Identifying the Effect of Bank of Japan's Liquidity Facilities: The Case of CP Operations During Financial Turmoil*

Yasuo Hirose† Shinsuke Ohyama‡

Monetary Affairs Department, Bank of Japan

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Abstract

To what extent did the Bank of Japan's liquidity facilities for corporate financing reduce commercial paper (CP) issue-rates in Japan? To answer this question, we propose a simple structural model that illustrates the market for the CP operations and their effects on the CP primary market. Based on the structural model, we measure the effects of the CP operations as differences between the actual rates in the primary market and the counterfactual rates without the operations, and decompose the effects into three factors. We apply our model to identifying effects of CP operations from October 2008 to May 2009, including the period after the Bank of Japan introduced the outright purchase of CP and its special funds-supplying operation accepting CPs as collateral in addition to the CP repo operation. Our results suggest that the CP repo operation and the outright purchase of CP had remarkable effects initially, however, later their effects were subdued, and that effects of the special funds-supplying operation were substantial and persistent from January to April 2009.

Keywords: Commercial paper; Corporate finance; Market operations; Monetary policy

JEL classification: E50; E52; E58; G10

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†E-mail: yasuo.hirose@boj.or.jp

‡E-mail: shinsuke.ooyama@boj.or.jp

1 Introduction

The current financial turmoil, triggered by the U.S. subprime mortgage problem, developed into a global financial crisis during the autumn of 2008. Central banks in major economies responded to this situation by significantly reducing policy interest rates and by expanding the tools of money market operations to undertake aggressive liquidity provisions in financial markets. The Bank of Japan (BoJ) was no exception.

Since autumn 2008, the BoJ has implemented monetary policy measures in three areas: reductions in the policy interest rate, measures to ensure stability in financial markets, and steps to facilitate corporate financing. This paper concerns the latter.

To facilitate corporate financing, the BoJ has taken five actions: (1) increase in the frequency and size of its commercial paper (CP) repo operations, (2) expansion in the range of corporate debt as eligible collateral, (3) introduction and expansion of the special funds-supplying operation,[1] (4) introduction of outright purchases of CP, and (5) introduction of outright purchases of corporate bonds.

Among these five actions, this paper focuses on three tools that improve functioning of the CP primary market in Japan: the CP repo operation, the special funds-supplying operations, and the outright purchases of CP (we hereafter refer to these three as "CP operations"). This paper proposes a new approach to identify the effects of CP operations in suppressing the upward pressure on CP rates in the primary market during the periods of financial turmoil.

Before detailing our approach, we will mention related studies to evaluate the effects of liquidity facilities on the functioning of financial markets. Although few researchers study the action taken by the BoJ,[2] many have examined liquidity facilities created by the U.S. Federal Reserve based on a time-series econometrics analysis. For instance, McAndrews, Sarkar, and Wang (2008), and Taylor and Williams (2009), investigate the effect of the Fed's Term Auction Facility (TAF) by regressing various indicators of counterparty risk and TAF dummy variables on the spreads between the London Inter-Bank Offered Rates (LIBOR) and the overnight indexed swap (OIS) rates in the U.S. dollar.[3] Those authors evaluate the effect of the TAF

[1] The special funds-supplying operations to facilitate corporate financing is the funds-supplying operations by which the BoJ extends loans to its counterparties for an unlimited amount against the value of corporate debt submitted to the BoJ as collateral by them at an interest rate equivalent to the target for the uncollateralized overnight call rate. We estimate the amount of liquidity provision through this operation against CP, by multiplying the total amount with the proportion of CP to all corporate debt submitted to the BoJ. We consider the estimated amount of liquidity provision against CP as one of the CP operations.

[2] Bank of Japan (2009) provides quantitative assessments of the influences of the CP operations on CP issue-rates using a time-series econometric method.

[3] Using a similar method, Wu (2008) estimates the effect of Fed's other facilities such as the Term Securities Lending Facility (TSLF) and Primary Dealer Credit Facility (PDCF). Another related approach is found in Christensen, Lopez, and Rudebusch (2009). They estimate an affine arbitrage-free term structure representation

by the estimated coefficients on the TAF dummies. The strength of such an approach is that estimates are based on reduced form equations with minimum structural assumptions on the model; its weakness is that the results might vary, depending on the data sets, sample periods, or econometric methods that researchers employ.[4]

In this paper, we propose a structural model encompassing the BoJ's CP operations and Japanese CP primary markets. The model characterizes those two markets as highly integrated, whereas the CP primary market is segmented from other markets during the financial turmoil.[5] Based on our structural model, we measure the effects of CP operations as differences between the actual issue-rates observed in the CP primary market with the CP operations implemented and the counterfactual issue-rates that would prevail without such operations. The innovation in our structural model is in identifying the unobservable latter rates from publicly available data on CP operations and CP rates in the primary market under several assumptions. Our identification takes the following three steps.

The first step is to identify bank's demand curve for the fund in the CP operation market from observables. Specifically, let us begin with the knowledge of the amount of offer, competitive bid, and resulting successful bid rate in the CP operation. From this knowledge, we first know that the amount of bid should lie on the banks' demand curve for the fund at the base rate. Second, since the amount of offer is determined by the BoJ exogenously, the successful bid rate at this amount of offer should be also on the banks' demand curve for the fund; namely, we identify another point on the banks' demand curve. Taking advantage of the fact that the amounts of bid and offer are close, we can connect those two points and obtain the banks' demand curve in the CP operation.

Second, armed with the banks's linear demand function obtained in the first step, we extrapolate the bid rate when the quantity is zero. Notice that the point corresponds to the situation in which the BoJ does not undertake any CP operations. In this way, we can pin down the counterfactual bid rate assuming no CP operations.

Finally, as the third step, we assume that CP issue-rates are proportional to CP bid rates. Then, we obtain the counterfactual issue-rates that correspond to the counterfactual bid rates identified in the second step. Since we know the actual issue-rates observed in the CP primary market with the CP operations implemented, we can calculate the effects of the CP operations

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of Treasury yields, the yields on bonds issued by financial institutions, and term LIBOR rates, and then conduct hypothesis testing and counterfactual analysis associated with the introduction of the Fed's liquidity facilities.

[4] While both McAndrews, Sarkar, and Wang (2008) and Taylor and Williams (2009) exploit a similar time-series approach, the former paper suggests that the TAF has statistically significant effects, but the latter does not.

[5] The basic idea is shared with the framework in Hirose, Ohyama, and Taniguchi (2009), who evaluate to what extent longer-term money market operations can reduce the term-end premium in the money market prior to the calendar and fiscal year-ends.

in our definition.

Our structural model has two advantages in measuring the effects of CP operations on the CP issue-rate: structural interpretation of the effects and the independence of results from the econometric method.

The first advantage is that our model can decompose the effects of the CP operations into three factors: (1) the amount of liquidity offered in the operations, (2) the steepness of banks' demand curve for the BoJ's fund-supply through the operations, and (3) the proportion of liquidity supplied through CP operations that flows into the CP primary markets. Hence, we interpret the development of CP operations' effects structurally, by referring to those factors.

Regarding the second advantage, our model yields the same results as long as we use the same data, because our model does not employ time-series econometric methods. Unlike a time-series econometric approach, our structural approach enables us to evaluate effects cross-sectionally, period by period. In this respect, we can examine the effect of the operations with a relatively small number of samples, whereas time-series econometric methods needs enough numbers of samples at the risk of structural changes in the data-generating process.

Based on our model, this paper empirically investigates the effects of the CP operations conducted by the BoJ in the face of the recent financial turmoil; from October 2008 to May 2009.[6] In October 2008, the BoJ initially responded by expanding CP repo operations, and followed in January 2009 with outright purchases of CP and the special funds-supplying operation. With a few additional assumptions, we extend our framework to identify the respective effects of these three operations simultaneously conducted since January 2009. According to our results, both the CP repo operation and the outright purchase of CP had reduced CP issue-rates in the primary market remarkably from October 2008 to January 2009. Our results also indicate that the special funds-supplying operation had substantially reduced CP issue-rates in the primary market from January to April 2009.

This paper is organized as follows. The next section presents our analytical framework to identify the effect of CP operations. Section 3 develops our structural model in order to identify the respective effects of three types of CP operations in response to the current financial turmoil. Section 4 explains the data used for our empirical analysis. In Section 5, based on our model, we identify the effects of CP operations from October 2008 to May 2009. Section 6 is the conclusion.

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[6] In an earlier version of this paper, we apply our model to the case of the CP repo operations from November 1998 to the first half of 2003. We consider these CP repo operations as an earlier effort to support the liquidity of financial institutions and foster improved conditions in financial markets, currently known as "credit-easing." Our results show a strong effect of the CP operations to reduce the CP issue-rates in the primary market, especially in the period from the end of 1998 to 2001 when banks and firms faced a severe funding condition.

2 Analytical Framework

In this paper, we measure the effects of CP operations as differences between the actual issue-rates observed in the CP primary market with the CP operations implemented and the counterfactual issue-rates that would prevail without such operations.[7] To this end, we need to identify the unobservable counterfactual rates of CPs in the primary market without the BoJ's CP operations. To overcome this problem, we propose a structural model that illustrates the market for the BoJ's CP operations and the Japanese CP primary markets. We assume those two markets are highly integrated, while the CP primary market is disconnected from other markets during financial turmoil. We show that, based on our model, we can identify the unobservables and can measure the effects of the CP operations from available data.

In this section, we consider a single measure of CP operations under competitive auction in order to illustrate our framework. We extend the model to analyze three types of CP operations that the BoJ had conducted during the current financial turmoil in Section 3.

2.1 The Model

The model consists of two markets: the market in which the BoJ's CP operation takes place and the primary market for CP. Figure 1 depicts the demand and supply relationship in each market in terms of quantity of liquidity against CPs and the interest-rate spread between market rates and the corresponding base rates. We will explain the details of each diagram in turn below.

First, in the market for the CP operations, banks "demand" liquidity against CPs submitted to the BoJ as collateral. Thus, in the left diagram of Figure 1, the downward-sloping demand curve represents banks' behavior. The central bank "supplies" liquidity through the operation by receiving CPs as collateral or by purchasing it. Thus, the supply curve characterizes the central bank's behavior. If there were no CP operations, the supply of liquidity is zero under any bid rates. Hence, the supply curve is vertical at the quantity zero. Suppose the central bank offers a certain amount of funds, which is characterized by the rightward shift in the supply curve to the amount denoted by "*offer*" in Figure 1. Banks decide whether to bid in the operation, referring the implied interest rate i_1', i.e., the counterfactual rate without the operation. They make bids to the operation, when i_1' is positive, that is, i_1' deviates from the corresponding base rate. The CP operation with successful bid is depicted as the intersection

[7] From a welfare perspective, the effect should be evaluated in terms of the changes in social surplus. In order to measure the social surplus, we need to identify both supply and demand curves in the CP primary market with and without the operations. It is, however, impossible to identify all of them from available data. In what follows, we assume that both demand and supply curves are linear, and that the implementation of the CP operation does not affect the slope and location of the supply curve in the CP primary market. Under these assumptions, the effect in our definition increases when the social surplus increases.

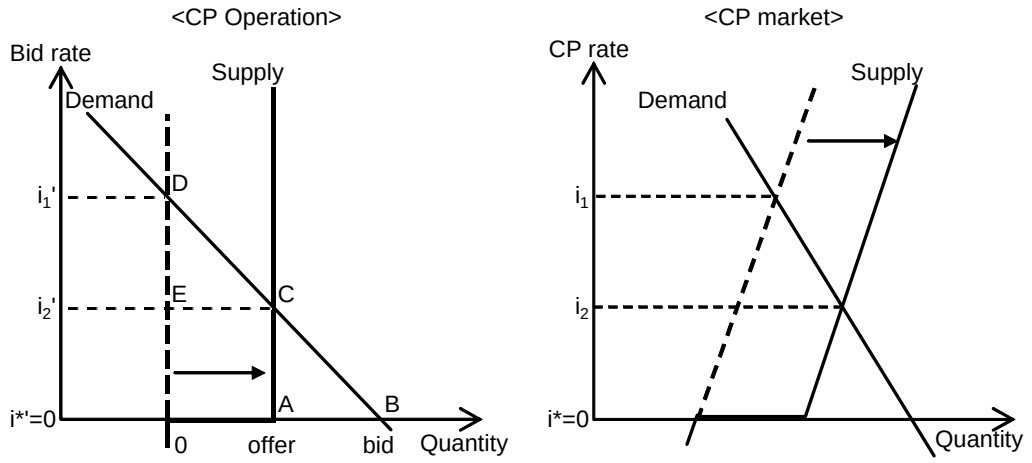

Figure 1: Supply and demand relationships in the market for CP operation and the CP primary market

of the supply and demand curve. The successful bid rate is i_2' which is lower than i_1'.[8] The amount of competitive bid, denoted by "*bid*," is equivalent to the intersection of the demand curve with the horizontal axis.

Second, we consider how the liquidity provision through CP operations affects supply and demand conditions in the CP primary market. In the CP primary market, firms demand funds while banks supply funds by underwriting CPs. For simplicity, we postulate that all banks in this market participate in the CP operation, and that the operation has no effect on the slope of the supply curve and the slope and position of the demand curve in the CP primary market. Suppose banks obtain liquidity through the CP operation. In this case, liquidity supplied in the CP primary market increases in parallel, since the banks obtain necessary funds to underwrite additional CP. Consequently, the CP issue-rate falls from i_1 to i_2, and the amount of CP issuance increases. According to our definition, we measure the effect of the CP operation by the difference $i_1 - i_2$.

Under the present framework, we evaluate the effect of the CP operation, i.e., $i_1 - i_2$ by identifying the unobservable i_1 in the following manner. Assuming that the demand curve in CP operation is linear, we can see from Figure 1 that $\triangle ABC \backsim \triangle ECD$ since the supply curve is vertical. Thus, the following relationship holds:

$$(bid - offer) : offer = i_2' : (i_1' - i_2'). \tag{1}$$

An additional assumption introduced here is that the CP rate in the primary market and the

[8] The decline in the interest rate owing to liquidity provision through money market operations is often referred to as "liquidity effect." The liquidity effects in the U.S. and Japan's money markets are empirically supported by a number of papers. See, for instance, Hamilton (1997), Carpenter and Demiralp (2006), Judson and Klee (2009), and Hayashi (2001).

bid rate of the CP operation have a linear relationship in terms of interest-rate spreads:

$$i = \gamma i'. \tag{2}$$

Then, we have:

$$i'_2 : (i'_1 - i'_2) = i_2 : (i_1 - i_2). \tag{3}$$

From equations (1) through (3), the effect of the CP operation is expressed as:

$$\begin{aligned} i_1 - i_2 &= i_2 \frac{offer}{bid - offer} \\ &= \gamma i'_2 \frac{offer}{bid - offer}. \end{aligned} \tag{4}$$

According to equation (4), given γ, the effect of the CP operation, $i_1 - i_2$, can be identified by the following observable data: the successful bid rate, the amount offered, and the amount of bid of the CP operation.[9] Parameterization of γ is discussed later in subsection 2.3.

2.2 The Case of Imperfect Pass-through to the CP Market

We postulated in the previous subsection that liquidity supplied through the CP operation leads to the increase in new issuance of CPs by the same amount. Such a situation is equivalent to the central bank directly purchasing CPs in the primary market. In this sense, we have assumed perfect pass-through from the CP operation to the CP primary market. In this subsection, we consider a more realistic case, where the degree of pass-through to the CP market is variable.

Figure 2 depicts the imperfect pass-through where only part of the liquidity supplied through the operation flows into the primary market. The rightward shift of the supply curve in the primary market is smaller than it would be with a perfect pass-through. In this case, the CP rate, i_3, observed in the market becomes higher than that in the preceding case, i_2. Under the assumption of the linearity in the model, the degree of pass-through, *ceteris paribus*, corresponds to the change in the CP rate. Let $\alpha \in [0, 1]$ denote a degree of pass-through, namely, the proportion of liquidity supplied through the CP operation that flows into the CP market and contributes to the increase in new issuance of CPs. Then, the effect of the CP operation on the issue-rate in the CP primary market is:

$$i_1 - i_3 = \alpha(i_1 - i_2). \tag{5}$$

Combining equation (5) with (4), the effect of the CP operation is expressed as:

$$i_1 - i_3 = \alpha\gamma i'_2 \frac{offer}{bid - offer}. \tag{6}$$

[9] The argument so far only consider the case where the amount of competitive bid exceeds the amount offered, and hence the amount of successful bid equal to the offer. However, it can be the case of the undersubscription where the amount of competitive bid does not reach the offer. For identification issues in such a case, see Appendix.

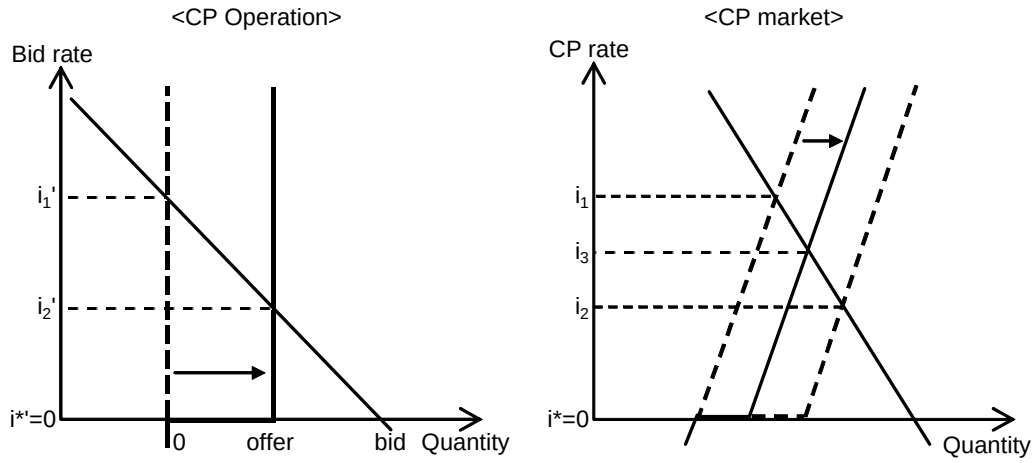

Figure 2: Imperfect pass-through to the CP primary market

Equation (6) shows that the effect of the CP operation is the product of the following three factors: α, *offer* and $i_2'/(bid-offer)$, with the assumption of the parameter γ being fixed. While the role of α is just described above, the other two factors, *offer* and $i_2'/(bid-offer)$, have the following structural interpretations.

First, regarding the factor of *offer*, we can see from Figure 1 and 2 that, given α, a larger shift of the amount offered gives rise to a larger shift of the supply curve in the CP primary market, and consequently a larger drop in the CP rate.

Second, the term $i_2'/(bid-offer)$ characterizes the slope of banks' demand curve for the CP operation. A steeper slope implies that banks' demand for liquidity through the CP operation is less elastic to changes of bid rates. In other words, banks whose funding positions are short recognize a more severe supply and demand condition in money markets and are willing to pay a higher cost to raise liquidity from the central bank.[10] As Figure 1 and 2 show, given the fixed amount offered, the steeper slope of the demand curve results in a larger difference between the actual bid rate and the counterfactual rate without the operation. In this model, we assume that CP rates in the primary market are proportional to bid rates in the CP operation. Thus, the difference between the observed CP rate in the primary market and the counterfactual CP rate without the operation, i.e., the effect of the operation, would also increase.

2.3 Specification of α and γ

To evaluate the effect of CP operations based on equation (6), we need to specify α and γ. We propose a specification that can be calculated from available data: the successful bid rate i_2' and the CP issue-rate i_3 in its primary market.

[10] Eisenschmidt, Hirsch, and Linzert (2009) analyze banks' bidding behavior in the ECB's operations using a micro data set. They find that banks tend to bid at significantly higher rates during the financial turmoil.

First, we consider how α is related to i_2' and i_3. We assume that $i_2' < i_3$.[11] Then, as argued below, α should be a decreasing function of i_3, given i_2', and α should be an increasing function of i_2', given i_3. When $\alpha = 1$, i.e., all liquidity supplied through the operation flows into the CP market, both the CP operation market and the CP primary market are considered completely integrated, and hence the interest-rate spread observed in both markets should move one-to-one, namely $i_3 = i_2 = \gamma i_2'$. On the other hand, consider the small upward deviation of i_3 from $\gamma i_2'$, i.e., $i_3 > \gamma i_2'$. Then, a decrease in i_2' or an increase in i_3 implies that both markets become less integrated, so that α decreases. Those considerations along with the range of $\alpha \in [0, 1]$ lead to a reasonable approximation of α:

$$\widehat{\alpha} = \frac{i_2'}{i_3}. \tag{7}$$

Second, concerning γ, notice that $i_3 = i_2 = \gamma i_2'$ holds when $\alpha = 1$. In a sample period, however, α does not necessarily attain unity. Thus, assuming γ is a fixed parameter, we have the following specification for γ:

$$\overline{\gamma} = \frac{i_3|_{\alpha=\max(\alpha)}}{i_2'|_{\alpha=\max(\alpha)}}. \tag{8}$$

Substituting the specifications (7) and (8) for α and γ in equation (6), we identify the effect of the CP operations from observable data by the following equation:

$$i_1 - i_3 = \widehat{\alpha}\overline{\gamma} i_2' \frac{offer}{bid - offer}. \tag{9}$$

2.4 Discussions on the Plausibility of the Model

Before proceeding to our empirical analysis, we discuss two crucial assumptions of our analytical framework. These capture the rationale of the BoJ's CP operation and the institutional feature of the Japan's CP primary markets.

First, our analytical framework is based on the partial equilibrium model that focuses exclusively on the relationship between CP operations and the CP primary market. Behind the assumption is that the BoJ conducts CP operations during financial turmoil when market functioning deteriorates under rapidly increasing uncertainty about financial asset valuations and counterparty risk. In such a situation, banks should face a tight supply and demand condition in money markets and should meet difficulties raising additional funds. Since banks are the dominant underwriters in CP primary markets and segmentation among financial markets is considered severe during financial turmoil, the CP primary market is significantly affected by banks' funding conditions. That circumstance during the financial turmoil justifies our partial equilibrium analysis.

Second, our framework is to postulate that CP operations affect only the supply curve in the CP primary market while the demand curve is fixed. This assumption is supportable

[11] Our data set, explained in Section 4, supports this assumption.

because most Japanese CPs are issued by non-banks and are underwritten by banks. Hence, in Japanese CP markets, liquidity provided through CP operations is supplied through banks' underwriting. Thus, it seems reasonable to assume that only the supply curve should shift in the CP primary market because of the BoJ's CP operations. If a considerable fraction of CPs were issued by banks, as in the U.S., another identification issue would arise, since CP operations would affect the supply and demand curves in primary markets.

3 Identifying the Effects of the CP Operations During the Current Financial Turmoil: An Extension of Analytical Framework

The current financial turmoil, triggered by the U.S. subprime mortgage problem, caused a global financial crisis in autumn 2008. The BoJ took three actions related to CP operations. First, in October 2008, the BoJ increased the frequency and size of its CP repo operation, which had generally been conducted quarterly. Second, the BoJ decided in December 2008 to introduce its special funds-supplying operation to facilitate corporate financing, and started it in January 2009. This special funds-supplying operation (the special operation hereafter) is a new measure that provides unlimited liquidity against the value of corporate debt submitted to the BoJ as collateral at an interest rate equivalent to the target for the uncollateralized overnight call rate. We consider the special operations whose collateral are CPs as one of the CP operations. Third, outright purchase of CP was introduced at the end of January 2009 against the backdrop of significant deterioration in functioning of markets for corporate financing instruments.

Because the BoJ had conducted these three CP operations simultaneously since January 2009 and the features of the newly-introduced operations are different from that of the CP repo operation, we need to extend our framework to identify the respective effects of these three CP operations.

3.1 Identification Issues and Additional Assumptions

There are two identification issues to investigate the effects of the three CP operations during the current financial turmoil: the CP repo operation, the outright purchase of CP, and the special operations.

First, all three types of operations should simultaneously contribute to improving conditions in the CP primary market. In the previous section, we consider only a single measure of the CP operation that provides liquidity from the BoJ to banks and lowers the CP rate in the primary market. In contrast, we now need to decompose the effect on the CP rate into each

contribution of these three operations.

Second, the special operation is conducted for an unlimited amount (within the value of CPs submitted to the BoJ as collateral) with a fixed loan rate. In identifying the effect of the CP operations based on the previous framework, it is crucial to infer the slope of banks' demand curve for the operation from the data, such as amounts of offer and bid, and the successful bid rate. However, under the special operation, irrespective of the amount of bid and offer, the successful bid rate remains the same at the policy rate. Hence, we cannot obtain the information to conjecture the slope of the demand curve.

To overcome these issues, we introduce two additional identifying assumptions.

First, we assume that banks determine their bids in the following order: (1) the special operation, (2) the CP repo operation, and (3) the outright purchase of CP. This assumption considers banks' funding cost and availability as explained below. From a bank's viewpoint, bidding in the special operation is the best way to raise funds in terms of cost and availability since it offers an unlimited amount with a fixed loan rate equivalent to the policy rate. The CP repo operation is conducted by competitive auction bidding, and the successful bid rates average is slightly above the policy rate in the recent sample period. Thus, funding cost is slightly higher than in the special operation but lower than the outright purchase of CP whose minimum yield is set at the policy rate plus a non-negative spread so that banks' incentive to bid declines according to the improvement of market functioning. In addition, the BoJ has set conditions on CPs to be purchased in terms of their creditworthiness and has limited the total amount of purchases of a single issuer's CP to avoid concentration of credit risks in a specific firm. Therefore, in terms of cost and availability outright purchase of CP is the most expensive option in raising funds, although it allows banks to transfer issuers' credit risk to the BoJ.[12]

Second, we assume the demand curve of the special operation has the same slope as the CP repo operation in December 2008, i.e., immediately before introduction of the special operation. This assumption takes account of the similarity between the CP repo operation and the special operation against CPs. For banks, the CP repo operation and the special operation against CPs are similar in that both are fund-raising measures using CPs as collateral and cannot transfer credit risk to the central bank. Thus, it seems reasonable to assume that parameter γ, which characterizes the relationship between the yield in the operation and the CP rate in the primary market, is common to both operations. However, once both operations are implemented simultaneously, a difference arises in funding costs, since the special operation offers an unlimited amount of liquidity at the fixed policy interest rate. Hence, it is plausible

[12] Another possible ordering is that banks determine their bids first in the outright purchase of CP if they are assumed to most prefer transferring credit risks of the issuers. However, we have confirmed that our results change little if we change our assumption on the ordering.

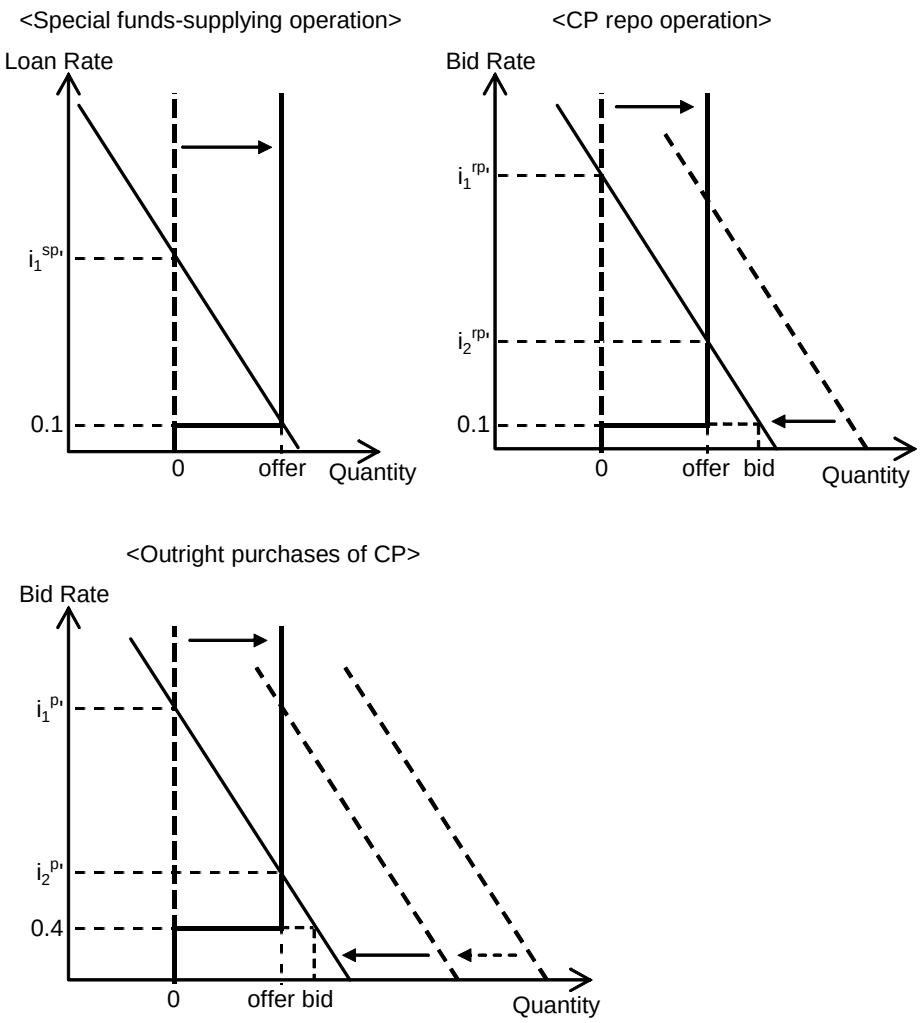

Figure 3: Operational frameworks in three CP operations

to set the slope of the demand curve in the special operation equal to that of the CP repo operation in the period before both operations were conducted.

3.2 The Extended Model

We extend the model incorporating additional assumptions made above. Figure 3 depicts the demand and supply relationships in each operation, where the interest rates (the vertical axis) are represented in terms of their own level, not in terms of their spreads, for explicit treatment of the fixed loan rate in the special operation and the minimum yield in the outright purchase of CP.

As for the special operation, the BoJ provides liquidity as much as banks bid within the value of CPs submitted to it as collateral, at the rate equivalent to the policy rate (0.1 percent as of June 2009). The execution of the special operation is described by the shift in the vertical

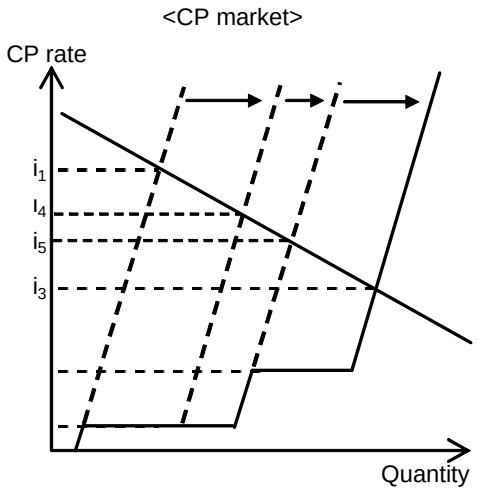

Figure 4: Effect of three CP operations

supply curve to the amounts of bid at the policy rate. Given the banks' demand curve for the operation, $i_1^{sp\prime}$ is the implicit cost of funds without the operation.

The CP repo operation is depicted similarly to Figure 1 and 2. However, notice that the demand curve is shifted to the left hand side, since banks have already obtained some amount of liquidity from the special operation, according to the assumption on the ordering of banks' bidding behavior. The successful bid rate and the counterfactual cost without the operation are $i_2^{rp\prime}$ and $i_1^{rp\prime}$ respectively.

The illustration of the outright purchase of CP is similar to that of the CP repo operation because both are conducted as competitive auctions. Furthermore, the demand for liquidity is partially satisfied by the two operations beforehand, as assumed above. In contrast to the repo operation, however, a minimum yield is set at the policy rate plus a spread (0.4 percent as of June 2009).[13] The successful bid rate is $i_2^{p\prime}$ while the implicit cost without the operation is $i_1^{p\prime}$.

Figure 4 illustrates demand and supply curves in the CP primary market when each operation is conducted in the same period of time. First, the special operation shifts the banks' supply curve rightward and lowers the CP rate from i_1 to i_4. Next, the CP repo operation shifts the supply curve farther, and the CP rate is lowered from i_4 to i_5. Finally, the outright purchase of CP causes the additional shift of the supply curve, and the CP rate falls from i_5 to i_3. As a result, the cumulative effect of these CP operations is calculated by:

$$i_1 - i_3 = (i_1 - i_4) + (i_4 - i_5) + (i_5 - i_3). \tag{10}$$

[13] Minimum yields can differ, depending on residual maturity. As of June 2009, the minimum yields are 30 basis points for a residual maturity of up to one month, and 40 basis points for that of more than one month and up to three months.

Equation (10) indicates that the overall effect of CP operations is decomposed into effects of each of the three CP operations, and the analytical framework presented in Section 2 can be applied for the evaluation of each operation. To implement these exercises, however, we need to identify i_4 and i_5, both of which are unobservable, as along with i_1. Our assumption on the ordering for bidding plays a crucial role to resolve this problem. In what follows, the unobservables, i_4 and i_5, can be calculated by identifying each effect. We now return to exploit the interest rates in terms of spread to apply equation (9) for identifying the effect of each operation.

First, we consider the effect of outright purchase of CP. Under our assumption, this effect is identified as $i_5 - i_3$ from equation (9). Data for identification, namely the successful bid rate and the CP rate spread in the primary market, are both available. Thus, the effect of outright purchase of CP is calculated by:

$$i_5 - i_3 = \widehat{\alpha}^p \overline{\gamma}^p i_2^{p\prime} \frac{offer^p}{bid^p - offer^p}, \tag{11}$$

where $\widehat{\alpha}^p = \frac{i_2^{p\prime}}{i_3}$, $\overline{\gamma}^p = \frac{i_3|_{\alpha^p = \max(\alpha^p)}}{i_2^{p\prime}|_{\alpha^p = \max(\alpha^p)}}$, and superscript p denotes the variable associated with the outright purchase of CP.

Second, the effect of the CP repo operation is similarly given by:

$$i_4 - i_5 = \widehat{\alpha}^{rp} \overline{\gamma}^{rp} i_2^{rp\prime} \frac{offer^{rp}}{bid^{rp} - offer^{rp}}, \tag{12}$$

where $\widehat{\alpha}^{rp} = \frac{i_2^{rp\prime}}{i_5}$, $\overline{\gamma}^{rp} = \frac{i_5|_{\alpha^{rp} = \max(\alpha^{rp})}}{i_2^{rp\prime}|_{\alpha^{rp} = \max(\alpha^{rp})}}$, and superscript rp represents the variable concerning the CP repo operations. In order to identify $i_4 - i_5$ from equation (12), the unobservable i_5 is required to calculate $\widehat{\alpha}^{rp}$ and $\overline{\gamma}^{rp}$. While i_5 is unobservable as a market data, we can recover i_5 from the result of equation (11), given observed i_3. Therefore, we can identify the effect of the CP repo operation as $i_4 - i_5$.

Finally, we explain how to identify the effect of the special operation. As argued in the previous subsection, we assume that the slope of the demand curve for the special operation is equivalent to that in the CP repo operation in December 2008, and that parameter γ is common to both operations. Then, the following relationship holds:

$$i_1 - i_4 = \widehat{\alpha}^{sp} \overline{\gamma}^{rp} i_{2,12/08}^{rp\prime} \frac{offer^{sp}}{bid_{12/08}^{rp} - offer_{12/08}^{rp}}, \tag{13}$$

where the superscript sp means that the variable is related to the special operation, and the subscript 12/08 indicates the value in December of 2008.

Note that another problem arises with regard to $\widehat{\alpha}^{sp}$, which corresponds to a proportion of liquidity supplied through the operation that flows into the CP primary market. We postulate that $\widehat{\alpha}^{sp} = 1$ in applying equation (13) for our subsequent analysis due to the following reasons. In Section 2, we have specified $\widehat{\alpha}$ by a ratio of the successful bid rate to the CP issue-rate. In contrast to the CP repo operation and the outright purchase of CP, however,

the special operation provides liquidity at the fixed rate equivalent to the policy rate. Thus, the information contained in the successful bid rate of the special operation is different from that of the other two operations. Hence, it is inappropriate to follow the same specification for $\widehat{\alpha}$. To specify $\widehat{\alpha}$ for the special operation, we acknowledge that terms in this operation are generally longer than the maturity of CPs, and that the penalty rate is high for a shortage of collateral. Thus, banks have incentives to underwrite newly-issued CPs and to substitute them for collateralized CPs expected to mature soon. In other words, it is plausible to assume that liquidity supplied through the special operation contributes to the increase in issuance of CPs by the same amount.

4 Data

Data used for our empirical analysis consists of the CP rate in the primary market, the successful bid rate of the CP operation, and the amounts of offer and competitive bid in the operation. The CP rate and the bid rate are used in terms of the spread between their actual rates and their respective base rates.

The CP rate spread is the difference between the average yield on three-month domestic CPs in the primary market and the OIS rate (the forward rate on the average target for the uncollateralized overnight call rate, three months).

The successful bid rate spreads are the differences between the average successful bid rates in each CP operation and the corresponding base rates. The base rate for the CP repo operation and that for the outright purchase of CP are the OIS rate (three months) and the minimum yield[14] determined by the BoJ, respectively. In the special operation, the bid rate spread is zero since both the successful bid rate and the base rate are equal to the fixed loan rate equivalent to the policy target.

The amounts offered and those of competitive bid as well as the bid rates are collected by the Financial Markets Department at the BoJ. Regarding the special operations, we cannot observe the exact amounts of $offer^{sp}$, i.e., the amounts of liquidity provided against CPs as collateral. We construct the corresponding series by calculating the ratio of the amounts of CPs to those of corporate debts submitted to the BoJ as collateral from the data of "Collateral Accepted by the Bank of Japan," and multiplying it by the total amounts offered in the special operation.

In the actual operations, the amount offered and the amount of successful bid can differ slightly, as the former is the amount offered in the conventional auction while the latter is the

[14]The minimum yield is 0.4 percent for a residual maturity of more than one month and up to three months, and is 0.3 percent for a residual maturity up to one month. While the successful bid rates are above 0.4 percent in January and February, they have been below 0.4 percent since March. For the latter period, we use the base rate of 0.3 percent.

Table 1: Effects of CP operations

	Oct,08	Nov	Dec	Jan,09	Feb	Mar	Apr	May
CP rate spread (%)	0.74	1.20	1.24	0.73	0.73	0.55	0.35	0.29
Total effect (%)	0.23	0.00	0.06	0.45	0.29	0.25	0.31	0.10
Repo (%)	0.23	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Outright purchase (%)	-	-	-	0.25	0.14	0.00	0.00	0.00
Special funds-supplying (%)	-	-	-	0.20	0.15	0.24	0.30	0.10

Note: Although the value of α for the outright purchase in January 2009 is more than one, we calibrate it so that $\alpha = 1$ following our definition.

amount actually provided pro rata to successful bidders. Even though we do not distinguish between the two, we exploit the term "the amount offered" throughout the paper. For our empirical analysis below, we use the data on the amounts of successful bid as the amounts offered so that we can take account of the actual transaction of liquidity.

We use monthly data. The CP rate is available only in monthly data, whereas the bid rate, amounts offered, and amounts of competitive bid are available in daily basis. The averaged bid rates are weighted by the term and the amount of each operation. The amounts offered and those of competitive bid are the summation of each amount multiplied by the term, which is normalized by 90 days (three months) in order to capture the volume of the operations.

5 Effects of the CP Operations during the Current Financial Turmoil: Results

Following equations (11) through (13), we identify the effects of the CP repo operation, the outright purchase of CP, and the special operation. Table 1 summarizes the results.

In October 2008, the CP repo operation had a remarkable effect in suppressing upward pressure on the CP issue-rate by 23 basis points. From November 2008 to December 2008, effects of CP repo operation had been limited. In January 2009, the outright purchase of CP and the special operation were introduced, and their cumulative effect was substantial up to 45 basis points. In February, the sum of the effects was 29 basis points. In March and April, although the effects of the CP repo operation and the outright purchase were virtually zero, the contribution of the special operation increased up to 24 basis points and 30 basis points, respectively.

One advantage in our structural approach is that we can decompose the effects into three factors: the volume of the CP operation, the steepness of banks' demand curve, and α as the proportion of liquidity supplied through the operation that flows into the CP primary market. In what follows, we decompose the effects of the operations and elucidate the background of

Table 2: Decomposition of the effects of CP operations

	Oct,08	Nov	Dec	Jan,09	Feb	Mar	Apr	May
Repo (%)	0.23	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Volume	0.18	0.84	1.48	1.20	0.87	0.93	0.99	0.80
Steepness	3.62	0.10	0.30	0.04	0.11	0.11	0.03	0.04
α	031	0.01	0.11	0.02	0.03	0.04	0.04	0.02
Outright purchase (%)	-	-	-	0.25	0.14	0.00	0.00	0.00
Volume	-	-	-	0.07	0.47	0.12	0.08	0.10
Steepness	-	-	-	3.49	0.69	0.69	0.69	0.69
α	-	-	-	1.00	0.42	0.05	0.01	0.00
Special funds-supplying (%)	-	-	-	0.20	0.15	0.24	0.30	0.10
Volume	-	-	-	0.58	0.44	0.70	0.88	0.28

Note: Although the value of α for the outright purchase in January 2009 is more than one, we calibrate it so that $\alpha = 1$ following our definition.

our results.

5.1 Decomposition of the Effect of CP Repo Operation since October 2008

In response to the current financial turmoil, the BoJ increased the frequency and the size of CP repo operations in October 2008 to facilitate corporate financing in the market. The CP repo operation contributed to lowering the CP rate by 23 basis points at its onset. As Table 2 shows, the steepness factor of the repo operation in October 2008 was quite large in comparison with its subsequent values. This result suggests that banks' demand for the central bank liquidity was inelastic to the interest rate because they faced the dysfunction of money markets. Thus, the liquidity provision through the CP repo operation had the remarkable effect in alleviating the tight funding condition for banks and relaxing the tension in the CP primary market.

However, the effect of the CP repo operation in 2009 had been negligible. We find that both the steepness factor and α had been small. These factors imply that the bank's demand for additional liquidity supplied through the repo operation had not been vigorous, and that the fund flow from the operation to the CP primary market had been limited.

5.2 Decomposition of the Effect of CP Outright Purchase since January 2009

The outright purchase of CP had a remarkable effect on the CP issue-rate in the two months after its introduction. It lowered the CP rate by 25 basis points in January 2009 and 14 basis points in February. We can see that the steepness factor and α exhibit high values, implying

that banks' demand for the outright purchase of CP by the BoJ was inelastic with regard to the interest rate, and that outright purchases contributed substantially to the increase in the new issuance of CPs.

One reason for this result is that outright purchases, in contrast to other CP operations, allowed banks to transfer credit risk to the BoJ. If banks primarily view this operation as a way to reduce credit risk rather than to raise funds, this operation is quite attractive and induces additional underwriting of CPs, assuming their risk appetite is constant.

In March and April, the effect of outright purchase of CP declined to almost zero. We attribute this result to the under-subscription where the amounts of competitive bid were less than those of the offer in the operations. Under such circumstances, the effect is likely to be small, as presented in the Appendix.

The condition of the CP primary market had improved since March 2009, owing to the outright purchases by the BoJ and the Development Bank of Japan plus the special operations. Because minimum yields on the outright purchase of CP had been set so that banks' bidding incentives decline according to the improvement of market functioning, improved market conditions since March 2009 led to the under-subscription for outright purchase of CP.

5.3 Effect of the Special Operation since January 2009

The special operation has the substantial and persistent effect on the CP issue-rate by 15-30 basis points from January 2009 to April. Recall that, under our assumptions, $\widehat{\alpha}^{sp} = 1$ and that the steepness is fixed at the same value as the one in the CP repo operation in December 2008.[15] Thus, the effect varies in parallel to the amounts offered.

We interpret the expansion of the special operation decided upon in mid-February as having substantial effect in March and April.[16] For banks, the special operation was appealing as a funding facility, and its expansion encouraged more banks to raise funds from this operation. Consequently, banks' demand for newly-issued CPs increased, and the CP spread declined more than what it was before.

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[15] For banks, however, the special operation might be more attractive than the CP repo operation, as argued in Section 6.1. This suggests that the slope of the demand curve could be steeper in the special operation than that of the CP repo operation in December 2008. In this respect, we cannot deny the possibility that our framework underestimates the effect of the special operation.

[16] Specifically, the frequency of the operations was increased, the duration of each loan was extended, and loans was to be offered through the end of September 2009 (previously through the end of March 2009).

6 Concluding Remarks

We have evaluated the effect of the CP operations conducted by the BoJ during financial turmoil. To this end, we have developed a simple structural model for the BoJ's CP operations and the CP primary market. Our model features the situation during the financial turmoil where the CP primary market is segmented from markets other than the CP operation market. Thanks to the structural model, we measure the effect of the operation as the difference between observed CP rates in the primary market with operations and the corresponding counterfactual CP rates without operations. We have shown that, under plausible assumptions, our framework enables us to identify the effect from available data. According to our results, the CP repo operation had a notable effect on the CP issue-rate at its onset, and that its effects had been marginal thereafter. The outright purchase had a remarkable effect on the CP issue-rate in January and February 2009; the special operation had the substantial and persistent effect on the CP issue-rate from January to April 2009.

Although our structural model has two advantages in measuring the effects of CP operations, namely, structural interpretation of its effects and the independence of results from the econometric methods, we should note several limitations in our analysis that depends on the model specification and its assumptions.

First, our model focuses on how and to what extent actual amounts of liquidity supplied through CP operations improve conditions of the CP primary market. Thus, we cannot capture the announcement effect at the introduction of the new facilities, or cannot examine the effect of the existence of the facilities itself that possibly works as a backstop for banks' funding management.

Second, we assume that banks' demand curve for the operations and the slopes of both curves in the CP primary market are unchanged regardless of the implementation of the operations. However, CP operations might improve firms' sentiment by changing their expectations about banks' funding conditions, or they might improve supply and demand conditions in both markets. Taking account of these limitations, the effects of operations would be larger than those identified in this paper.

Third, the assumption of the linear relationships between the successful bid rates in the CP operations and the CP issue-rates in the primary market might be strong. This assumption implies that banks' margins on underwriting CPs are stable.

Our approach can be applied to other facilities that support financial institutions' liquidity and improve financial market conditions. For example, Hirose, Ohyama, and Taniguchi (2009) have examined how and to what extent longer-term operations contributed to suppressing the upward pressure on the term-end premium in money markets due to the end-of-year effect. Analyses about other facilities are left for future research.

Appendix

This Appendix explains how we identify the slope of the demand curve under the case of under-subscription, where the amounts of competitive bid do not reach the amounts offered.

The left diagram of Figure 5 shows the case of under-subscription. The left diagram also depicts a demand curve (dashed line) in a situation where the amount of competitive bid exceeds amount offered in the previous period.

In the present case where the bid is less than the offer, the amount of successful bid equals to the amount of competitive bid at the successful bid rate equivalent to the base rate or the minimum yield. Then, the effect of the CP operation is evaluated by i_1 in the right diagram. In such a case, we cannot pin down the slope of the demand curve as we can in Section 2. Thus, we postulate that the slope in the present period is the same as the one in the previous period when the bid is more than the offer. Under this assumption, since $\triangle ABC \backsim \triangle FGH$, we have

$$(bid_{t-1} - offer_{t-1}) : bid = i'_{2,t-1} : i'_1, \tag{14}$$

where subscript $t-1$ denotes the previous period when the bid is more than the offer. Then, equation (9) that evaluates the effect of operation is modified as:

$$i_1 = \widehat{\alpha\gamma} i'_{2,t-1} \frac{bid}{bid_{t-1} - offer_{t-1}}. \tag{15}$$

Based on this equation, we can see that the effect tends to be small since the amount of bid should be relatively small in the present case.

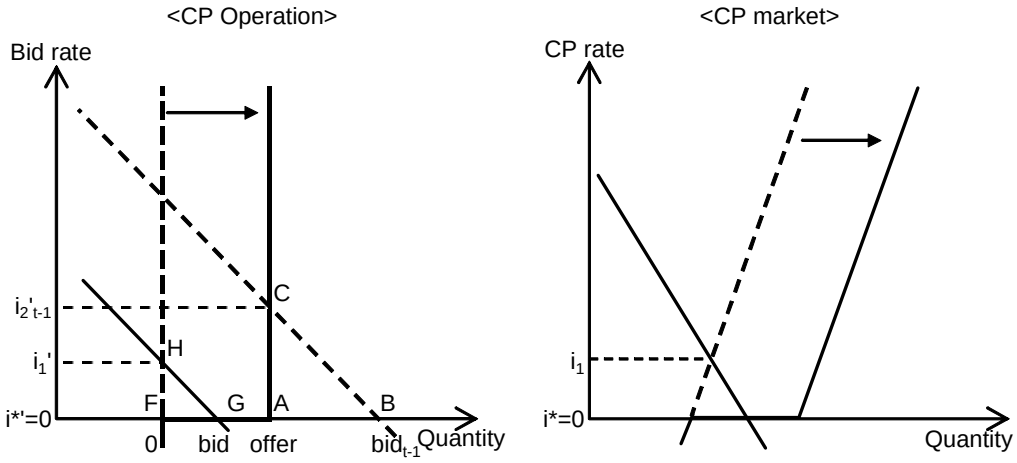

Figure 5: Effect of CP operation when bid < offer

References

Bank of Japan (2009): "Financial Markets Report," BOJ Reports & Research Papers, August 2009, Financial Markets Department, Bank of Japan.

Carpenter, Seth and Selva Demiralp (2006): "The Liquidity Effect in the Federal Funds Market: Evidence from Daily Open Market Operations," *Journal of Money, Credit, and Banking*, 38, 901-920.

Christensen, Jens H. E., Jose A. Lopez, and Glenn D. Rudebusch (2009): "Do Central Bank Liquidity Facilities Affect Interbank Lending Rates?" Working Paper 2009-13, Federal Reserve Bank of San Francisco.

Eisenschmidt, Jens, Astrid Hirsch, and Tobias Linzert (2009): "Bidding Behavior in the ECB's Main Refinancing Operations During the Financial Crisis," Working Paper Series No. 1052, European Central Bank.

Hamilton, James (1997): "Measuring the Liquidity Effect," *American Economic Review*, 87(1), 80-97.

Hayashi, Fumio (2001): "Identifying a Liquidity Effect in the Japanese Interbank Market," *International Economic Review*, 42(2), 287-315.

Hirose, Yasuo, Shinsuke Ohyama, and Ken Taniguchi (2009): "Identifying the Effect of the Bank of Japan's Liquidity Provision on the Year-End Premium: A Structural Approach," Working Paper Series 09-E-6, Bank of Japan.

Judson, Ruth and Elizabeth Klee (2009): "Whither the Liquidity Effect: The Impact of Federal Reserve Open Market Operations in Recent Years," Finance and Economics Discussion Series 2009-25, Federal Reserve Board.

McAndrews, James, Asani Sarkar, and Zhenyu Wang (2008): "The Effect of the Term Auction Facility on the London Inter-Bank Offered Rate," Staff Reports 335, Federal Reserve Bank of New York.

Taylor, John B. and John C. Williams (2009): "A Black Swan in the Money Market," *American Economic Journal: Macroeconomics*, 1(1), 58-83.

Wu, Tao (2008): "On the Effectiveness of the Federal Reserve's New Liquidity Facilities," Working Paper 0808, Federal Reserve Bank of Dallas.