of the 8 remaining LIBOR submissions.

The game is being played from t_{-1} to infinity. 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 a necessary conditions, but useful for the sake of simplicity and clarity of argument in this paper,

In the first round (at t_{-1}) all 16 banks faced the same (largely known) funding cost (M), as they were perceived to be equally creditworthy and had similar access to liquidity. The banks had no endowments. Therefore, M was the clear focal point and all banks submitted LIBOR quotes at, or close to, the funding cost at the time (assumed to by, say, 1.00%). Hence, as outliers were omitted through the trimming process, the LIBOR fixing at t_{-1} was 1.00%. In effect, this can be seen as having been a *p*-beauty contest with p=1.

Now, let us assume that four significant changes takes place at t_0, without altering the fixing mechanism as such.

First, some players are given a LIBOR-indexed derivatives portfolio, or an endowment (E), which is private knowledge. 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):

$$\pi^E_{i(t)} = E_i \Delta L^F, \qquad (1)$$

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.

This could now be seen as a *p*-beauty contest game, where we have 3 types of players not knowing what type the others are or the distribution among them, not dissimilar from the single-period LIBOR games in Stenfors (2012). Player type 1 shall guess *p* times the mean where *p* = 2/3 (in other words E^-), player type 2 where *p* = 1 (E^0) and player type 3 where *p* = 4/3 (E^+). The strategy of each player would simply depend on the sign of the endowment at each point of time.

The second change is the introduction of a 'stigma' attached to 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. Due to the crisis, the average bank funding cost has now increased from 1.00% to 2.00%. Let us assume that the overnight index swap (OIS) price is unchanged, implying that the increase in the funding cost is purely a reflection of increased credit and liquidity strains. As a result, higher market volatility also allows for larger day-to-day moves (0.20% instead of 0.10%), and an increase in the tolerable LIBOR range to [0.00%, 4.00%].

Further, the wider distribution of the perceived creditworthiness at t_0 calls for the introduction of an independent an 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 (CDS) 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 minimize the stigma (σ) attached to having a relatively high funding cost. 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:

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

The third in change in the game is the introduction of a reputational constraint. Namely, each player is subject to a reputational fine (expressed as 'ϕ') of how much the player's LIBOR quote deviates from the mean of the others:

$$\pi_{i(t)}^{\phi} = \left| L_{i(t)} - \frac{\sum_{j \neq i} L_{j(t)}}{15} \right| \phi \tag{5}$$

This is to protect third-party actors with exposure to the LIBOR from being affected by potential incentives individual banks might have to submit either too high, or too low, quotes.

Finally, the fourth change is the introduction of an integrity constraint, where each player is also subject to a integrity 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:

$$\pi^{\omega}_{i(t)} = f\left(F_i^{LT}, F_i^{ST}\right)\omega \tag{6}$$

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

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

Next, let us discuss the outcomes of this game.

4. Outcome: A Process towards 'Endogenous Deception'

To analyse 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 average increase in the 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. Importantly, the mechanics of this game can imply a totally different outcome.

The endowments change the dynamics of the game. As LIBOR banks are now given incentives to submit deceptive quotes (like in the single-period LIBOR games), 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 would therefore, on average, increase their quotes towards the expected 2.00%.

A player with E^- would choose to submit 0.80% and a player with E^+ 1.20% in the first round. Moreover, they would gradually move towards the respective extreme points of the tolerated range (0.00% or 4.00%). Many quotes would naturally be omitted through the fixing process. Nonetheless, the outcome after a number of rounds have been played would depend on the distribution of the endowments, and in this case also the learning process that follows from the signalling in each round.

However, the reputational constraint (expressed in 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 his quote by a large increment, as this could cause a reputational fine. Should the groups with E^+ and E^- be equally distributed, the LIBOR would have a tendency to move (albeit slowly) higher. 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 if 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 a 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.

Now, since t_0, the individual bank funding costs are diverse, which 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 and possibly even nationalizion).

From the players' perspective, however, the worsening perceived long-term, as well as the short-term, funding cost have a direct negative impact. In this game, the long-term funding cost is exogenous determined, expressed by the CDS market. However, whereas the proxy 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.

Leaving the endowments aside for a moment, the integrity 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 integrity constraint). The market or the wider public, comparing the CDS spreads between the players, would simply not believe that the player's own assessment of its credit and liquidity standing is correct.

If the reputational cost 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 into the 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 he *knows* that the best strategy of $Bank_A$ is to quote 0.90% (as 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 his initial move and therefore takes this into already with his first move.

The economics imply that the average funding cost is 2.00% and that the LIBOR fixing should not trend lower, but higher. This LIBOR *p*-beauty contest game, 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 take place. Therefore, this LIBOR 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, result in a slow process towards an equilibrium not necessarily equalling the 'expected' average funding cost of the panel banks. Furthermore, quotes can be narrowly distributed which might not be justified by the distribution of perceived creditworthiness among the panel banks.

Naturally, banks with strong incentives (from endowments or 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 better 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 of *not* following the crowd. 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 peculiar form of a *p*-beauty contest game, we have illustrated how the LIBOR can systematically deviate from what could be regarded as its fundamental value, namely the consensus view of where the average money market funding cost is. The exclusive privilege to be able to influence the LIBOR rate rests with the LIBOR panel banks. However, in contrast to the games using a Bayes Nash solution, the LIBOR *p*-beauty contest game is not driven by probability functions. Rather, players are guided by the anticipation of what others will do, and the anticipation of the others what the others will do.

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 paper, 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’.

However, seen in isolation, the ‘stigma’ works against collusion, as individual banks are judged individually compared to their peers. Therefore, another incentive to submit a deceptive quote is derived from the stigma of signalling a relatively high funding cost. This is perhaps the single most important explanation why anecdotal evidence throughout the global financial crisis has suggested that the LIBOR consistently has been too low. This view is also supported by recent investigations into the conduct of a number of LIBOR panel banks.

The LIBOR *p*-beauty contest game modelled in this paper highlights another feature of the stigma: its relation to market 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 is problem is highlighted through the 'integrity 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 exist officially, 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 integrity constraint in the LIBOR *p*-beauty contest game 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'[4], and how the different LIBOR quotes among the panel banks can be more narrowly distributed than would be suggested by other financial indicators. As such, it might give the false impression that the money market is stable, and that banks have fairly similar funding costs.

The 'reputational constraint' appears as an incentive not to submit a LIBOR quote that deviates too much from the others. In essence, the goal becomes not to outsmart the market, but to imitate the crowd. 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 similar way as to paying above market for a distraught asset. Moreover, communication and signalling becomes endogenous to the LIBOR *p*-beauty contest game, as it is played 5 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 (see Schelling, 1980: pp. 94-95).

The trimming process has often been regarded as an effective prevention method against systematic manipulation[5]. This assumes either that artificially low and high quotes are normally distributed, or

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

that a LIBOR panel bank knows that a deceptive quote will be omitted from the calculation and therefore will be ineffective. However, neither the outcomes of the single-period LIBOR games in Stenfors (2012), nor the *p*-beauty contest game, support this argument. Moreover, a typical LIBOR panel composition is probably not heterogeneous, but fairly homogenous at the outset. Namely, 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.

Most importantly though, as players are also guided by the anticipation of what others will do and what they anticipate others will do, some LIBOR panel banks can also 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. As such, the LIBOR fixing mechanism is characterized by a fundamental and systematic flaw.

References

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

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

British Bankers Association (2012) *BBALIBOR explained* [Online]. Available from: 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, 165-194.

Duffy, J. & Nagel, R. (1997) On the Robustness of Behaviour in Experimental Beauty Contest games. *Economic Journal*, 107 (445), 1684-1700.

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

Financial Services Agency (2011b) *Administrative Action on Citigroup Global Markets Japan Inc* [press release], 16 December. Available online: http://www.fsa.go.jp/en/news/2011/20111216-2.html [accessed 21 February 2012].

Financial Services Agency (2011c) *Administrative Actions against UBS Securities Japan Ltd and UBS AG, Japan Branches* [press release], 16 December. Available online: http://www.fsa.go.jp/en/news/2011/20111216-3.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 online: 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 (1), 19-39.

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

Gyntelberg, J. & Wooldridge, P. (2008) Interbank Fixings during the Recent Turmoil. *BIS Quarterly Review*, March, 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 (4), 947-969.

Keynes, J. M. (1936 [1964]) *The General Theory of Interest, Employment and Money*. New York, NY: Harcourt, Brace & World, Inc.

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 (2), 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.

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

Nagel, R. (1999) A Survey of Experimental Beauty Contest Games: Bounded Rationality and Learning. In: Budescu, D., Erev, I. & Zwick, R. (eds.) *Games and Human Behavior: Essays in Honor of Amnon Rapoport*. New Jersey: Lawrence Erlbaum, pp. 105-142.

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, 1687 -1701.

Ochs, J. (1995) Coordination Problems. In: Kagel, J. & Roth, A. E. (eds.) *Handbook of Experimental Economics*. Princeton. NJ: Princeton University Press, 1995, pp. 195-252.

Poskitt, R. (2011) Do liquidity or credit effects explain the behaviour of the LIBOR-OIS spread? Working Paper (unpublished). Available online: http://economics-finance.massey.ac.nz/documents/seminarseries/manawatu/LIBOR-OISspreadMassey25May2011.pdf [accessed 1 September 2012].

Rubinstein, A., Tversky, A. & Heller, D. (1997) Naïve strategies in competitive games. In: Albers, W. et al. (eds.) *Understanding strategic interaction: Essays in honor of Reinhard Selten*. Heidelberg: Springer, pp. 394-402.

Schelling, T.C. (1980) *The Strategy of Conflict*, 2nd edition. Cambridge, MA: Harvard University Press.

Schwartz, K., 2010. Minding the Gap: Disentangling Credit and Liquidity in Risk Spreads. *Working Paper* (unpublished). Available online: http://finance.wharton.upenn.edu/~kschwarz/Spreads.pdf [accessed 1 September 2012].

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

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 online: http://www.cftc.gov/PressRoom/PressReleases/pr6289-12 [accessed 5 August 2012].