An Empirical Assessment of Collusion in the Negotiable Certificates of Deposit Market in Korea: A Discriminant Analysis

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March 2022

Abstract

This paper econometrically evaluates if there actually occurred a collusion in the negotiable certificates of deposit (CD) market during the period of Korea Fair Trade Commission's (KFTC) investigation. We propose a general mixture regression model to discriminate the collusion period from the competitive period. We apply our method to Korean CD market data from January 1, 2009, to May 23, 2019, and forecast the probability of collusion for each day. We find only a small portion—163 days out of 2,579 days—of the whole sample is discriminated as a possible collusion. We also find that the banks did not issue the CDs on almost all dates discriminated as colluded in our empirical results. Our findings imply a strong possibility that the stickiness of the CD rates was induced by the depressed CD market conditions rather than a collusion.

JEL Classification: L40, G21, G14

Keywords: Negotiable Certificate of Deposit; Discriminant Analysis; Collusion Detection

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I. Introduction

The Korea Fair Trade Commission (KFTC) launched an investigation in July 2012 into the potential collusion of the negotiable certificates of deposit (CDs) rates by six domestic banks. The KFTC suspected that, since 2009, the six banks had been intentionally setting the CD issuance rates at the same level as the previous day's market average rate.[1] The investigation received much attention because the CD rates had been widely used as the benchmark for short-term interest rates in the Korean financial market. After four years of investigation, the KFTC concluded it could not prove collusion beyond a reasonable doubt, although there existed a lot of circumstantial evidence.

One of the reasons for the suspicion of collusion was the London Interbank Offered Rate (LIBOR) manipulation that made headlines worldwide around the same time. Since 2008, it had been alleged that several big global banks had manipulated LIBOR to manage their reputation for fiscal soundness and increase their profits. In June 2012, Barclays admitted its manipulation and agreed to pay approximately USD 450 million in fines.[2] Suspicions about the Korean CD rates surfaced because the LIBOR and Korean CD rates were similar in some respects. First, both rates were published as average market rates calculated from the reported interest rates. In the reporting process, the submitters had an incentive to manipulate the interest rates. Second, both interest rates were major reference rates in the financial market system, LIBOR internationally and the Korean CD rates domestically.

However, there were some differences between the LIBOR manipulation and the alleged Korean CD rates collusion. For example, the global banks were suspected of reporting *lower* LIBOR submissions than actual for their reputation and profits because LIBOR submissions are based on interbank borrowing rates. In contrast, the banks in Korea were suspected of setting *higher* CD issuance rates for their profits because the interest rates on their bank loans are indexed with the CD rates. The literature contains numerous studies on econometric identification of the LIBOR manipulation, including Gyntelberg and Wooldridge (2008), Abrantes-Metz et al. (2012), Fouquau and Spieser (2015), and Gandhi et al. (2019). Yet, surprisingly, few academic papers investigate the possibility of collusion over Korean CD rates.

This paper attempts to econometrically evaluate if there occurred a collusion in the CD

market during the period of KFTC's investigation. There have been a number of empirical methods for collusion detection in the literature. The surveys by Abrantes-Metz and Bajari (2009), Bajari and Summers (2002), Doane et al. (2014), and Harrington (2008) among others elucidate the various approaches in this vast literature. Harrington (2008) categorizes the previous studies into four groups: (1) tests of whether firm behavior is inconsistent with competition, (2) tests for a structural change in firm behavior, (3) tests of whether the behavior of a suspected group of firms is different from the one of the competitive firms, and (4) tests of whether firm behavior is more consistent with collusion than with competition.

We apply a discriminant analysis to empirically evaluate the probability of collusion in the CD market. Our approach belongs to (4) in the above categories. The reason why we employ the discriminant analysis is a limitation in the data on Korean CD market. Until September 2012, the CD rates of each bank had not been collected, and we only have a daily time-series of the market average CD rates. Among the above four approaches, (1) and (3) usually require the data not only on the winning bid but on the failed bids from all participating firms, as the methods focus on each firm's bidding behavior. While (2) can be useful when only the equilibrium prices (winning bids) exist, it usually requires firm-level data to be conclusive. When the data are available only on the market-level equilibrium prices, (4) would be the most effective approach.

Discriminant analysis is first formulated by Fisher (1936) and developed by Goldfeld and Quandt (1972), Kiefer (1980), Quandt and Ramsey (1978), and Schmidt (1982). In the field of industrial economics, Spiller and Huang (1986) apply a discriminant analysis utilizing a stochastic frontier switching regression to a regional market definition problem. In this paper, we propose a general mixture regression model to discriminate the collusion period from the competitive period without utilizing any prior switching information. We apply our method to Korean CD market data from January 1, 2009, to May 23, 2019, and estimate the probability of collusion for each day. The results will show us how collusive the market actually was in the period that the KFTC investigated for possible collusion. We find that it looks as though there was collusion with the market average CD rate on the discriminated dates, although this rigidity of the CD rate was actually caused by the lack of issuance of CDs during the period. In other words, our findings imply a strong possibility that the stickiness of the CD rates was induced by the depressed CDs market conditions rather than collusion.

II. The Korean CD Market[3]

A negotiable CD is a time deposit issued by a bank, which can be traded in the secondary market until its maturity date. In Korea, negotiable CDs have been one of the most important money market instruments since 1984.[4] CDs are issued by banks as a useful source of financing short-term funds to meet their liquidity needs. CDs also provide purchasers with the opportunity to diversify their portfolios and reduce financial risk. CDs are issued in a bearer form at a discount from face value. For example, the purchaser of a CD with a 3% interest rate will pay 97% of the face value to the seller and redeem the CD at par value on the maturity date. The maturity period cannot be less than 30 days; there are no other restrictions on the issuance of CDs.[5] In the primary market, CDs are mostly issued with less than one year to maturity and with a face value of more than KRW 5 million or KRW 10 million. CDs are issued by the banks that must keep a certain percentage of their deposits on reserve at the central bank to meet reserve requirements. Except for the Export–Import Bank of Korea, any bank, including nationwide banks, local banks, specialized banks, and Korean branches of foreign banks, can issue CDs in Korea.

The Korea Financial Investment Association (KOFIA) releases the daily market average CD rate, more specifically the last quoted yield on CDs. The process of computing the last quoted yield on CDs is as follows.[6] The association selects 10 reporting securities companies in consideration of their CD-related performance every six months. When reporting the CD rates twice a day to the association, the 10 companies should consider "the details of issuance and trading of CDs on the relevant day, yields on similar bonds such as bank bonds, etc., the Bank of Korea's benchmark interest rate and the trends for short-term interest rates, etc." (KOFIA, 2012). The CDs subject to yield reporting are 91-day CDs issued by nationwide banks assigned an AAA credit rating and specialized banks, such as the Korea Development Bank and the Industrial Bank of Korea. KOFIA calculates the last quoted yield on CDs as the arithmetic mean of the remaining reported CD rates after trimming the highest and lowest values.

The market average CD rates disclosed by the KOFIA have been a reference rate of

CDs transactions, the floating rates on the loans, and the interest rate swap contracts in Korea. However, the effectiveness of CD rates has deteriorated as the market size decreases. Korean CD markets declined sharply after the proposal for loan-to-deposit ratio (LDR) regulation in December 2009. Banks were required to keep the ratio of monthly average loan balance to monthly average deposit balance, excluding CDs, equal to or less than 100% after this regulation came into effect in June 2012. The reason for excluding CDs from the deposit balance calculation in the regulation seemed to be to reduce liquidity risk. During the 2007–2008 financial crisis, there was a general concern in Korea about the liquidity risk due to the banks' increased nondeposit liability, such as CDs and bank bonds.[7] Increased nondeposit liability can put banks at risk because of its instability relative to deposit liability. Thus, the financial authority wanted to restrict the number of loans and financing of short-term funds, especially CDs. That is why the outstanding balance of CDs was not included in the total deposit balance for the LDR under this regulation.[8] After the announcement of the regulation, the issued CD balance substantially decreased from KRW 107.6 trillion in 2009 to KRW 43.1 trillion in 2010 and continued to decline until 2012. The CD market shrinkage seriously weakened its role as the reference rate in Korean financial markets.

The financial authority implemented various measures to solve this problem with CD rates. First, some alternative reference rates were developed and used as the base rates in bank loan markets. According to Jung et al. (2015), 76.8% of household loans and 45.0% of enterprise loans were indexed to CD rates in December 2009. However, as the alternative reference rates of loans—such as the COFIX (Cost of Funds Index) and the KORIBOR (Korea Inter-Bank Offered Rate)—were adopted or replaced the CD rates, the percentages of bank loans indexed to CD rates decreased to 19.1% of household loans and 22.9% of enterprise loans in December 2014. As of December 2018, the bank loans indexed to CD rates accounted for only 13.3% of the total bank loans (Bank of Korea [BOK], 2019). Despite their drastic decrease in proportion, it is not an insignificant number so that it seems that CD rates still have a significant influence upon bank loan markets. Therefore, the financial authority also made an effort to revive CD markets to have CD rates properly serve as the base rate in financial markets. In August 2012, the financial authority imposed on the banks a duty to issue marketable CDs, and this administrative guidance has been continuously implemented. Moreover, in July 2018, the financial authority modified the LDR regulation. To increase the issuance of CDs, the

outstanding balance of marketable CDs (up to 1% of total deposits) is permitted to be included in the category of deposit when computing the LDR.

III. The KFTC's Investigation

In July 2012, the KFTC suspected that six banks had tacitly colluded to maintain a high level of CD rates since 2009. The KFTC alleged that the banks intentionally set the issuance rates of CDs at the previous day's market average rate, which is the last quoted yield from KOFIA. As explained previously, the last quoted yield on CDs was the primary benchmark for short-term interest rates in Korean financial markets. It also provided the basis for bank lending and deposit rates. Thus, the effects of high quoted CD rates for the banks are twofold. First, the high quoted CD rates raise the bank deposit rates so that the fund-financing cost for the banks becomes higher. Second, the high quoted CD rates raise the bank lending rates, enhancing the banks' profitability. If the second positive effect is greater than the first negative effect, the banks benefit from the high quoted CD rates. It actually depends on the bank interest rate margin, which is the difference between the lending rate and the deposit rate, if there is no default risk. According to the KFTC, the banks' outstanding balance of loans indexed to CD rates was much larger than that of deposits indexed to CD rates. The KFTC thus extrapolated that the banks' margins increased. Another reason for the KFTC's suspicion related to the CD market conditions at that time. The quoted CD rates can be affected by various market variables. However, if the CD markets become depressed, the quoted rate would be evaluated with less market data than before. Correspondingly, the change in the issuance rates of banks, one of the market variables, can have a larger influence on the quoted CD rates.[9] Given that during the period of investigation, the primary CD market was depressed due to the LDR regulation, the banks were likely trying to keep the high CD issuance rates. This explanation calls to mind Knittel and Stango's (2003) study of tacit collusion over the credit card interest rates in the United States using firm-level data. They find that the interest rate ceiling may serve as a focal point, thereby encouraging tacit collusion when the ceiling is not binding. In the case of the Korean CD markets, the high level of the market average rate might serve as a focal point, and tacit collusion might occur.

The investigation by the KFTC revealed some circumstantial evidence of collusive behavior in the primary CD market.[10] First, the banks made decisions on the issuance rates of CDs differently from the issuance rates of similar bonds. A bank bond is an instrument similar to a CD with the same maturity; both are considered instruments that help banks finance funds. When banks issued their bonds, they examined not only the mark-to-market yields but also several market variables, such as market demand and a trend in the primary market price of similar bonds. In contrast, when banks issued CDs, they tended to examine only the previous day's last quoted yield on CDs. This tendency could also explain the stickiness of the quoted CD rates shown in Figure 1. Recall that the quoted CD rate is the average of the rates submitted by securities companies to KOFIA. If the securities companies consider only banks' CD issuance rates when deciding their submitted rates,[11] the quoted CD rate would be almost the same as the banks' issuance rates. Then, if banks set their issuance rates at the previous quoted rate and this process is repeated, the quoted CD rates will be kept constant.

Second, the CD rates in the suspected period never reflected the market mechanism in terms of heterogeneity. It is well known that financial commodity issuers face heterogeneous prices. For example, in the money market, the issuing banks with high reputations and high credit ratings can borrow money at lower interest rates. In the bond market, the yields on bonds issued by the banks with high credit ratings are lower than those issued by banks with low credit ratings. Similarly, the CD issuance rates of nationwide banks are usually lower than local banks. However, in the period of investigation, the CD issuance rates of some nationwide banks were almost identical to local banks, which were close to the last quoted yields on CDs. Furthermore, the CD issuance rates did not seem to adequately respond to the excess demand for CDs in the period. The overall size of money market funds (MMFs), one of major investors in CDs, was larger over that period than the previous period due to increasing liquidity in the market. Additionally, although the size of MMFs increased during one year since June 2011, the quoted CD rates were remarkably stable, as seen in Figure 1. It seems that there existed high demand for CDs in the market, but the CD issuance rates did not reflect this market condition.

Third, a specialized bank issued CDs at the same rate as the nationwide banks during the investigation period. As specialized banks had an advantage in borrowing government funds, the CD rates of special banks were generally lower than nationwide banks.[12] In terms

of financing costs, it would be rational for specialized banks to set their CD issuance rates based on their own quoted yield. However, one specialized bank, which was under investigation for collusion and had a large amount of CD rate-linked loans, tended to issue its CDs at the same rate as the last quoted yield on CDs issued by nationwide banks. Finally, the KFTC raised the possibility of collusion via online and offline communication among banks' issuing officers.

Additional circumstantial evidence supported the KFTC's claim. Since around 2009, CD issuance had decreased sharply, and the last quoted yields on the CDs became more rigid than other similar interest rates in money markets and bond markets. However, the CD rates started to decrease around July 2012, when the KFTC began investigating. The news media also reported some changes in the CD markets after the investigation began. For example, while almost all securities companies had reported the same rate to KOFIA for 170 business days a year before the investigation, they began reporting five different CD rates shortly after the investigation.[13] Such change in practices seemed to provide evidence of collusion in the CD markets.

This scandal received great attention because the CD rates were widely used as the benchmark for short-term interest rates in the Korean financial market. According to the Financial Supervisory Service (2011), the bank loans indexed to CD rates accounted for 41.3% of the total bank loans as of December 2010. Due to the influence of CD rates on the bank loan markets, the banks' unfair profits were expected to be immense. The Korea Finance Consumer Federation (2012) estimated the damage to households was approximately KRW 315.6 billion[14] a year for every 0.1%p increase in collusive CD rates.

However, the banks under the KFTC's investigation denied colluding.[15] They claimed that the stickiness of the CD rates occurred as a result of a drastic decrease in the amount of CDs issued and traded in the markets after the implementation of the LDR regulation; therefore, they had no choice but to use the market average CD rate as the base rate in setting the CD issuance rates. Their claim would mean that the allegation was raised because the CD rates no longer involve the price mechanism.

In 2016, the KFTC ended its investigation, concluding it did not find enough evidence of collusion to indict. It would be worth examining if there exists statistical evidence of

collusion in the period of the KFTC's investigation through econometric methodology.[16] However, there are few quantitative analyses of the Korean CD market scandal compared to the numerous empirical studies addressing the LIBOR manipulation. To the best of our knowledge, this is the first study to empirically detect a possible collusion in the Korean CD market scandal.

IV. Discriminant Analysis

As we explain in Introduction, there exists a vast literature on empirical tests for collusion. We use a classical discriminant analysis, the mixture regression model, for our test. We use the methodology because the nature of our data fits quite well for the mixture regression framework. As we explain in Introduction, there are basically four different approaches in the collusion detection literature. Among those four, the first three approaches need more data than we could collect on the Korean CD market.

Thus, our empirical test for collusion takes the fourth approach, 'tests of whether firm behavior is more consistent with collusion than with competition,' referring to Harrington (2008). This approach basically compares which regime explains the firms' observed behavior better, collusion or competition. Thus, the mixture of two regression models—one for collusion and the other for competition—would be a natural setup for the comparison. What the mixture regression analysis does is to compute the probabilities of a firm's behavior in collusion and in competition respectively, and to compare those probabilities. The mixture regression methodology, though it is not a totally new method, seems the best for our test.[17] It should be noted, however, that we did not mechanically apply the classical mixture regression model to our data. To incorporate the heterogeneity in the market, we have improved the model by adding a logistic process of various market characteristics affecting the regime switching probability, similar to Ellison (1994).

This paper proposes a discriminant analysis for econometrical identification of collusion in CD rates. Discriminant analysis is a statistical method separating a distribution from a mixture of distributions. Fisher (1936) first shapes up the method, and a number of procedures have been developed by Goldfeld and Quandt (1972), Kiefer (1980), Quandt and

Ramsey (1978) and Schmidt (1982), among others. Our method utilizes a mixture regression model to separate the colluded interest rate from the mixture distribution of colluded CD rates and competitive CD rates.

We consider the following CD rates equation in reduced form.

$$P_t = \beta' X_t + \delta I_t + u_t \tag{1}$$

Where P_t is the market average rate of CD at the period *t*, X_t is a set of variables explaining the CD rates, for example, bank bond yield, the size of money market funds, CD outstanding balance, etc. I_t is a dummy variable for collusion; 1 if it is colluded, 0 otherwise. u_t is the error term of the regression model. As the collusion dummy will raise the price, the coefficient δ is expected to have a positive value.

In reality, the collusion dummy, I_t, is not observed a priori. We assume that the unobservable I_t has the following binomial distribution:

$$I_t = 1 \quad \text{with probability} \quad \lambda_t \tag{2}$$

$$I_t = 0 \quad \text{with probability} \quad 1-\lambda_t \tag{3}$$

In equation (2), λ_t is the unconditional probability that the CD rate is colluded at period *t*. In discriminant analyses, this unconditional probability is often assumed to be a constant, as in Lee and Porter (1984). It is unrealistic, however, to assume the probability of $I_t = 1$ should be constant over time. For example, if the economy is in recession and the banks are desperate, collusions are more likely to occur. The more loans indexed to CD rates the banks make, the higher the possibility of collusions is. The volume of CD transactions might also change the possibility of collusion. To incorporate the possibility of heterogeneous unconditional probability of collusion, we specify λ_t as a function of multiple covariates. As λ_t is a probability function, we employ a logistic function similar to Ellison (1994).[18]

$$\lambda_t = \frac{e^{\alpha' Z_t}}{1+e^{\alpha' Z_t}} \tag{4}$$

where Z_t is a set of variables which affect the occurrence of collusion.

From equation (1) through (4), we can derive the likelihood function of the data generation process. The likelihood function of the regression model is as follows:

$$L = \Pi\left[f_1(P_t)\lambda_t + f_2(P_t)(1-\lambda_t)\right] \tag{5}$$

where $f_1(P_t)$ is the probability density function of the CD rate if the rate is actually a colluded one (i.e., $I_t = 1$), while $f_2(P_t)$ is the probability density function if the rate is competitive (i.e., $I_t = 0$). We assume that the CD rate follows a normal distribution as follows[19]:

$$f_1(P_t) = \frac{1}{\sqrt{2\pi}\sigma} \exp\{-\frac{1}{2\sigma^2}(P_t - \beta' X_t - \delta)^2\} \quad (6)$$

$$f_2(P_t) = \frac{1}{\sqrt{2\pi}\sigma} \exp\{-\frac{1}{2\sigma^2}(P_t - \beta' X_t)^2\} \quad (7)$$

After substituting equations (6) and (7) into equation (5), the parameters in the regression model, β, α and σ^2 are estimated by maximizing the likelihood function (5).[20] With the estimates of the parameters, we can calculate the estimated conditional probabilities, $\Pr(I_t = 1 | P_t)$ and $\Pr(I_t = 0 | P_t)$, for each observation. By comparing the two conditional probabilities, we can decide to which distribution the observation belongs. Lee and Porter (1984) show that the simplest rule is the best: if $\Pr(I_t = 1 | P_t) > \Pr(I_t = 0 | P_t)$, then the rate is discriminated as colluded, and if $\Pr(I_t = 1 | P_t) < \Pr(I_t = 0 | P_t)$ then the rate is discriminated as competitive.[21] As the sum of the two conditional probabilities must be 1, the rule can be also stated as: the rate is discriminated as colluded if $\Pr(I_t = 1 | P_t) > 0.5$.

If we have prior information on the collusion dummy (I_t), we can employ a modified discriminant analysis to utilize the information. The 'switching regression with imperfect sample separation information' applied on the US railroad cartel from 1880 to 1886 by Porter (1983), Lee and Porter (1984), and Ellison (1994) would be a good alternative. However, unlike the US railroad cartel, collusion was never officially declared by the authority in the Korean CD market, although it was suspected and investigated. If we impose wrong prior information on the collusion dummy, the estimation results would be distorted. More specifically, if we pre-mark the suspected collusion period in the likelihood function, the estimated probability of collusion for that period could be amplified. To be impartial about the suspected collusion, we employ a general mixture model without imposing any prior information on the collusion period.

V. Data

The data are obtained from KOFIA, the BOK, and Statistics Korea. The market average CD rate (the last quoted yield on CDs issued by nationwide banks) is used as the dependent variable in the main equation (1). Each bank's CD issuance rates are more suitable for the dependent variable. However, the data are available only from October 23, 2012, onward that do not cover the whole suspected collusion period. The last quoted yield on CDs seems to be suitable for the alternative because it is not only the average of reported CD rates but also the reference rate in CD issuance markets. Indeed, as shown in Figure 2, there is little difference between the market average CD rates and the banks' CD issuance rates over the period.

The explanatory variables are the yields on three-month bank bonds with AAA credit rating, the size of money market funds, and the CD outstanding balance. In addition, a dummy variable is included, indicating before and after the implementation of the financial administrative guidance to revive the CD issuance markets; 1 for the period before August 1, 2012, and 0 otherwise. Including this dummy variable in the main equation, we can control the structural break caused by the enforcement of the administrative guidance. In the lambda equation (4), the set of variables affecting the occurrence of collusion consists of the outstanding balance of enterprise loans made by commercial and specialized banks,[22] the index of all industry production, and the volume of CD transactions. The logarithmic transformation is applied to the level variables. The data are daily time-series[23] and cover the period from January 1, 2009, to May 23, 2019, providing 2,579 observations in total. Table 1 shows the descriptive statistics of the variables, and Table 2 presents the augmented Dickey–Fuller (ADF) test results. For all the variables except bank bond yields, the test rejects the unit root null hypothesis at least at the 10% level.

VI. Empirical Results

In this section, we present our estimation results of the general mixture regression described in Section IV, along with the posterior probabilities of collusion. Table 3 shows the maximum likelihood estimation result. First of all, δ, indicating the possible collusion effect

estimate, is 0.279 and statistically significant at the 1% level. This means that CD rates over the collusion periods are 0.279%p higher than those over the competitive periods. The estimated collusion effect is slightly higher than 0.2%p, which was the groundless but general conjecture of the CD rate increase by the suspected collusion.[24]

Second, CD rates increase by 0.984%p as the bank bond yields increase by 1%p, and it is statistically significant at the 1% level. This result implies that the two variables move closely together over the sample period. In consideration of this correlation, we also estimated the equation of the spread - CD rate minus bank bond yield and found that the result is similar as given in Appendix 1. Third, a 1% increase in the size of money market funds leads to a 0.027%p decrease in CD rates, although the significance level is relatively low. There is a negative relationship because the money market funds are a major source of demand for CDs. An increase in demand for CDs leads to an increase in CD price and a decrease in CD rates.

Fourth, the estimate of the regulation dummy coefficient is 0.067, which means that the CD rates have decreased by 0.067%p after the implementation of the financial administrative guidance. This positive estimate is consistent with the banks' contention that CD rates remained at a high level because the volume of CDs issuances and transactions had plummeted, as explained in Section III. In accordance with the arguments given above, *ceteris paribus*, the CD rates should decrease after enforcing the financial guidance that encourages banks to issue more CDs. Fifth, the coefficient of the CD outstanding balance is significantly negative. This supports the banks' claim that the stickiness of the CD rates occurred as a result of a drastic decrease in the amount of CDs issued and traded in the markets after the implementation of the LDR regulation.

The estimation results of equation (4) for λ_t, the logistic probability of the suspected collusion periods, seem quite reasonable. The coefficient of the outstanding balance of enterprise loans is significantly positive. If the banks' lending rates on loans to enterprises are indexed to CD rates, the banks are motivated to keep their CD rates high when the banks hold a large amount of loans to enterprises. In contrast, the coefficient of the index of all industry production is negative. This result means that an economic recession causes banks to seek higher profit margins, thus the probability of collusion increases. Moreover, the coefficient of the volume of CD transactions is significantly negative. It appears that the banks have higher incentives to collude on CD rates under the circumstance of low volumes of CD transactions. This finding supports Kang's (2006), BOK's (2017), and Lee and Kim's (2010) argument that

although a small number of banks make a change in the issuance rates on CDs, its impact on the last quoted yields on CDs would be significant when the market is not active.

Figure 3 shows the posterior probabilities over the period of our analysis. As mentioned in Section IV, when the posterior probability is higher than 0.5, we could conclude that those are in the period of plausible collusion. Out of 2,579 days, 163 days are discriminated as possible collusion. As seen in the graph, the years classified as possible collusion are 2009, 2010, 2012, and 2014. The detailed discriminated periods are shown in the first column of Table 4. As shown in Figure 3, most days in the collusion-suspected period (January 1, 2009–January 27, 2016) are not discriminated as collusion. Only 163 days out of 1,765 business days are sporadically discriminated as colluded. We need to take a closer look at those discriminated dates.

Here, we need to note that the dependent variable in our CD rate equation is not the CD issuance rate but the last quoted yield on CDs due to the lack of data. Thus, the above results do not indicate that CD issuance rates were colluded exactly during the discriminated periods listed in the first column of Table 4. It would be reasonable to interpret that the informative contents for banks' collusion were reflected in the last quoted yields on CDs during those periods. For this reason, we should check on actual CD issuance dates and see if each matches with the dates discriminated as colluded. The second column of Table 4 presents the dates on which the banks actually issued 3-month CDs. The banks did not issue the CDs on almost all dates discriminated as colluded in our empirical results. For example, 72 days during the period from January 2, 2009, to April 24, 2009, are discriminated as the collusion dates. However, during those periods, the banks issued CDs only on three dates (January 19, February 27, and April 24). Such a discrepancy can also be seen in 2010, 2012, and 2014. In other words, the CDs were not issued on the dates discriminated by our model.

To sum up, the periods classified as possible collusion are only a small portion of the whole sample, as shown in Figure 3. Moreover, CDs were not actually issued by the banks for most of the dates discriminated as colluded, as seen in Table 4. These could be interpreted that it looks as though the CD rates had been colluded on the discriminated dates, although this rigidity of the CD rates was actually caused by the lack of issuance of CDs during the period. As noted earlier, BOK (2018b, 2019) points out that there is a tendency for the securities companies reporting CD rates to KOFIA to adjust their submitted CD rates only when the CDs

are issued or traded in the markets. Thus, it is highly likely that the securities companies report the previously released CD rate to KOFIA on the day any CDs are not issued. Overall, our findings reveal that it is highly likely that the stickiness of the CD rates was induced by the depressed CD market conditions rather than collusion.

We present some simple statistical results to support our findings. First, we compare the CD rates and the 3-month Monetary Stabilization Bond (MSB) yields.[25] BOK issues MSBs, which are generally regarded as risk-free bonds in Korea, along with Korean government bonds. Figure 4 plots the spreads between the CD rates and the MSB yields. If banks colluded to maintain a high level of CD rates, the spread would significantly widen more in the period of potential collusion (the shaded area in Figure 4) than in other periods. However, as seen in Figure 4, no apparent differences exist across the periods. Instead, the spread increases dramatically due to the global financial crisis starting around 2008 but then decreases to around 0 in September 2010 and moves within a similar range afterward.

Second, we conduct the Bai and Perron (2003) test for multiple structural breaks, which determines break dates endogenously. We use a time series of both the daily CD rates and the spread between CD rates and BOK base rates from January 1, 2000, to May 23, 2019. The reason for testing on the series of the spreads is that the changes of the BOK base rates usually influence the CD rates. Indeed, one reason for the sharp decrease in CD rates after 2009 would be the decrease in the BOK base rate over that period. Table 5 presents the results of the Bai and Perron (2003) test. We find four breaks for both the spreads and the CD rates. In the case of the spreads, it is interesting that the third break date (April 9, 2010) was around December 2009, when the LDR regulation was proposed. Moreover, the fourth break date (February 25, 2013) was around August 2012, when the financial administrative guidance was implemented. These break dates are closer to the dates of implementing the regulations and the administrative guidance than the related dates of potential collusion.

VII. Conclusion

This paper econometrically evaluates if there occurred a collusion in the CD market during the period of the KFTC's investigation. We employ a discriminant analysis to estimate

the posterior probability of collusion in the CD market. More specifically, we propose a general mixture regression model to discriminate the collusion period from the competitive period without utilizing any prior switching information. We apply our method to Korean CD market data from January 1, 2009 to May 23, 2019 and forecast the probability of collusion for each day.

We find, through our discriminant analysis, only a small portion—163 days out of 2,579 days—of the whole sample is classified as possible collusion. We also find that the banks did not issue the CDs on almost all dates discriminated as colluded in our empirical results. The CD market was so stagnant that the issuance of CDs sharply decreased during the period of potential collusion. The market average rates were calculated and released daily even when no bank issued CDs. In light of our finding that the dates on which the banks did not issue CDs were discriminated as colluded, it seems that the observed rigidity of the CD rates was actually caused by the lack of CD issuance during the period. Overall, our results reveal that it is highly likely that the stickiness of the CD rates was induced by the depressed CDs market conditions rather than a collusion.

From a broader perspective, our findings imply that the market conditions should be considered when detecting collusion in a financial market where the quoted interest rates are calculated and released. In the depressed market, the issuers would tend to anchor the issuance rates at the released market average rates because there are not enough market data on which to base the accurate issuance rates. Thus, the released market average rates might look like the focal point for tacit collusion, even though it is not actually the case.

Our main contribution is to empirically detect a possible collusion for the Korean CD market scandal for the first time, to the best of our knowledge, and to provide evidence to support the KFTC's conclusion and the banks' claim that the rigidity of the CD rates was not due to collusion. The limitation of this study is that we used the market average CD rates as a variable in the discriminant analysis instead of the banks' CD issuance rates due to data availability.

[1] The Korea Financial Investment Association (KOFIA) estimates the daily market average rate using the last quoted yield on CDs.

[2] https://www.cftc.gov/sites/default/files/idc/groups/public/@lrenforcementactions/documents/legalpleading/enfbarclaysorder062712.pdf
https://www.justice.gov/criminal-fraud/file/933756/download
https://www.fca.org.uk/publication/final-notices/barclays-jun12.pdf

[3] A more detailed explanation on the Korean CD market is available from the Bank of Korea (BOK; 2017, 2018a).

[4] The CD was first introduced in Korea in 1974 but discontinued in 1977 due to low demand. The reintroduction in 1978 also failed and discontinued in 1981. Afterwards, it was successfully reintroduced in 1984.

[5] In 1984, there were quite a few limitations imposed on CD issuance, such as the ceiling rates (11% annual rate), maturity period (90-day to 180-day), and minimum CD face value (KRW 100 million). Since then, the restrictions kept modified, and as of July 7, 1997, only the provision of the minimum maturity period (30-day) regulation remained. (Regulation on Conditions of Issuing CDs, Monetary Policy Board, BOK).

[6] (Proposed) Standards on Yield Reporting for Disclosure of Last Quoted Yield, KOFIA Regulations.

[7] Park, Jun and Lee (2015) show that the LDR at the end of 2008 in Korea was around 135.8%.

[8] Financial Services Commission, Regulation on Banks' Loan-to-Deposit Ratios, Press Release (26 March 2010).

[9] BOK (2017) and Lee and Kim (2010) discuss that if some banks issue CDs with high interest rates, the last quoted yield on CDs can fluctuate drastically under the circumstance of low volumes of issuance and transactions in CDs. Similarly, Kang (2006) explains that the effect of an increase in the issuance rates of CDs depends on the market conditions. When the secondary market is not active, if even a few banks increase their issuance rates of CDs, the reference rates on CDs could be affected so that banks' lending rates on loans could be eventually increased.

[10] The results of the KFTC's investigation are reported in 'KFTC Review Report 2016-Ka-Chong-0689.'

[11] BOK (2018b, 2019) points out that there is a tendency for the securities companies reporting the CD rates to adjust their submitted rates only when the 91-day CDs are issued or traded in the markets.

[12] These two types of CD rates (the last quoted yields on CDs) have been separately released by KOFIA.

[13] Chosun Daily (Chosun Ilbo), August 1st 2012.
(http://biz.chosun.com/site/data/html_dir/2012/08/01/2012080100636.html)

[14] As of May 2012, the amount of household loans linked to CD rates was approximately KRW 315.6 trillion, which accounted for 49.1% of the total household loans (Korea Finance Consumer Federation, Press Release No. 315).

[15] For more details, see Noh and Kim (2012) and Lee and Lee (2014). Both argue that the issuance of CDs drastically decreased due to the LDR regulation. Especially, Noh and Kim (2012) provide some

statistical evidence to support the banks' views. They demonstrate the series of term spread of CD rates (4m–3m, 3m–2m) and present yield curves consisting of the actual transaction rates and the quotes. They point out that there is no unusual change or distortion in the trend of series. They insist that CDs should be included again in calculating the LDR to revitalize the CD markets.

[16] There is no quantitative analysis in the KFTC Review Report.

[17] We are grateful for the insightful challenge by an anonymous referee about our method being quite an old technique.

[18] Unlike Ellison (1994), we do not use a Markov structure for the logit function.

[19] We have also applied a logarithmic transformation to all the variables, assuming the CD rate follows a log-normal distribution. The empirical results are quite similar no matter which distributional assumption is applied.

[20] We use GAUSS and R for the numerical maximization.

[21] Lee and Porter (1984, pp 400–401).

[22] It is more proper to use the time series of loans indexed to CDs rates as the variable. However, those are not publicly available, thus we collect the outstanding balance of total loans instead. Among others, we use enterprise loans data in light of the fact that the proportion of household loans indexed to CDs rates have been drastically reduced relative to enterprise loans indexed to CDs rates as given by Jung (2015).

[23] Monthly data are also used for some variables—CD outstanding balance, volume of CD transactions, index of all industry production, and outstanding balance of enterprise loans—because the daily data are not available. Concerning a nonsynchronous data problem, equations (1) and (4) are also estimated using the monthly data. The estimation results are not much different from the daily data results, except that the statistical significance of some estimates are lower probably due to the reduced sample size. We are grateful to an anonymous referee for suggesting this line of extension.

[24] Chosun Daily (Chosun Ilbo), July 20, 2012. "CD rates did not drop – The possibility that households and corporates lost about 620 billion won per year (in Korean)" (https://biz.chosun.com/site/data/html_dir/2012/07/20/2012072000317.html)

[25] Fouquau and Spieser (2015) also investigate the behavior of LIBOR by comparing LIBOR and the yields on the US Treasury Bills across the periods.

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Appendix

Appendix 1: Maximum Likelihood Estimation Result of Equation of Spread between CD rate and Bank Bond Yield

Variable	Main Equation	Lambda Equation
Constant	0.3422*** (0.0998)	−72.3321** (31.5222)
log(Size of Money Market Funds)	0.0089 (0.0086)	
dum_201208	0.062*** (0.0065)	
log(CD Outstanding Balance)	−0.0415*** (0.0061)	
δ	0.2756*** (0.007)	
σ^2	0.005*** (0.0002)	
log(Outstanding Balance of Enterprise loans)		11.6663*** (2.7763)
Index of All Industry Production		−0.6766*** (0.0662)
log(Volume of CD Transactions)		−2.2492*** (0.2205)

Notes: ** indicates a significance at the 5% level and *** at the 1% level.
Standard errors are in parentheses.

<Table 1> Descriptive Statistics

Variable	N	Mean	Standard Deviation	Min	Max
CD Rates	2579	2.347953	0.706471	1.34	3.93
Bank Bond Yields	2579	2.278647	0.67973	1.253	3.73
Size of Money Market Funds	2579	944761	225053	513723	1380038
CD Outstanding Balance	2579	41982.66	28116.63	20579.6	120911.4
Volume of CD Transactions	2579	27737.78	16083.78	4666.5	102987.5
Index of All Industry Production	2579	97.97487	6.681257	79.8	108.3
Outstanding Balance of Enterprise Loans	2579	676285.9	113613.4	514828.2	886478.4

Notes: CD rates and Bank Bond Yields are measured in percent per annum. Size of MMF and Volume of CD Transactions are measured in hundreds of millions of KRW. CD Outstanding Balance and Outstanding Balance of Enterprise Loans are measured in billions of KRW.

<Table 2> Augmented Dickey–Fuller (ADF) Test Result

Variable	ADF Test Statistic	p-value
CDs Rates	–2.3460**	0.0184
Bank Bond Yields	–1.2571	0.1925
log(Size of Money Market Funds)	–3.2833*	0.0692
log(CD Outstanding Balance)	–2.2281**	0.025
log(Outstanding Balance of Enterprise Loans)	–3.2812*	0.0696
Index of All Industry Production	–5.2484***	0.0001
log(Volume of CD Transactions)	–6.1574***	0

Notes: * indicates a significance at the 10% level, ** at the 5% level, and *** at the 1% level.

<Table 3> Maximum Likelihood Estimation Result of Equations (1) and (4)

Variable	Main Equation (1)	Logistic Equation (4)
Constant	0.8592*** (0.224)	−83.4847*** (31.9576)
Bank Bond Yields	0.9844*** (0.0065)	
log(Size of Money Market Funds)	-0.0268* (0.0159)	
dum_201208	0.0673*** (0.0073)	
log(CD Outstanding Balance)	−0.0408*** (0.0061)	
δ	0.2791*** (0.0072)	
σ^2	0.005*** (0.0002)	
log(Outstanding Balance of Enterprise loans)		12.7559*** (2.831)
Index of All Industry Production		−0.7049*** (0.0686)
log(Volume of CD Transactions)		−2.3229*** (0.2261)

Notes: * indicates a significance at the 10% level and *** at the 1% level.
Standard errors are in parentheses.

<Table 4> Comparison of Discriminated Dates and CDs Issuance Dates

Discriminated Date			CDs Issuance Date	
Year	Date	The Number of Business Days	Month	Day
2009	Jan. 2 ~ Mar. 26	58	Jan. Feb.	19 27
	Apr. 7 ~ Apr. 24	14	Apr. May June July Aug.	24, 28, 29 11, 13, 19, 25, 26, 27, 28, 29 1, 2, 5, 8, 17, 23, 25 2, 3, 10, 14, 15, 30, 31 4
	Oct. 14 ~ Oct. 22	7	Oct.	12, 23, 28, 30
	Nov. 17 ~ Nov. 19	3	Nov.	3, 4, 10, 13, 16, 18, 27
2010	Mar. 12 ~Apr. 7	19	Mar., Apr.	-
2012	July 10 ~ July 11	2	Jan. Feb. Mar. Apr. July Aug. Sep. Oct. Nov. Dec.	12, 17, 20, 30 1, 14, 17, 22 6 20 - 21, 22, 28, 30, 31 10, 18, 19, 20, 26 2, 4, 15, 17, 18, 23, 24, 26 5, 6, 14, 15, 28 11
	July 17 ~ Sep. 25	50		
	Oct. 10	1		
2014	Aug. 1 ~ Aug. 13	9	June July Aug.	12, 13 - 26
Total		163		

Notes: Discriminated dates are the dates when the estimated probability of collusion is higher than 0.5. The sources of CD issuance dates are as follows.

(1) Apr. 2009 ~ Aug. 2009: The KFTC Review Report. Dates on which the banks under the KFTC's investigation issued 3-month CDs.

(2) Jan. 12, 2012 ~ Oct. 22, 2012: The Korea Securities Depository. Dates on which nationwide banks and specialized banks issued 3-month CDs. Data for individual banks are not available for this period. The six banks under the KFTC's investigation consist of five nationwide banks and one specialized bank. (Only Oct. 15, 2012 is cited from KFTC Review Report.)

(3) Oct. 23, 2012 ~ Dec. 31, 2012 and June 2014 ~Aug. 2014: The Korea Financial Investment Association (KOFIA). Dates on which the banks under the KFTC's investigation issued 3-month CDs.

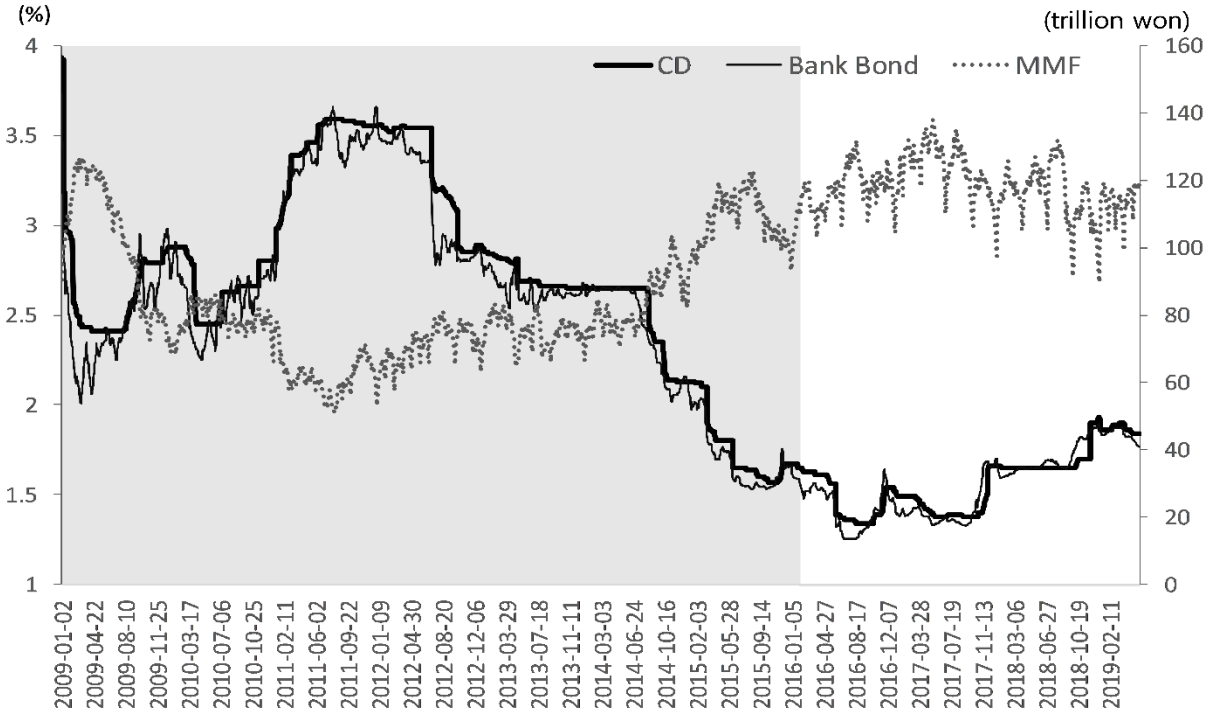
(4) The others: Data are not publicly available, thus we extract the dates from the details of CD transactions released by KOFIA. We select the dates when the CDs having time to maturity of 3 months were transacted and issued on the same date. (Only Jan. 19, 2009, is cited from the KFTC Review Report.)

<Table 5> Bai and Perron (2003) Test for Structural Breaks

Variable	Max. Breaks	Break Dates Identified	LWZ Criterion Value
Spreads between CD rates and BOK base rates	5	<u>Four</u> Dec. 9, 2002 Jan. 16, 2007 Apr. 9, 2010 Feb. 25, 2013	−2.3064
	2	<u>Two</u> Dec. 9, 2002 July 12, 2012	−2.24713
CD rates	5	<u>Four</u> Jan. 10, 2003 Feb. 9, 2006 Dec. 23, 2008 Oct. 15, 2014	−1.20399
	2	<u>Two</u> Dec. 23, 2008 Oct. 15, 2014	−0.57005

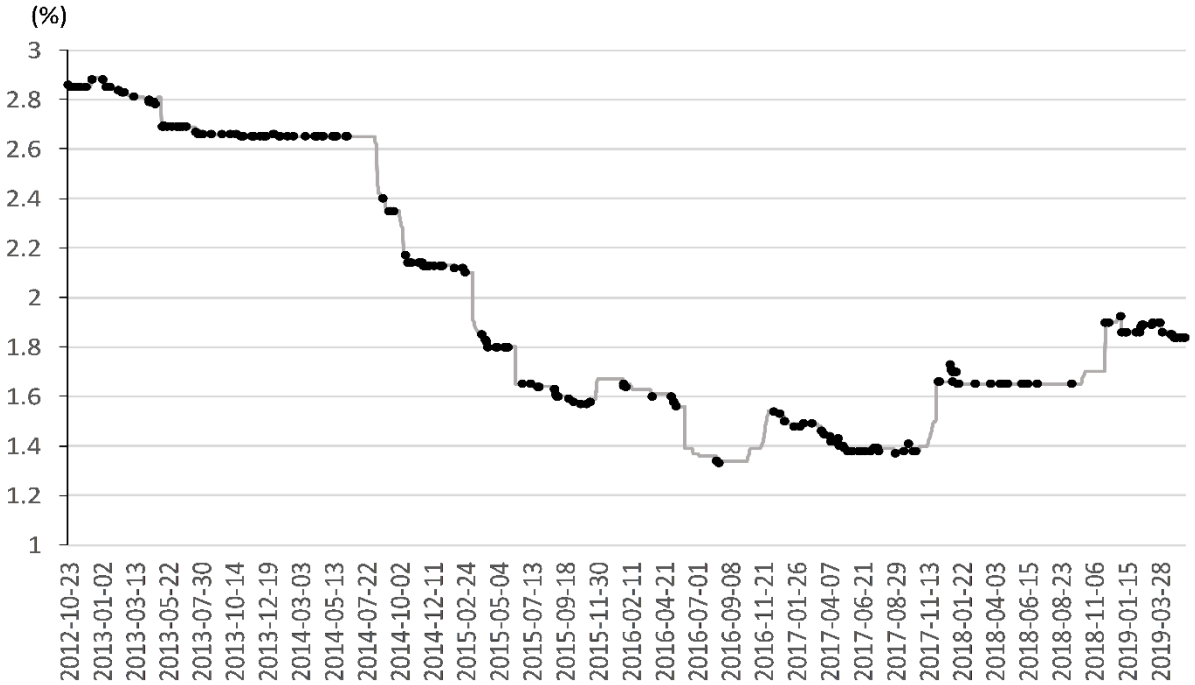
Notes: Liu, Wu, and Zidek's (1997) criterion is the modified Schwarz' criterion.

<Figure 1> Last Quoted Yields on CDs (91-day) and Bank Bond Yields (3m, Mark-to-Market Benchmark)



Notes: The shaded area represents the KFTC's investigation period. The left vertical axis is for the two yields, and the right vertical axis is for the size of MMFs.

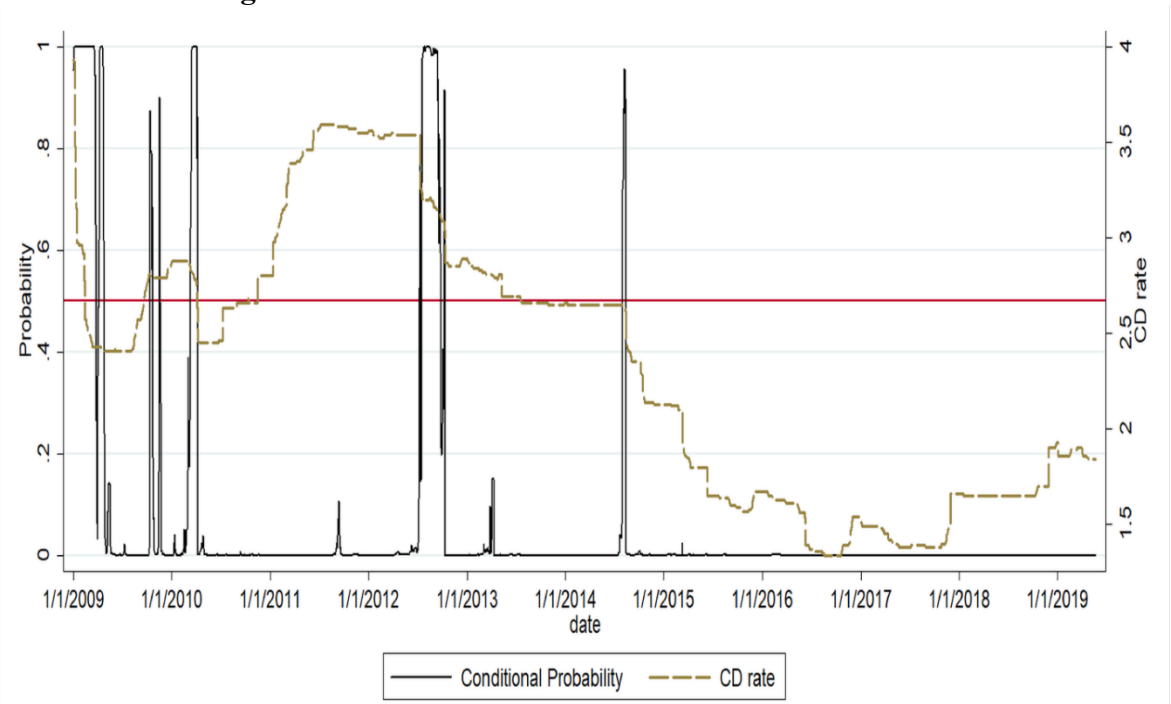
<Figure 2> Market Average CD rates and Six Banks' CD Issuance Rates



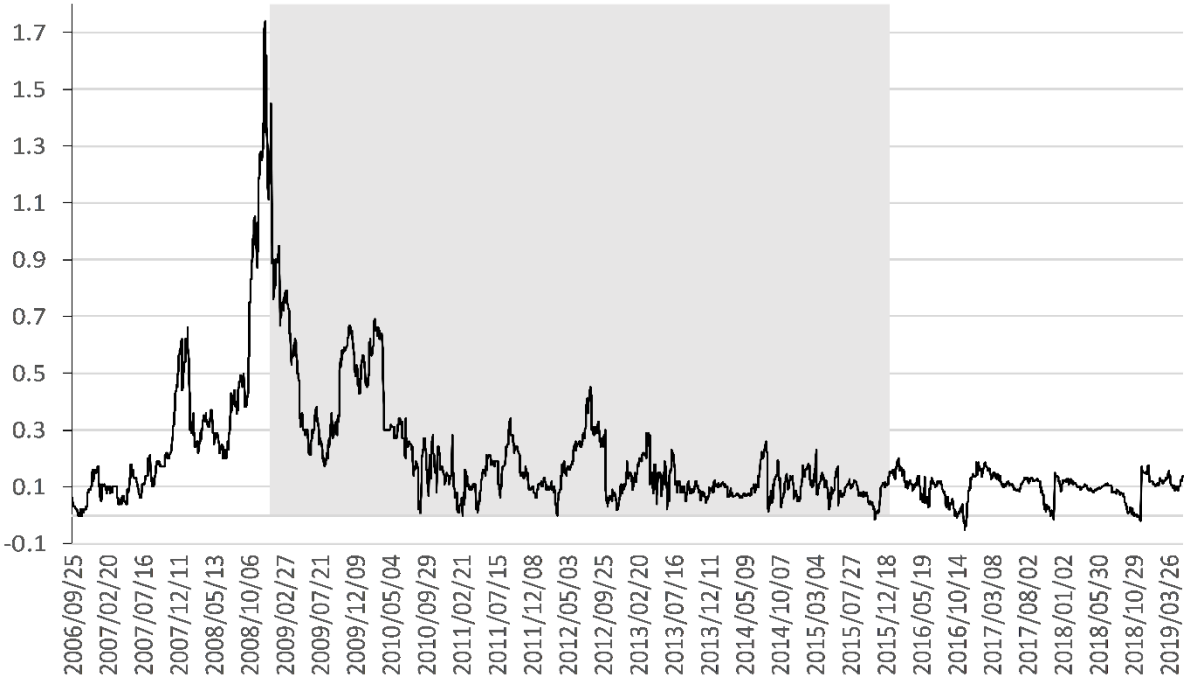
Notes: The solid line in the graph represents the market average CD rates, while the dots represent the

issuance rates on CDs (3-month) issued by the six banks under the KFTC's investigation.

<Figure 3> Posterior Probabilities and the Market CD rates



<Figure 4> Spreads between CD Rates and MSB Yields (3m)



Notes: The shaded area represents the KFTC's investigation period.