Integrity of Financial Benchmarks*

Dániel Béres

This study presents how financial benchmarks have become beacons for the world of economy and finance. Through the example of the Budapest Interbank Offered Rate (hereinafter: BUBOR), the study evaluates the practical applicability of the methods that may be used to prevent or detect attempts at manipulating interbank rates used as financial benchmarks. It points out that a payment system-based financial benchmark model could contribute significantly to eliminating the manipulation risk associated with the fixing of benchmark rates. The author reviews the extent to which the given benchmark (BUBOR) is exposed to potential manipulation attempts in two different periods, each comprising 6 scenarios. He finds that a low interest rate environment and the low standard deviation of the fixing submissions combined with the methodology applied essentially reduced the manipulation potential to almost zero. This also means that in periods of less volatile fixing submissions it is justified and substantiated to reduce the resources spent on supervising and auditing the production process of benchmark rates. Introducing specific methods may prompt an adjustment on the part of the banks contributing to the fixing (panel banks), which may weaken or strengthen the efficiency of the method concerned.

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1. Introduction

In Hungarian literature, interbank benchmark rates are often referred to as beacons for the financial community (*MNB 2000*; *Erhart – Mátrai 2015*; *Horváth et al. 2017*). This picturesque expression could not be more appropriate, as interbank rates exert an impact, whether directly or indirectly, on the price of numerous financial instruments. Accordingly, besides playing an important role in the implementation of monetary policy, they also carry key significance for market participants.

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Owing to their special nature, we rightly view benchmark interbank rates as public goods (*Horváth et al. 2017*) nowadays. Setting these rates requires active participation on the part of market participants. Similar to *Hardin's* (*1968*) concept, the tragedy of the commons phenomenon in relation to interbank reference rates arises from overuse. In this case, however, it is not the public good that loses its value (i.e. disappears) but the incentives to transform public good into private interest increase in number or change their nature. To put it simply, the greater the number of financial instruments whose pricing and value depend on the benchmark rates, the stronger the incentive to influence (manipulate) reference rates.

The LIBOR scandal erupting in 2008 around the London Interbank Offered Rate drew the supervisory authorities' attention to the vulnerability of financial benchmarks. As a result, the regulatory wave unravelling in the wake of the financial crisis could not ignore the need to strengthen the integrity of rates used as benchmarks.

This study aims to show how interbank offered rates have become beacons for the world of economy and finance, and to evaluate, through the example of the Budapest Interbank Offered Rate (hereinafter: BUBOR), the practical applicability of the methods that may be used to curb or detect attempts at manipulating interbank benchmark rates. The article also aims to launch a debate on a payment system-based model, which could, to a large degree, eliminate the manipulation risk arising with respect to the calculation of reference rates.

The first half of the study describes the evolution of interbank rates using LIBOR as an example. The second structural part describes the procedure developed for defining the manipulation potential of the interbank rate, and proposes a number of methods which may be applied to mitigate the manipulation potential or detect it once materialised. Subsequently, the practical applicability and efficiency of the methods discussed will be tested using BUBOR as an example. The paper ends with a summary of the author's conclusions.

2. Financial benchmarks and the manipulation incentives

In order to understand the incentives to manipulate interbank rates, it is important to shed light on the circumstances that led to the development of interbank rates and to grasp the original purpose of these rates. This chapter puts this topic in a historical context.

2.1. The development of interbank reference rates

The years following the end of the Second World War saw substantial capital flows (around USD 12 billion) from the United States to (Western) European countries, primarily within the framework of the Marshall Plan (*Tarján 2018*), which paved the way for dynamic growth in the countries concerned. By the beginning of the 1960s,

excess liquidity had accumulated in the Western-European and North-American banking sectors, which enabled the banking industry to shift its focus to riskier foreign investments. In addition to the upswing in trade and the abundant liquidity mentioned above, the dynamic rise of dollar-based lending was another important indicator of the international capital flows. This lending, however, fell outside the scope of the regulatory regimes applied both in the United States and in Europe. Interest collection (in the form of non-interest-bearing deposits) was practically unrestricted, and capping interest rates on deposits did not apply in the Eurodollar market (*Altunbas et al. 2006*).

The emergence of the Eurodollar market combined with the relative price stability that characterised currencies under the Bretton Woods system (*Borszéki 2009*) collectively provided fertile ground for international private investments. Internationalisation, however, also implied increased risk. Syndicated loans were created to mitigate this risk. Banks with abundant liquidity at their disposal were in a position to grant loans to foreign entities (mainly non-resident banks) while also being able to mitigate their own risks as well as lending costs. In syndicated lending a single bank (*administrative agent*) is designated to pool the funds and carry out the administrative tasks associated with the loan. Accordingly, the lending costs and lending risks are shared by a syndicate of lenders; moreover, smaller creditors for whom such lending was previously out of reach on their own may also join the syndicate. Repayment risk could be reduced even further if the country of the syndicate's administrative agent had close economic ties with the borrower's country, because this diminished the political risk associated with the repayment. Not only creditors but also borrowers enjoyed the benefits of syndicated loans, given that the level of lending costs was no longer determined by a single creditor (*Gadanecz 2004; Altunbas et al. 2006; Gyntelberg – Wooldridge 2008; Ridley – Jones 2012*).

Since syndicated lending was popular both among creditors and borrowers, both the market and the volume of syndicated loans grew dynamically (*Altunbas et al. 2006*), which deepened the relationships between the banks involved in syndicated lending.

The pricing structure of syndicated loans largely comprised three types of component. There were "permanent" fees, such as legal and administration costs, the creditor's funding costs, and a "spread" for profit (*Gadanecz 2004; Ridley – Jones 2012*).

In practice, in full awareness of the permanent fees of the agent bank, shortly before the lending transaction the creditors indicated their lending intention and their funding costs for the given transaction to the agent bank. The volume-weighted average of these costs plus the profit (spread) on the weighted average became the

price (interest level) of the syndicated loan. In fact, it was the weighted average of the funding costs of banks participating in syndicated lending that was first called the London Interbank Offer Rate, or LIBOR.

Due to the weighted average there was initially no incentive to underreport the fixing rate because any bank that submitted unreasonably low funding costs could have done so only to the detriment of the others, and was therefore ejected from the syndicate (*Ridley – Jones 2012*). There was no cap on the interest rate level (or more precisely, only market demand could put a limit on the rates). The interest rates were renegotiated every three or six months.

In 1986 the British Bank Association took control of the LIBOR calculation and renamed the rate BBALibor (British Bank Association London Interbank Offered Rate). The goal was to formalise the process of collecting interbank rates and to boost efficiency, transparency and governance (*Ridley – Jones 2012*). It was this process that made LIBOR a publicly available and widely used benchmark.

2.2. Appearance of manipulation incentives

Parallel to the rise in syndicated lending, banks were also keen on investing the largest possible portion of their own assets in the same way because the profits achievable through syndicated lending were higher than what could have been obtained by lending the same amount in their own country in accordance with the relevant (income-limiting) domestic regulations, at full risk costs and lending costs. In other words, the return on equity was maximised, which is understandable or necessary in the case of profit-oriented organisations. Banks' operating costs were increasingly financed from cheap external (mainly domestic) funds. This led to a situation where, thanks to the abundant liquidity, banks operated on cheap domestic funds while they realised higher than ever returns on equity through syndicated loans granted to foreign borrowers. Of course, the demand created by the export market of syndicated loans was far higher than the banks' capacity to supply. This increased the popularity of syndicated lending even further, since its profitability was able to remain high and stable. As banks increasingly borrowed their own funding from external sources, they had a growing interest in keeping their cost of funds at low levels. Ultimately, this process provided the incentive to push LIBOR rates as low as possible (*Ridley – Jones 2012*).

The innovation of financial products provided another impetus to the manipulation incentives. By the end of the 1970s the global economy had been through two oil crises and the gold standard system was long since consigned to the past as well. Accordingly, risks had also changed at the international level: the surge in oil prices gave rise to inflation which, in turn, raised interest rate and exchange rate risks to previously unseen levels. Interest Rate Swaps (IRS) and Forward Rate Agreements (FRA) were specifically developed with a view to mitigating these risks.

Trading in IRS began in 1981, while the first FRA contract was concluded in 1983 (*Kuprianov 1993*; *Farkas et al. 2004*; *Gyntelberg – Wooldridge 2008*). Floating rates play an important role in both transactions; they determine whether a transaction is settled with a gain or a loss for the investor. Initially, floating rates were represented by various indices, which were gradually replaced by LIBOR after it officially commenced in 1986. As a result, on the one hand LIBOR practically became the most important benchmark rate, while on the other hand key IRS and FRA trading days created a new incentive to manipulate the interest rates[1]. In all fairness, it should be noted that a number of other important financial benchmarks co-existed with LIBOR; however, LIBOR's status as the most recognised and most widely accepted rate was unquestionable.

Last but not least, it should be mentioned that the pricing of an increasing number of products was – and still is – linked to interbank rates in view of the interest rate risk involved (e.g. the interest level of mortgage loans or corporate credit) which, similar to the derivative transactions referred to above implies additional manipulation incentives with respect to the interbank rates (and thus LIBOR).

2.3. Manipulation of LIBOR and the counter-measures taken – the regulatory environment

Interbank benchmark rates came under the scrutiny of regulatory authorities for the first time in 2007 in relation to the manipulation scandal unfolding around LIBOR. It was in that year that Barclays alerted the US money market supervision that certain banks may be manipulating the value of the London Interbank Offered Rate LIBOR (*Cutler – Ridley 2013*). In order to rig the LIBOR rate, some banks submitted dishonestly low interbank rates. At the global level, however, the scandal erupted only in 2008 in the wake of a revelatory article published in *The Wall Street Journal* (*Mollencamp 2008*). The investigations launched in response to the LIBOR scandal found that the manipulation of LIBOR went all the way back to 1991 – since that year the 11 banks named in the conspiracy had manipulated the value of LIBOR on a regular basis (*Fliszár 2016; Cutler – Ridley 2013; Mollencamp 2008*).

In an effort to clamp down on manipulation, in July 2013 the International Organisation of Securities Commissions (hereinafter: IOSCO) issued its recommendations on financial reference rates (also known as financial benchmarks) (*IOSCO 2013*). IOSCO defined a set of recommended practices primarily for benchmark administrators but indirectly, the recommendations also affect the institutions submitting the fixings for the benchmark. The 19 recommendations essentially target the following three areas:

[1] The days on which traders settle the deal at the prevailing interest rate level.

1. Integrity of the data used for constructing the benchmarks should be protected.
2. Adequacy and transparency of the methodology used to make benchmark determinations should be ensured.
3. Conflicts of interest should be identified and eliminated and appropriate controls applied.

All three objectives are intended to ensure (restore) the reliability of financial benchmarks.

In the European Union, the requirements of benchmark determination were laid down by law on 8 June 2016 when the so-called Benchmark Regulation[2] (hereinafter: BMR) entered into force. The provisions of the BMR are directly applicable to both administrators – institutions responsible for calculating the reference rate – and contributors – institutions reporting their rates – in all Member States of the European Union.

3. Methods for preventing and detecting manipulation of interbank benchmark rate submissions

The BMR Regulation sets out numerous provisions that are intended to ensure the reliability of interbank reference rate submissions while curbing the incentives for their manipulation. One such provision, for example, is the requirement for the contributor to keep and preserve retrievable records of all external and internal communications of the persons participating in the fixing process (the contributors and the endorsers of reference rates). At the same time, no matter how strict the legislative provisions, they will never fully guarantee that the submissions are free of manipulation; they merely raise the potential costs of the intention to manipulate. For example, the recording of an institution's official communications may be circumvented by phone conversations on an employee's personal phone or by informal discussions in lunch breaks. Since controls involve costs which should be kept at a reasonable level, the preferred methods should be those that are likely to prevent manipulation or signal suspected manipulations of the benchmark rate. By doing so we can avoid the creation of unnecessarily long lines of defence.

However, it should be pointed out at the start that any method described below – irrespective of whether it was adapted from literature or reflects the author's own thoughts – is only suitable for signalling suspected manipulations or reducing the probability of manipulation occurring, as changes in the value of the reference rate

[2] Regulation (EU) 2016/1011 of the European Parliament and of the Council of 8 June 2016 on indices used as benchmarks in financial instruments and financial contracts or to measure the performance of investment funds and amending Directives 2008/48/EC and 2014/17/EU and Regulation (EU) No 596/2014.

may be – and are – influenced by the liquidity positions, strategic objectives and applied monetary policy instruments of the banks participating in the submission process of interbank benchmark rates (*Gereben 2000*).

The methods below are presented irrespective of whether they are applied by the administrator, the contributor or the external auditor.

3.1. Definition of manipulation potential

In their study, *Eisl et al.* (*2017*) examined the manipulation potential of interbank benchmark rates in such a way that they set the lowest LIBOR fixing rate of the current day equal to the highest observed fixing rate. With this scenario the authors attempted to simulate how much a single bank could move the value of the benchmark rate if it intended to manipulate it. The value of the manipulation potential was derived as the difference between the value of the original LIBOR and that of the modified LIBOR. In the context of this study the model constructed by *Eisl et al.* (*2017*) was adapted and applied under a number of different scenarios.

3.2. Trimmed mean (trimming procedure)

The LIBOR value was initially computed as the weighted average of the cost of funds of participants in the lending syndicate and the sizes of loans granted by them. After the first official publication of LIBOR in 1986, the weighting no longer had a base; consequently, it was removed from the methodology and the interbank rate was ultimately calculated as the arithmetic mean of the submissions. However, the drawback of the simple arithmetic mean method is that it is extremely sensitive to outliers. In practice, this means that even a single bank can alter the value of the interbank benchmark rate potentially significantly.

The trimming procedure is designed to eliminate this possibility. Essentially, this method means that in order to prevent outliers from skewing the mean excessively, the highest and lowest submissions (or a certain percentage thereof) are discarded from the calculation of the mean, and the resulting mean will be the final value of the official interbank benchmark rate.

In their study, *Eisl et al.* (*2017*) tested the efficiency of the trimmed mean. They sought to measure the extent to which underreporting (where the bank's submitted fixing is below the mean, i.e. the interbank offered rate) can move the value of the interbank rate. They demonstrated that the trimming procedure significantly improves the reliability of the benchmark rate, yet despite using a trimmed mean, manipulation by even a single bank could result in a shift in the interbank reference rate which, according to the authors' calculations, may amount to 0.48 basis points in the case of the 3-month USD LIBOR and 0.17 basis points in the case of the 3-month EURIBOR. This value grew progressively where several panel banks acted in concert to modify the submissions. The authors found that increasing the number

of contributors reduced the manipulation potential substantially. The study by *Choy et al.* (*2012*) confirms these findings: even a single bank can influence the reference rate despite the trimming procedure.

From an audit perspective, one key finding of *Eisl et al.* (*2017*) is that given the volatile nature of individual banks' submissions – underreported and overreported rates – detecting manipulation immediately is close to impossible.

3.3. Median fixing

In the course of median fixing, contributors (banks) submit the required data (fixings) to the administrator. The administrator institution puts the fixings in ascending order. The reference rate, in this case, will be the median of the submitted rates; i.e. the one that divides the data arranged in ascending order into two equal parts (with an even number of contributor banks, the value of the reference rate will be the simple arithmetic mean of the two fixings in the middle).

The analysis by *Eisl et al.* (*2017*) demonstrated that the median method reduces the potential for manipulation to a minimum (to one third compared to the value received for the trimmed mean method).

3.4. Dynamic extreme value analysis

The dynamic extreme value analysis examines the absolute difference between current day fixing submissions and fixing submissions on the previous day. The fixing submissions of the contributors with the highest absolute change (either in a positive or negative direction) compared to the previous day are discarded from the calculation of the reference rate. In this respect, the reference rate computed on the basis of the dynamic extreme value corresponds to a kind of trimmed mean.

One potential benefit of the method is its ability to screen for one-off effects whereby the value of the reference rate will flatten out across individual days. Such a one-off effect can be a data error or even an exceptional liquidity position of the contributing institution.

Under the dynamic extreme value analysis approach, a reporting agent can only manipulate if it keeps its submissions continuously within a value range that could be acceptable for it on a given day. In this case, however, the probability of being caught (in other words, the transaction cost of the manipulation) increases.

3.5. Analysis of the pricing of correlating products

According to Monticini – Thornton (*2013*), if the interbank reference rate is manipulated, there will be a positive or negative difference between the benchmark rate and the pricing of a product with a correlating return. In their paper, the authors explore the correlation between LIBOR and the yield on Certificates of Deposit

(CDs). Based on their hypothesis, there is a near-identical difference between LIBOR and CD rates over time (expressed in basis points); in other words, the correlation between the two points to a fairly constant difference (spread) that has a constant standard deviation. A marked change in the spread between LIBOR rates and CD rates (a mean value computed from the time series of the LIBOR – CD spreads) may signal a manipulation of the reference rate. Processing data for the period between 2004 and 2010, the authors found evidence that the spread between LIBOR rates and CD rates increased in the case of misreporting, and that after the manipulation the LIBOR – CD spreads eventually returned to their pre-underreporting levels. *Brousseau* et al. (*2009*) came to a similar conclusion in relation to the Overnight Index Swap (OIS) and LIBOR.

The method is suitable for ex-post audits, and an active market for the correlating product is an important prerequisite for its application.

3.6. Outlier analysis

The outlier analysis may be used to examine two aspects: firstly, the change in contributors' fixing submissions relative to their previous fixing submissions, and secondly, changes in the fixing submissions relative to the benchmark rate. When the difference between the current day fixing submission and the base date fixing submission exceeds a certain level, manipulation or error can be suspected in both cases, and the value of the current day fixing submission should be inspected.

The difference that triggers such an action once it has been exceeded can be defined using a number of approaches. The first and perhaps simplest procedure is to set a pre-defined time horizon which will be considered for the calculation of the standard deviation (with respect to the calculation of the standard deviation of an institution's own submissions and that of the benchmark rate). If the absolute value of the current day difference exceeds the standard deviation or twice the value of the standard deviation, the current day submission should be considered an outlier. Accordingly, the standard deviation should be defined every day for an identical horizon (lookback period), and the value of the current day submission should be compared to that.

A less dynamic solution is to define the standard deviation based on a longer time series (e.g. 10 years). The advantage of this method is the likelihood of having both stressed and unstressed periods, as well as low and high interest environments in the calculation. For longer time series, in view of the higher standard deviation value, the size of the change should be compared to only a fraction of the deviation.

It is a somewhat more sophisticated method to define the percentage of the submissions that should be brought under scrutiny. In that case, the change in the value of a fixing can be determined based on historic data in such a way that a pre-

defined percentage of the cases (the percentage that should be inspected) falls within the range. Despite its sophistication, the disadvantage of the latter method is its reduced ability to signal potential manipulation because it may also include cases where the change between the submissions of the two days is insignificant.

A common trait of these methods is their need to select the lookback period – the period to be considered for the purposes of the calculations – appropriately. Therefore the models presented here need to be calibrated before application.

3.7. Analysis of fixing dynamics

The analysis of fixing dynamics examines the rate at which an individual contributor submitted a rate which eventually ended up above or below the current day value of the benchmark. The differences between fixing contributing banks may result in the emergence of typically 'underreporting' or 'overreporting' banks. Obviously, this does not mean that this is always the case over the short term, so analysing fixing dynamics may be useful to identify signs of manipulation based on certain patterns. While this method is less objective in this regard, applying it together with other methodologies may be an efficient tool in signalling potential manipulation or confirming suspected manipulation. In addition, an analysis of fixing dynamics provides information about the liquidity of the contributors and about the extent to which liquidity is concentrated in the market.

3.8. Analysis of trading days that impact asset pricing

The greatest risk associated with misreporting the benchmark interbank rate arises with respect to the key dates on which derivative transactions are settled if an employee of the contributing institution is simultaneously authorised to conclude derivative contracts, because this allows the trader to influence the outcome (profitability) of his deals through the fixing submission. The manipulation risk associated with the trader involved in the derivative transaction is reduced if the counterparty in the given transaction is also a contributor in the fixing procedure of the benchmark rate, given that it will have a conflicting interest. However, the risk is exacerbated if traders who also act as contributors conclude a contract with a party who does not submit fixing rates.

In addition to the above, the days on which assets are substantially repriced at the contributing bank based on the interbank offered rate also carry risk in an indirect way. Such a case, for example, can be when the interest rate on the bank's (or all banks') housing loan or corporate loan portfolio is repriced on the same day (e.g. the 2nd working day preceding the end of the month[3]).

[3] Pursuant to Section 17/D (1) of Act CLXII of 2009 ("Fair Bank Act"), where loan contracts are tied to reference interest rates, the reference rate shall be adjusted at intervals aligned with the tenor of the reference rate defined in the loan contract to the reference rate effective 2 days before the last working day of the month preceding the anniversary date.

Based on the above, the essence of the method is to inspect the fixing submissions of the days that coincide with the settlement day of derivative transactions or with the days of large-scale asset repricing actions.

It should be noted and stressed emphatically that the mere fact a bank 'overreports' or 'underreports' the fixing on such key dates does not automatically mean that it is trying to rig the rate, because submissions are also influenced by market specificities, a bank's liquidity position and current monetary policy instruments. With that in mind, fixing submissions on such key dates should always be examined ex-post, on a time series basis and focusing on their trends.

Apart from the above, we refrain from discussing this method in further detail in this study as the data required to apply it, are not publicly available.

3.9. Cluster analysis

Choy et al. (*2012*) examined whether applying a multivariate statistical approach can be used to detect manipulation and collusion between banks. With a hierarchical cluster analysis on LIBOR submission data between 2005 and 2012 they successfully detected the cases where a bank's submissions differed excessively from those of the others (i.e. it misreported its funding costs). In the authors' view, the method may be suitable for identifying well-concerted interbank collusions. Indeed, in the case of concerted manipulation, the cluster analysis classifies colluding banks into the same group. The co-authors also warn not to draw definitive conclusions from the dendrogram (grouping) that illustrates the results of the cluster analysis, even though it is suitable for pointing towards potential manipulation. This is consistent with the wording of *Sajtos – Mitev* (*2007*), who indicated that cluster analysis is primarily an exploratory technique.

In practice, grouping with a cluster analysis should be performed based on two or more different distance and similarity measures. If two contributors display similar submissions consistently, the two different techniques will yield nearly identical results. Since collusion (manipulation) may be suspected in this case, further investigation is required.

One drawback of the methodology is that its applicability is limited to complete time series. Consequently, if a contributing bank appears or disappears within the review period (in other words, there is no full time series for the institution concerned), it needs to be excluded from the analysis. Moreover, the method is sensitive to outliers, which means that some procedure needs to be applied to address the outliers before the analysis.

3.10. Payment system operators as benchmark rate administrators

Defining the benchmark rate through the payment system is a new approach. Assuming that interbank rates are calculated on the basis of unsecured interbank loans, actual transactions executed via high-value payment systems provide the information required for setting the benchmark rate; consequently, the payment system operator can play the role of the benchmark rate administrator. In the case of the European Central Bank, the Euro Short-Term Rate (ESTER) – which is based on the high-value TARGET2 payment system – serves as such a reference rate (*ECB 2018*). A slightly different approach was proposed in the United States by *Frost* (*2017*) in relation to the Secured Overnight Financing Rate (SOFR). The difference is that Frost proposes to obtain the data required to produce the benchmark rate from a data repository rather than through the payment system.

In this context, the manipulation incentive will be eliminated on the bank side as the interbank offered rate is determined on the basis of actual transaction data. From a social optimum perspective, this could also reduce the resources expended by market participants and supervisory authorities to verify the integrity and market conformity of the submissions.

4. BUBOR

In this chapter, we present the methods discussed in detail in the previous chapter through the example of the Budapest Interbank Offered Rate (BUBOR), limiting the methods to those where sufficient data were publicly available.

4.1. Tenors under review

At the time the study was prepared, in its capacity as the administrator of BUBOR, the MNB published official BUBOR rates for nine tenors (maturities): overnight[4], 1 week, 2 weeks, 1 month, 2 months, 3 months, 6 months, 9 months and 1 year. Due to the limited scope of this study, we only address overnight fixings below; but the methodologies applied can be used for all tenors, including the 3 and 6-month tenors[5].

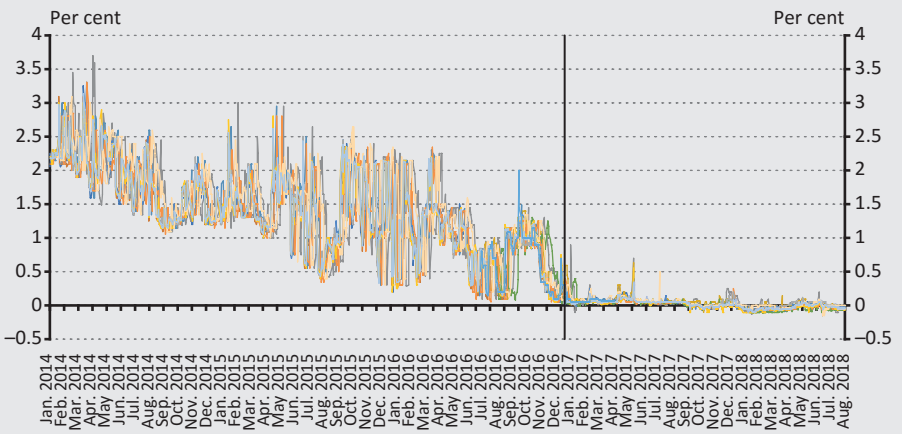
4.2. Period under review

The BUBOR time series was available – through REUTERS – from January 2014 to 15 August 2018 at the time this study was written; so this entire period was processed. Two periods should be examined separately within the review period because, given the near-zero interest environment, the standard deviation of BUBOR fixings decreased sharply compared to the preceding period from the beginning of

[4] O/N
[5] In their study, *Kocsis et al.* (*2013*) demonstrated that the 3 and 6-month tenors play an important role in the interest rate derivative market.

2017. The review period is therefore split into a pre-2017 and a post-2017 period (*Figure 1*).

Figure 1
O/N BUBOR fixings (individual panel bank submissions)
(January 2014 – August 2018)



Source: Based on REUTERS data

4.3. Mean, median, trimmed mean and trimmed median fixings

Based on *Eisl et al.* (*2017*), we sought to explore the manipulation potential of the interbank offered rate in the case of overnight unsecured interbank offered rate submissions as well. At the same time, however, in addition to 'underreporting', we also included the 'overreporting' potential in the analytical framework. Accordingly, the 'underreporting' and 'overreporting' potential was established for the two distinct periods, each comprising 6 scenarios as follows:

- collusion of three banks for overreporting;
- collusion of two banks for overreporting;
- overreporting by one bank;
- underreporting by one bank;
- collusion of two banks for underreporting;
- collusion of three banks for underreporting;

The mean, median, trimmed median and trimmed median values of the submissions were calculated under each scenario. Trimming was performed in accordance with the BUBOR Regulation in effect since 1 January 2018 (*MNB 2018*). Based on the calculations, the less the manipulation altered the originally computed result on average, the better the given method performed. *Table 1* summarises the results.

Table 1
Manipulation potential of O/N BUBOR according to methods applied

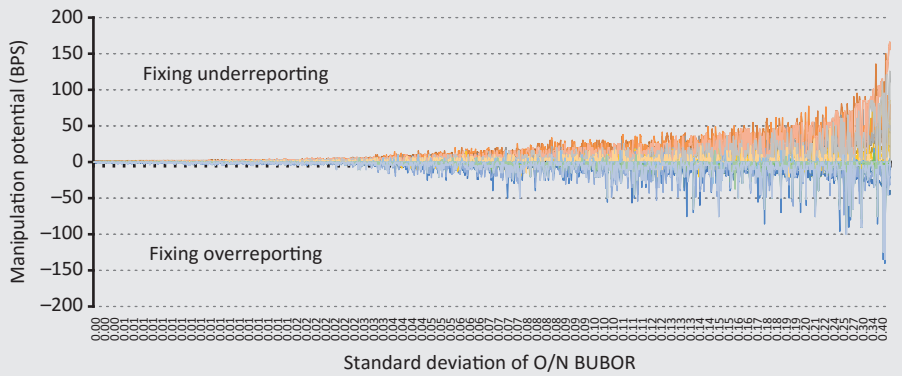
BUBOR O/N manipulation potential	High volatility of fixing submissions				Low volatility of fixing submissions			
	Difference (bp)		Name of method		Difference (bp)		Name of method	
	min	max	best	worst	min	max	best	worst
Overreporting (3 banks)	–9.64	–12.70	Trimmed median	Mean	–0.02	–2.06	Mean	Trimmed median
Overreporting (2 banks)	–5.46	–10.09	Trimmed median	Mean	–0.01	–1.21	Mean	Trimmed median
Overreporting (1 bank)	–0.92	–7.28	Trimmed mean	Mean	–0.01	–0.63	Mean	Trimmed median
Underreporting (1 bank)	1.19	7.28	Trimmed median	Mean	0.01	0.45	Mean	Trimmed mean
Underreporting (2 banks)	10.08	13.77	Trimmed median	Trimmed mean	0.02	1.11	Mean	Trimmed mean
Underreporting (3 banks)	18.16	25.27	Mean	Trimmed mean	0.02	2.02	Mean	Trimmed median

According to *Table 1*, when fixing submission volatility is low the smallest manipulation potential is produced by the arithmetic mean method, whereas the greatest manipulation potential is produced by the trimmed median and trimmed mean procedures. By contrast, with high fixing submission volatility the trimmed median method appears to be the most reliable (smallest manipulation potential) and the arithmetic mean method proved to be the worst (greatest manipulation potential). Supplementing the results of *Eisl et al.* (*2017*) we found that this manipulation potential increased in volatile periods (where the standard deviation of the fixings increased) and decreased in less volatile periods.

The values shown in the table also indicate that in the context of low fixing submission volatility, the 'underreporting' and 'overreporting' potential is nearly identical in all scenarios, whereas the 'underreporting' potential is higher in periods of high fixing submission volatility. This can be attributed to a number of reasons. The liquidity position of the panel banks (contributors) is at play as a factor, but the contributors' respective strategies should also be considered. For example, an

institution does not always wish to place its liquidity in the unsecured interbank market – in this case it will 'overreport', and according to the methodology used to measure the manipulation potential, BUBOR's value will shift downwards more sharply. A summary of the manipulation potentials calculated for each scenario under review clearly shows that the underreporting manipulation potential is stronger (*Figure 2*).

Figure 2
Manipulation potential of O/N BUBOR submissions in function of the standard deviation of the fixing submissions in each scenario under review



Note: Individual colours mark individual scenarios.

Last but not least, there is evidence that median-based fixing is more likely to reduce the manipulation potential when the trimming procedure leaves a greater number of bank submissions in the calculation basket. There is no exact number to show how many institutions should submit rates in order to reduce the manipulation potential to the minimum under median-based submissions. At the same time, with the median calculation methodology it is expedient to have a selection basis include at least three banks' submissions after the trimming procedure, which means that lined up in ascending order, the value in the middle would be the value of the benchmark.

4.4. Dynamic extreme value analysis

Since the dynamic extreme value analysis corresponds to a trimming procedure in itself, in this case only two methods were scrutinised: the dynamic mean and the dynamic median.

Table 2
Manipulation potential of O/N BUBOR according to the methods applied

BUBOR O/N manipulation potential	High volatility of fixing submissions				Low volatility of fixing submissions			
	Difference (bp)		Name of method		Difference (bp)		Name of method	
	min	max	best	worst	min	max	best	worst
Overreporting (3 banks)	–21.25	–24.62	Dynamic mean	Dynamic median	–0.02	–2.18	Dynamic mean	Dynamic median
Overreporting (2 banks)	–16.96	–19.89	Dynamic mean	Dynamic median	–0.02	–1.32	Dynamic mean	Dynamic median
Overreporting (1 bank)	–9.97	–10.27	Dynamic median	Dynamic mean	–0.01	–0.56	Dynamic mean	Dynamic median
Underreporting (1 bank)	10.09	10.26	Dynamic mean	Dynamic median	0.01	0.59	Dynamic mean	Dynamic median
Underreporting (2 banks)	17.63	21.72	Dynamic mean	Dynamic median	0.02	1.73	Dynamic mean	Dynamic median
Underreporting (3 banks)	22.69	28.47	Dynamic mean	Dynamic median	0.02	3.19	Dynamic mean	Dynamic median

Table 2 indicates the manipulation potential of O/N BUBOR values produced by the dynamic extreme value analysis. We found that the dynamic extreme value analysis carries a higher manipulation potential when the standard deviation of the submissions is higher. It should be added, however, that applying the dynamic mean approach carries lower manipulation potential than the trimmed mean method currently used, when the standard deviation of the submissions is low.

4.5. Analysis of pricing of correlating products

Horváth – Makay (*2015*) found that BUBOR did not present any additional information compared to the base rate. Moreover, consistent with the conclusions of *Csizmadia* (*2014*), *Horváth – Makay* (*2015*) concluded that all alternative benchmarks (with which BUBOR could correlate) either had some kind of methodological deficiency (e.g. FRA rates[6]) or they had no active market (e.g. CDs). As a result, applying this method to detect potential BUBOR manipulations would be subject to strong constraints. Moreover, the effects of one-off market phenomena and monetary policy instruments should also be considered in each case, which is beyond the scope and purpose of this study.

[6] They present market expectations but do not reflect credit risk.

4.6. Outlier analysis

In the framework of the outlier analysis we compared the difference between contributors' current day and base day fixing submissions to the standard deviation of their own submissions for the past 250 fixing days and to double its value on the one hand, and to the similarly computed standard deviation of BUBOR as well as double its value (standard deviation with a 250-day lookback period) on the other. If the difference between the current day and base day exceeds the standard deviation or double its value (selected at one's discretion), there is a suspicion of manipulation and the current day fixing procedure should be inspected at institution level. The results of the outlier analysis are displayed in *Table 3* and *Table 4*.

Table 3
Number of cases to be inspected at panel bank level according to outlier analysis between 2015 and 2018
(1 standard deviation)

Change is greater than 1 standard deviation	Change is greater than standard deviation of own fixing submissions				Change is greater than standard deviation of BUBOR			
	2018	2017	2016	2015	2018	2017	2016	2015
Bank 12	1	0	11	43	8	0	11	42
Bank 14	5	4	12	43	6	4	12	41
Bank 6	7	3	16	36	22	4	16	39
Bank 1	5	2	0	0	15	6	0	0
Bank 3	3	0	11	34	3	0	10	37
Bank 13	12	3	0	0	18	7	0	0
Bank 7	2	3	8	31	2	4	8	31
Bank 10	6	4	16	37	5	7	17	39
Bank 5	0	0	12	41	0	0	12	41
Bank 11	4	3	11	43	10	4	11	43
Bank 4	0	0	0	0	0	0	0	0
Bank 15	0	0	0	0	0	0	0	0
Bank 8	0	0	0	0	0	0	0	0
Bank 16	0	0	0	0	0	0	0	0
Bank 9	0	0	0	0	0	0	0	0
Bank 2	7	2	15	27	8	3	15	33
Total:	**52**	**24**	**112**	**335**	**97**	**39**	**112**	**346**

Note: The complete time series was only available for the BUBOR quoting institutions shaded in dark-grey.

Table 4
Number of cases to be inspected at panel bank level according to outlier analysis between 2015 and 2018
(2 standard deviations)

Change is greater than 2 standard deviations	Change is greater than standard deviation of own fixing submissions				Change is greater than standard deviation of BUBOR			
	2018	2017	2016	2015	2018	2017	2016	2015
Bank 12	0	0	1	14	0	0	1	13
Bank 14	2	0	1	7	2	0	1	7
Bank 6	1	0	2	8	5	1	2	14
Bank 1	1	0	0	0	2	2	0	0
Bank 3	0	0	0	9	0	0	0	11
Bank 13	1	0	0	0	4	0	0	0
Bank 7	0	2	2	10	0	2	2	9
Bank 10	0	2	3	10	0	4	3	11
Bank 5	0	0	1	10	0	0	1	9
Bank 11	0	0	1	8	2	0	1	8
Bank 4	0	0	0	0	0	0	0	0
Bank 15	0	0	0	0	0	0	0	0
Bank 8	0	0	0	0	0	0	0	0
Bank 16	0	0	0	0	0	0	0	0
Bank 9	0	0	0	0	0	0	0	0
Bank 2	4	0	1	8	4	0	1	11
Total:	**9**	**4**	**12**	**84**	**19**	**9**	**12**	**93**

Note: The complete time series was only available for the BUBOR quoting institutions shaded in dark-grey.

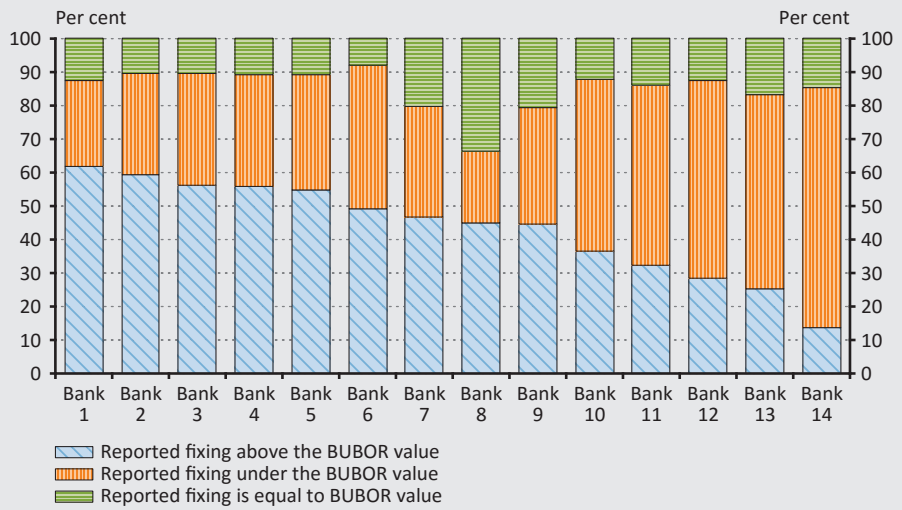
In a yearly breakdown, *Tables 3* and *4* provide a summary of the number of cases when individual contributors should have inspected the current day fixing procedure; i.e. the number of cases where manipulation could have been suspected based on the methodology.

With regard to this method, it is important to emphasise that the lookback period applied fundamentally influences the number of suspected manipulations, so the results should always be evaluated with that in mind. The 250-day lookback period applied in this article is a generally accepted horizon in risk management. Moreover, as is the case with the rest of the methods, this method only gives rise to the suspicion of manipulation and it is unsuitable in itself to serve as evidence.

4.7. Analysis of fixing dynamics

Compared to the methods presented above, the analysis of fixing dynamics is less objective as in the case of BUBOR it is more likely to reflect the liquidity position or risk management practice of the panel bank (contributor) rather than anomalies in the fixing procedure itself. The longer the horizon, the more stable the view we get regarding the individual banks. It is clearly shown on *Figure 3* which banks tended to 'overreport' and which institutions were more likely to 'underreport' the fixing in the period between 2014 and 2018.

Figure 3
Fixing dynamics of O/N BUBOR contributors between 2014 and 2018



Note: The Figure shows submissions without a tolerance band around the mean.

To detect suspected manipulation through the analysis of fixing dynamics, the long-run trend should be compared with an institution's behaviour in a selected period. When there is a marked difference between the short-term behaviour and the long-term trend, the period should be scrutinised with respect to manipulation. It is important to ensure that the shorter period reflects at least a one-month – or better still, quarterly – fixing practice, as a period shorter than this is likely to yield a marked difference. As is the case with the rest of the methods, this method in itself can only indicate a suspicion of manipulation. Considering that the result of the method is also influenced by other factors (e.g. an enduring change in liquidity position), it should therefore primarily be used as a double-checking method (when another method has already pointed to potential manipulation).

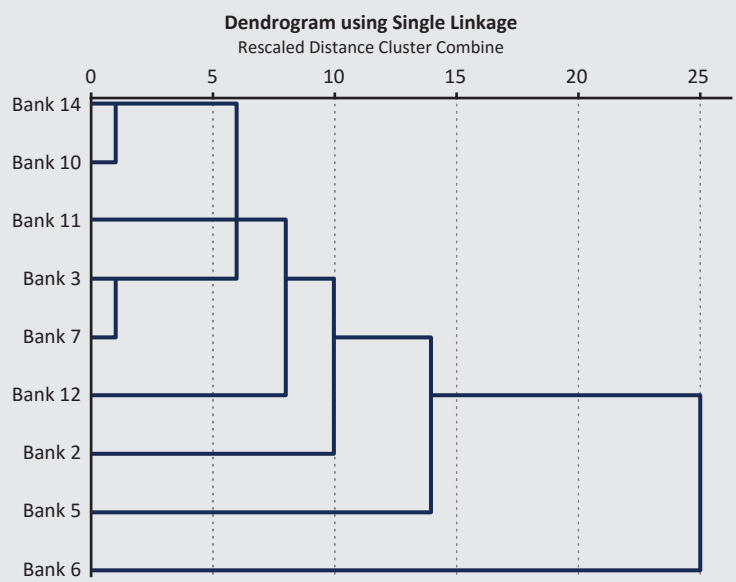
4.8. Cluster analysis

Concerted fixing submissions were examined by way of a cluster analysis, relying on two methods (nearest neighbour and Ward procedures). In examining such collusions, it is once again important to select the appropriate period. If the period selected is too long, the result will be less likely to capture any suspected collusions because other characteristics of the contributor will also be reflected indirectly (e.g. household/corporate profile). In other words, the cluster analysis should be focused on behaviour over a shorter horizon (less than 1 year but not less than a quarter[7]).

For the purposes of this study, O/N BUBOR submissions in 2018[8] were compared at each individual institution where a time series for the entire period of January 2018 – August 2018 was available.

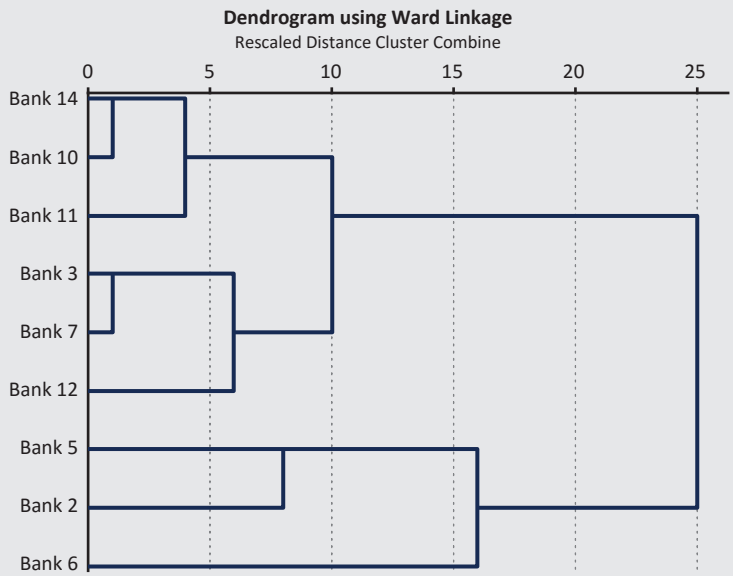
Collusion may be suspected if the submissions by two or more contributors are consistently the same when a method using various distance and similarity measures is applied. Simply, the method puts them into the same group, irrespective of the method applied. The resulting dendrograms are displayed on *Figure 4* and *Figure 5*.

Figure 4
Cluster analysis (nearest neighbour)
(Jan – Aug 2018)



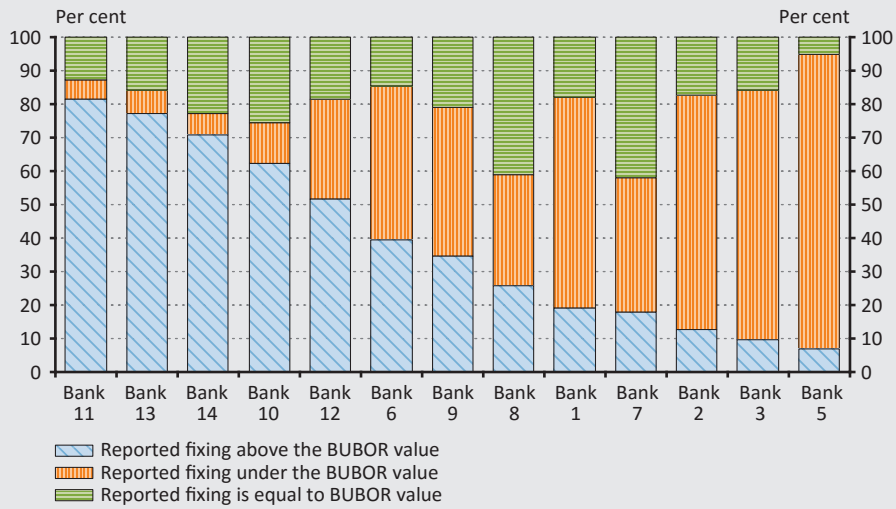
[7] Cluster analyses may only be conducted with a sufficient number of submissions.
[8] From 1 January 2018 to 15 August 2018

Figure 5
Cluster analysis (Ward)
(Jan – Aug 2018)



As the dendrograms indicate, the submissions of some institutions are identical according to both methods (Bank 10 and Bank 14, as well as Bank 3 and Bank 7); consequently, manipulation should be suspected in their case. Applying the fixing dynamics analysis for the same period – to double check – partly confirms the result of the cluster analysis, with Bank 10 and Bank 14 'overreporting' at a nearly identical rate (see *Figure 6*). In the case of Bank 7 and Bank 3, however, the correlation is not that clear: apparently, Bank 7 was far more likely to have fixing submissions consistent with the mean than Bank 3.

Figure 6
Fixing dynamics of O/N BUBOR contributors in 2018



Considering the low interest environment and excess liquidity that characterised the market throughout the review period, and the low standard deviation of the fixing submissions (partly due to the former factors), the suspected manipulation cannot be confirmed even in the case of Bank 10 and Bank 14. Based on the methodology applied by the central bank, the manipulation potential of the benchmark rate would not be significant in quantitative terms even in the case of collusion between two banks (*Table 5*).

Table 5
Manipulation potential under trimmed mean and low fixing volatility

Trimmed mean	Manipulation potential (basis points)
Underreporting manipulation (3 banks)	2.02
Underreporting manipulation (2 banks)	0.94
Underreporting manipulation (1 bank)	0.38
Overreporting manipulation (1 bank)	–0.63
Overreporting manipulation (2 banks)	–1.21
Overreporting manipulation (3 banks)	–2.06

Based on the above we may conclude that the cluster analysis of co-submissions may be a more efficient tool if the fixing submissions underlying the benchmark rate had a higher – rather than a lower – standard deviation. In any event, also in view of the manipulation potential pertaining to the review period, we found evidence – as mentioned before – that this method, like the others, is not suitable in itself to confirm suspected manipulation.

5. Conclusions

To reduce the manipulation risk of interbank rates used as financial benchmarks to a minimum level, it is indispensable to understand the historic processes that shaped the emergence and development of reference rates. In this regard, it was *Fliszár* (*2016*) who captured the main difference between the calculation of the scandal-ridden LIBOR and that of BUBOR. As pointed out by the author, before the eruption of the LIBOR scandal the data underlying the LIBOR calculation were based on the self-assessments of the reporting institutions and in theory, the submissions reflected the cost of funds of the institutions concerned. By contrast, in the case of BUBOR the data reflected the cost of funds at which banks would be willing to grant unsecured loans to each other. Put simply, one rate was based on self-rating, while the other rated the market. In this regard, the incentive for manipulation is far higher in the case of self-assessment, whereas in the other case, the rating of partner institutions' market or partner risk also functioned as a significant counter-incentive for manipulation.

It is also important to be aware of the extent to which a benchmark rate is exposed to a potential manipulation attempt. For BUBOR, this was examined for two different periods under 6 scenarios in each period. At a low level of fixing submission volatility, the results indicated that even with the collusion of 3 banks and applying the worst method (dynamic mean) the manipulation potential was far below 4 basis points. The corresponding value calculated with the best method (arithmetic mean) was 0.01 bps. With high fixing submission volatility, a manipulation potential of 28.47 bps was yielded by the worst method (dynamic median) assuming a collusion of 3 banks, while the best method (trimmed median) produced a corresponding value of as low as 9.64 bps. It is also important to stress that BUBOR is far more likely to be 'underreported' than 'overreported'. As regards the methods applied, the simple arithmetic mean performed the best under low fixing submission volatility, while under high submission volatility the trimmed median and trimmed mean methods were the best.

Considering that manipulations of the financial benchmark cannot be detected immediately (as they occur) under reasonable audit costs, priority should be given to methods which reduce the manipulation potential on the one hand, and increase

the likelihood of detecting manipulation on the other hand. *Table 6* presents the methods applied in this article and their possible areas of implementation with respect to the data available.

Table 6
Methods that may be used to prevent and detect fixing manipulations, by possible area of institutional implementation

Name of method	Administrator	Data provider (contributor)	Supervision
Mean, median, trimmed mean and trimmed median fixings	X		X
Dynamic extreme value analysis	X		X
Analysis of pricing of correlating products	X		X
Outlier analysis	X	X	X
Analysis of fixing dynamics	X	X	X
Analysis of trading days that impact asset pricing		X	X
Cluster analysis	X	X	X

The table does not include determining the benchmark rate based on payment system data. This is because operators of high-value payment systems may appear in several different roles (e.g. administrator, central bank, supervision, etc.).

The methods applied in constructing the benchmark rate reduce the manipulation potential, while the methods that can be implemented at the institutional and supervisory level increase the likelihood of detecting manipulations.

Overall, we can state that the low interest rate environment and the low standard deviation of the fixings combined with the applied methodology essentially reduced the manipulation potential to a near-zero level. This also means that when fixing submission volatility is low, it is justified and substantiated to reduce the resources deployed on supervising and auditing the process of producing reference rates.

Last but not least, it should be noted that introducing specific methods may prompt an adjustment on the part of the contributors, which may weaken or strengthen the efficiency of the method concerned.

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