Libor Manipulation: Cui Bono?

Priyank Gandhi, Benjamin Golez, Jens Carsten Jackwerth, and Alberto Plazzi*

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ABSTRACT

Using data on Libor submissions from 1999 to 2012, we find weak support for the hypothesis that banks manipulate submissions to appear less risky and strong support for the hypothesis that banks manipulate Libor to generate higher cash flows. Our results are stronger for the manipulation period as identified by regulators (January 2005 to May 2009), for currencies and maturities with substantial notional amounts of interest-rate derivatives outstanding, for European banks, and for banks that have already paid fines related to manipulation. We calculate the cumulative gains in bank market capitalization due to manipulation to be $16 to $19 billion.

*Gandhi: Mendoza College of Business, University of Notre Dame, Notre Dame, IN 46556, USA, Tel.: +1-574-631-3450, pgandhi@nd.edu. Golez: Mendoza College of Business, University of Notre Dame, Notre Dame, IN 46556, USA, Tel.: +1-574-631-1458, bgolez@nd.edu. Jackwerth: Corresponding author. University of Konstanz, PO Box 134, 78457 Konstanz, Germany, Tel.: +49-(0)7531-88-2196, Fax: +49-(0)7531-88-3120, jens.jackwerth@uni-konstanz.de. Plazzi: University of Lugano and Swiss Finance Institute, Via Buffi 13 Lugano, 6900, Switzerland, alberto.plazzi@usi.ch.

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1 Introduction

Some $300 trillion of financial assets tied to the London Interbank Offer Rate (Libor) are traded every year.[1] This important reference rate is calculated daily from interest rates (henceforth submissions) self-reported by a select group of banks (henceforth panel banks). For each panel bank, submissions should reflect the true, lowest interest rate at which it can borrow in the London interbank market.

A Wall Street Journal article in 2008 was the first to suggest that panel banks may have manipulated submissions.[2] Since then, several banks have been fined for their role in the Libor scandal and the penalties paid by these banks amount to approximately $5.5 billion. Given the number of banks and the size of financial markets tied to Libor, the price tag associated with the scandal is only set to increase.

In this paper, we add to understanding the Libor manipulations by estimating the size of the manipulations, identifying the currencies and maturities which were impacted the most, and determining the characteristics of manipulating banks. Furthermore, we attempt to disentangle the two main reasons for banks to manipulate Libor - namely, the "stigma" and the "cash flow" hypotheses.

Four key results emerge from our empirical analysis. First, we test if the stigma or the cash flow hypothesis is the dominant reason for panel banks to manipulate Libor. Using data on Libor submissions by panel banks from 1999 to 2012, we can disentangle the two hypotheses the following way. According to the stigma hypothesis, submissions should always be lowered, whereas, according to the cash flow hypothesis, submissions should go up or down in line with exposure to Libor to increase cash flows. In our regressions, we use proxies for the stigma and the cash flow hypotheses and can thereby identify the relative contributions of the two effects. We find weak evidence for the stigma hypothesis and strong evidence for the cash flow hypothesis.

Second, we investigate if empirical support for the stigma or the cash flow hypothesis varies across time and in the cross-section of panel banks. As one might expect, attempts to manipulate Libor based on the stigma hypothesis are concentrated among the riskiest banks and only during

[1] See Wheatley (2012).

[2] Mollenkamp and Whitehouse (2008) alleged that 5 banks (namely, Citigroup, WestLB, HBOS, JP Morgan Chase, and UBS) may have manipulated their submissions and thereby Libor.

the financial crisis of 2007 - 2009. Attempts to manipulate Libor based on the cash flow hypothesis are concentrated mainly in the alleged period of manipulation as identified by regulators (i.e. from January 2005 to May 2009). They mainly affect those currency and maturities with a substantial notional value of interest rate derivatives outstanding namely the United States Dollar, British Pound, Japanese Yen, and Swiss Francs of 1-, 3-, and 6-month maturities. These currencies and maturities account for the vast majority of the volume in the markets for interest rate derivatives.

Third, we explore whether there are differences in attempts to manipulate Libor across banks. One may expect that the legal and regulatory framework that a particular panel bank faces affects its incentives to manipulate Libor. So far for example, only European banks were fined by the regulators, with the U.S. regulators collecting the largest fines. As a result, a concern is that the U.S. regulators used the Libor scandal to target only European banks, while U.S. and other non-European banks might have been equally guilty but were spared.[3] We find that the intent to manipulate is stronger for the panel banks incorporated in the European Union (E.U.). Our results are also stronger for panel banks that have already settled Libor related regulatory investigations by paying fines.

Fourth, our empirical methodology also allows us to quantify the gains from manipulation to the panel banks by a counter-factual argument. Under the assumption that the panel banks did not lower their submission because of the stigma hypothesis and that they had no exposure to Libor, we work out their hypothetical, true submissions. From those, we calculate a hypothetical Libor which we compare with the actual Libor so that we arrive at the size of Libor manipulations. Multiplying with the equity return sensitivity to Libor changes gives us the impact on bank equity returns; further multiplying by bank market valuation gives us the total. We estimate these gains to be between \$16 to \$19 billion in terms of the market value of banks. The majority of these gains reflect panel banks' attempts to manipulate Libor based on the cash flow hypothesis and only around \$1 billion reflect the gains based on the stigma hypothesis.

Our empirical analysis proceeds in three stages. In the first stage, for each panel bank in our sample, we regress the time-series of excess equity returns on changes in the differences between its submissions and the average submissions for all banks (ΔSub) and on changes in Libor ($\Delta Libor$). For each panel bank, we carry out this weekly regression separately for each currency and maturity

[3]See The Economist, July 2013.

and in each regression we control for bank-level and aggregate risk factors.

We interpret the coefficient on ΔSub as a proxy for the panel bank's incentive to manipulate submissions based on the stigma hypothesis. Our intuition is as follows: a negative coefficient on ΔSub measures how much investors penalize a panel bank's equity returns for submissions that are above the average submission of other panel banks.

On the other hand, the coefficient on $\Delta Libor$ measures a panel bank's exposure to Libor and thus is a proxy for its incentive to manipulate Libor based on the cash flow hypothesis. Our approach to estimate panel bank's exposure to Libor is based on a common technique to estimate interest rate exposure in the banking literature when such data is not available at a high frequency (see Flannery and James (1984), Brunnermeier and Nagel (2004), and Acharya and Steffen (2013)). Using balance sheet data (for a limited set of panel banks) and data from the market for syndicated loans (for all our panel banks), we confirm that the coefficient on $\Delta Libor$ indeed proxies for a particular panel bank's Libor exposure.[4]

In the second stage, we test if $\beta^{\Delta Sub}$ (the coefficient on ΔSub) or $\beta^{\Delta Libor}$ (the coefficient on $\Delta Libor$) predict a particular panel bank's future Libor submissions for a particular currency-maturity pair. Here, we use monthly panel regressions over January 1999 to November 2012. The coefficient on $\beta^{\Delta Sub}$ should be positive in order to be consistent with our stigma hypothesis: such positive coefficient multiplied with a negative value of $\beta^{\Delta Sub}$ (i.e. a bank generates higher returns from lower submissions) leads to a lowered submission by that bank. Our evidence is mostly weak and insignificant for the stigma hypothesis except for the riskiest banks which we view as particularly perceptible to the stigma hypothesis because of their high risk. Concerning the cash flow hypothesis, the coefficient on $\beta^{\Delta Libor}$ should be positive: such positive coefficient multiplied with a positive value of $\beta^{\Delta Libor}$ (i.e. a bank generates higher returns because it has positive exposure to Libor) leads to a higher submission by that bank. We find strong empirical support for such positive coefficient during the manipulation period (January 2005 to May 2009) and thus for the cash flow hypothesis.

A one standard deviation increase in a panel bank's exposure to Libor is accompanied by a 0.07

[4]Panel banks do not release detailed information regarding their interest rate exposures except via quarterly financial statements. Even the detailed Call Reports (collected by the U.S. Federal Reserve for all FDIC-insured banks) have only limited information regarding the interest rate exposures of panel banks. In any case, balance sheet data by itself is inadequate to assess panel banks' Libor exposure as it excludes off-balance sheet exposure stemming from interest rate derivatives.

basis point increase in its average submission over the subsequent month. While the magnitude appears modest, it is economically significant, given that interest rate derivatives of nearly $180 trillion tied to Libor are traded daily.[5]

Our results hold when we control for several bank-level and aggregate risk factors including panel banks' market beta, volatility, market capitalization, and credit default swap (CDS) premium. They also hold when we re-estimate the proxies for panel banks' incentives to manipulate Libor using an instrumental variable approach.

In the third stage, we quantify the gains from manipulation to panel banks. To compute those gains, we first construct a time-series of unmanipulated submissions that each panel bank in our sample would have hypothetically submitted, if it had no incentive to manipulate Libor, i.e. if it had no second stage coefficients on the sensitivities $\beta^{\Delta Sub}$ and $\beta^{\Delta Libor}$. Next, we follow the exact procedure specified by the British Bankers Association and compute a trimmed mean from these hypothetical submissions to construct a hypothetical, unmanipulated Libor. We already have the actual monthly Libor provided by the British Bankers Association. A comparison of the hypothetical, unmanipulated Libor with the actual monthly Libor, along with proxies for panel banks' incentives to manipulate Libor based on the stigma or the cash flow hypotheses allows us to compute the increase in monthly market capitalization of the panel banks due to manipulation. We assess the actual cumulative increase in market capitalization from manipulation based on the stigma hypothesis to be about $1 billion. These gains are concentrated during the financial crisis and among the riskiest panel banks in our sample. On the other hand, our estimates of cumulative gains from manipulation due to the cash flow hypothesis range from $16 to $18 billion.

Overall, we document evidence consistent with pervasive Libor manipulation, which operated mainly through the cash flow channel and resulted in substantial gains to the banks involved in the scandal. Our analysis also implies that collusion is not a necessary condition for actual manipulation. As long as the interest rate exposures of the panel banks do not exactly offset each other, all that is required for manipulation to take place is that banks behave rationally in their own interest and report submissions aligned with their exposures.

The rest of the paper proceeds as follows: Section 2 discusses related literature. Section 3 summarizes how Libor is computed, the potential sources of Libor manipulation, and develops the

[5]See http://www.lchclearnet.com/swaps/volumes/daily_volumes.asp.

testable hypotheses. In Section 4, we explain our empirical strategy. Section 5 presents the data while Section 6 details our key results followed by robustness tests in Section 7. Section 8 concludes.

2 Related literature

The literature on Libor manipulation started with a Wall Street Journal article published at the beginning of the financial crisis alleging that banks have been underreporting Libor submissions to appear less risky (Mollenkamp and Whitehouse (2008)). Accordingly, the first academic studies focus on testing the stigma hypothesis. Most of these studies compare Libor submissions to other proxies for borrowing costs (Wong (2009), Abrantes-Metz, Kraten, Metz, and Seow (2012), Kuo and Vickery (2012), Monticini and Thornton (2013)). However, the evidence regarding manipulation in these papers is rather mixed. For example, Abrantes-Metz, Kraten, Metz, and Seow (2012) and Kuo and Vickery (2012) do not find conclusive evidence that the Libor diverges from comparable rates during the crisis. More circumstantially, Abrantes-Metz and Villas-Boas (2011) and Rauch, Goettsche, and Mouaaouy (2013) show that Benford's law on the distribution of leading digits in random numbers is violated for Libor rates. In a similar vein, Fouquau and Spieser (2014) document breaks in the individual bank Libor submissions.

Motivated by the observation that the bankers at the trading desks were often in contact with the colleagues responsible for Libor submissions, as also admitted in Barclays settlement agreement, Snider and Youle (2012) go beyond the above analysis based on the stigma hypothesis. They explore the Libor manipulation driven by portfolio holdings of Libor sensitive derivatives, which we refer to as the cash flow hypothesis. In their model of the submission process, panel banks balance the cash flow gains from manipulation against the cost of being discovered. Their model predicts a bunching effect around particular submission levels, which they confirm empirically. In a contemporaneous paper, Youle (2014) builds a similar model based on a non-cooperative game. Led by the model, he estimates constant bank exposures to Libor and shows that Libor was downward biased during the recent crisis.

In comparison to these studies, we explore both mechanisms for Libor manipulation simultaneously. Moreover, we quantify their relative importance, and show that manipulation operated mainly through the cash-flow channel. In contrast to Youle (2014), our methodology allows the

estimation of time-varying exposure to Libor. Also, we allow for collusion that in our setting arises endogenously from the similarities in Libor exposures. Last but not least, in comparison to the literature, we use much larger dataset of Libor submissions and show how manipulation varies across Libor currency-maturity pairs and panel banks.

Our paper is also related to the literature that focuses on market-design to prevent future Libor manipulation (Wheatley (2012), Abrantes-Metz and Evans (2012), Duffie, Skeie, and Vickery (2013), Chen (2013), Duffie and Stein (2014), Hou and Skeie (2014), Duffie and Dworczak (2014), Eisl, Jankowitsch, and Subrahmanyam (2014), and Coulter and Shapiro (2014)). This literature calls for greater reliance on transaction based measures of borrowing costs and improvements in the method used to calculate Libor.

Finally, our paper contributes to the literature on financial misconduct and misreporting in the financial intermediation sector. Ackermann, McEnally, and Ravenscraft (1999) and Hartzell and Starks (2003) show that incentive contracts influence fund manager behavior. Bollen and Pool (2009), Agarwal, Daniel, and Naik (2011) and Ben-David, Franzoni, Landier, and Moussawi (2013) show that these incentives drive hedge fund managers to misreport returns. In a similar vein, we argue that incentives for increased bank valuation (which subsequently determine management bonuses) may drive panel banks to manipulate Libor submissions.

3 Libor computation and sources of manipulation

In this section, we review how Libor is computed. We then discuss how Libor can be subject to manipulation and develop our two main hypotheses.

3.1 Libor computation

Libor is a major benchmark rate for short-term interest rates and is used as a reference rate for a broad range of financial contracts and instruments. Interest rate derivatives with a notional value in excess of $180 trillion are traded every day. Most of these use Libor as a reference rate. Since at least 2007, Libor is also seen as a measure of the health of the financial money markets and the banking sector.

Libor rates are provided by the British Bankers' Association (BBA) for 10 distinct currencies

and 15 different maturities from overnight to one year. These 150 combinations are referred to as currency-maturity pairs. Appendix A provides further details.

Libor is computed as follows: Around 11 am each day interest rate data for each currency and maturity is collected from panel banks via a survey which requires them to answer the following question: "At what rate could you borrow funds, were you to do so by asking for and then accepting inter-bank offers in a reasonable market size just prior to 11am?". The number of panel banks varies across different currencies ranging from 6 (for Swedish Krona) to 18 (for US Dollar). The panel banks answers are referred to as submissions. Submissions need not be based on actual transactions but should reflect a panel banks true borrowing costs. Submissions should also not aim to maximize the cash flows that accrue to a panel bank from its Libor related assets.

For each currency-maturity pair, Libor is computed as a trimmed average of the submissions. That is, for each currency-maturity pair submissions are ranked in descending order from the highest to the lowest. The largest and smallest 25% of the submissions are trimmed and the average of the remaining submissions is published at 12:00 noon as the Libor rate for that currency-maturity pair. Also, at that time all submissions become publicly available. Note that trimming does not neutralize panel banks' incentives for manipulation. In fact, each panel bank's submission for each day is relevant for the ordering of all submissions from all panel banks and the computation of the order statistic (i.e. the trimmed sample mean).

3.2 Potential sources of manipulation and hypotheses

Panel banks have two main incentives to manipulate Libor. First, panel banks may underreport their submissions in order to appear less risky. A panel bank's submission supposedly reflects the true cost at which other banks are willing to lend to it. Therefore, market participants can use published submissions to infer the credit risk of a panel bank. A high submission by a panel bank (relative to other banks) could indicate that such a bank is of higher credit risk. This in turn may lower the panel banks valuation and increase the demand for collateral from its counterparties.

Thus, risky banks may want to lower their submissions in order to appear safer. Such underreporting should be more pronounced when (extra) capital for collateral is especially costly, for example during times of financial distress, and especially for the riskiest banks in our sample. We refer to this behavior on the part of the panel banks as manipulation based on "stigma" and this

motivates our first hypothesis:

H1: Stigma hypothesis Panel banks' Libor submissions underestimate their true borrowing costs in order to make them appear financially sound compared to their peers. Underestimation will increase in times of financial distress for the riskiest banks in our sample.

Panel banks may also use submissions to manipulate Libor in the direction of their Libor exposure as this would lead to higher cash flows and valuations, which in turn benefit traders and managers through increased pay and bonuses. This suggests that panel banks may align submissions in the direction of their unhedged exposure to Libor. Unhedged exposure to Libor is defined as a panel bank's net asset-liability position in all markets where pricing is linked to Libor. A panel banks long positions in Libor related assets will benefit from an increase in Libor and generate positive cash flows and higher valuations. Just the same, short positions will benefit from a decrease in Libor and again generate cash flows and higher valuations. Thus, manipulation should occur most often in currency-maturity pairs with high notional volume of interest rate derivatives, since those are the contract most likely to be held by banks and thus to generate substantial cash flows.[6] This leads to our second hypothesis:

H2: Cash flow hypothesis: Panel banks' Libor submissions are aligned with the direction of their Libor exposure in an attempt to manipulate Libor in the direction of exposure to Libor related positions. Alignment of submissions to exposure is expected to be more pronounced for those currency-maturity pairs with the highest notional value of interest rate derivatives outstanding.

Note that there are key differences between the stigma and cash flow hypotheses which we use for identification. The stigma hypothesis suggests that panel banks always bias their Libor submissions downwards regardless of their Libor exposure, the currency, and the maturity of their submissions. Instead, the cash flow hypothesis suggests that a panel banks submissions will be biased in the direction of exposure to Libor. These differences are important for our identification strategy and enable us to assess the relative importance of the two sources of manipulation in the data.

[6] One may argue that the panel banks' intent to manipulate should be stronger for currencies with low notional value of interest rate derivatives as the small number of participants in these markets makes it easier for banks to manipulate Libor. However, note that manipulation in the Libor markets is not exactly analogous to manipulation in other financial markets. It is generally true that price manipulation is easier in illiquid markets with low participation rates. However, given that the number of panel banks remains fixed for each currency, it is natural that the panel banks focus their efforts where their gains from manipulation are the highest.

4 Methodology

Our empirical analysis proceeds in three stages. In the first stage, we estimate proxies for panel banks' incentives to manipulate individual submissions based on the stigma or the cash flow hypothesis. In the second stage, we test if these proxies predict a particular panel banks' future Libor submissions. Finally, in the third stage, we calculate the potential gains to panel banks from Libor manipulation.

4.1 Bank's incentives to manipulate Libor submissions (Stage 1)

Manipulating individual submissions based on the stigma and cash flow hypothesis increases panel banks' market valuation. Under the stigma hypothesis, underreporting borrowing costs decreases panel banks' perceived riskiness. Outside investors reward the lower risk in terms of higher bank valuations. Under the cash-flow hypothesis, aligning individual submissions with Libor exposure increases cash flows that accrue to panel banks from Libor related positions. These mechanisms suggest a direct link between panel bank's equity returns and its incentives to manipulate Libor.

We measure a particular panel bank's incentives to manipulate Libor under either hypothesis in a multi-factor model that expresses bank equity returns as a function of changes in its individual submissions, changes in computed Libor, and other control variables. Specifically, using weekly data, for each panel bank i, for each currency-maturity pair, in our sample, we estimate the following time-series regression:

$$r_{i,t} - r_{f,t} = \alpha + \beta_i^{\Delta Sub} \Delta Sub_{i,t} + \beta_i^{\Delta Libor} \Delta Libor_t + \beta_i^{Mkt}(r_{Mkt,t} - r_{f,t}) + \beta_i^{VIX} \Delta VIX_t + \epsilon_{i,t} \quad (1)$$

In this equation, r_i is the (dollar-denominated) weekly return on bank i's equity, r_f is the weekly USD OIS rate, and Sub_i is the difference between bank i's Libor submission and the average Libor submission for all other panel banks for each currency-maturity pair. *Libor* is the Libor computed by Thomson Reuters for a particular currency-maturity pair. ΔSub and $\Delta Libor$ represent the weekly change in these quantities. To ensure that our estimates are not contaminated by systematic risk we control for aggregate risk factors in each regression, namely the weekly market excess returns $(r_{mkt} - r_{f,t})$, and the weekly changes in the Chicago Board Options Exchange Market Volatility

Index (VIX). All variables are measured as of week t.

We estimate the regression in equation 1 separately for each currency-maturity pair. This implies that the sensitivities (βs) in equation (1) should be further indexed by currency-maturity pair (c, m). We omit these subscripts to simplify notation.

At each t, we carry out the above regression using data for the prior 26 weeks (i.e. from $t-26$ to t). We roll the regression forward one week at a time to obtain a time series for our proxies for banks incentives to manipulate Libor based on the stigma and the cash flow hypothesis, $\beta^{\Delta Sub}$ and $\beta^{\Delta Libor}$. The choice for the length of the rolling windows is somewhat arbitrary. We choose windows of 26-weeks to balance the staleness of estimated parameters ($\beta^{\Delta Sub}$ and $\beta^{\Delta Libor}$) measured over a longer window against the statistical uncertainty of the same parameters measured over a smaller window. We show in Section 7.4 that our results are robust to changes in the window size.

4.2 Testing hypotheses (Stage 2)

In the second stage, we test if either (or both) of $\beta^{\Delta Sub}$ or $\beta^{\Delta Libor}$, estimated at time t, predict a particular panel bank's average Libor submission for a particular currency-maturity pair over the following month. There are at least two reasons for doing so. First, for a given currency maturity both Libor and submissions for the panel banks are extremely persistent at both the daily and weekly frequencies. We therefore rely on non-overlapping average monthly observations as our dependent variable to avoid spurious correlation impacting the results of our panel regressions in equation 2. Second, many Libor denominated assets such as interest rate swaps or Asian interest rate options are sensitive to Libor measured over an extended period of time. Thus, we estimate the following monthly panel regression:

$$\overline{Submission_{i,t+1}} = a + \lambda^{Sub}\beta_{i,t}^{\Delta Sub} + \lambda^{Libor}\beta_{i,t}^{\Delta Libor} + Controls + Fixed\ effects + u_{i,t+1} \qquad (2)$$

Here, $\beta^{\Delta Sub}$ and $\beta^{\Delta Libor}$ denote the proxies for incentives to manipulate Libor based on the stigma and cash flow hypothesis from Stage 1. $\overline{Submission_{i,t+1}}$ is the average submission of panel bank i for the same currency-maturity over weeks $t+1$ to $t+4$. We introduce time subscripts for the βs to highlight the fact that they vary over time. To avoid a look-ahead bias both $\beta^{\Delta Sub}$ and $\beta^{\Delta Libor}$ are estimated using data only up to and including month t.

Since Libor reflects the cost at which a panel bank can borrow funds, we add several proxies that control for bank level risk in equation 2. These include the exposures to the market risk factor (β^{Mkt}) and the VIX (β^{VIX}) as estimated from equation (1), the logarithm of bank market capitalization ($Size$), the domestic 12-month Treasury rate ($Yield$), and the realized volatility which we compute as the within-month standard deviation of daily equity returns for bank i (Vol). These control variables are also measured as of end of month t.

Under the null hypothesis of absence of manipulation based on the stigma and the cash flow hypothesis, we expect the slope coefficients λ^{Sub} and λ^{Libor} to be zero. We interpret the evidence that $\beta^{\Delta Sub}$ significantly influences subsequent Libor submissions as empirical support for the stigma hypothesis ($\lambda^{Sub} > 0$), and the evidence that $\beta^{\Delta Libor}$ influences subsequent Libor submissions as empirical support for the cash flow hypothesis ($\lambda^{Libor} > 0$).

4.3 Banks' gains from manipulation (Stage 3)

We calculate gains to panel banks in terms of an increase in their market capitalizations for the cash flow hypothesis. We present details for this calculation for the cash flow hypothesis. Calculations for gains to panel banks based on the stigma hypothesis are similar.

Note that the intent to influence Libor by manipulating submissions and actual realized gains from manipulation are two distinct concepts. To see this, consider a scenario where the BBA collects submissions from just two panel banks (banks A and B) for a particular currency-maturity pair. Assume also that the two panel banks' Libor exposures exactly offset each other. If $\beta^{\Delta Libor}$ (accurately and perfectly) measures Libor exposures for banks A and B, then in this setup the $\beta^{\Delta Libor}$ will be of the exact same magnitude but opposite signs. Further, value-maximizing banks that rationally align their submissions with their respective $\beta^{\Delta Libor}$ will manipulate submissions by the exact same amount but in the opposite directions. These manipulations offset each other, leaving the Libor (calculated as a trimmed average) unaffected.

To document gains from manipulation we construct an unmanipulated average monthly submission ($Submission^{Unm}$) that each panel bank in our sample would have hypothetically submitted if it had no incentive to manipulate Libor due to the cash flow hypothesis, i.e. if $\beta^{\Delta Libor}$ had been zero. For each panel bank, i, for each currency-maturity pair, the average monthly unmanipulated

submission equals the predicted value from the second stage regression computed as follows:

$$\overline{Submission_{i,t+1}^{Unm}} = \overline{Submission_{i,t+1}} - \lambda^{Libor}\beta_{i,t}^{\Delta Libor} \quad (3)$$

$$= a + \lambda^{Sub}\beta_{i,t}^{\Delta Sub} + Controls + Fixed\ effects + u_{i,t+1} \quad (4)$$

We then apply the exact procedure specified by the BBA to these hypothetical average monthly submissions to compute the *hypothetical, unmanipulated* average Libor ($\overline{Libor_{t+1}^{Unm}}$) for a particular currency-maturity pair. We compute the *actual* average monthly Libor from the *actual* average monthly submissions over the same period ($\overline{Libor_{t+1}}$). A comparison of the *hypothetical, unmanipulated* average monthly Libor to the *actual* average monthly Libor, along with $\beta^{\Delta Libor}$ and the bank's market capitalization, allows us to compute the impact on the monthly market capitalization of panel bank i due to manipulation.

Specifically, the dollar manipulation gain (or loss) for panel bank i in month $t+1$ for a given currency-maturity pair equals its end-of-month equity market capitalization ($MV_{i,t}$) times $\beta^{\Delta Libor}$ times the difference between the (changes in) *hypothetical, unmanipulated* average monthly Libor and the (changes in) *actual* average monthly Libor. This is given by

$$GAIN_{i,t+1}^{Libor} = MV_{i,t}\beta_{i,t}^{\Delta Libor}\left(\Delta Libor_{t+1} - \Delta Libor_{t+1}^{Unm}\right) \quad (5)$$

We accumulate dollar manipulation gains due to the cash flow hypothesis for all panel banks across all currency-maturity pairs

To estimate the gains based on the stigma hypothesis, we follow the exact same procedure outlined above except that we now compute unmanipulated average monthly submissions from equation 6:

$$\overline{Submission_{i,t+1}^{Unm}} = \overline{Submission_{i,t+1}} - \lambda^{Sub}\beta_{i,t}^{\Delta Sub} \quad (6)$$

$$= a + \lambda^{Libor}\beta_{i,t}^{\Delta Libor} + Controls + Fixed\ effects + u_{i,t+1} \quad (7)$$

The other stages of the calculation are much as above but we compute the gains as:

$$GAIN_{i,t+1}^{Sub} = MV_{i,t}\beta_{i,t}^{\Delta Sub}\left(\Delta Sub_{t+1} - \Delta Sub_{t+1}^{Unm}\right) \quad (8)$$

5 Data

This section presents our data sources, definition of variables, and summary statistics.

5.1 Libor and individual Libor submissions

We collect daily data for Libor from Bloomberg from January 1, 1999 to November 28, 2012. The British Bankers Association (BBA) computes daily Libor rates for 10 currencies and 15 maturities. Wheatley (2012, Table C.1 on page 76) estimates that in 2012 that the total outstanding notional value of Libor-linked derivatives is approximately $300 trillion. Nearly 77% of this volume is in markets for interest rate swaps. Table 1, reproduced from Wheatley (2012), shows that 4 currencies (namely, the United States Dollar (USD), Great British Pound (GBP), and Japanese Yen (JPY), and the Swiss Franc (CHF)) together account for the entire volume of interest rate swaps in June 2012. Further, nearly all these swap contracts reference the 1-, 3-, or 6-month Libor. Therefore, we restrict our analysis to these 12 currency-maturity pairs.[7]

[Table 1 about here]

We also collect data for individual panel banks' submissions for these 12 currency-maturity pairs. The panel banks are the banks which are being surveyed by the BBA for determining the daily Libor and their composition varies with currency. The full list of panel banks for each currency is in Appendix B.

While the BBA commenced communicating Libor for various currencies on January 1, 1986, our analysis begins only on January 1, 1999. The primary reason is that prior to this date, data for individual panel bank submissions are generally not available. Also, the BBA made a significant change in the way Libor submissions were collected in 1999. Prior to 1999, panel banks submitted interest rates by estimating other panel banks' borrowing costs and were not asked to provide the specific rate at which they themselves could borrow in the London interbank market. We thus begin our analysis in 1999.

[7] A report published by the Bank of International Settlement in June 2012 (BIS (2012a)) indicates that nearly 92% of the notional value of all over-the-counter interest rate derivatives are denominated in USD, GBP, or the JPY. Further, note that floating payments for derivatives denominated in Euro are often tied to Euribor and not the Euro Libor (See BIS ((2012b)), p.21-22). For this reason we exclude Euro Libor from our analysis.

Summary statistics for the submissions and the daily computed Libor for the selected currency-maturity pairs are presented in Table C.1 in the appendix. Note that both the individual panel banks' submissions, as well as the daily Libor, are highly persistent. Panel A, in Figure 1 plots the average submission across all panel banks (and its cross-sectional two-standard-deviation bands) for the USD 3-month Libor. Panels B, C, and D of Figure 1 show similar plots for the GBP 6-months, JPY 6-months, and CHF 6-months Libor, respectively. That is, within each currency we plot the maturity with the highest notional value of interest rate swap contracts outstanding according to Table 1. Figure 1 shows that average submissions from panel banks track the interest rate regime for each currency. Interestingly, the cross-sectional standard deviation of the submissions by the panel banks for each currency-maturity pair is low until 2009 but increases steadily thereafter.

[Figure 1 about here]

It is clear from Table C.1 and Figure 1 that the level of Libor varies widely across different currencies. Therefore, in our Stage 2 regressions, we standardize all dependent and independent variables cross-sectionally within each month and currency-maturity pair.

5.2 Returns and risk measures

We obtain data for daily equity returns for the panel banks in our sample from Datastream. For each panel bank these are the returns for the entire bank holding company and not just the commercial bank. This ensures that our proxies for panel banks' incentives to manipulate submission ($\beta^{\Delta Sub}$ and $\beta^{\Delta Libor}$) are measured accurately, regardless of the subsidiary (commercial bank, investment bank, insurance company, etc.) in which this exposure is held. We also obtain from Datastream the daily returns for the aggregate stock market index for each country in which each of the panel banks in our sample is headquartered. Datastream also provides us with the weekly observations for panel banks' equity market capitalizations and the data for the 1-, 3-, 6-, and 12-month risk-free rate for each currency in our sample. Weekly excess equity returns for each panel bank are computed by subtracting the weekly return on a 3-month risk-free investment. We use the OIS rate instead of the Treasury bill rate as the latter was contaminated by a significant flight-to-liquidity component during the crisis. The OIS rate is available from November 26, 2003 onward. Before that we first regress the OIS on the Treasury bill during 2004, and then use the resultant estimates to construct

an artificial OIS series as the predicted value during January 1999 to November 2003. Our results are robust to using the T-bill as a proxy for the risk-free rate instead of the OIS rate.

We convert all returns such that they are denominated in the U.S. dollar. This ensures that our results are not impacted by fluctuations in exchange rates. We verify in Section 7.4 that keeping equity returns in their respective local currencies does not impact our results.

In equation 2 we control for bank-level and aggregate risk factors. Our main measure of bank-level risk is the realized volatility of daily bank equity returns. In Section 7.4, we use alternative bank-level risk measures such as at-the-money option implied volatilities and the spread in basis point on the standard 1-year credit default swap (CDS) contract that references the panel bank. These alternative data (also from Datastream) are only available for shorter samples.[8] Table C.2 in the appendix provides summary statistics for our control variables.

We further define three dummies, High, Cheat, and EU. High is one if the currency-maturity pair has high notional value of Libor related derivatives outstanding according to Table 1 (USD 1-month, USD 3-month, GBP 3-month, GBP 6-month, JPY 3-month, and JPY 6-month). Cheat is one if the bank has already settled a Libor related fine with the regulator (HSBC, Barclays, UBS, Royal Bank Scotland, and Deutsche Bank). EU is one if the bank is headquartered in Europe (Credit Suisse, UBS, BNP Paribas, Societe General, Deutsche Bank, Banco Santander, Barclays, HSBC, Lloyds, Royal Bank of Scotland, and Credit Agricole). Note that our Stage 1 and Stage 2 analysis excludes data for two privately listed panel banks with no publicly traded equity, namely, Rabobank (which is a panel bank for all currencies) and Norinchukin (which is a panel bank for JPY and USD).

5.3 Call reports and syndicated loan data

To validate our measure of Libor exposure, we compare $\beta^{\Delta Libor}$ to a measure of Libor exposure computed from bank balance sheet data. For this, we require income statement and balance sheet data for panel banks in our sample. We collect this data from the quarterly Call Reports required to be filed by all FDIC-insured banks in the U.S. This data are only available for banks that are either incorporated or have significant operations in the U.S. (namely, Bank of America, Citigroup,

[8] CDS spreads for all panel banks in our sample are only available from 2004. CDS spreads are not available for banks headquartered in Canada. Data for implied volatilities for all panel banks in our sample are only available from 2000.

Deutsche Bank, HSBC, and J. P. Morgan Chase).

We also validate our measure of Libor exposure, $\beta^{\Delta Libor}$, by using data for syndicated loans. Data for syndicated loans are collected over 1999 - 2012 from the Thomson Reuters SDC database. We restrict ourselves to those syndicated loans where any of our panel banks were part of the syndicate. Data on syndicated loans includes the amount, the currency, the maturity, and the interest rate of the loan.

6 Results

We start by presenting summary statistics for $\beta^{\Delta Sub}$ and $\beta^{\Delta Libor}$ from Stage 1 followed by the Stage 2 results which relate subsequent submissions to proxies for incentives to manipulate. Finally, we present results for Stage 3 where we quantify the gains from manipulation for the panel banks.

6.1 Estimating $\beta^{\Delta Sub}$ and $\beta^{\Delta Libor}$ (Stage 1)

We estimate the regression in equation (1) for each panel bank for each currency-maturity pair in our sample.[9] In each week t, we carry out the regression using data for prior 26 weeks (i.e. from $t-26$ to t). We roll the regression forward one week at a time to obtain a time series for our proxies for banks incentives to manipulate Libor for the cash flow or the stigma hypothesis, $\beta^{\Delta Sub}$ and $\beta^{\Delta Libor}$. Since our data starts on January 6, 1999, this results in a time-series of $\beta^{\Delta Sub}$ and $\beta^{\Delta Libor}$ from June 30, 1999 to November 28, 2012.

[Table 2 about here]

Table 2 presents the summary statistics for $\beta^{\Delta Sub}$ (in Panel A) and $\beta^{\Delta Libor}$ (in Panel B) for each currency-maturity pair over our entire sample. In Panel A, the coefficient $\beta^{\Delta Sub}$ is on average positive except for the 1- and 3-month USD, and the 1-month JPY. This seems counter-intuitive as one would expect $\beta^{\Delta Sub}$ to be always negative, reflecting the fact that a panel bank's equity investors care about its relative submissions and will penalize (reward) it for higher (lower) submissions. However, it is likely that investors attention and hence their concern regarding a given panel bank's relative submissions varies over time. For example, investors may be concerned about

[9] We exclude two privately listed panel banks namely, Rabobank and Norinchukin, with no publicly traded equity.

a panel bank's relative submissions during times of financial distress but not otherwise. Equity investors may not also react to an individual panel banks relative submission if they are already aware that the bank is in distress. Thus a relatively high submission may not reveal any new information to a panel banks equity investors.

This intuition accounts for the fact that there is substantial time-series and cross-sectional variation in $\beta^{\Delta Sub}$. In unreported results, we find that the average $\beta^{\Delta Sub}$ is negative for all currency-maturity pairs during September 2008, a time of financial distress when Lehman filed for bankruptcy.

The last three columns in Panel A report the within currency correlations for the time-series of $\beta^{\Delta Sub}$ across different maturities which are generally low and range from 0.020 to 0.521. For USD, $\beta^{\Delta Sub}$ estimated for 3-month Libor has a correlation of only 0.26 with the $\beta^{\Delta Sub}$ estimated for 1-month Libor.

Panel B of Table 2 reports the summary statistics for $\beta^{\Delta Libor}$. Unlike $\beta^{\Delta Sub}$, our hypothesis does not predict a sign for the average $\beta^{\Delta Libor}$ for a given panel bank and currency-maturity pair as Libor related holdings for an individual panel bank can be positive or negative. Panel B of Table 2 shows that $\beta^{\Delta Libor}$ is on average negative for the USD and the JPY but positive for the GBP and the CHF. Again, there is substantial time-series and cross-sectional variation in exposures.

The last three columns of Panel B again report the within currency correlations for the time-series of $\beta^{\Delta Libor}$ across different maturities which again are generally low. This fact is reassuring as it suggests that Libor exposure measured by $\beta^{\Delta Libor}$ varies with maturity even within the same currency. Thus, it is unlikely that $\beta^{\Delta Libor}$ simply proxies for the general interest rate or currency risk for a given panel bank.

To prevent outliers from influencing our results in Stage 2 regressions we winsorize the βs estimated from Stage 1 regressions at the 1st and 99th percentile.[10]

A natural question that arises at this stage is whether the βs truly measure panel banks' incentives to manipulate submissions or if the measurement error in $\beta^{\Delta Sub}$ and $\beta^{\Delta Libor}$ renders them useless for the purpose of our empirical analysis. We return to this question in section 7. However, we should point out that, if measurement error renders $\beta^{\Delta Sub}$ and $\beta^{\Delta Libor}$ useless, we should find that they have no impact on subsequent Libor submissions in Stage 2 regressions, and

[10] All our results are robust when we instead trim these estimates.

this is what we turn to next.

6.2 Did panel banks manipulate Libor submissions? (Stage 2)

Table 3 reports the estimates of the panel regression in equation (2) which relates future submissions (in basis points) to manipulation proxies and controls. Each column in table 3 refers to a different specification of equation (2). In each regression we allow for bank and time fixed-effects within each currency-maturity pair. The standard errors are computed by clustering residuals for each month. The sample period is 1999 to 2012.

[Table 3 about here]

We first investigate the cash flow hypothesis. Column (1) shows that, for a given panel bank, Libor exposure measured at end-of-month ($\beta^{\Delta Libor}$) has a significant (at the one percent level) positive impact on the bank's average Libor submission for the subsequent month.[11] A one standard deviation increase in the Libor exposure of a panel bank leads to a submission which is higher by 0.029 standard deviations. The cross-sectional standard deviation of submissions is 2.28 basis points. This implies that a one standard deviation increase in the Libor exposure of a panel bank results in a submission being higher by 0.066 basis points over the following month. While the magnitude of the effect seems modest, the large notional value of interest rate derivatives tied to Libor implies that manipulation of even a fraction of a basis point can result in large cash flows and wealth transfers among investors that trade in these securities.

The magnitude of the effect only decreases marginally from 0.029 in column (1) to 0.025 in column (4) when we include all control variables. The estimates, however, remain highly statistically significant. In columns (3) and (4), the signs of the coefficients for the control variables are also as expected. Since submissions reflect bank risk and are primarily a measure of borrowing costs, we find that a panel bank's submission increases with its exposure to market risk and volatility risk. The latter is measured either with the panel bank's exposure to VIX or its historical monthly volatility. The submission for a panel bank also mechanically increases when interest rates for a particular currency-maturity pair increase but this does not affect our central result. Furthermore,

[11] For better readability we drop henceforth the qualification 'average Libor submission for the subsequent month' and simply use 'submission'.

the submission decreases as the size of the bank increases as large banks are deemed safer by market participants.

We next investigate the stigma hypothesis. Column (2) shows that there is only weak evidence that $\beta^{\Delta Sub}$ measured at the end of each month influences a panel bank's submission. In univariate regressions, the coefficient on $\beta^{\Delta Sub}$ is -0.009 and not statistically significant, while we expected a positive and significant coefficient according to the stigma hypothesis. The estimated coefficient on $\beta^{\Delta Sub}$ hardly changes with the addition of control variables as reported in columns (3) and (4).

We interpret the positive and significant coefficient on $\beta^{\Delta Libor}$ as indicative of panel banks' intent to manipulate submissions due to the cash flow hypothesis. On the other hand, we conclude that there is no evidence for the stigma hypothesis when we analyze all panel banks over our entire sample.

Note that we cannot rule out that some unobservable risk factor drives both $\beta^{\Delta Libor}$ and a panel bank's submission. To the extent that such an unobservable risk factor is bank specific, it would be captured by the bank and time fixed effects included in each specification in Table 3. While not impossible, it is unlikely that an unobservable risk factor explains the cross-sectional and time-series variation in our results discussed in the following section.

6.3 Did manipulation based on the cash flow hypothesis vary across time and across banks?

Regulators have alleged that banks primarily attempted to manipulate Libor from 2005 through 2007 and thereafter engaged in such behavior occasionally until 2009.[12] This suggests that the intent of the panel banks to manipulate submissions may have varied over time. To explore this possibility, we estimate a variation of the regression in equation (2), where we add an additional interaction term between $\beta^{\Delta Libor}$ and a dummy variable *Manip*. *Manip* takes the value one for the manipulation period from January 2005 to May 2009 and is zero otherwise. If the panel banks' intent to manipulate Libor was stronger during the specified manipulation period, the estimated coefficient on $\beta^{\Delta Libor} \times Manip$ should be positive and statistically significant.

[Table 4 about here]

[12] http://www.justice.gov/opa/pr/barclays-bank-plc-admits-misconduct-related-submissions-london-interbank-offered-rate-and.

Results are reported in column (1) in Table 4. The estimated coefficient on $\beta^{\Delta Libor}$ remains positive, but loses significance. The estimated coefficient on the added interaction term, however, is large and statistically significant. This is in line with the regulators claim that the intent to manipulate for the cash flow hypothesis was indeed stronger during the manipulation period identified by the regulators. During January 2005 to May 2009, a one standard deviation increase in the Libor exposure of a panel bank now causes its Libor submission over the following month to be higher by 0.043 standard deviations. Given the standard deviation of submissions, this implies that a one standard deviation increase in the Libor exposure of a panel bank results in a 0.098 basis points higher submission, i.e. the effect is much larger during the manipulation period.

Next, we explore whether there are significant differences in the intent to manipulate Libor across currencies and panel banks. In theory, one may expect that all panel banks manipulate Libor in the direction of their exposure for all currencies-maturity pairs. In reality, however, there are important differences in regulatory regimes across the countries of incorporation of panel banks that may lead to cross-sectional differences in incentives to manipulate. The notional value of interest rate derivatives referencing Libor also varies substantially across different currency-maturity pairs. Our hypothesis suggest that manipulation is driven by incentives for increased cash flows from a panel banks' Libor exposure and this effect is expected to be more pronounced for those currency-maturity pairs with large notional value of interest rate derivatives outstanding.

To investigate cross-sectional differences across currency-maturity pairs, we now interact $\beta^{\Delta Libor}$ and *Manip* with two additional dummy variables *High* or *Low*. *High* (*Low*) takes the value one when the submission from the panel bank is for a currency-maturity pair with a large (small) notional value of interest rate derivatives outstanding. We identify the currency-maturity pairs with a large notional value of interest rate derivatives from Table 1 to be the USD 1-month, USD 3-month, GBP 3-month, GBP 6-month, JPY 3-month, and the JPY 6-month. Since the results in Column (1) of Table 4 suggest that the panel banks intent to manipulate is only statistically significant from January 2005 to May 2009, we interact the dummy variables *High* and *Low* with the dummy variable *Manip*.

As is clear from column (2) of Table 4, the relation between Libor exposure and submissions is indeed concentrated in the 'High' currency-maturity pairs. For these pairs, a one standard deviation increase in the Libor exposure of a panel bank is accompanied with a 0.022 basis points

(0.088 standard deviations) higher submission. The magnitude of the effect is therefore nearly three times the size of the effect documented in Table 3.

Finally, we investigate whether the intent to manipulate Libor varies across panel banks. We consider two additional specifications for equation (2). For the first specification, we define the dummy variable *EU* (*NoEU*) that takes the value one if the panel bank is incorporated in (outside) the European Union. For the second specification, we define the dummy variable *Cheat* that takes the value one for those panel banks that have already settled or agreed to settle a regulatory investigation related to Libor, and zero otherwise. The dummy *ExCheat* is defined as one minus *Cheat*, and captures the effect for the remaining banks.

As reported in column (3) of Table 4, the effect of Libor exposures on a subsequent submission is stronger for banks incorporated in the EU. For those banks, a one standard deviation increase in the Libor exposure of a panel bank causes a 0.088 standard deviation higher submission and the effect is statistically significant. For banks incorporated outside the EU, the estimate is minus 0.014 and it is not statistically significant. This result lines up with the known Libor settlements that so far have only involved European banks. In particular, we do not find evidence that U.S. regulators systematically favored U.S. banks by not prosecuting them while targeting European banks.

Column (4) shows that the effect we document is mainly driven by banks that have already settled or agreed to settle a regulatory investigation related to Libor. Our results are economically and statistically significant for the banks identified as *Cheat* (coefficient of 0.097). There is also some evidence that banks identified as *ExCheat* engaged in an attempt to manipulate Libor as the coefficient is positive but statistically insignificant.

6.4 Did manipulation based on the stigma hypothesis vary across time and across banks?

Although we find no support for the stigma hypothesis for all panel banks over our entire sample in Table 3, it is likely that incentives to manipulate submissions based on the stigma hypothesis are stronger for the riskiest panel banks during times of financial distress.

To explore this, we estimate a variation of the regression in equation (2), where we add additional interaction terms between $\beta^{\Delta Sub}$ and two dummies, *Crisis* and *Weak*. *Crisis* takes the value one

for the period July 2007 through March 2009, and zero otherwise. *Weak* takes the value one for the banks in the top credit default spread (CDS) tercile in a given month, and zero otherwise.

Column (5) of Table 4 reports the result for the interaction term $\beta^{\Delta Sub}$ times the dummy variable *Crisis*. The estimated coefficient on the interaction term is positive but is statistically insignificant. The coefficient on $\beta^{\Delta Sub}$ alone is negative and becomes marginally significant. This suggests that banks only mildly care about investor perceptions inferred from their relative submissions even during the crisis.

A similar pattern is observed in column (6), where we add the interaction term between the $\beta^{\Delta Sub}$ and the dummy *Weak*. In this case, the interaction term is positive and marginally significant; providing some support for the stigma hypothesis for the riskiest banks.

Finally, in column (7), we include both interaction terms $\beta^{\Delta Sub} \times Crisis$ and $\beta^{\Delta Sub} \times Weak$. Now the estimated parameter on $\beta^{\Delta Sub}$ becomes even more negative and significant. The estimated coefficients on both interaction terms, however, are positive and the interaction term $\beta^{\Delta Sub} \times Weak$ remains significant while the interaction term $\beta^{\Delta Sub} \times Crisis$ is only marginally significant. Importantly, the combined effect across all estimates is positive. This leads us to conclude that, although there is no evidence in favor of the stigma hypothesis in general, there appears to be some support for the stigma hypothesis when we restrict our analysis to the riskiest banks during times of financial distress.

Note that in all specifications in columns (5) - (7), we include both $\beta^{\Delta Libor}$ and $\beta^{\Delta Libor} \times Manip$. This is because the results in the previous section confirm that manipulation for the cash flow hypothesis was primarily concentrated in the manipulation period as identified by the regulators.

6.5 How much did the panel banks gain from manipulation? (Stage 3)

Table 5 presents the estimated gains from manipulation using the methodology outlined above for the cash flow hypothesis, for the stigma hypothesis, and their sum. Since the results in Table 4 suggest that the panel banks' intent to manipulate is only statistically significant during the manipulation period from January 2005 to May 2009, we compute the manipulation gains during this period.

As described in Section 4, we compute the gains as the cumulative sum of monthly changes in the market value from manipulation for all panel banks included in all currency-maturity pairs.

The calculation of gains in columns (1) through (7) corresponds to the results reported in the corresponding columns of Table 4. The t-statistics in parenthesis below the estimated dollar amounts refer to the statistical significance of the average monthly gain for the panel banks involved in the computation of the cumulative gains in each column.

[Table 5 about here]

The total cumulative gains from manipulation range from \$16.24 to \$18.57 billion. We note that the bulk of these gains (between \$15.82 and \$18.15 billion) stems from manipulations due to the cash flow hypothesis. Given that interest rate derivatives with a notional value of nearly \$700 billion are traded every week and the effect on submissions is on the order of a fraction of a basis points, the estimated cumulative gains appear reasonable.

In line with the results in Table 4 and as expected, we find that the cumulative gains over the manipulation period are higher for the 'High' currency-maturity pairs (\$15.51 billion) as compared to the 'Low' pairs (\$0.31 billion). Cumulative gains are also somewhat higher for banks located in the E.U. (\$9.30 billion) as compared to those incorporated outside the E.U. (\$7.42 billion). Finally, we estimate the cumulative gains for the banks already identified by the regulators ('Cheat') to be nearly \$10.33 billion as compared to the cumulative gains for the other banks, \$7.64 billion.

The gains based on the stigma manipulation are overall small at \$0.4 billion and increase during the crisis period for the riskiest panel banks to \$1.38 billion.

7 Balance Sheet Information, Endogeneity, and Robustness

We validate our Stage 1 estimation approach using data from markets for syndicated loans and from the quarterly Call Reports. Both analyses confirm that a factor-based approach captures Libor-related exposures for panel banks. Next, we carry out a battery of robustness tests to address potential endogeneity and other concerns in our baseline empirical approach.

7.1 Comparison of estimated exposure with syndicated loan data

To ensure that $\beta^{\Delta Libor}$ estimates indeed reflect a panel bank's exposure to Libor, we conduct two tests. In this section, we use data from the market for syndicated loans. In the following section

we compare $\beta^{\Delta Libor}$ to Libor exposures constructed from quarterly balance sheet data.

We collect data for syndicated loans from Thomson Reuters SDC database over 1999 to 2012. Data for syndicated loans includes the loan amount, the currency, the maturity, the date the loan is executed, and the interest rate of the loan. SDC indicates if the interest rate on the loan is floating or fixed. If the interest rate is floating, SDC lists the reference rate (e.g. Libor, Euribor, Treasury bill, etc.). SDC also lists the maturity of the specified reference rate. Thus, for loans with USD Libor as the reference rate, SDC indicates (when such information is available) if the reference rate is the 1-, 3-, 6- or the 12-month USD Libor.

While we collect data for approximately 159,248 distinct syndicated loans over 1999 to 2012, we keep transaction data only for those syndicated loans that are relevant for our analysis. We eliminate all observations where the interest rate on the syndicated loan is fixed, does not reference Libor denominated in USD, GBP, JPY, or CHF Libor, or where no panel bank is part of the syndicate.[13] This leaves us with 37,104 observations with at least 1 observation for each panel bank in our sample.

When a panel bank, i, issues a loan with a floating interest rate referencing Libor of a particular currency-maturity, its unhedged exposure to Libor for that particular currency-maturity pair increases. Thus, our estimate of the unhedged exposure to Libor for panel bank i ($\beta^{\Delta Libor}$) in equation (1) for this currency-maturity pair should increase after the execution of this loan. The effect should be all the more significant if the loan amount for the syndicated loan is sizeable as compared to the market capitalization of the bank.

To test this, we run a variation of the regression specified in equation (1). Specifically, we run the following panel regression for each panel bank for each currency-maturity pair:

$$r_i - r_f = a + b^{Mkt}(r_{Mkt} - r_f) + b^{VIX}\Delta VIX + b^{\Delta Libor}\Delta Libor + b^{Synd}\Delta Libor \times Synd + b^{\Delta Sub}\Delta Sub + \epsilon_i \tag{9}$$

Here, we define *Synd* to be the log ratio of the total syndicated loans outstanding for panel bank i to its market capitalization at the end of week t. We expect the coefficient on the interaction

[13] In a few instances SDC provides information regarding the currency but not the maturity of the reference Libor. In these cases we assume that the reference rate is for that maturity with the highest notional value of interest rate derivatives outstanding (3-month for the USD and 6-month for GBP, JPY, and CHF, respectively). We confirm that this choice does not influence our results. Dropping observations with the missing maturity information has no qualitative impact on our results.

term ($\Delta Libor \times Synd$) to be positive and significant.[14]

Note that most syndicated loans are executed jointly by several banks. In these cases, SDC does not indicate the loan amount that each bank in the syndicate is responsible for. We assume that the loan amount is divided amongst the banks equally.[15] There may also be cases when a particular syndicated loan is executed jointly by several panel banks in our sample. Such a syndicated loan is treated as a new loan for each panel bank in our sample that is party to the syndicated loan.

[Table 6 about here]

Table 6 presents the results for the regression in equation (9). The evidence in table 6 for the pooled model in column (1) supports the conclusion that $\beta^{\Delta Libor}$ indeed measures a particular panel bank's unhedged exposure to Libor for a particular currency-maturity pair. When panel bank i executes a syndicated loan whose rate references Libor for a particular currency-maturity pair in week t, its sensitivity to that Libor increases by 0.3% and the effect is statistically significant at the 5% level. Adding the variable ΔSub in column (2) only reduces the statistical significance but does not affect the coefficient. We also carry out the regression for each currency and the currency specific results (USD in columns 3 and 4; GBP in columns 5 and 6) further support our analysis.

7.2 Comparison of estimated exposure with balance sheet data

In this section, we validate our Stage 1 estimation approach using data from the quarterly Call Reports. While balance sheet data for panel banks is available from several sources, none of these (including Compustat) provide detailed information regarding the interest rate derivatives portfolio of the panel banks. Including interest rate derivatives in our analysis is desirable, as each of the panel banks has a large trading portfolio that in many cases exceeds the size of their loan portfolios. Therefore, we use quarterly balance sheet data from the 'Report of Condition and Income' (henceforth, Call Report) required to be filed by all FDIC-insured banks in the U.S. The Call Report contains detailed information on the interest sensitive assets and liabilities including

[14] Normalizing the dollar amount of syndicated loans by the market capitalization in equation 9 does not lead to a mechanical relationship between the equity returns and $Synd$ and in fact biases our estimates for the interaction term downwards. Indeed, consider a panel bank that does not execute any new syndicated loans in week t. If the equity returns (market capitalization) of such a bank as measured in week t increases, this predicts a mechanical negative coefficient for b^{Synd}.

[15] An alternate method would be to assume that the loan amounts are divided amongst banks in direct proportion to their market capitalizations. However, not all banks participating in the market for syndicated loans are publicly traded and for private banks there is no data regarding market capitalization.

the notional value of interest rate derivatives used for hedging and proprietary trading. The Call Reports also provide us with data regarding trading income generated by a bank's interest rate derivatives portfolio. Unfortunately, restricting our analysis to the banks in the Call Reports limits us to panel banks with substantial operations in the United States. Only five panel banks, namely, Bank of America, Citigroup, Deutsche Bank, HSBC, and J. P. Morgan Chase, file quarterly Call Reports with the FDIC.[16]

From the Call Reports we collect data for total assets (TA), total liabilities (TL), total debt (TD), notional value of interest derivatives used for hedging ($IRDH$) or proprietary trading ($IRDT$), and the net trading income generated by a bank's interest rate derivatives portfolio (NTI). Summary statistics for these variables are discussed in Appendix D, Table D.1.

To compute a time-series of portfolio exposure to interest rate changes for each bank for each quarter we subtract from TA the sum of TL, TD, and $IRDH$. Finally, we adjust this net amount for $IRDT$. While the Call Reports provide us with the notional value of interest rate derivatives held for trading, they provide no information on the direction of this exposure (i.e. we have no information if the bank is long or short Libor in its trading portfolio). To estimate the net direction of the interest rate derivatives trading portfolio, we divide the quarterly net trading income generated by a bank's interest rate derivatives portfolio with the quarterly change in the m-month Libor denominated in USD. If this term is positive (negative) for a particular bank, we assume that the overall direction of the interest rate trading portfolio for that bank for that quarter is long (short) Libor. We therefore add (subtract) the value of $IRDT$ to (from) the net value obtained in the previous paragraph. We repeat this calculation for each maturity $m = \{1, 3, 6\}$. To summarize, the interest sensitive assets (ISA) for maturity m of a given bank on a given quarter are obtained as follows:

$$ISA_m = \frac{TA - \left(TL + TD + IRDH + IRDT_{i,t} \times \text{sign}\left[\frac{NTI}{\Delta Libor_m}\right]\right)}{TA} \tag{10}$$

where interest sensitive assets for each bank are normalized by total assets. Note that the Call Reports do not specify the actual interest rate to which the assets, liabilities, debt, and interest rate derivatives are related to. Thus, we are making the strong assumption that all interest sensitive

[16] Of these five banks, information regarding Deutsche Bank and HSBC only covers their U.S subsidiaries and not the entire bank holding company.

assets, liabilities, and derivatives positions are benchmarked to the Libor denominated in USD. This will be innocuous as long as the proportion of interest sensitive holdings related to Libor does not vary too much.

Next, we explore the link between a bank i's $\beta_{USD}^{\Delta Libor}$ and its ISA via the following pooled regression carried out separately for each maturity m for the five banks in our sample:

$$\overline{\beta}_{m,t}^{\Delta Libor} = a_m + b_m ISA_{m,t} + \varepsilon_t \tag{11}$$

Here, $\overline{\beta}_{m,t}^{\Delta Libor}$ denotes the average USD estimate from equation (1) over quarter t and $ISA_{m,t}$ is the interest sensitive measure derived above at the end of quarter t. Note that we establish a link between the average $\beta_{m,t}^{\Delta Libor}$ and $ISA_{m,t}$ as we use NTI_t over the whole quarter t to sign the interest rate derivatives portfolio. Since $NTI_{i,t}$ reflects the trading income from interest rate derivatives over the whole quarter it is likely influenced by the time-variation in interest rate exposure over the whole quarter and not just the $\beta_{m,t}^{\Delta Libor}$ as measured over the last week of quarter t.[17]

The results are reported in Table 7. The first row of the table indicates the maturity (m) for which the equation (11) is estimated. Rows 2-4 report the estimate, the t-statistic, and the R^2 from the regression in equation (11). The coefficients are multiplied by 100 and expressed in percentages. The column titled 'Average' presents the results of the estimation where the LHS and RHS variables in equation (11) have been averaged across the 3 maturities.

[Table 7 about here]

It is clear that $\beta^{\Delta Libor}$ correlates positively with interest rate exposures measured using balance sheet data. For the 3- and 6-month Libor, the coefficients are statistically significant at the 1 percent level with t-statistics of 2.48 and 3.90 respectively. The highest R^2 of 0.14 is observed for the 6-months maturity which implies that the correlation between $\beta_{m,y}^{\Delta Libor_{6m}}$ and $ISA_{6,t}$ is approximately 38%. For the average specification, the R^2 is about 0.08, which corresponds to an implied correlation of nearly 30%. This implies that there are substantial similarities between the measure of interest rate exposure from equation (1) and the measure of interest rate exposure from

[17] We also run this regression using just the $\beta_{m,t}^{\Delta Libor}$ measured over the last week of quarter t. We find that the two measures of interest rate exposure are positively correlated regardless of whether we use the average $\beta_{m,t}^{\Delta Libor}$ or its value as measured over the last week of the quarter. The coefficient b_m is still statistically significant at the 10% level or better and the correlation between the two variables is still 30% or higher.

balance sheet data.[18]

7.3 Endogeneity

Our measure of Libor sensitivity ($\beta^{\Delta Libor}$) is the slope coefficient in the regression of bank stock returns on changes in Libor and control variables in equation (1). Our subsequent analysis suggests that Libor is manipulated. We therefore consider the possibility that our Stage 1 estimates may be endogenous and hence biased. The nature of this endogeneity implies that if all panel banks manipulate Libor in the direction of their interest rate exposure, the fixed Libor will be a function of the average $\beta^{\Delta Libor}$. Hence, banks with positive (negative) sensitivities would experience ex-post positive (negative) returns, everything else being constant, and this, in turn, creates a spurious positive (negative) correlation between changes in Libor and the residual term in equation (1). This violates the orthogonality assumption in the OLS regressions.

To address this concern, we adopt an instrumental variable approach to estimate the exposure of a panel bank to changes in Libor for a particular currency-maturity pair. This requires us to select an instrumental variable that varies across currency-maturity pairs and is correlated with Libor but not with manipulation, so that the resultant $\beta^{\Delta Libor}$ is unbiased. We therefore opt for the risk-free interest rate for each currency as an appropriate instrumental variable for our analysis. In each case, the maturity of the risk-free interest rate corresponds to the maturity of the Libor, for which we attempt to estimate $\beta^{\Delta Libor}$. The selection of the risk-free rate as an instrument implies that, to the extent that these rates contain a risk-premium for sovereign default, the cost of borrowing for panel banks in a particular currency-maturity pair is also correlated. However, unlike Libor, the risk-free rates for any currency-maturity pair are not expected to be affected by manipulation.

To estimate a panel bank's sensitivity to changes in Libor, we adopt the standard two-stage least-squares approach. First, we regress the changes in Libor for each currency-maturity pair on the changes in the risk-free rate for that currency and maturity, the excess market returns, and the changes in VIX. Next, we replace the changes in Libor in equation (1) with the fitted value from the previous regression. Again the regressions are estimated over rolling windows of 26-weeks. We

[18] In a recent working paper, Begenau, Piazzesi, and Schneider (2013) also develop a high frequency measure of a bank's interest rate exposure. Our approach is distinct from theirs in that we do not make any assumptions about the underlying interest rate model at work.

then take the sensitivity to changes in Libor estimated from this second equation to the equations estimated in Stage 2 and Stage 3.

[Table 8 about here]

Results for the panel regression in equation (2) using sensitivity estimates from our two-stage least-squares approach are reported in Table 8. Our main results remain economically and statistically significant. The point estimate on the manipulation period decreases slightly from 0.043 to 0.035, but remains significant. Similarly, the coefficients on the interaction terms with dummies 'High', 'EU', and 'Cheat' all remain highly significant, although the point estimates decrease slightly.

As in the main analysis, we find no support for the stigma hypothesis when we analyze all currency-maturity pairs and all banks. The only differences are the interaction terms with the dummies *Crisis* and *Weak*. In the main analysis the estimated coefficient on the interaction term with the dummy *Weak* is marginally significant, it is now insignificant. In comparison, the interaction term with the dummy *Crisis*, which is insignificant in the main analysis, is now significant. Importantly, the combined effect of the crisis and the weak banks remains positive.

7.4 Robustness analysis

We conduct a battery of tests to ensure that our results are robust to a variety of statistical issues and modeling choices. We discuss the results for each stage separately below. Since the main conclusions of our paper are robust to these different specifications, we provide only a brief discussion of each robustness test in this section, and make all tables available in an Internet Appendix. Each Table is organized such that Panel A presents results of Stage 2, and Panel B reports the Stage 3 estimated total gains from either source of manipulation.

Stage 1: Our main concern is the choice of 26-week rolling windows to estimate $\beta^{\Delta Libor}$ and $\beta^{\Delta Sub}$. In order to show that our results are not driven by this choice, we vary the window size from 15- to 45-week in steps of 5-week. Results for panel regression (Stage 2) and gains (Stage 3) for each window size are tabulated in Table IA.1. The coefficient on $\beta^{\Delta Libor} \times$ *Manip* (from Stage 2) displays a decreasing pattern with the length of the window size. It decreases from 0.061 for the

15-week window size to 0.021 for the 45-week window size. The estimated coefficient, however, is significant for any window size between 15 and 30 weeks. This pattern is consistent with the fact that, at longer horizon windows, estimates of $\beta^{\Delta Libor}$ are diluted by older observations and do not adequately measure the instantaneous exposure of a panel bank to changes in Libor required for our analysis. In comparison, the estimated parameter on $\beta^{\Delta Sub}$ is always negative and even marginally significant at the 15- and 20-week window sizes. All our main conclusions remain unchanged.

Table IA.2 present the results when the panel bank equity returns and market returns are denominated in the currency of the country of incorporation of the panel bank, and not in USD. The main conclusions of the paper remain largely unchanged.

Much of the extant literature on the stigma hypothesis has focused on the comparison between Libor and other measures of borrowing costs such as the credit default swaps (CDS) that reference the panel banks. We therefore ensure that our results survive when we control for the change in the difference between the CDS spread that references a panel bank and the average CDS spread of all banks in Stage 1. The results are reported in Table IA.3. The main conclusions pertaining the cash flow hypothesis remain unaltered. However, for the stigma manipulation we lose significance (both economically and statistically) for the *Weak* interaction term. This may be due to some of the effect of weak banks being absorbed by the coefficient on the CDS spread in Stage 1.

Stage 2: Table IA.4 presents results when adding the spread on the standard 1-year credit default swap contract that references the bank (*CDS*) as an additional control in Stage 2. The coefficient on *CDS* is positive, and strongly statistically significant. Its inclusion renders the coefficient on *Vol* insignificant, but it does not affect the significance of $\beta^{\Delta Libor}$ over the manipulation period. It also does not significantly alter the gains from manipulation for the panel banks. However, similarly to what happened in Stage 1, including the CDS turns the *Weak* interaction effect for $\beta^{\Delta Sub}$ insignificant, although it increases the significance of the *Crisis* effect.

We identify the manipulation period to be from January 2005 to May 2009 based on Barclays' settlement agreement. In Table IA.5, we investigate if our results depend on this exact choice of the manipulation period. Extending the manipulation period one year backward (i.e. January 2004 to May 2009), or one year forward (i.e. January 2005 to June 2010) or restricting it to the pre-Lehman period (i.e. January 2005 to August 2008) does not significantly affect our results.

The corresponding gains during 2004 to 2009 are just as large as those documented in Table 5. The gains from 2005 to 2010 more than double to $48 billion, while they are only $7.5 billion from 2005 to 2008. Much of the gain was apparently achieved in 2009 and 2010.

While the analysis in the main paper focuses just on those currency and maturities with non-zero total notional value of interest rate derivatives, we notice that some minuscule notional value of interest rate derivatives also references the EUR 6-month and the USD 12-month rates. It could be the case that the notional value of interest rate derivatives tied to these two additional currency-maturity pairs has reached a significant level at some point in time over our entire sample, even though the volume is insignificant in Table 1. Therefore, we re-estimate our baseline model for an expanded set that includes the Euro and the 12-month maturity, for a total of 20 currency-maturity pairs. Results are reported in Table IA.6 and are consistent with our main hypotheses. Adding these additional currency-maturity pairs with low notional value of interest rate derivatives indeed lowers the coefficients on $\beta^{\Delta Libor} \times Manip$, but they remain statistically significant. The conclusions for $\beta^{\Delta Sub}$ are also unchanged.

Finally, Table IA.7 verifies that trimming the Stage 1 betas produces very similar results to those of Table 4 where betas are winsorized.

8 Conclusion

Libor is a primary reference rate for a wide range of financial derivatives and instruments, such as interest rate swaps and loans. Given the sizeable notional value of these contracts, even relatively small attempts to manipulate Libor can lead to substantial wealth transfers among investors.

In this paper, we examine the issue of Libor manipulation using the quotes submitted daily by banks to the British Bankers Association, from which the daily Libor fixing is subsequently computed. We document a significant relation between a measure of bank exposure to a given Libor currency-maturity pair and the corresponding bank's average Libor submission in the following month during 1999 to 2012. Our estimated Libor exposure is related to measures of accounting based and syndicated loan based exposure. The effect peaks during the January 2005 to May 2009 manipulation period as identified in the Barclays' settlement. During this period, the relation is only significant for currency-maturity pairs with high notional value outstanding, and it is largely driven

by banks domiciled in the E.U. and by banks that have already settled investigations leveled by the regulators concerning Libor manipulations. We argue that these time-series and cross-sectional patterns are strong evidence consistent with panel banks attempting to manipulate Libor in the direction of their exposures. We provide an assessment of the gains from such behavior in terms of banks' increased market value to the tune of $16 to 18 billion. A much smaller gain of around $1 billion stems from lowering submissions in order to make banks look less risky. This second effect is statistically insignificant and seems to be concentrated in weak banks during the height of the financial crisis. Our results are robust to changes in the methodology and to endogeneity concerns. Beyond the gains to the panel banks, there is also a much larger wealth transfer caused to other investors: half the outside investors will have gained on any manipulated position while the other half will have lost.

While our analysis is based on monthly submissions, it may be argued that attempts to manipulate Libor should concentrate around reset dates, when the cash flows of derivative contracts that reference Libor are being determined. We also note that an alternative approach to our rolling-window estimation in Stage 1 would be filtering techniques. However, given the persistence in daily Libor it is not clear whether the efficiency gains in estimation would be large enough to warrant the effort. Finally, while banks' collusion is not a necessary condition for manipulation to show up in the Libor fixing, it would be interesting to investigate if collusion plays a role in Libor manipulation. We leave these interesting topics for future research.

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Table 1: The use of Libor as a reference rate

This table reports the notional value for interest rate swap contracts and floating rate notes referenced to Libor for different currencies and maturities as a percentage of the size of the total market. Data is from Dealogic and the Depositary Trust and Clearing Corporation. Table is adapted from Wheatley (2012, Table 5.A on page 36). The last row and column report notional value as a percentage of the size of the total market for each maturity and currency, respectively.

	1m	3m	6m	12m	**Total**
USD	5.6%	52.8%	0.3%	0.1%	59%
EUR	-	-	0.1%	-	0%
GBP	0.4%	2.9%	8.9%	-	12%
JPY	0.1%	3.6%	23.5%	-	27%
CHF	0.1%	0.4%	1.6%	-	2%
AUD	-	-	-	-	0%
CAD	-	-	-	-	0%
NZD	-	-	-	-	0%
SEK	-	-	-	-	0%
DKK	-	-	-	-	0%
Total	6%	60%	34%	0%	100%

Table 2: Summary statistics of sensitivities to Libor and Libor submissions

This table reports summary statistics for sensitivities to changes in Libor ($\beta^{\Delta Sub}$) and to changes in Libor submissions ($\beta^{\Delta Libor}$) for four currencies (USD, GBP, JPY, and CHF) and three maturities (1-, 3-, and 6-month) from the following regression:

$$r_{i,t} - r_{f,t} = \alpha + \beta_i^{\Delta Sub} \Delta Sub_t + \beta_i^{\Delta Libor} \Delta Libor_{i,t} + \beta_i^{Mkt}(r_{Mkt,t} - r_{f,t}) + \beta_i^{VIX} \Delta VIX_t + \epsilon_{i,t}.$$

We regress bank excess returns on the (change in) Libor, (change in) the difference between the individual Libor submission and the average Libor submission, market excess returns, and changes in VIX. The statistics are: mean; standard deviation; minimum; 25th, 50th, and 75th percentile; maximum. The last three columns report the correlation matrix of different maturities m for the same currency c. Weekly observations from January 6th, 1999 to November 28th, 2012.

Panel A: $\beta^{\Delta Sub}$

Currency-maturity	mean	sd	min	p25	med	p75	max	skew	corr(1m)	corr(3m)	corr(6m)
USD-1m	-0.066	1.291	-4.540	-0.613	-0.036	0.513	4.425	-0.106	1		
USD-3m	-0.091	1.054	-3.031	-0.635	-0.083	0.409	3.475	0.237	0.258	1	
USD-6m	0.036	0.951	-2.863	-0.428	0.015	0.510	2.875	-0.068	0.126	0.309	1
GBP-1m	0.060	0.905	-3.095	-0.280	0.046	0.410	3.251	0.040	1		
GBP-3m	0.044	0.788	-2.316	-0.352	0.027	0.404	2.928	0.428	0.521	1	
GBP-6m	0.024	0.714	-2.057	-0.342	0.023	0.393	2.431	0.163	0.399	0.519	1
JPY-1m	-0.210	2.534	-15.001	-0.520	0.021	0.454	7.761	-2.412	1		
JPY-3m	0.008	2.753	-11.752	-0.583	0.001	0.615	12.932	0.447	0.230	1	
JPY-6m	0.287	2.982	-8.789	-0.496	0.046	0.637	18.526	2.789	0.020	0.317	1
CHF-1m	0.097	0.830	-2.091	-0.294	0.019	0.354	3.819	1.338	1		
CHF-3m	0.021	0.764	-2.285	-0.335	0.025	0.352	2.768	0.422	0.447	1	
CHF-6m	0.044	0.600	-1.956	-0.243	0.040	0.352	2.003	-0.082	0.196	0.410	1

Panel B: $\beta^{\Delta Libor}$

Currency-maturity	mean	sd	min	p25	med	p75	max	skew	corr(1m)	corr(3m)	corr(6m)
USD-1m	-0.062	1.022	-4.593	-0.123	-0.007	0.110	4.266	-0.478	1		
USD-3m	-0.051	0.552	-2.633	-0.149	-0.004	0.121	1.936	-1.141	0.602	1	
USD-6m	-0.006	0.399	-1.908	-0.095	0.002	0.099	1.588	-0.741	0.534	0.681	1
GBP-1m	0.047	0.985	-3.412	-0.105	-0.009	0.105	4.233	0.763	1		
GBP-3m	0.002	0.524	-2.035	-0.129	-0.003	0.111	2.059	0.042	0.524	1	
GBP-6m	0.012	0.433	-1.580	-0.095	-0.002	0.089	1.819	0.434	0.428	0.804	1
JPY-1m	-0.147	3.937	-18.350	-0.704	0.001	0.706	16.720	-0.513	1		
JPY-3m	-0.218	4.581	-23.660	-0.640	0.033	0.966	14.970	-1.620	0.353	1	
JPY-6m	-0.261	5.588	-28.940	-0.769	0.029	0.808	20.720	-1.448	0.264	0.529	1
CHF-1m	-0.002	0.779	-3.479	-0.102	0.004	0.143	3.060	-0.748	1		
CHF-3m	0.071	0.872	-3.510	-0.099	0.031	0.202	4.087	0.506	0.537	1	
CHF-6m	0.025	0.660	-2.670	-0.119	0.019	0.181	2.586	-0.330	0.272	0.468	1

Table 3: Panel regression of Libor submissions

This table reports estimates of the OLS pooled regression of the monthly average bank Libor submissions on lagged sensitivities to Libor changes and lagged sensitivities to Libor submissions, control variables, and bank, currency-maturity, and time fixed effects:

$$Submission_{i,t+1} = a + \lambda^{Sub}\beta_{i,t}^{\Delta Sub} + \lambda^{Libor}\beta_{i,t}^{\Delta Libor} + Controls + Fixed\ effects + u_{i,t+1}.$$

The regression is estimated by pooling observations for panel banks across four currencies (USD, GBP, JPY, and CHF) and three maturities (1-, 3-, and 6-month). The independent variables include the sensitivities of bank excess returns to: the changes in Libor for a given currency-maturity ($\beta^{\Delta Libor}$), the changes in the difference between the bank Libor submission and the average Libor submission for a given currency-maturity ($\beta^{\Delta Sub}$), the domestic market excess return (β^{Mkt}), and the changes in VIX (β^{VIX}). All sensitivities are estimated jointly on 26-week backward-looking rolling windows. Additional control variables include the log market capitalization (*Size*), the one-year yield of the domestic country (*Yield*), and the realized stock return volatility estimated by the standard deviation of daily returns (*Vol*). All variables are standardized. All regressions include bank and time fixed effects, separately for each currency-maturity pair. In parentheses, below the estimated coefficients are the t-statistics based on robust standard errors clustered by time. Statistical significance at the 1%, 5%, and 10% is denoted by three, two, and one asterisks respectively. The R^2 is from the regression of the residuals of the dependent and independent variables on the fixed effects. The sample contains monthly observations from July 1999 until November 2012.

Control	(1)	(2)	(3)	(4)
$\beta^{\Delta Libor}$	0.029***		0.028***	0.025**
	(2.910)		(2.761)	(2.517)
$\beta^{\Delta Sub}$		-0.009	-0.011	-0.012
		(-1.193)	(-1.484)	(-1.593)
β^{Mkt}			0.071***	0.055***
			(4.423)	(3.600)
β^{VIX}			0.012	0.012
			(0.896)	(0.903)
Size				-0.158***
				(-7.998)
Yield				0.151***
				(6.539)
Vol				0.033**
				(2.441)
Obs.	20,745	20,745	20,745	20,745
R^2	0.008	0.000	0.026	0.026

Table 4: Panel regression of Libor submissions, interaction effects

This table reports estimates of the OLS pooled regression of the monthly average bank Libor submissions on lagged sensitivities to Libor changes and lagged sensitivities to Libor submissions in isolation and with interaction terms, control variables, and bank, currency-maturity, and time fixed effects:

$$Submission_{i,t+1} = a + \lambda^{Libor}\beta^{Libor}_{i,t} + \lambda^{Libor}_{D}\beta^{Libor}_{i,t} \times D_{Libor} + \lambda^{Sub}\beta^{Sub}_{i,t} + \lambda^{Sub}_{D}\beta^{Sub}_{i,t} \times D_{Sub} + Controls + Fixed\ effects + u_{i,t+1}.$$

The regression is estimated by pooling observations for panel banks across four currencies (USD, GBP, JPY, and CHF) and three maturities (1-,3-, and 6-month). The independent variables include the sensitivities of bank excess returns to: the changes in Libor for a given currency-maturity ($\beta^{\Delta Libor}$), the changes in the difference between the bank Libor submission and the average Libor submission for a given currency-maturity ($\beta^{\Delta Sub}$), the domestic market excess return (β^{Mkt}), and the changes in VIX (β^{VIX}). All sensitivities are estimated jointly on 26-week backward-looking rolling windows. Additional control variables include the log market capitalization (*Size*), the one-year yield of the domestic country (*Yield*), and the realized stock return volatility estimated by the standard deviation of daily returns (*Vol*). D_{Libor} collects dummy variables which are interacted with $\beta^{\Delta Libor}$, defined as follows: *Manip* equals 1 for the alleged Jan2005-May2009 manipulation period; *High* equals 1 for currency-maturity pairs with high Libor-referenced outstanding notional from Table 1 (USD-1m, USD-3m, GBP-3m, GBP-6m, JPY-3m, JPY-6m); *Low* is defined as $1-High$; *EU* equals 1 for European banks; *NoEU* is defined as $1-EU$; *Cheat* equals 1 for banks that have either settled or expect to settle Libor litigations; *ExCheat* is defined as $1-Cheat$. D_{Sub} collects dummy variables which are interacted with β^{Bid}, defined as follows: *Crisis* equals 1 for the July 2007 to March 2009 period; *Weak* equals 1 for the banks in the top CDS tercile on a given month. All variables are standardized. All regressions include bank and time fixed effects, separately for each currency-maturity pair. In parentheses, below the estimated coefficients are the *t*-statistics based on robust standard errors clustered by time. Statistical significance at the 1%, 5%, and 10% is denoted by three, two, and one asterisks respectively. The R^2 is from the regression of the residuals of the dependent and independent variables on the fixed effects. The sample contains monthly observations from July 1999 until November 2012.

Control	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\beta^{\Delta Libor}$	0.010	0.010	0.010	0.010	0.010	0.011	0.011
	(0.807)	(0.813)	(0.825)	(0.799)	(0.827)	(0.761)	(0.792)
$\beta^{\Delta Libor} \times$ *Manip*	0.043**				0.043**	0.038*	0.038*
	(2.083)				(2.078)	(1.741)	(1.731)
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *High*		0.088***					
		(3.713)					
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *Low*		-0.007					
		(-0.305)					
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *EU*			0.088***				
			(3.596)				
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *exEU*			-0.014				
			(-0.497)				
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *Cheat*				0.097***			
				(3.496)			
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *exCheat*				0.013			
				(0.571)			
$\beta^{\Delta Sub}$	-0.011	-0.012	-0.011	-0.011	-0.015*	-0.026**	-0.031***
	(-1.545)	(-1.572)	(-1.460)	(-1.465)	(-1.896)	(-2.319)	(-2.825)
$\beta^{\Delta Sub} \times$ *Crisis*					0.026		0.035
					(1.210)		(1.614)
$\beta^{\Delta Sub} \times$ *Weak*						0.031*	0.031*
						(1.909)	(1.918)
β^{Mkt}	0.056***	0.055***	0.055***	0.055***	0.056***	0.041**	0.041**
	(3.609)	(3.601)	(3.615)	(3.598)	(3.616)	(2.444)	(2.449)
β^{VIX}	0.011	0.011	0.011	0.012	0.011	0.020	0.020
	(0.885)	(0.873)	(0.881)	(0.893)	(0.871)	(1.417)	(1.402)
Size	-0.159***	-0.160***	-0.160***	-0.159***	-0.158***	-0.184***	-0.183***
	(-8.046)	(-8.087)	(-8.075)	(-8.014)	(-8.019)	(-7.701)	(-7.653)
Yield	0.150***	0.150***	0.152***	0.151***	0.149***	0.130***	0.129***
	(6.503)	(6.500)	(6.547)	(6.525)	(6.454)	(4.595)	(4.546)
Vol	0.033**	0.033**	0.033**	0.033**	0.033**	0.034**	0.034**
	(2.416)	(2.440)	(2.496)	(2.441)	(2.420)	(2.451)	(2.455)
Obs.	20,745	20,745	20,745	20,745	20,745	17,771	17,771
R^2	0.026	0.027	0.028	0.027	0.026	0.026	0.026

Table 5: Estimated gains from manipulation

This table reports estimated gains across banks and currency-maturity pairs during the alleged manipulation period. Gains for each bank are computed using the procedure outlined in Section 4.3. Panel A reports estimated gains from cash-flow manipulation, Panel B those from stigma manipulation, and Panel C their sum. Columns (1) through (7) use the estimated coefficients from the corresponding columns in Table 4. *High* equals 1 for currency-maturity pairs with high Libor-referenced outstanding notional from Table 1 (USD-1m, USD-3m, GBP-3m, GBP-6m, JPY-3m, JPY-6m); *Low* is defined as $1-High$; *EU* equals 1 for European banks; *NoEU* is defined as $1-EU$; *Cheat* equals 1 for banks that have either settled or expect to settle Libor litigations; *ExCheat* is defined as $1-Cheat$. Below the estimates, t-statistics for the average weekly gain series are reported in parenthesis. Statistical significance at the 1%, 5%, and 10% is denoted by three, two, and one asterisks respectively. Units are Millions USD. The sample contains monthly observations from July 1999 until November 2012.

Panel A: Estimated gains from cash flows manipulation ($\beta^{\Delta Libor}$)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Total gains	\$18,153				\$18,106	\$15,943	\$15,957
	(2.891)				(2.888)	(2.907)	(2.906)
High		\$15,512					
		(3.032)					
Low		\$309					
		(0.593)					
EU			\$9,299				
			(2.960)				
exEU			\$7,417				
			(2.882)				
Cheat				\$10,326			
				(2.846)			
exCheat				\$7,641			
				(3.017)			

Panel B: Estimated gains from stigma manipulation (β^{Bid})

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gains	\$416	\$423	\$393	\$395	\$362	\$1,059	\$1,382
	(0.671)	(0.671)	(0.671)	(0.671)	(0.499)	(1.161)	(1.357)

Panel C: Estimated total gains

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Total gains	\$18,569***	\$16,244***	\$17,109***	\$18,362***	\$18,467***	\$17,002***	\$17,339***
	(2.839)	(2.866)	(2.997)	(2.891)	(2.960)	(2.826)	(3.111)

Table 6: Syndicated Loans and Libor exposure

This table reports OLS estimates of the weekly regression:

$$r_i - r_f = a + b^{Mkt}(r_{Mkt} - r_f) + b^{VIX}\Delta VIX + b^{\Delta Libor}\Delta Libor + b^{Synd}\Delta Libor \times Synd + b^{\Delta Sub}\Delta Sub + \epsilon_i$$

$\Delta Libor$ is the (change in the) corresponding currency-maturity Libor underlying the syndicated loan contracts for which information on the maturity is available. For loans when information of the Libor maturity is missing, we use the 3-month for USD and 6-month for GBP, JPY, and CHF. *Synd* is the ratio of the outstanding amount of syndicated loans to the bank' equity market capitalization, in logs. ΔSub is the (change in the) difference between a bank's Libor submission and the average Libor submission across panel banks. Data are weekly for 46,037 syndicated loans involving Libor panel banks during the January 2000 to November 2012 period. Columns (1)-(2) pool information across currencies, columns (3)-(4) restrict to USD loans, and columns (5)-(6) restrict to GBP loans. Below the estimates, *t*-statistics are reported in parenthesis. Statistical significance at the 1%, 5%, and 10% level is denoted by ***, **, and * respectively.

	(1) pooled	(2) pooled	(3) USD	(4) USD	(5) GBP	(6) GBP
$r_{Mkt} - r_f$	1.477***	1.485***	1.442***	1.493***	1.459***	1.423***
	(16.312)	(13.304)	(17.043)	(13.038)	(15.817)	(13.226)
ΔVIX	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
	(-1.189)	(-0.991)	(-1.326)	(-1.097)	(-1.457)	(-1.239)
$\Delta Libor$	0.010	0.008	0.009	0.008	0.007	0.006
	(0.666)	(0.543)	(0.580)	(0.438)	(0.483)	(0.444)
$\Delta Libor \times Synd$	0.003**	0.003	0.003**	0.004	0.008	0.012**
	(2.236)	(1.522)	(2.246)	(1.429)	(1.565)	(2.008)
ΔSub		-0.018		-0.034		-0.003
		(-0.457)		(-0.656)		(-0.127)
Obs.	37,104	26,154	14,940	10,204	10,793	7,812
R^2	0.510	0.505	0.513	0.500	0.507	0.507

Table 7: Balance sheet and beta exposures to Libor

This table reports OLS estimates of the regression:

$$\overline{\beta}_{m,t}^{\Delta Libor} = a_m + b_m ISA_{m,t} + \varepsilon_t,$$

where $\overline{\beta}_{m,t}^{\Delta Libor}$ denotes the quarterly average of the weekly sensitivity of excess returns to (changes in the) m-month Libor denominated in USD, and ISA_m is the amount of interest sensitive assets of a given bank for maturity m from equation 10 using Call Reports data at the end of that quarter. The regression is estimated by pooling quarterly observations for Bank of America, Citigroup, Deutsche Bank, HSBC, and JP Morgan Chase over the 1999-2012 period. The table shows the estimated coefficient b_m for m equal to 1, 3, and 6 months and for the regression where β and ISA are respectively averaged across maturities for a given bank-quarter ('Average'). Below the estimates, t-statistics are reported in parenthesis. The coefficients are multiplied by 100, and are expressed in percentages. Statistical significance at the 1%, 5%, and 10% level is denoted by ***, **, and * respectively.

	1m	3m	6m	Average
$ISA_{m,t}$	0.256***	0.064*	0.036*	0.119**
	(3.314)	(1.691)	(1.735)	(2.247)
Obs.	214	214	214	214
R^2	0.045	0.057	0.007	0.037

Table 8: Panel regression of Libor submissions, TSLS

This table reports estimates of the OLS pooled regression of the monthly average bank Libor submissions on lagged sensitivities to Libor changes and lagged sensitivities to Libor submissions in isolation and with interaction terms, control variables, and bank, currency-maturity, and time fixed effects:

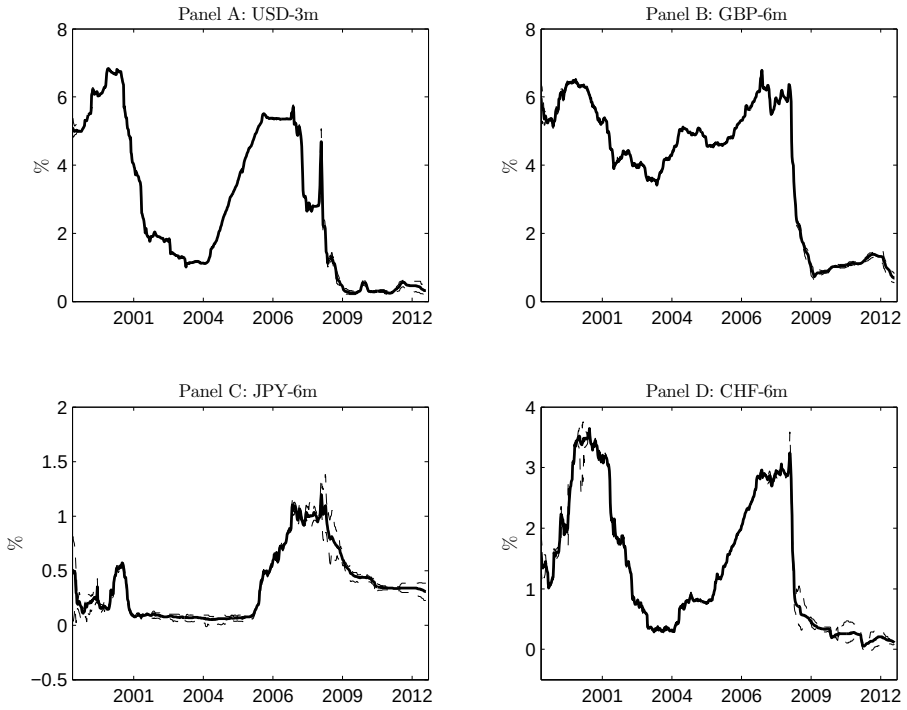
$$Submission_{i,t+1} = a + \lambda^{Libor}\beta^{\Delta Libor}_{i,t} + \lambda^{Libor}_{D}\beta^{\Delta Libor}_{i,t} \times D_{Libor} + \lambda^{Sub}\beta^{\Delta Sub}_{i,t} + \lambda^{Sub}_{D}\beta^{\Delta Sub}_{i,t} \times D_{Sub} + Controls + Fixed\ effects + u_{i,t+1}.$$

The regression is estimated by pooling observations for panel banks across four currencies (USD, GBP, JPY, and CHF) and three maturities (1-,3-, and 6-month). The independent variables include the sensitivities of bank excess returns to: the changes in Libor for a given currency-maturity ($\beta^{\Delta Libor}$), the changes in the difference between the bank Libor submission and the average Libor submission for a given currency-maturity ($\beta^{\Delta Sub}$), the domestic market excess return (β^{Mkt}), and the changes in VIX (β^{VIX}). All sensitivities are estimated jointly on 26-week backward-looking rolling windows, where Libor fixing is instrumented by the corresponding currency-maturity Treasury rate and the other regressors; log market capitalization (*Size*), the one-year yield of the domestic country (*Yield*), and the realized stock return volatility (*Vol*). Additional control variables include the log market capitalization (*Size*), the one-year yield of the domestic country (*Yield*), and the realized stock return volatility estimated by the standard deviation of daily returns (*Vol*). D_{Libor} collects dummy variables which are interacted with $\beta^{\Delta Libor}$, defined as follows: *Manip* equals 1 for the alleged January 2005 to May 2009 manipulation period; *High* equals 1 for currency-maturity pairs with high Libor-referenced outstanding notional from Table 1 (USD-1m, USD-3m, GBP-3m, GBP-6m, JPY-3m, JPY-6m); *Low* is defined as 1−*High*; *EU* equals 1 for European banks; *NoEU* is defined as 1−*EU*; *Cheat* equals 1 for banks that have either settled or expect to settle Libor litigations; *ExCheat* is defined as 1−*Cheat*. D_{Sub} collects dummy variables which are interacted with β^{Bid}, defined as follows: *Crisis* equals 1 for the Jul2007-Mar2009 period; *Weak* equals 1 for the banks in the top CDS tercile on a given month. All variables are standardized. All regressions include bank and time fixed effects, separately for each currency-maturity pair. In parentheses, below the estimated coefficients are the *t*-statistics based on robust standard errors clustered by time. Statistical significance at the 1%, 5%, and 10% is denoted by three, two, and one asterisks respectively. The R^2 is from the regression of the residuals of the dependent and independent variables on the fixed effects. The sample contains monthly observations from July 1999 until November 2012.

Control	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\beta^{\Delta Libor}$	0.004	0.004	0.004	0.004	0.005	0.008	0.008
	(0.386)	(0.387)	(0.398)	(0.387)	(0.413)	(0.683)	(0.736)
$\beta^{\Delta Libor} \times$ *Manip*	0.035**				0.035*	0.030*	0.029
	(1.975)				(1.949)	(1.689)	(1.649)
$\beta^{\Delta Libor} \times$ *Manip* × *High*		0.066***					
		(3.143)					
$\beta^{\Delta Libor} \times$ *Manip* × *Low*		0.003					
		(0.120)					
$\beta^{\Delta Libor} \times$ *Manip* × *EU*			0.057***				
			(2.761)				
$\beta^{\Delta Libor} \times$ *Manip* × *exEU*			0.007				
			(0.264)				
$\beta^{\Delta Libor} \times$ *Manip* × *Cheat*				0.071***			
				(3.089)			
$\beta^{\Delta Libor} \times$ *Manip* × *exCheat*				0.015			
				(0.786)			
$\beta^{\Delta Sub}$	-0.005	-0.005	-0.004	-0.004	-0.010	-0.011	-0.018*
	(-0.690)	(-0.719)	(-0.637)	(-0.617)	(-1.340)	(-1.125)	(-1.836)
$\beta^{\Delta Sub} \times$ *Crisis*					0.036*		0.043**
					(1.890)		(2.242)
$\beta^{\Delta Sub} \times$ *Weak*						0.010	0.010
						(0.665)	(0.661)
β^{Mkt}	0.040***	0.040***	0.040***	0.040***	0.040***	0.025	0.025
	(2.806)	(2.796)	(2.799)	(2.804)	(2.812)	(1.628)	(1.629)
β^{VIX}	0.009	0.009	0.009	0.009	0.009	0.020	0.020
	(0.745)	(0.756)	(0.728)	(0.730)	(0.744)	(1.491)	(1.496)
Size	-0.163***	-0.163***	-0.164***	-0.163***	-0.162***	-0.191***	-0.189***
	(-8.187)	(-8.209)	(-8.201)	(-8.199)	(-8.156)	(-7.911)	(-7.862)
Yield	0.149***	0.149***	0.151***	0.150***	0.148***	0.131***	0.130***
	(6.420)	(6.410)	(6.462)	(6.444)	(6.369)	(4.635)	(4.579)
Vol	0.036***	0.036***	0.036***	0.036***	0.036***	0.037***	0.037***
	(2.614)	(2.631)	(2.632)	(2.616)	(2.616)	(2.657)	(2.657)
Obs.	20,536	20,536	20,536	20,536	20,536	17,572	17,572
R^2	0.023	0.024	0.024	0.024	0.024	0.023	0.023

Figure 1: Time-series of Libor individual submissions

The plots display the time series of weekly averages (solid line) of Libor submissions (in percentage), with bands based on plus/minus two cross-sectional standard deviations (dotted lines), for the following four maturity-currency pairs: USD-3m, GBP-6m, JPY-6m, and CHF-6m. The sample is weekly observations from January 6th, 1999 to November 28th, 2012.



Appendix

A Further Details on Libor Computation

Libor is a major benchmark rate for short-term interest rates and is used as a reference rate for a range of financial contracts and instruments including floating rate bonds, interest rate swaps, forward rate agreements, interest rate floors, interest rate caps, and mortgage agreements.

The organization responsible for the computation of Libor is the British Bankers' Association (BBA), a trade association of over 200 banks based in London. The actual collection of the data and the computation of Libor is performed by Thomson Reuters. Libor is computed for 10 distinct currencies (the U.S. dollar, the Australian dollar, the British pound sterling, the Canadian dollar, the Danish krone, the Euro, the Japanese Yen, the New Zealand dollar, the Swedish krona, and the Swiss franc) and 15 different maturities. The 15 maturities range from overnight to one year.

While any bank that trades in London can apply to become a panel bank for any currency for which Libor is computed, the selection by BBA is based on three factors: (i) the scale of market activity, (ii) the reputation, and (iii) the perceived expertise of the bank. Thus, the number of panel banks are not held constant across different currencies but range from 6 (for the Swedish krona) to 18 (for the USD). However, within a given currency, the number of panel banks does not vary across maturities.

Interest rate data from the panel banks are collected via a survey that asks just one question: 'At what rate could you borrow funds, were you to do so by asking for and then accepting inter-bank offers in a reasonable market size just prior to 11am?'.[19] The panel banks respond to the survey question with the lowest perceived interest rate at which the bank can borrow an unsecured, 'reasonable loan amount' in the London interbank market for a given currency and maturity. A submission is not necessarily based on an actual transaction as not all panel banks will borrow 'reasonable' loan amounts in all currencies and maturities each day. The definition of a 'reasonable loan amount' is also not specified. Finally, the maturity dates are standardized (ISDA norms) so that all submissions are for loans maturing at the exact same date in the future.

[19] This question has changed only once since the inception of Libor. From 1986 to 1998, the panel banks submitting data to the BBA answered the question: 'At what rate do you think interbank term deposits will be offered by one prime bank to another prime bank for a reasonable market size today at 11am?' Market participants refer to this question, which is no longer in use, as banks providing interest rate submissions by referencing other panel banks.

The BBA insists submissions be entered by the bank's staff primarily responsible for its cash or liquidity management rather than a panel bank's derivative trading desk. Further, submissions may not depend on the pricing of any Libor derivative financial instrument help by panel banks. In other words, a panel bank's submission should not be influenced by its motive to maximize profit but should reflect its true borrowing costs.

The panel banks, via a secure computer application, enter submissions to Thomson Reuters by 11:10am, London time. Thomson Reuters analyzes the data for errors, allows the panel banks to correct obvious errors, and publishes Libor by 11:30am. At that time, Thomson Reuters also releases the individual submissions provided by all the panel banks. If any errors are identified post publication, Thomson Reuters corrects these and publishes recomputed Libor and individual submissions by 12:00 noon, London time. Note that the panel banks do not have access to individual submissions and cannot legally view other panel banks' submissions prior to the publication of the official Libor. After the publication, all Libor and individual submissions are publicly available to panel banks and other market participants.

For computing the trimmed averages, the number of contributing banks is rounded to next nearest number divisible by 4. For example, for the USD with 18 panel banks the number of banks will be rounded off to 16. No submissions are excluded at this stage. Thomson Reuters then excludes the 25% highest and lowest submissions of the rounded number. For the USD example cited above, this means Thomson Reuters will exclude the highest and lowest 4 (25% of 16) submissions. The remaining 10 submissions are simply averaged to compute the Libor for USD for any given maturity.

B List of Panel Banks, by Currency

USD: CS, UBS, RBC, BNP, CA, SG, DB, MITF, SMFI, BARC, HSBC, LLO, RBS, BOA, CITI, JPM, NOR, RABO

GBP: UBS, RBC, BNP, CA, SG, DB, MITF, MIZ, BS, BARC, HSBC, LLO, RBS

JPY: UBS, CA, SG, DB, MITF, MIZ, SMFI, BARC, HSBC, LLO, RBS, CITI, JPM, NOR, RABO

CHF: CS, UBS, SG, DB, MITF, BARC, HSBC, LLO, CITI, JPM, RABO

Legend: CS, Credit Suisse Group; UBS, Union Bank of Switzerland; RBC, Royal Bank of

Canada; BNP, BNP Paribas; CA, Credit Agricole; SG, Societe Generale; DB, Deutsche Bank; MITF, Bank of Tokyo-Mitsubishi UFJ Ltd.; MIZ, Mizuho; SMFI, Sumitomo Mitsui Banking Corporation; BS, Banco Santander (formerly Abbey National); BARC, Barclays; HSBC, HSBC Hdg; LLOY, Lloyds Banking Group; RBS, Royal Bank of Scotland Group; BOA, Bank of America; CITI, Citigroup; JMP, JP Morgan Chase & Co.

C Summary Statistics

In Table C.1 we report summary statistics for the time-series of Libor (Panel A) and for the corresponding panel of banks' submissions (Panel B), expressed in percentage. Across currencies and maturities, we note that the average cross-sectional standard deviation of submissions is in the order of 2.3 to 4.1 basis points.

Table C.2 displays summary statistics (Panel A) and correlations (Panel B) for the raw data that are used in our analysis. As expected, the correlation between *vol*, *CDS*, and *IV* is positive and quite large (from 0.54 to 0.75). For the other control variables the correlations are relatively small, and do not exceed 0.46 in absolute value.

D Call Report Data

In Table D.1, we collect summary statistics for the items we use from the Call Reports, and for the resultant interest rate sensitive asset ratios. We note that the magnitude (absolute value) of the mean of the interest sensitive assets for all banks and maturities are much larger than 1. From equation (10), this implies that the size of off-balance sheet derivatives for the five banks in our sample far exceeds the size of total balance sheet assets. A similar conclusion can be drawn by looking at the average size of trading assets for the five banks, which are fairly large (on average, 20.55 times total assets). This evidence confirms the claim that using Call Reports data is necessary in order to properly capture the net exposure of banks to interest rates movements.

Further, the mean of the interest sensitive assets for all five banks for all maturities is negative. On average the five banks in our sample were short Libor over the sample period 1999-2012. Given that we restrict our analysis to Libor rates denominated in USD for maturities of 1, 3, and 6 months, this is exactly what we expected.

Finally, the standard deviation of the interest sensitive assets for all banks for all maturities is around 15%. This indicates that these banks were not always either long Libor or short Libor, but they change their exposures often over the sample period.

Table C.1: Summary statistics for LIBOR fixing and submissions

Panel A reports summary statistics of LIBOR fixing for the three maturities (1-, 3-, and 6-month) of the four currencies USD, GBP, JPY, and CHF. Panel B reports the same statistics for the corresponding submissions by the individual banks listed in Appendix B. The statistics are: the number of available observations (N); mean; for Panel A, the time-series standard deviation ('sd'); for Panel B, the average cross-sectional standard deviation of submissions ('csd'); minimum; 25th, 50th, and 75th percentile; maximum; and skewness. The sample contains daily observations from January 6th, 1999 to November 28th, 2012. The number of observations varies due to different holidays and different numbers of banks in the panels.

Panel A: Libor fixing

Currency-maturity	N	mean	sd	min	p25	p50	p75	max	skew
USD-1m	3515	2.693	2.166	0.185	0.347	2.016	4.958	6.821	0.341
USD-3m	3515	2.810	2.143	0.245	0.629	2.163	5.030	6.869	0.347
USD-6m	3515	2.943	2.086	0.383	1.110	2.321	5.062	7.109	0.363
GBP-1m	3515	3.734	2.046	0.496	0.770	4.581	5.382	6.750	-0.623
GBP-3m	3515	3.875	1.999	0.523	1.256	4.590	5.475	6.904	-0.594
GBP-6m	3515	3.993	1.919	0.680	1.474	4.582	5.546	6.799	-0.557
JPY-1m	3515	0.224	0.241	0.036	0.054	0.139	0.330	1.588	1.576
JPY-3m	3515	0.286	0.281	0.046	0.068	0.194	0.412	1.094	1.294
JPY-6m	3515	0.358	0.305	0.057	0.081	0.329	0.504	1.185	0.952
CHF-1m	3515	1.152	1.083	-0.013	0.192	0.740	2.135	3.552	0.718
CHF-3m	3515	1.263	1.118	0.003	0.257	0.770	2.210	3.590	0.648
CHF-6m	3515	1.356	1.119	0.043	0.333	0.850	2.280	3.768	0.614

Panel B: Libor submissions

Currency-maturity	N	mean	csd	min	p25	p50	p75	max	skew
USD-1m	49164	2.514	0.023	0.110	0.300	1.840	4.900	6.890	0.449
USD-3m	49261	2.638	0.025	0.200	0.510	1.900	4.970	6.890	0.446
USD-6m	49155	2.770	0.028	0.300	0.770	2.060	4.950	7.130	0.464
GBP-1m	44102	3.472	0.025	0.400	0.670	4.130	5.270	6.930	-0.401
GBP-3m	44116	3.619	0.027	0.450	0.980	4.230	5.313	6.930	-0.381
GBP-6m	44115	3.749	0.029	0.550	1.275	4.410	5.344	6.850	-0.354
JPY-1m	44565	0.233	0.041	-0.060	0.060	0.140	0.340	2.000	1.529
JPY-3m	45114	0.296	0.024	-0.060	0.070	0.190	0.420	1.350	1.246
JPY-6m	45113	0.373	0.027	-0.030	0.090	0.330	0.530	1.430	0.882
CHF-1m	37603	1.078	0.041	-0.250	0.150	0.730	2.060	4.950	0.790
CHF-3m	34721	1.199	0.031	-0.150	0.250	0.750	2.150	5.230	0.703
CHF-6m	34721	1.292	0.034	0.010	0.320	0.810	2.180	5.430	0.668

Table C.2: Summary statistics for returns and conditioning variables

Summary statistics (Panel A) and correlation matrix (Panel B) for banks' returns (r), domestic aggregate stock market returns (r_{Mkt}), change in VIX (ΔVIX), banks' log market capitalization ($Size$), 1-year domestic Treasury rate ($Yield$), realized weekly volatility of banks' equity returns (vol), 1-year CDS premium on banks' equity in bps (CDS), and implied volatility on banks' equity (IV). The statistics are: mean; standard deviation; minimum; 25th, 50th, and 75th percentile; maximum; and skewness. The sample contains weekly observations from January 6, 1999 to November 28, 2012.

Panel A: Summary statistics

	mean	sd	min	p25	med	p75	max	skew
r	0.001	0.076	-0.717	-0.028	0.001	0.029	1.332	1.570
r_{Mkt}	0.001	0.033	-0.161	-0.014	0.003	0.020	0.135	-0.490
ΔVIX	-0.007	3.335	-19.340	-1.390	-0.100	1.100	19.610	0.394
$Size$	11.058	0.594	8.730	10.688	11.038	11.465	12.362	-0.167
$Yield$	2.158	1.802	-0.477	0.670	1.377	3.650	6.514	0.748
vol	0.025	0.023	0.001	0.011	0.018	0.029	0.369	3.892
CDS	67.686	82.422	0.400	4.600	44.945	98.406	917.500	2.792
IV	0.400	0.277	0.100	0.225	0.331	0.475	5.398	4.125

Panel B: Correlation matrix

	r	r_{Mkt}	ΔVIX	$Size$	$Yield$	vol	CDS	IV
r	1							
r_m	0.705	1						
ΔVIX	-0.493	-0.661	1					
$Size$	0.044	0.054	0.012	1				
$Yield$	-0.029	-0.038	0.048	0.260	1			
vol	0.032	-0.074	0.023	-0.348	-0.151	1		
CDS	-0.005	-0.040	-0.021	-0.422	-0.384	0.542	1	
IV	-0.099	-0.141	0.065	-0.461	-0.202	0.754	0.685	1

Table D.1: Summary statistics for balance sheet variables

Summary statistics for pooled quarterly balance sheet variables of Bank of America, Citigroup, Deutsche, HSBC, and JP Morgan Chase over the 1999-2012 period. *TA* is total assets, *TL* denotes total liabilities that are repriceable within one year due to interest rate movements, *TD* is total debt that is repriceable within one year due to interest rate movements, *IRDH* is the notional value of interest rate derivatives used for hedging, and IRDT is the notional value of interest rate derivatives used for trading. All of these items are expressed in USD millions. Finally ISA_{1m}, ISA_{3m}, and ISA_{6m}, are the 1-, 3-, and 6-month interest sensitive assets expressed as a fraction of total assets of banks as in equation (10). The statistics are: mean; standard deviation; minimum; 25th, 50th, and 75th percentile; maximum; and skewness.

	mean	sd	min	p25	p50	p75	max	skew
TA	1075.665	750.978	52.076	398.935	861.026	1829.515	2370.594	0.260
TL	199.794	155.140	0.084	80.839	167.027	318.140	549.800	0.560
TD	56.824	52.956	0.000	14.387	36.648	95.752	249.855	1.070
IRDH	234.048	350.195	0.000	47.551	96.133	282.047	2080.694	3.080
IRDT	22101.279	22138.174	9.761	2665.961	13492.374	38742.848	77816.394	0.820
ISA_{1m}	-11.800	15.630	-50.510	-25.070	-11.680	0.600	22.990	-0.120
ISA_{3m}	-12.460	15.090	-50.510	-25.070	-11.930	-0.020	22.990	-0.110
ISA_{6m}	-12.010	15.470	-50.510	-25.070	-11.680	0.270	22.990	-0.100

Internet Appendix

Libor Manipulation: Cui Bono?

In this Internet Appendix we present additional results that are discussed in Section 7 of the paper. In particular, Table IA.1 contains the estimates when changing the window length in our Stage 1 regression, while Table IA.2 considers using local-currency returns. Table IA.3 and Table IA.4 add the CDS spread to the set of controls in stage 1 and 2, respectively. CSD spreads are available on a much shorter sample (CDS data are missing for Canadian banks). In Table IA.5 we consider various definitions of the manipulation period. In Table IA.6 we include also submissions for the EUR and 12-month maturity. Finally, Table IA.7 reports results for the specification where all Stage 1 betas are trimmed, instead of winsorized, at the top and bottom 1%.

Table IA.1: Changing rolling window size

Panel A reports estimates of the OLS pooled regression of the monthly average bank submissions on lagged Libor sensitivity alone and with interaction terms, control variables, and bank, currency-maturity, and time fixed effects:

$$Submission_{i,t+1} = a + \lambda^{Libor}\beta_{i,t}^{\Delta Libor} + \lambda_T^{Libor}\beta_{i,t}^{\Delta Libor} \times Manip + \lambda^{Sub}\beta_{i,t}^{\Delta Sub} + Controls + Fixed\ effects + u_{i,t+1}.$$

The regression is estimated by pooling observations for panel banks across four currencies (USD, GBP, JPY, and CHF) and three maturities (1-, 3-, and 6-month). Variables definition follows from Tables 3 and 4. Compared to Table 4, the Stage 1 regressions are estimated on backward-looking rolling windows whose length varies between 15 and 45 weeks. All variables are standardized. Below the estimates, t-statistics based on robust standard errors clustered by time are reported in parenthesis. The R^2 is from the regression of the residuals of the right- and left-hand-side variables on the fixed effects. The sample contains monthly observations from July 1999 until November 2012. Panel B reports the estimated gains (in millions USD) during the manipulation period from cash-flow and stigma manipulation, obtained using the procedure in Section 4.3. Below the estimates, t-statistics for the average weekly gain series are reported in parenthesis. Statistical significance at the 1%, 5%, and 10% is denoted by ***, **, and * respectively.

Panel A: Stage 2

	rolling window size (in weeks)						
Control	15	20	25	30	35	40	45
$\beta^{\Delta Libor}$	-0.014	-0.003	0.004	0.013	0.020	0.019	0.025**
	(-1.227)	(-0.257)	(0.355)	(1.074)	(1.616)	(1.557)	(2.028)
$\beta^{\Delta Libor} \times$ *Manip*	0.061***	0.051**	0.047**	0.034*	0.030	0.026	0.021
	(3.138)	(2.418)	(2.220)	(1.670)	(1.480)	(1.345)	(1.051)
$\beta^{\Delta Sub}$	-0.012*	-0.012*	-0.011	-0.009	-0.005	-0.005	-0.003
	(-1.873)	(-1.705)	(-1.530)	(-1.225)	(-0.732)	(-0.627)	(-0.379)
β^{Mkt}	0.037***	0.045***	0.053***	0.053***	0.057***	0.067***	0.070***
	(2.733)	(2.978)	(3.519)	(3.411)	(3.708)	(4.477)	(4.806)
β^{VIX}	-0.002	0.004	0.016	0.022*	0.023*	0.026**	0.033**
	(-0.182)	(0.311)	(1.195)	(1.668)	(1.752)	(2.082)	(2.597)
Size	-0.155***	-0.156***	-0.156***	-0.156***	-0.156***	-0.152***	-0.149***
	(-8.069)	(-8.183)	(-8.048)	(-7.719)	(-7.358)	(-7.062)	(-6.792)
Yield	0.138***	0.140***	0.148***	0.156***	0.162***	0.166***	0.168***
	(5.753)	(6.089)	(6.519)	(6.809)	(7.085)	(7.129)	(7.228)
vol	0.039***	0.035***	0.034**	0.032**	0.031**	0.030**	0.029**
	(2.972)	(2.669)	(2.531)	(2.335)	(2.264)	(2.176)	(2.080)
Obs.	20,995	20,910	20,805	20,651	20,524	20,373	20,240
R^2	0.022	0.023	0.026	0.026	0.028	0.029	0.031

Panel B: Stage 3, estimated gains

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
From cash-flows manipulation	$34,081***	$23,818***	$17,930***	$10,381***	$10,257***	$9,652***	$6,980***
	(3.443)	(3.951)	(4.663)	(4.768)	(3.443)	(3.440)	(3.440)
From stigma manipulation	-$906	$207	$356	$110	$166	$20	$45
	(0.321)	(0.366)	(0.408)	(0.432)	(0.702)	(1.360)	(1.383)

Table IA.2: Using local currency returns in Stage 1

Panel A reports estimates of the OLS pooled regression of the monthly average bank submissions on lagged Libor sensitivity alone and with interaction terms, control variables, and bank, currency-maturity, and time fixed effects:

$$Submission_{i,t+1} = a + \lambda^{Libor}\beta^{\Delta Libor}_{i,t} + \lambda^{Libor}_{D}\beta^{\Delta Libor}_{i,t} \times D_{Libor} + \lambda^{Sub}\beta^{\Delta Sub}_{i,t} + \lambda^{Sub}_{D}\beta^{Sub}_{i,t} \times D_{Sub} + Controls + Fixed\ effects + u_{i,t+1}.$$

The regression is estimated by pooling observations for panel banks across four currencies (USD, GBP, JPY, and CHF) and three maturities (1-, 3-, and 6-month). Variables definition follows from Tables 3 and 4. Compared to Table 4, the Stage 1 regressions are estimated on local-currency denominated, rather than USD-denominated, returns. All variables are standardized. Below the estimates, t-statistics based on robust standard errors clustered by time are reported in parenthesis. The R^2 is from the regression of the residuals of the right- and left-hand-side variables on the fixed effects. The sample contains monthly observations from July 1999 until November 2012. Panel B reports the estimated gains (in millions USD) during the manipulation period from cash-flow and stigma manipulation, obtained using the procedure in Section 4.3. Below the estimates, t-statistics for the average weekly gain series are reported in parenthesis. Statistical significance at the 1%, 5%, and 10% is denoted by ***, **, and * respectively.

Panel A: Stage 2

Control	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\beta^{\Delta Libor}$	0.008	0.008	0.008	0.008	0.008	0.002	0.003
	(0.642)	(0.647)	(0.658)	(0.633)	(0.662)	(0.176)	(0.204)
$\beta^{\Delta Libor} \times$ *Manip*	0.049**				0.049**	0.053**	0.052**
	(2.428)				(2.421)	(2.469)	(2.462)
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *High*		0.097***					
		(4.124)					
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *Low*		-0.002					
		(-0.107)					
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *EU*			0.099***				
			(3.917)				
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *exEU*			-0.011				
			(-0.391)				
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *Cheat*				0.117***			
				(3.993)			
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *exCheat*				0.012			
				(0.548)			
$\beta^{\Delta Sub}$	-0.007	-0.008	-0.007	-0.006	-0.012	-0.021*	-0.027**
	(-0.997)	(-1.028)	(-0.899)	(-0.883)	(-1.496)	(-1.847)	(-2.421)
$\beta^{\Delta Sub} \times$ *Crisis*					0.030		0.036
					(1.284)		(1.514)
$\beta^{\Delta Sub} \times$ *Weak*						0.033*	0.033*
						(1.956)	(1.960)
Obs.	20,746	20,746	20,746	20,746	20,746	17,772	17,772
Controls	YES	YES	YES	YES	YES	YES	YES
R^2	0.025	0.026	0.027	0.027	0.025	0.025	0.025

Panel B: Stage 3, estimated gains

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
From cash-flows manipulation	$18,092***	$15,462***	$17,021***	$17,565***	$18,060***	$17,378***	$17,265***
	(2.914)	(2.946)	(3.854)	(3.84)	(2.913)	(3.008)	(3.001)
From stigma manipulation	$183	$187	$166	$164	$506	$519	$1,025
	(0.505)	(0.577)	(0.657)	(0.686)	(0.656)	(0.875)	(0.951)

Table IA.3: Adding CDS in Stage 1

Panel A reports estimates of the OLS pooled regression of the monthly average bank submissions on lagged Libor sensitivity alone and with interaction terms, control variables, and bank, currency-maturity, and time fixed effects:

$$Submission_{i,t+1} = a + \lambda^{Libor}\beta^{\Delta Libor}_{i,t} + \lambda^{Libor}_{D}\beta^{\Delta Libor}_{i,t} \times D_{Libor} + \lambda^{Sub}\beta^{\Delta Sub}_{i,t} + \lambda^{Sub}_{D}\beta^{Sub}_{i,t} \times D_{Sub} + Controls + Fixed\ effects + u_{i,t+1}.$$

The regression is estimated by pooling observations for panel banks across four currencies (USD, GBP, JPY, and CHF) and three maturities (1-, 3-, and 6-month). Variables definition follows from Tables 3 and 4. Compared to Table 4, the Stage 1 regressions now include the change in the difference between the banks CDS and the average CDS of panel banks. All variables are standardized. Below the estimates, t-statistics based on robust standard errors clustered by time are reported in parenthesis. The R^2 is from the regression of the residuals of the right- and left-hand-side variables on the fixed effects. The sample contains monthly observations from July 1999 until November 2012. Panel B reports the estimated gains (in millions USD) during the manipulation period from cash-flow and stigma manipulation, obtained using the procedure in Section 4.3. Below the estimates, t-statistics for the average weekly gain series are reported in parenthesis. Statistical significance at the 1%, 5%, and 10% is denoted by ***, **, and * respectively.

Panel A: Stage 2

Control	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\beta^{\Delta Libor}$	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	(0.221)	(0.230)	(0.241)	(0.204)	(0.233)	(0.260)	(0.274)
$\beta^{\Delta Libor} \times$ *Manip*	0.047**				0.047**	0.047**	0.047**
	(2.308)				(2.310)	(2.281)	(2.283)
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *High*		0.084***					
		(3.737)					
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *Low*		0.008					
		(0.353)					
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *EU*			0.085***				
			(3.637)				
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *exEU*			0.002				
			(0.056)				
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *Cheat*				0.099***			
				(3.559)			
$\beta^{\Delta Libor} \times$ *Manip* $\times$ *exCheat*				0.020			
				(0.930)			
$\beta^{\Delta Sub}$	-0.010	-0.010	-0.009	-0.009	-0.012	-0.011	-0.013
	(-1.295)	(-1.319)	(-1.190)	(-1.193)	(-1.396)	(-1.184)	(-1.322)
$\beta^{\Delta Sub} \times$ *Crisis*					0.011		0.012
					(0.535)		(0.551)
$\beta^{\Delta Sub} \times$ *Weak*						0.002	0.002
						(0.224)	(0.217)
Obs.	17,138	17,138	17,138	17,138	17,138	17,078	17,078
Controls	YES	YES	YES	YES	YES	YES	YES
R^2	0.023	0.024	0.023	0.024	0.023	0.023	0.023

Panel B: Stage 3, estimated gains

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
From cash-flows manipulation	$12,687***	$10,433***	$12,277***	$12,637***	$12,756***	$12,643***	$12,687***
	(3.022)	(3.063)	(4.543)	(4.006)	(3.021)	(3.018)	(3.017)
From stigma manipulation	$550	$558	$490	$497	$521	$839	$926
	(1.011)	(1.170)	(1.252)	(1.361)	(1.625)	(1.104)	(1.402)

Table IA.4: Adding CDS in Stage 2

Panel A reports estimates of the OLS pooled regression of the monthly average bank submissions on lagged Libor sensitivity alone and with interaction terms, control variables, and bank, currency-maturity, and time fixed effects:

$$Submission_{i,t+1} = a + \lambda^{Libor}\beta^{\Delta Libor}_{i,t} + \lambda^{Libor}_{D}\beta^{\Delta Libor}_{i,t} \times D_{Libor} + \lambda^{Sub}\beta^{\Delta Sub}_{i,t} + \lambda^{Sub}_{D}\beta^{Sub}_{i,t} \times D_{Sub} + Controls + Fixed\ effects + u_{i,t+1}.$$

The regression is estimated by pooling observations for panel banks across four currencies (USD, GBP, JPY, and CHF) and three maturities (1-, 3-, and 6-month). Variables definition follows from Tables 3 and 4. Compared to Table 4, the Stage 2 regressions now include the bank CDS as an additional control. All variables are standardized. Below the estimates, t-statistics based on robust standard errors clustered by time are reported in parenthesis. The R^2 is from the regression of the residuals of the right- and left-hand-side variables on the fixed effects. The sample contains monthly observations from July 1999 until November 2012. Panel B reports the estimated gains (in millions USD) during the manipulation period from cash-flow and stigma manipulation, obtained using the procedure in Section 4.3. Below the estimates, t-statistics for the average weekly gain series are reported in parenthesis. Statistical significance at the 1%, 5%, and 10% is denoted by ***, **, and * respectively.

Panel A: Stage 2

Control	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\beta^{\Delta Libor}$	-0.013	-0.013	-0.012	-0.013	-0.012	-0.013	-0.012
	(-0.679)	(-0.668)	(-0.650)	(-0.682)	(-0.650)	(-0.681)	(-0.652)
$\beta^{\Delta Libor} \times$ *Manip*	0.064**				0.064**	0.064**	0.063**
	(2.459)				(2.457)	(2.444)	(2.442)
$\beta^{\Delta Libor} \times$ *Manip* × *High*		0.099***					
		(3.424)					
$\beta^{\Delta Libor} \times$ *Manip* × *Low*		0.027					
		(1.006)					
$\beta^{\Delta Libor} \times$ *Manip* × *EU*			0.101***				
			(3.421)				
$\beta^{\Delta Libor} \times$ *Manip* × *exEU*			0.013				
			(0.412)				
$\beta^{\Delta Libor} \times$ *Manip* × *Cheat*				0.111***			
				(3.415)			
$\beta^{\Delta Libor} \times$ *Manip* × *exCheat*				0.036			
				(1.363)			
$\beta^{\Delta Sub}$	-0.018**	-0.019**	-0.018**	-0.018**	-0.026***	-0.027**	-0.035***
	(-2.219)	(-2.229)	(-2.125)	(-2.126)	(-2.876)	(-2.283)	(-2.914)
$\beta^{\Delta Sub} \times$ *Crisis*					0.041*		0.041*
					(1.947)		(1.953)
$\beta^{\Delta Sub} \times$ *Weak*						0.020	0.020
						(1.055)	(1.052)
β^{Mkt}	0.032*	0.032*	0.031*	0.031*	0.032*	0.032*	0.032*
	(1.731)	(1.728)	(1.716)	(1.710)	(1.737)	(1.730)	(1.736)
β^{VIX}	0.014	0.014	0.014	0.014	0.014	0.014	0.014
	(0.854)	(0.850)	(0.837)	(0.852)	(0.839)	(0.857)	(0.841)
Size	-0.136***	-0.137***	-0.139***	-0.136***	-0.135***	-0.136***	-0.135***
	(-5.386)	(-5.419)	(-5.434)	(-5.380)	(-5.357)	(-5.363)	(-5.333)
Yield	0.171***	0.171***	0.173***	0.173***	0.170***	0.171***	0.170***
	(5.809)	(5.803)	(5.850)	(5.833)	(5.759)	(5.804)	(5.754)
Vol	0.016	0.016	0.017	0.016	0.016	0.016	0.016
	(1.082)	(1.109)	(1.171)	(1.098)	(1.094)	(1.061)	(1.072)
CDS	0.071***	0.071***	0.072***	0.073***	0.071***	0.071***	0.071***
	(5.554)	(5.499)	(5.654)	(5.710)	(5.524)	(5.570)	(5.540)
Obs.	14,296	14,296	14,296	14,296	14,296	14,296	14,296
R^2							

Panel B: Stage 3, estimated gains

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
From cash-flows manipulation	$17,301***	$15,592***	$16,513***	$17,065***	$17,273***	$17,195***	$17,243***
	(2.933)	(3.193)	(4.273)	(4.179)	(2.938)	(2.934)	(2.933)
From stigma manipulation	$515	$518	$494	$496	$50	$1,158	$1,173
	(0.525)	(0.596)	(0.678)	(0.719)	(0.044)	(1.021)	(1.015)

Table IA.5: Changing manipulation period

Panel A reports estimates of the OLS pooled regression of the monthly average bank submissions on lagged Libor sensitivity alone and with interaction for manipulation period, control variables, and bank, currency-maturity, and time fixed effects:

$$submission_{i,t+1} = a + \lambda\beta_{i,t}^{\Delta Libor} + \lambda_T\beta_{i,t}^{\Delta Libor} \times Manip + Controls + Fixed\ effects + u_{i,t+1}$$

The regression is estimated by pooling observations for panel banks across four currencies (USD, GBP, JPY, and CHF) and three maturities (1-, 3-, and 6-month). Variables definition follows from Tables 3 and 4 except for *Manip*. The manipulation period is defined alternatively as January 2004 to May 2009, January 2005 to June 2010 (UBS settlement), and January 2005 to August 2008 (pre-Lehman period). All variables are standardized. Below the estimates, t-statistics based on robust standard errors clustered by time are reported in parenthesis. The R^2 is from the regression of the residuals of the right- and left-hand-side variables on the fixed effects. The sample contains monthly observations from July 1999 until November 2012. Panel B reports the estimated gains (in millions USD) during each corresponding manipulation period from cash-flow and stigma manipulation, obtained using the procedure in Section 4.3. Below the estimates, t-statistics for the average weekly gain series are reported in parenthesis. Statistical significance at the 1%, 5%, and 10% is denoted by ***, **, and * respectively.

	one year back	UBS core	Pre Lehman
Panel A: Stage 2			
		Manip period	
Control	Jan2004-May2009	Jan2005-Jun2010	Jan2005-Aug2008
$\beta^{\Delta Libor}$	0.011	0.000	0.014
	(0.830)	(0.011)	(1.209)
$\beta^{\Delta Libor} \times$ *Manip*	0.032	0.056***	0.037*
	(1.647)	(2.861)	(1.689)
$\beta^{\Delta Sub}$	-0.011	-0.011	-0.011
	(-1.569)	(-1.500)	(-1.549)
β^{Mkt}	0.055***	0.055***	0.056***
	(3.575)	(3.584)	(3.644)
β^{VIX}	0.011	0.012	0.011
	(0.883)	(0.925)	(0.872)
Size	-0.159***	-0.160***	-0.159***
	(-8.027)	(-8.183)	(-8.015)
Yield	0.150***	0.150***	0.150***
	(6.511)	(6.488)	(6.518)
Vol	0.033**	0.033**	0.033**
	(2.442)	(2.419)	(2.436)
Obs.	20,745	20,745	20,745
R^2	0.026	0.026	0.026

Panel B: Stage 3, estimated gains

		Manip period	
	Jan2004-May2009	Jan2005-Jun2010	Jan2005-Aug2008
From cash-flow manipulation	$19,658***	$48,097***	$7,559***
	(3.363)	(4.455)	(3.957)
From stigma manipulation	$1,188	$1,443	$74
	(1.553)	(1.360)	(0.353)

Table IA.6: Extended set of currencies and maturities

Panel A reports estimates of the OLS pooled regression of the monthly average bank submissions on lagged Libor sensitivity alone and with interaction terms, control variables, and bank, currency-maturity, and time fixed effects:

$$Submission_{i,t+1} = a + \lambda^{Libor}\beta_{i,t}^{\Delta Libor} + \lambda_D^{Libor}\beta_{i,t}^{\Delta Libor} \times D_{Libor} + \lambda^{Sub}\beta_{i,t}^{\Delta Sub} + \lambda_D^{Sub}\beta_{i,t}^{Sub} \times D_{Sub} + Controls + Fixed\ effects + u_{i,t+1}.$$

The regression is estimated by pooling observations for panel banks across five currencies (USD, EUR, GBP, JPY, and CHF) and four maturities (1-, 3-, 6-, and 12-month). Variables definition follows from Tables 3 and 4. All variables are standardized. Below the estimates, t-statistics based on robust standard errors clustered by time are reported in parenthesis. The R^2 is from the regression of the residuals of the right- and left-hand-side variables on the fixed effects. The sample contains monthly observations from July 1999 until November 2012. Panel B reports the estimated gains (in millions USD) during the manipulation period from cash-flow and stigma manipulation, obtained using the procedure in Section 4.3. Below the estimates, t-statistics for the average weekly gain series are reported in parenthesis. Statistical significance at the 1%, 5%, and 10% is denoted by ***, **, and * respectively.

Panel A: Stage 2

Control	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\beta^{\Delta Libor}$	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	(0.088)	(0.086)	(0.117)	(0.092)	(0.089)	(0.115)	(0.118)
$\beta^{\Delta Libor} \times Manip$	0.035**				0.035**	0.033*	0.033*
	(2.048)				(2.045)	(1.798)	(1.794)
$\beta^{\Delta Libor} \times Manip \times High$		0.099***					
		(4.315)					
$\beta^{\Delta Libor} \times Manip \times Low$		0.007					
		(0.372)					
$\beta^{\Delta Libor} \times Manip \times EU$			0.069***				
			(3.234)				
$\beta^{\Delta Libor} \times Manip \times exEU$			-0.003				
			(-0.127)				
$\beta^{\Delta Libor} \times Manip \times Cheat$				0.088***			
				(3.454)			
$\beta^{\Delta Libor} \times Manip \times exCheat$				0.008			
				(0.428)			
$\beta^{\Delta Sub}$	-0.006	-0.006	-0.006	-0.006	-0.006	-0.019**	-0.020**
	(-1.090)	(-1.103)	(-1.010)	(-0.994)	(-1.035)	(-2.221)	(-2.246)
$\beta^{\Delta Sub} \times Crisis$					0.003		0.004
					(0.168)		(0.223)
$\beta^{\Delta Sub} \times Weak$						0.028*	0.028*
						(1.947)	(1.941)
Controls	YES	YES	YES	YES	YES	YES	YES
Obs.	35,039	35,039	35,039	35,039	35,039	29,739	29,739
R^2	0.022	0.023	0.023	0.023	0.022	0.021	0.021

Panel B: Stage 3, estimated gains

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
From cash-flow manipulation	$22,062***	$13,590***	$20,462***	$20,795***	$22,061***	$20,482***	$20,482***
	(3.443)	(3.951)	(4.663)	(4.768)	(3.443)	(3.480)	(3.480)
From stigma manipulation	$123	$124	$112	$112	$229	$2,268*	$2,329**
	(0.321)	(0.366)	(0.408)	(0.432)	(0.702)	(1.951)	(2.089)

Table IA.7: Trimming βs

Panel A reports estimates of the OLS pooled regression of the monthly average bank submissions on lagged Libor sensitivity alone and with interaction terms, control variables, and bank, currency-maturity, and time fixed effects:

$$Submission_{i,t+1} = a + \lambda^{Libor}\beta^{\Delta Libor}_{i,t} + \lambda^{Libor}_{D}\beta^{\Delta Libor}_{i,t} \times D_{Libor} + \lambda^{Sub}\beta^{\Delta Sub}_{i,t} + \lambda^{Sub}_{D}\beta^{Sub}_{i,t} \times D_{Sub} + Controls + Fixed\ effects + u_{i,t+1}.$$

The regression is estimated by pooling observations for panel banks across four currencies (USD, GBP, JPY, and CHF) and three maturities (1-, 3-, and 6-month). Variables definition follows from Tables 3 and 4. Compared to Table 4, the β estimates have been trimmed, rather than winsorized, at the 1st and 99th percentiles. All variables are standardized. Below the estimates, t-statistics based on robust standard errors clustered by time are reported in parenthesis. The R^2 is from the regression of the residuals of the right- and left-hand-side variables on the fixed effects. The sample contains monthly observations from July 1999 until November 2012. Panel B reports the estimated gains (in millions USD) during the manipulation period from cash-flow and stigma manipulation, obtained using the procedure in Section 4.3. Below the estimates, t-statistics for the average weekly gain series are reported in parenthesis. Statistical significance at the 1%, 5%, and 10% is denoted by ***, **, and * respectively.

Panel A: Stage 2

Control	(1)	(2)	(3)	(4)	(5)	(6)	(7)
β^{Libor}	0.011	0.011	0.011	0.010	0.011	0.012	0.012
	(0.836)	(0.838)	(0.855)	(0.827)	(0.841)	(0.834)	(0.846)
$\beta^{Libor} \times$ *Manip*	0.038*				0.038*	0.036	0.036
	(1.858)				(1.859)	(1.654)	(1.656)
$\beta^{Libor} \times$ *Manip* $\times$ *High*		0.081***					
		(3.425)					
$\beta^{Libor} \times$ *Manip* $\times$ *Low*		-0.008					
		(-0.357)					
$\beta^{Libor} \times$ *Manip* $\times$ *EU*			0.082***				
			(3.343)				
$\beta^{Libor} \times$ *Manip* $\times$ *exEU*			-0.020				
			(-0.687)				
$\beta^{Libor} \times$ *Manip* $\times$ *Cheat*				0.090***			
				(3.175)			
$\beta^{Libor} \times$ *Manip* $\times$ *exCheat*				0.007			
				(0.332)			
β^{Sub}	-0.011	-0.011	-0.011	-0.011	-0.013	-0.033***	-0.036***
	(-1.510)	(-1.510)	(-1.441)	(-1.446)	(-1.568)	(-3.119)	(-3.441)
$\beta^{Sub} \times$ *Crisis*					0.009		0.020
					(0.400)		(0.876)
$\beta^{Sub} \times$ *Weak*						0.043**	0.043**
						(2.564)	(2.548)
Controls	YES	YES	YES	YES	YES	YES	YES
Obs.	19,512	19,512	19,512	19,512	19,512	16,676	16,676
R^2	0.029	0.03	0.031	0.031	0.029	0.029	0.029

Panel B: Stage 3, estimated gains

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
From cash-flow manipulation	$13,227***	$10,521***	$11,915***	$12,483***	$13,065***	$12,738***	$12,774***
	(3.264)	(3.194)	(2.998)	(3.075)	(3.259)	(3.2)	(3.198)
From stigma manipulation	$451	$451	$422	$424	$419	$1,870**	$1,511**
	(0.819)	(0.82)	(0.806)	(0.806)	(1.181)	(1.468)	(1.363)