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Walking After Midnight: Measurements and Pricing Implications of Market Liquidity on Corporate Bonds

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Abstract

This paper proposes a theoretically motivated proxy for the degree of market liquidity in corporate bond market (GAP: the highest minus lowest simultaneously reported spreads among multiple market makers), and studies its pricing implication by quantifying the correlation between GAP and the median reported spreads among market makers, which presumably approximate market prices conjectured by market makers. While the issue of market liquidity has been extensively examined over the last decade for stock and sovereign bond markets, our understanding is still limited for corporate bond market mainly due to the unavailability of widely accepted liquidity proxies, such as bid-ask spreads in other markets. Through various panel estimations for the median reported spreads in Japanese corporate bond market, we find that (i) inclusion of the lagged GAP to the standard multi-factor model significantly improves the explanation power, (ii) the quantitative impact of such an illiquidity measure on bond spreads becomes larger as credit ratings get worse, (iii) the GAP proxy is valid even after controlling the persistency on spreads, which has been considered as another proxy for illiquidity in the extant literature (i.e., resiliency), and (iv) the degree of such persistency increases as the credit ratings of corporate bonds deteriorate. These results jointly explain how market makers construct their opinions about bond prices by (a) learning from the dispersion of reported prices, (b) recalling the past reporting, as well as (c) considering standard covariates of bond spreads (i.e., JGB Yield, credit ratings etc). Our results also support the empirical implication provided by theoretical literature on the correlation between the degree of opinion differences and market liquidity premium.

Key words: Corporate Bond Spreads; Illiquidity Measure; Difference in Opinion
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1. Introduction

During the past financial crisis including the recent episode triggered by "Lehman shock", we have observed large time-series and cross-sectional variations in asset prices (stock prices, corporate bond spreads etc), which are not necessarily co-moving well with others, and occasionally show bumpy dynamics (Figure-1). As demonstrated in a number of extant studies, however, classic asset pricing models focusing on credit risk factors cannot generally explain these actually observed asset price variations (Collin-Dufresne et al. (2001)). Responding to the presumption that such a misalignment between model prediction and data is sounding particularly when the liquidity of markets dries up as well as the volumes and frequencies of trades are plunging, it has been a main concern in the field of asset pricing over the last decade to search appropriate proxies for liquidity factors.

Following such a strand of literature, this paper proposes one theoretically motivated proxy particularly targeting the market liquidity of corporate bonds (GAP: the highest minus lowest simultaneously reported spreads among multiple market makers). We study its pricing implication by quantifying the correlation between GAP and the median reported spread, which we believe approximates the market price conjectured by market makers.[1]

To motivate the research question featuring corporate bonds and necessitate the usage of the multiple quote data from market makers, we should recall the characteristics of corporate bond markets. Namely, most of the investors of corporate bonds rely on "buy & hold" type investment strategy, the transaction volume is usually limited and, reflecting this, market making is not very active for corporate bonds, which is different from the markets with highly frequent trades as stock market.[2] Under such illiquid market environment, it is not easy even for the professional market makers to find out a "unique" market clearing price. As a result, the quote of market makers has some distribution with non-zero variance and the distribution seldom converges to one point, which reflects

[1] In this paper, the asset price of corporate bond is represented by "spread" which denotes the yield difference between corporate bonds and Japanese Government Bond (JGB).

[2] As far as we know, even the U.S. and Euro corporate bond markets do not have highly liquid secondary markets where we can occasionally observe actual trading prices. Recent initiatives in Asian countries promoting corporate bond markets further exemplify how the current environment in the Asian corporate bond markets are far behind the U.S. and Euro markets.

the divergence or heterogeneity on market maker's bond evaluation.[3] In this paper, we take a view that corporate bond market is one illustrative example of such an illiquid market generically with low frequencies of trades. Notably, the extant studies for the asset pricing implication of market liquidity have been focusing on the markets having a certain volume of trades most of the time, where researchers could observe actually transacted prices without any difficulty, and widely accepted liquidity proxies, such as bid-ask spreads, are available. In the markets for corporate bonds, CDO, ABS, and many other financial markets, however, we could at most observe quoted prices and/or estimates provided by market makers from the reason described above, and it is relatively difficult to use the liquidity proxies referenced in other markets.[4] Such a nature of the corporate bond markets motivates us to study how multiple market makers construct their opinions about bond prices, and how the median reported spread vary with the diverged opinions.

The data we analyze is provided by Japan Securities Dealers Association (JSDA). Consistent with our presumption about corporate bond markets, the data of market makers' reporting prices are just indication and no obligation of trade with those prices. In this sense, what we observe would be rather the market makers' best guess on the market clearing prices.[5] Note that a series of extant studies taking into account several notions of liquidity tend to treat the bond spreads as market-clearing prices and apply the analytical framework mainly used for more liquid market such as stock markets or sovereign bond markets. The starting point of our paper is to recognize the spreads data as the evaluation of corporate bonds provided by market makers and study how market makers alter their conjecture about market clearing prices with considering the variation in the distribution of reported prices by multiple market makers.

In order to preview how the GAP measure is informative, Figure-2 (1) depicts the share of firms staying under a certain level of GAP (i.e., equal to or smaller than 5, 10, 15, and 20bp) out of the total sample firms at each date. For example, the share of firms

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[3] Recent development of market microstructure literature considers this aspect and tries to model how the heterogeneous belief or the disagreement among market makers on public information generates the dynamics of trade volume (Banerjee and Kremer (2010)) and prices (Tychon and Vannetelbosch (2005)).

[4] In fact, Japan Security Dealers Association (JSDA) from which we obtain our data stores almost no data for bid-ask spreads although they prepare the category for recording.

[5] Even Euro markets cannot provide the complete set of the actual transaction prices in daily base. Recently, the accessibility of the corporate bond data in the U.S. has been largely improved by FINRA TRACE Corporate Bond Data (http://www.finra.org/).

showing GAP smaller than 5bp reached more than 80% in the second half of 2005 where the market condition was relatively good and the liquidity was presumably high. In contrast, there were several periods where such a share went below 10% (e.g., 2003, 2008-2009). It seems that these dynamics coincide to some extent with the change in market condition. Our guess is if the market is illiquid, such a market condition is represented by the larger GAP for a given corporate bond, and the spreads become wider.

Such a view on the correlation between the heterogeneous views about bond prices, which presumably works as a proxy for liquidity, and the corporate bond spreads has been gradually accepted in theoretical literature (Tychon and Vannetelbosch (2005), Banerjee et al. (2009), Cao and Ou-Yang (2009), Banerjee and Kremer (2010)). Only a few studies (Hauweling et al. (2003)), however, establishes the quantitative results directly corresponding to their theoretical prediction. This paper intends to contribute to this recent development of empirical studies by using the GAP measure to proxy the illiquidity of individual corporate bonds.[6]

As detailed later, another characteristic of our data is the persistency on the quoted median bond spread provided by market makers. This property can be understood in the context of "resiliency" concept discussed in classic market liquidity literature (e.g., BIS (1999)), which is another good illustration for illiquid markets.[7] This induces us to consider the time-series measurement of market illiquidity as well as the cross-sectional measurement such as GAP. As in the extant studies (Nakamura (2009)), we can infer the illiquidity of corporate bonds by checking whether the reported prices by market makers has persistency or some stickiness. If the market becomes highly illiquid, the lesser portion of their quotes depends on the concurrent information and we will observe the stronger persistency in their previous quotes.

To summarize, the purpose of our quantitative discussion is to illustrate that the market makers price corporate bonds not only by (a) considering standard covariates of bond spreads, but (b) learning from the dispersion of reported prices by other market

[6] It is natural to conjecture the positive correlation between the GAP measure and firm's credit worthiness. As we will demonstrate later, the panel estimation we employ in this paper is suitable to disentangle those two correlated effects.

[7] A standard definition of the resiliency is the speed of the restoration of normal market prices. The extant literature has been treating this as one independent dimension representing market liquidity.

makers as illustrated above, as well as (c) recalling the past reports, which eventually gives us a tip for understanding various other low liquid financial securities such as ABS, CDO, and securitized products. Another interest of this paper is also in understanding the market maker's forecast for the market-clearing prices. Shedding light on the pricing mechanism of those illiquid assets would be very useful to understand the financial markets that have been facing tremendous difficulty in objective evaluation.[8]

Through such an analysis, we also attempt to provide an empirical evidence of the so called "Flight-to-Liquidity" view. If the sensitivity of bond spreads with respect to illiquidity measure differs among different credit ratings, it can be interpreted as the reflection of the investor's attitude toward low credit quality.

This paper is structured as follows. Section 2 briefly surveys the related literature. Before going into empirical studies, we go over a theoretical framework motivating the following empirical section in section 3. Then, section 4 goes over our empirical framework and formulates our hypothesis. Section 5 and 6 describe the data and shows the estimated results, respectively. Section 7 compares our empirical results with existing studies. Section 8 concludes and presents future research questions.

2. Related Literature

In this section, we briefly survey the related literature to our study. In the long strand of asset pricing literature, there are three types of papers we need to consider. The first group is the theoretical study for the relationship between illiquidity and asset prices. In the context of market microstructure, there are a few theoretical studies explicitly modeling the market illiquidity risk considered in our paper. A theoretical model closest to our motivation is Tychon and Vannetelbosch (2005), which develops a corporate bond valuation model containing both the credit risk and the liquidity/marketability risk generated by a matching friction between bondholders and potential investors in a secondary market. They assume that each bondholder is matched with whole population in illiquid market, which might not result in the match up providing the gain from trade,

[8] It is highly difficult to directly observe the prices of so called "Level-3 assets" categorized by U.S. Financial Accounting Standard Boards and SEC.

while the matching is guaranteed to always generate the gain in liquid market.[9] Their main idea is that the liquidity premium is actually coming from the interaction between (i) the difference of matching frictions under the illiquid and liquid market environments, and (ii) the heterogeneity of investors' valuations. To illustrate, bondholders/investors put lower relative value on the bonds in the illiquid market than in the liquid market as the heterogeneity of belief becomes larger. This is because it becomes less likely for bondholders/investors to find an appropriate counterpart to sell the bonds in future as the matching friction is amplified by larger heterogeneity.[10] Most of the theoretical models categorized as "inventory model" share the similar perspective. Although our data is not precisely an actual transaction price, we believe the GAP measure briefly described in the previous section can capture the degree of heterogeneity on the belief among market makers.

The recently developed "differences of opinion literature" (Banerjee et al. (2009), Cao and Ou-Yang (2009), Banerjee and Kremer (2010)) further pursues this direction. They construct a theoretic model incorporating investors with heterogeneous belief about common public information and characterize how such heterogeneous views are reflected in market maker's opinion, market prices (average opinion), and trading volumes through learning process.[11]

There also exist several other theoretical explanations for why illiquid financial securities need to be accompanied with higher premium from the stand point of investor's liquidity demand (e.g., Holmstrom and Tirole (2001)) or transaction cost (Acharya and Pedersen (2005)).[12] Instead of digging into such theoretical pricing foundation of liquidity risk, we intend to establish empirical findings which can contribute to the development of those theoretical studies.

Papers in the second category are the ones performing a classic empirical analysis

[9] In other words, each bondholder will be matched with the investor who put higher evaluation for the bond held by the bondholder. They assume that the liquidity market makes it possible to have such a profitable matching always.

[10] Consider the environment with no heterogeneous belief. Regardless of the matching friction, no trade emerges and the heterogeneity among bondholders/investors do not matter.

[11] Easley and O'Hara (2010) constructs a model generating equilibrium quotes and the nonexistence of trading at the quotes, which can be observed in financial crisis period.

[12] Liquidity Asset Pricing Model(LAPM) in Holmstrom and Tirole (2001) studies the endogenous determination of liquidity premium, which is treated as somewhat ad-hoc in the previous literature. Their main idea is (i) investor's optimal choice generates liquidity preference and (ii) corporate bond spreads are determined in a general equilibrium framework.

for corporate bond spreads. The key implication shared by the literature is the insufficient ability of macro and/or micro credit factors to explain the corporate bond spreads (e.g., Jarrow et al. (2000), Edwin et al. (2001), Huang and Huang (2003), Eom et al. (2004)). For example, Collin-Dufresne et al. (2001) confirms that credit risk factors cannot explain bond spreads even after incorporating various aggregate variables (e.g., S&P 500 returns, the slope of sovereign bond yields, the sovereign yields etc.) into the estimation. Note this empirical finding is discussed in another form as "Credit Spread Puzzle". The seminal works by Hull et al. (2004、2005) show that the default probability implied by the corporate bond yield in the secondary market is more than ten times that the default rate calculated from the historical data. They also point out that there exists a significant gap between corporate bond spread and CDS spread. It is our motivation to fill such an inconsistency between the classic model prediction and the observed data.

These results naturally motivate the third strand of the papers on the empirical analysis incorporating illiquidity factor. This literature starts from choosing an appropriate proxy capturing market-level liquidity. Most of the extant studies (Fleming (2003), Goldreich et al. (2005)) in this direction use the sovereign bond yield which is theoretically not affected by credit factor in order to evaluate the performance of various proxies. Then, with controlling those established market-level liquidity proxies, several papers started to further incorporate individual liquidity factor. Amihud (2002) is a pioneering paper for measuring such an individual illiquidity by introducing ILLIQ measure, which is computed as the average of daily variation in stock return[13]. Including this ILLIQ measure, Houweling et al. (2005) comprehensively studies several illiquidity factors associated with individual company and portfolio to a standard multi-factor model and establishes the illiquidity premium by using the data in euro area. Our paper has a very close motivation to their paper. The difference is that we use panel estimation techniques to analyze the conditionality of the impacts of market liquidity and verify the robustness by also incorporating a classic liquidity proxy (resiliency) explicitly. For

[13] Precisely speaking, the ILLIQ measure is computed as the absolute price change divided by trading volume for a given stock on a given day. Since this ratio is a very noisy measure on any day, in practice, it is averaged over all trading days in a month or year to get a monthly or annual liquidity estimate for the targeted stock.

quantifying the pricing implication of illiquidity risk for stocks, Acharya and Pedersen (2005) directly incorporates the "illiquidity transaction cost" notion to an otherwise standard CAPM structure and price the illiquidity risk explicitly.[14] Apart from these papers originated from a standard factor model specification, Bao et al. (2008) studies the price dynamics of corporate bonds and establishes a proxy of corporate bond's market liquidity from the dynamics. Our paper shares the spirit with their study that the price dynamics has some information related to market liquidity[15].

About Japanese corporate bond market, the existing studies are rather limited. First, in the recent paper, Hongo and Oyama (2010) studies the mechanism governing the corporate bond spreads through a model without liquidity factor. Second, the importance of liquidity factor is studied in Saito et al. (2001) and Hori et al. (2008) by explicitly focusing on Holmstrom and Tirole (2001) type liquidity demand. Shirasu and Yonezasa (2008) also challenge the same question by using Japanese corporate bond market data. Third, Nakamura (2009) employs two methods to quantify the illiquidity risk on bond spreads, which largely shares its motivation with our paper. One difference is on our novel proxy for bond illiquidity and the estimation strategy.

3. Theory: Heterogeneous Belief and Corporate Bond Spreads

In this section, we review one theoretical underpinning of the relationship between corporate bond spreads and the distribution of the quote provided by market makers. Our target is the simple presentation of an economic idea demonstrated in Tychon and Vannetelbosch (2005), which motivates the following empirical sections; no attempt is made to provide either exhaustive survey or create original theoretical models.

3-1. Model

The economy consists of many risk-neutral potential investors and bond holders.

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14 Although our paper does not have an explicit asset pricing formulation as theirs, the model structure is actually an extension of Fama and French (1993). In this sense, we follow to some extent a traditional factor model/CAPM structure.

15 Bao et al. (2008) hypothesizes that the amount of price reversal or the negative of auto-covariance of prices is associated with the illiquidity of corporate bonds, with referring to the extant theoretical studies such as Roll (1984). It is one remaining issue how to reconcile their view with the traditional measurements - tightness, depth, and especially resilience.

After a corporate bond with coupon c and principal P is issued in date-1, the bond holder is randomly matched with a potential investor in each period t until its maturity date T.[16] The value of the bond-issuing company V_t follows a binomial process with a probability of moving upward (q) and downward $(1-q)$, respectively. The default of a bond is characterized as the case where V_t goes below its principal P. In the case of default, the bond holder could receive $(1-\alpha)V_t$ where α denotes the cost of bankruptcy. Figure-3 (1) illustrates the considered binomial tree with an absorbing state corresponding to default.

The heterogeneity of investors and bondholders, which is an essential assumption for modeling the non-degenerated distribution of the quoted spreads, is represented by $\{\alpha_i\}_{i=1}^{I}$ where the type index i takes from 1 to I and the large index corresponds to a smaller bankruptcy cost.[17] As a notation, $\gamma(i)$ and $\#(i)$ denote the probability of being type$-i$ and the numbers of type$-i$ investor among the global population of investors, which satisfies the following relation. $\gamma(i)$ is assumed to be constant over time.

$$\gamma(i) = \frac{\#(i)}{\sum_{j=1}^{I} \#(j)}$$

Important assumption here is that investors have heterogeneous prior beliefs not explained by differences in information about bankruptcy cost. The heterogeneity is potentially obtained, for example, through different abilities and/or evaluation methods.[18]

The distinction of liquidity and illiquidity markets is modeled through the two different matching schemes in each market. If the market is liquid, the bondholder$-k$ is matched only with the investors with whom he/she can obtain the gain from trades (i.e., matched with the investor$-j$ where $j \geq k$). The probability for the bondholder$-k$ to be matched with the investor$-i$ such that $i \geq k$ is denoted as follows.

[16] We omit the description for the primary market, which is detailed in the paper, for the presentation purpose.
[17] Thus, the bondholder/investor with a large i put a greater value for a given bond as the collateral value of the bond $(1-\alpha)V_t$ is evaluated larger by the bondholder/investor.
[18] The difference in opinion literature (e.g., Banerjee and Kremer (2010)) intends to explicitly model how such heterogeneity is observed and reflected in the learning process of each player. Tychon and Vannetelbosch (2005) largely abstracts from the learning aspect and focus on how the degree of a given heterogeneity affects the corporate bond spreads.

$$\frac{\gamma(i)}{\sum_{j=k}^{I}\gamma(j)}$$

On the other hand, bondholders in illiquid market will be matched with whole population. Hence, the probability for the bondholder-k to be matched with the investor−i is simply $\gamma(i)$.

In each period and node denoted by (t, m) where m denotes the number of upward moves required for reaching the node, each bondholder−i is matched with a potential investor−j through the matching scheme described above and bargains over the price $p_{t,m}^{i,j}$ based on the following Nash-bargaining procedure if $j \geq i$.

$$\begin{cases} pl_{t,m}^{i,j} = \text{argmax}\{\pi_i(t,m) - \pi_i^0(t,m)\}^{\lambda}\{u_j(t,m) - u_j^0(t,m)\}^{1-\lambda} & \text{if the market is liquid} \\ p_{t,m}^{i,j} = \text{argmax}\{\pi_i(t,m) - \pi_i^0(t,m)\}^{\lambda}\{u_j(t,m) - u_j^0(t,m)\}^{1-\lambda} & \text{if the market is illiquid} \\ \text{Where} & \\ \pi_i(t,m)\text{: Bondholder's value by selling, } \pi_i^0(t,m)\text{: Bondholder's value by not selling} & \\ u_j(t,m)\text{: Investor's value by buying, } u_j^0(t,m)\text{: Investor's value by not buying} & \\ \lambda\text{: Bondholder's bargaining power} & \end{cases}$$

We can immediately notice that $\pi_i(t,m) = p_{t,m}^{i,j}$ or $pl_{t,m}^{i,j}$, and $u_j^0(t,m) = 0$. The rest of the values $\pi_i^0(t,m)$ and $u_j(t,m)$ can be constructed as follows.

$$\begin{cases} \pi_i^0(t,m) = q\left(\frac{1}{1+r}\right)\left(c + B_{t+1,m+1}^i\right) + (1-q)\left(\frac{1}{1+r}\right)\left(c + B_{t+1,m}^i\right) \\ u_j(t,m) = q\left(\frac{1}{1+r}\right)\left(c + B_{t+1,m+1}^j\right) + (1-q)\left(\frac{1}{1+r}\right)\left(c + B_{t+1,m}^j\right) \\ \text{where} \\ B_{t+1,m+1}^i\text{: Expected value at } (t,m) \text{for the bondholder} - i \end{cases}$$

Thanks to the setting with a finite maturity period, we can solve for all the expected values of the bonds corresponding to both liquid and illiquid markets, hence can obtain all the prices in every (t, m) backwards by beginning at the end of the binomial tree and solving for the prices from bargaining problems.[19] Note that the difference between $p^{i,j}_{t,m}$ and $pl^{i,j}_{t,m}$ solely comes from the matching procedures with belief heterogeneity in illiquid and liquid markets.

By using those prices, the bond values for bondholder$-i$ at (t, m) in liquid and illiquid markets are defined as follows, respectively.

$$BL^{i}_{t,m} = \frac{\sum_{j=i}^{I} p^{i,j}_{t,m} \times \gamma(j)}{\sum_{j=i}^{I} \gamma(j)} \text{: Liquid market}$$

$$B^{i}_{t,m} = \sum_j p^{i,j}_{t,m} \times \gamma(j) \text{: Illiquid market}$$

Then, we can define the liquidity/marketability risk premium in the following form.

$$LP_{t,m} = BL_{t,m} - B_{t,m} \equiv \sum_j BL^{j}_{t,m} \times \gamma(j) - \sum_j B^{j}_{t,m} \times \gamma(j) \ \cdots (1)$$

This premium is originated from both the lack of marketability (i.e., the bond can be traded only once in a market with heterogeneous prior beliefs) and the lack of liquidity (i.e., bondholders are matched with population in illiquid market whereas with the investors providing the gain from trade in liquid case). Note that both the factors are necessary for the premium. Suppose all the players share a common bankruptcy cost α, then no trade occurs and $LP_{t,m}$ becomes zero.[20] Given the difference between liquid and illiquid market structure, the liquidity/marketability risk premium takes a positive value only if the economy contains heterogeneous beliefs. And there is a positive correlation between the premium and the degree of heterogeneous beliefs. We take this point to construct our testable hypothesis.

[19] One trick they invent is to reduce the nodes necessarily considered in order to solve for the prices. We only need to consider the nodes inside the bargaining zone in Figure-3 (2).

[20] Similarly, there will be no trade if the frequency of trade is high enough and/or obviously the difference between the liquid and illiquid markets does not exist.

3-2. Empirical Implication and Hypothesis Formulation

The model presented in the previous section effectively puts a linkage between the degree of heterogeneous beliefs among bondholders/investors and the relative value of bonds suffering from matching friction. In particular, the existence of heterogeneous belief induces the spread difference between the liquid and illiquid markets, which implies that the larger the heterogeneity of bondholder/investor beliefs, the higher the liquidity premium is.

Although the model does not explicitly describe market makers, we can apply the current setup to the market with market maker since the candidates for the sources of heterogeneous prior beliefs discussed in the model (i.e., different information processing abilities, evaluation methods etc.) are also applicable to market makers. Based on the discussion above, we construct the first hypotheses we verify in the following sections.

Hypothesis-1: Median quoted spread is positively correlated with the absolute dispersion of market maker's quoted prices, which is captured by the GAP measure in our setup, even after controlling the market factor as well as its individual factors (e.g., credit ratings, the volatilities of stock returns etc.).

Note that our dataset described in the following section does not contain the actual transaction price but rather the prices conjectured by market makers. Although the available data from JSDA is limited in this sense, we think the data should account to considerable extent for the market behavior and its illiquidity. About the (i) market and (ii) individual credit factors, and (iii) the market liquidity factor, we use (i) 10-year JGB yield minus 2-year JGB yield, 10-Year JGB yield, the growth rate of Nikkei Average Stock Index, (ii) the unexpected historical volatility of individual stocks, the credit ratings, (iii) 3-month Tibor minus 3-month JGB yield, which represents the tightness of short-term financial market.[21] We will summarize the expected signs of each coefficient in the

[21] The unexpected historical volatility is estimated as the residual obtained from the regression of the individual historical volatility on the historical volatility of Nikkei average index. Various other potential proxies we used for robustness check are omitted for saving the space. Those additional results are provided upon request.

following section.

Second, in the extant literature, some conditionality has been pointed out in stock market return (e.g., Watanabe and Watanabe (2008)). They establish the result that the pricing impact of liquidity risk is larger for the firms with lower credit ratings. The following hypothesis corresponds to this established empirical fact in other financial markets.

Hypothesis-2: ***The impact of the GAP measure onto bond spreads has conditionality.***

This can be verified, for example, by checking whether the coefficient associated with the GAP measure times the standard deviation of the GAP measure is different among the samples split based on the credit-ratings and/or market conditions. This perspective is also quite consistent with the widely shared flight-to-liquidity view.

Third, in order to identify the role of the heterogeneous belief, we need to control the liquidity proxy discussed in the classic market liquidity literature. For this purpose, we need to control at least one of the individually treated dimensions of market liquidity in literature such as tightness, depth, and resiliency (BIS (1999)). Considering the data availability described in the previous section, we feature the resiliency and construct the third hypothesis.

Hypothesis-3: ***GAP measure is valid to measure the impact of illiquidity on the spreads even after controlling the resiliency (i.e., persistency on spreads).***

We could conjecture the conditionality considered in the second hypothesis also for the resiliency factor, from which we can construct our last hypothesis.

Hypothesis-4: ***The quantitative impact of resiliency has conditionality.***

We will test this hypothesis by checking the coefficient representing the persistency on the median reported prices changes as firms' individual characteristics (e.g., credit ratings) and the market condition of liquidity vary.

4. Empirical Framework

In this section, we go over our empirical framework. Different from the typical time-series estimation for sorted hypothetical portfolios employed in the extant literature, we use panel estimation with using a balanced panel data of monthly Japanese corporate bond spreads detailed in the next section. The benefits of employing the panel estimation are twofold. First, it can fully extract both the time-series and cross-sectional properties of our firm-level data. By applying the panel estimation framework to such a data set, we can examine the potential determinants of individual corporate bond spreads precisely. Second, our dynamic panel estimation enables us to establish the empirical implication of our GAP measure with precisely controlling the persistency in median quoted bond spreads.

Following the usual asset pricing literature, we start from an extended version of a multi-factor model proposed, for example, in Fama and French (1993).

$$SP_{it} = \beta_1 + \beta_2 F_t + \beta_3 L_t + \alpha_i + \epsilon_{it} \cdots (2)$$

Here, the dependent variable SP_{it} denotes the spread of firm$-i$ at time$-t$. As an explanatory variable, F_t denotes various market indexes (e.g., stock market index, the growth rate of the index, and/or its historical volatility) at time$-t$. In addition to these aggregate credit factors, we incorporate the market liquidity factor L_t, which can be proxied by, for example, trading volume of corporate bonds, the number and/or volume of newly issued corporate bonds, and/or Tibor - JGB spread. We attempt to confirm that each coefficient has an expected sign implied by the extant theoretical studies, which will be presented later. As in the standard panel estimations, α_i captures the firm-specific individual effect, which takes either a fixed value (fixed-effect model) or an independent random variable for each group with mean zero and a standard deviation σ_α.

Next, we advance to the further extended version of such a basic multi-factor model by incorporating f_{it}, which denotes the individual firm-specific credit risk factor of firm$-$i at time$-$t. Potential proxies could be credit ratings and/or historical volatility of stock returns.

$$SP_{it} = \beta_1 + \beta_2 f_{it} + \beta_3 F_t + \beta_4 L_t + \alpha_i + \epsilon_{it} \cdots (3)$$

The most important twist in this paper is the inclusion of the individual liquidity proxy l_{it} to the extended multi-factor model above.

$$SP_{it} = \beta_1 + \beta_2 f_{it} + \beta_3 F_t + \beta_4 L_t + \beta_5 l_{it} + \alpha_i + \epsilon_{it} \cdots (4)$$

This additional factor is the key object in our paper and represented by GAP, which denotes the highest minus lowest reported yields among market makers at time$-$t.[22] Through this model, we try to extract pricing implications of individual liquidity risk in a market under very low liquidity. Note we observe that most of the corporate bonds including the one issued by highly rated utility companies etc (e.g., electricity companies) maintain a significant GAP over our sample period (see Figure-2 (2)).[23] Although we could potentially use bid-ask spreads under a market environment with high liquidity, we think that corporate bond markets do not satisfy such a criterion[24]. To summarize, our main concern is how the model (4) is better than (2) and (3), and if the sign of estimated coefficients is consistent with our predictions.[25]

The estimation will be implemented through pooled OLS, fixed-effect (within), and random-effect GLS estimations. There are a few points to be discussed for model selection. First, we have a hunch that the estimators provided by those three specifications share a similar feature. This conjecture comes from the fact that the

[22] Precisely speaking, we use one-day lagged GAP in order to avoid the simultaneous bias problem.
[23] In Japan, utility companies in the electricity and gas industries etc (e.g., Nippon Telegraph and Telephone Corporation, Japan Railway Company) have been keeping highest ratings from the institutional reason.
[24] We think securitization markets all over the world do not necessarily satisfy this condition either, in particular, after the sub-prime shock.
[25] The expected signs of macro and micro credit factors and the macro liquidity factor will be discussed in the next section when we present our data.

observed variables stored in financial data tend to be further comprehensive than, for example, the data in the field of labor economics. From this reason, it is natural to guess that the individual effect, particularly the firm-specific constant in a fixed-model specification, is largely washed away by using a rich set of explanatory variables. Second, although the estimated coefficients are largely similar among models, we think that the random-effect model, which allows the independent random component for each group, fits the characteristics of our observations relatively well. The inclusion of the appropriate explanatory variables contributes to capture the level of the individual effect (i.e., fixed-effect) but it is safe to assume the variation of the individual effect (random-effect) is not completely controlled. As we will see later, these two conjectures are confirmed in the following section.

Note that from a technical point of view, we might need to control the level of the quoted yield by following the standard finance literature in order to appropriately incorporate the GAP variable. One way to do so is to simply include the level of either highest or lowest quoted spread as well as the GAP itself while another treatment can be constructing a so called "relative distance measure" as in Houweling et al. (2003), which divides GAP by some appropriate level variable (e.g., concurrent JGB yield). We employ the latter method as a robustness check for our results in the later section.

Finally, we extend our model to dynamic panel estimation. Specifically, the lagged dependent variable SP_{it-1} is incorporated in the model (5). As mentioned in the previous section, this formulation is motivated by the notion of resiliency. Supposedly, the coefficient γ takes a value close to one, which implies that the median reported spread has persistency, if the market exhibits low resiliency.

$$SP_{it} = \gamma SP_{it-1} + \beta_1 + \beta_2 f_{it} + \beta_3 F_t + \beta_4 L_t + \beta_5 l_{it} + \alpha_i + \epsilon_{it} \cdots (5)$$

As Arellano (2003) carefully demonstrates, the dynamic models with lagged dependent variables are suitable for the estimation of economic variables with adjustment costs and/or habit formation.[26] In the current context, the persistency represents the dependence of market maker's bond evaluation on the spreads reported in the previous period.[27] From the practical perspective, this specification actually replicates the pricing/reporting scheme implemented by marker makers such that (1) check the price on the previous period, (2) add some adjustment with taking into account the concurrent covariates, and (3) report the prices, which is somewhat resembling "walking after midnight".[28]

The estimation for this dynamic model will be implemented through pooled OLS, fixed-effect estimation, random-effect GLS estimation, Arellano-Bond GMM estimation, and random-effect MLE.[29] There are a few points to be discussed for model selection. First, we have the similar conjecture to the ones for the static model that the estimators provided by those specifications (i.e., OLS, GLS, GMM, and MLE) look similar. We guess that this issue is more prominent in the dynamic model since one potentially missed observation (i.e., a lagged dependent variable) is additionally included in the current model.

Second, we prefer MLE to the other specifications. Under the existence of individual effect (either fixed or random), OLS obviously could not provide a consistent estimator. Moreover, it is well known that fixed-effect and random-effect estimation with a lagged dependent variable could not give a consistent estimator either. This can be easily shown by the modified expression of the individual effect model.

$$\mathrm{SP}_{it} = \gamma \mathrm{SP}_{it-1} + \alpha_i + \epsilon_{it} \Leftrightarrow \mathrm{SP}_{it} = \alpha_i(1 + \gamma + \gamma^2 + \cdots) + \epsilon_{it} + \gamma\epsilon_{it-1} + \gamma^2\epsilon_{it-2} + \cdots$$

Hence,

$$\mathrm{SP}_{it-1} = \alpha_i(1 + \gamma + \gamma^2 + \cdots) + \epsilon_{it-1} + \gamma\epsilon_{it-2} + \gamma^2\epsilon_{it-3} + \cdots$$

[26] The typical example could be the capital investment and employment.
[27] As we will detail later, we use monthly data.
[28] We appreciate a number of anonymous practitioners for pointing us this practice.
[29] We also estimate the model with an AR(1) structure on its disturbance for reference.

This implies that both SP_{it} and SP_{it-1} are correlated with α_i, which leads to a simultaneous bias. Although Arellano-Bond type GMM estimator, which takes into account this problem, is widely used for dynamic models, recent studies point out that the over-identification restriction test does not work. For example, Bowsher (2002) explains it is general that Sargan test based on the full instrument set essentially never rejects when T (and hence the number of moment conditions) becomes too large for a given value of I.[30] Considering that our sample contains a relatively large $T = 82$, it is problematic to use GMM.[31] In order to apply MLE, in which we can ignore the issue of correlation between the residuals and lagged dependent variables, to our dynamic model, however, we need to know the distribution for the initial dependent variable (i.e., SP_{i0}) in advance. Fortunately, the large-T of our sample, in turn, alleviates this problem and we could almost ignore the initial observation problem. Hsiao (2003) shows that the parameters estimated through MLE become consistent as $N \to \infty$ for a given T.[32]

Third, related to the first point, the bias of pooling OLS/GLS estimator associated with the random-effect is shown to be smaller as the time-invariant standard deviation σ_α becomes smaller. Hsiao (2003) concisely shows the following expression for the estimated AR(1) coefficient.

$$\hat{\gamma} = \frac{\sum_{i=1}^{N}\sum_{t=1}^{T} SP_{it}SP_{it-1}}{\sum_{i=1}^{N}\sum_{t=1}^{T} SP_{it}^2} = \gamma + \frac{\sum_{i=1}^{N}\sum_{t=1}^{T}(\alpha_i + \epsilon_{it})SP_{it}}{\sum_{i=1}^{N}\sum_{t=1}^{T} SP_{it}^2}$$

and

$$\text{plim}_{N\to\infty}\hat{\gamma} = \frac{1}{NT}\sum_{i=1}^{N}\sum_{t=1}^{T}(\alpha_i + \epsilon_{it})SP_{it}$$

$$= \frac{1}{T}\frac{1-\gamma^T}{1-\gamma}\text{cov}(y_{i0}, \alpha_i) + \frac{1}{T}\frac{\sigma_\alpha^2}{1-\gamma}[(T-1) - T\gamma + \gamma^T]$$

Evidently, the last term of the second expression becomes smaller as σ_α becomes smaller.

After describing our data in the following section, we show our estimation results

[30] The size of T needs to be judged in the comparison with the size of I.
[31] Blundell and Bond (1998) also points out that the instruments used in the standard first-differenced GMM estimator become less informative in two important cases - the value of γ increases toward unity, and the relative variance of the fixed effects increases. We judge the long$-T$ problem is more prominent in our analysis.
[32] The key idea is the effect coming from the initial observation for the estimation of model parameters through MLE becomes almost negligible as the length of data becomes longer enough. Note that the validity of assuming the normal distribution remains as usual.

and discuss the implication in Section 6.

5. Data

As briefed already, the data is obtained from Japan Securities Dealers Association (JSDA). It contains the reference data about Japanese corporate bond markets. The data is daily-frequency and consists of the highest, lowest, mean, and median bond yields among all the yields reported by selected market makers ("member security firms") after cutting the outliers based on predetermined percentages.[33] Those member security firms report the yield of each company's existing bonds for different maturities by 4:30 pm every day as if they are asked to price the 500 million yen of the bonds as of 3:00 pm. JSDA collects the data and release the four reference data mentioned above (i.e., highest, lowest, mean, and median) on its website at 5:30 pm.[34]

From this data, we pick up the median spread as our dependent variable. Since we use the difference between highest and lowest spreads as GAP measure, the median is more preferable than mean since it is not directly affected by the highest and lowest spreads from its arithmetic manner. Considering that the data has high persistency, we decide on using monthly-frequency data. We also use the 1-day lagged GAP measure in order to avoid the simultaneous bias. Table-1 shows the summary statistics of our explanatory variables with its definition and Table-2 summarizes the correlation.[35]

For the market-level liquidity proxy (T_JGBGAP) and the individual credit factors (eHV and RATE_RI), we expect the positive correlation with the median reported spread. For the macro credit factors (JGBSLOPE, JGB10Y, and NKYGROWTH), however, the existing literature provide mixed predictions. Thus, we would rather treat these variables as control variables without assigning specific expected signs. GAP and the adjusted GAP measures are expected to have positive signs on our estimations.

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[33] The selected market makers are as follows: SMBC Friend, Okasan, Credit Swiss, Cosmo, Goldman Sachs, Citi Group, Shinsei, JP Morgan, Daiwa SMBC, Deutch, Tokai Tokyo, Nomura, BNP Paribas, Marusan, Mizuo, Mizuho Investors, Mitsubishi UFJ, Merril Rinch Japan, Morgan Stanley, UBS. If reporting firms are 34 to 40, cut 6 firms from the highest and lowest respectively. The cutting criteria is as follows: 27 to 33 security firms report, cut 5 from the highest and lowest. 21 to 26 security firms report, cut 4 from the highest and lowest. 15 to 20 security firms report, cut 3 from the highest and lowest. 10 to 14 security firms report, cut 2 from the highest and lowest. 5 to 9 security firms report, cut 1 from the highest and lowest.

[34] If the gap between the highest and lowest (yield) becomes more than 500bp, the data is not released.

[35] For the reference for the estimation based on the sample splits detailed later, we also list the summary stats and the correlation tables for those cases.

While we have almost 120 firms in our original sample, the number of groups (i.e., firms) is reduced to about 52 because of the maturity control we explained below. It is important to note that our sample still contains a large variation in the credit ratings and GAP measure[36]. The sample period is 82 months from July 2003 to April 2010.

Although the original data covers bit longer time periods, we focus on the period over which we can always observe the GAP measure. We also consider the data only for Japanese listed firms which maintain a certain number of issued bonds. This is mainly because we want to transform the yield data of each corporate bond with various maturities into specific yields corresponding to maturities 3-year and 5-year, instead of using the raw data for corporate bond yields. Most of the existing literature incorporates the maturities in the explanatory variables instead of adjusting the maturity prior to estimation. From the standard practical manner, the assumption in the extant empirical studies that the maturities have a linear relation with the yields is too restrictive. Evidently, we almost always observe non-linear shaped yield curve in reality. In order to control the heterogeneity in maturity, we use the information of multiple corporate bonds issued by each company. The different bonds for a given company are used to construct an interpolated yield curve. Then, our targeted spreads corresponding to maturity 3-year and 5-year are taken out from the yield curve with considering the concurrent JGB yield curve. [37] Thanks to this operation, we do not need to control the maturity by including the maturities as explanatory variables. Figure-4(1) and Figure–4(2) show the resulting yield curves for two firms in our sample. We apply this procedure in order to construct the yield curves for highest, lowest, mean, and median reported spreads. Considering the shape of time-series data constructed in this way (see Figure-5), we believe this interpolation does not generate any severe problems.

6. Estimation Results

In this section, we implement the estimations proposed in the previous section.

[36] The current sample is a highly balanced panel data. We are planning to incorporate the unused data with proper treatment for missing values.
[37] We gave up to construct 10-year spreads since we do not have enough number of long-term corporate bond data. On the other hand, we do not contain 1-year spreads in our analysis simply because the bonds close to its maturity tend to exhibit irregular dynamics.

First, we apply pooled OLS estimation, fixed-effect estimation, random-effect estimation, and MLE to the static model. The results are summarized in Table-3. The sensitivity analysis of each coefficient with respect to the credit ratings and/or market conditions is further demonstrated in Table-5 (1). Considering the fact that our static panel estimation potentially suffers from heteroskedasticity, we employ the heteroskedasticity-robust standard error proposed by White.[38]

The coefficients of introduced covariates are as follows: First, higher Tibor - JGB spreads (T_JGBGAP), which represents the tightness in the short-term financial market, contributes to higher median spread. This is consistent with our prediction that the spreads are positively correlated with the market-level liquidity index. Second, the residual in the regression of the individual stock price volatility on that of Nikkei Index (eHV), which corresponds to the extra volatility of individual firm's value after controlling the aggregate shock, has a positive effect on the corporate bond spreads. Third, the credit ratings of each company provided by R&I (RATE_RI), which covers the largest number of Japanese companies, has the same implication as eHV.

About the GAP variable, we can establish a strong positive correlation between GAP and median reported spreads. One remarkable point is that the inclusion of the GAP measure significantly improves the R^2 of the model. We also find that the impact of the GAP coefficients depends negatively on the credit ratings (i.e., as the credit ratings are worse, the GAP coefficients times the standard deviation of GAP becomes larger).[39] Namely, the impact is 0.11 (=1.37×0.08) if the credit ratings at the beginning of our sample period is better than or equal to 4 (i.e., AA-) while it takes almost the double size 0.24 (=1.50×0.16) otherwise.[40] The variation of the impact of GAP coefficients with respect to market condition has a similar feature. If the share of firms satisfying "GAP is equal to or smaller than 10bp" is greater than 75% (i.e., the market condition is GOOD), the impact of GAP coefficient is 0.13 (2.09×0.06) while it becomes 0.19 (1.12×0.17) otherwise.[41]

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[38] In order to implement the test for model specification, fixed-effect and random-effect models are estimated without this consideration.
[39] We transform each rating into numbers. The detailed computation results are provided upon request.
[40] The numbers come from Table-5 (1), Table-1 (2), and Table-1 (3).
[41] The numbers come from Table-5 (1), Table-1 (4), and Table-1 (5).

Although it seems that we succeed on improving the model by using the GAP measure in static panel estimation, the residual plot of the model in Figure-6 tells us a substantial problem. Apparently, it shows heteroskedasticity. The first component is the lower part of the residual plot (i.e., the spreads of firms with good credit and those of good market environment period), which seems to form the down-sloped concentration. The second component (i.e., the spreads of firms with weak credit or those of bad environment period) can be found in the upper scattered portion. Because of the potential omitted variables that could capture the behavior of the latter component, the static model generates a bunch of very large positive residuals over the high spread range. These outliers attract the regression line upward and make the former portion over-estimated.

Before adding another explanatory variable in order to overcome this problem, we tested a model assuming the serial correlation of the disturbance term (see the first column of Table-4). This model seems to partially ease the above problem (see Figure-7). Evidently, it can explain the behavior of the firms with good credit and good environment rather well. Unfortunately, this remedy still remains a problem - the upper scattered portion still exists. Ultimate solution seems to be the adoption of the lagged dependent variable (i.e., the lagged spread). As already mentioned, the notion of resiliency which pronounces in illiquid market and the actual reporting procedure, incorporating a persistency term is plausible. We also strengthen this conjecture by taking look at the residual plot over time horizon (see Figure-6(2) and -7(2)). It is apparent that the underestimation is typical under the weak market conditions and the spreads tend to stay at the high level even though its covariates including GAP got back to the normal situation.

Considering these results, the dynamic models proposed in (5) are estimated through pooled OLS, fixed-effect, random-effect GLS, Arellano-Bond GMM, and MLE.[42] The results summarized in Table-4 shows, that all the estimation methods lead to almost similar coefficients, which is consistent with our conjecture in the previous section.

[42] The default setting of STATA for MLE does assume that initial value is exogenously given and does assume nothing on its distribution. Although this naïve ML estimation works well and is justified by our discussion in the previous section, it might be better for us to assume the more consistent distribution derived from the model. We recognize it is our future task to employ the MLE methods proposed in Anderson and Hsio (1982), Bhargava and Sargan (1983).

Looking at the scattered plot (Figure-8 and -9) corresponding the Arellano-Bond GMM and MLE estimations for the dynamic model, the problem stemmed from omitted variables seems to be resolved satisfactorily.[43] We can also confirm that the dynamic panel still provides similar results as in the static model.[44] One point to be noted for the models with lagged dependent variable is that the AR(1) coefficient is 0.86 to 0.89, which indicates a strong auto-correlation. The conjectured persistency of the reported bond spreads is successfully confirmed through our dynamic panel estimation.

Another interesting point is that AR(1) coefficient seems to have conditionality on the credit ratings and/or business cycle. Table-5 (2) summarizes the spectrum of AR(1) coefficient for different levels of credit ratings and market environments. The purpose of this additional analysis is to see the AR(1) coefficient with respect to the characteristics of cross-section and time-series sample variation.[45] It is clear that we have a negative conditionality of the AR(1) coefficient on credit ratings and/or market conditions. More precisely, the persistency of the median reported spread becomes higher as credit ratings and/or market conditions get worse, which actually looks like "walking after midnight" (i.e., not walk away from the previous step when really dark). In the extant literature, some conditionality has been pointed out in stock market return (e.g., Watanabe and Watanabe (2008)) such that the pricing impact of liquidity risk is larger for the firms with lower credit ratings.[46] As far as we know, however, the conditionality of the resiliency component with respect to the variations of credit ratings and/or market conditions has never been analyzed.

Note that σ_α in the MLE for the dynamic model is substantially smaller than that for the static model. We think that this is consistent with the fact that the estimated coefficients are almost similar among the estimation methods. If the individual effect is

[43] There still remain a very few outliers but we think this is no longer the big problem. It is not difficult for us to identify these outliers and tells that is the result of detection of window dressing. It is very easy to trim out these by setting a dummy variable.

[44] As the coefficient of the slope of JGB yield curve calculated by the difference between 10-year JGB yield and 2-year JGB yield increases, the spreads decrease. This result is somewhat controversial if we consider the discussion in Fama and French (1993) where the slope index is treated as a risk or a sigh of boom. One interpretation of this result is that the higher 10-year JGB yield is accompanied with boom while the lower 2-year JGB yield is generated by easing monetary policy.

[45] In order to split the sample, we use (i) whether the credit ratings at the beginning of sample period is better than or equal to 4 (i.e., AA-), or worse than or equal to 5 (A+), and (ii) whether the share of firms satisfying "GAP is equal to or smaller than 10bp" is greater than 75% (i.e., the market conditions is GOOD) or not (BAD market condition). Note that if firms in our sample do not have their credit ratings from R&I but from other rating agencies, we transform those ratings into hypothetical R&I ratings (e.g., AAA=1, AA+=2, and so on). This transformation is done by referring to the companies holding both the R&I ratings and the ratings provided by other agencies.

[46] Their analysis is based on the hypothetical portfolio as in the other extant studies and does not employ the panel estimation.

properly controlled, it is natural to have very small variations in the estimators among the model specifications.

In order to check the robustness of the result, Table-6 reports the revised regression results in (2) to (4) under an adjusted GAP measure, which is constructed by dividing the GAP with the concurrent JGB yield. The results obtained in the previous estimations are all confirmed in this additional estimation.

7. Comparison with existing studies

Mainly because of the data limitation, there are only few studies directly comparable with our results. As one limited example, Hauweling et al. (2005) employs the measurement constructed by dividing the standard deviation of market makers concurrent quotes in a given day by the average quoted spreads in order to construct sorted hypothetical portfolios. Their main conclusion is such a relative distance measure of quoted spreads is valid to capture the market liquidity among the other proxies. Our result presented in the previous section is consistent with theirs.

8. Concluding Remarks

This paper proposes a theoretically motivated proxy for the degree of market liquidity in corporate bond market (GAP: the highest minus lowest simultaneously reported spreads among multiple market makers), and studies its pricing implication by quantifying the correlation between GAP and the median reported spreads among market makers, which presumably approximate market prices conjectured by market makers. While the issue of market liquidity has been extensively examined over the last decade for stock and sovereign bond markets, our understanding is still limited for corporate bond market mainly due to the unavailability of widely accepted liquidity proxies, such as bid-ask spreads in other markets. Through various panel estimations for the median reported spreads in Japanese corporate bond market, we find that (i) inclusion of the lagged GAP to the standard multi-factor model significantly improves the explanation power, (ii) the quantitative impact of such an illiquidity measure on bond spreads becomes larger as credit ratings get worse, (iii) the GAP proxy is valid even after controlling the persistency on spreads, which has been considered as another proxy for illiquidity in the extant literature (i.e., resiliency), and (iv) the degree of such persistency increases as the credit ratings of corporate bonds and/or market condition deteriorate. These results jointly explain how market makers construct their opinions about bond prices by (a) learning from the dispersion of reported prices, (b) recalling the past reporting, as well as (c) considering standard covariates of bond spreads (i.e., JGB Yield, credit ratings etc). Our results also support the empirical implication provided by theoretical literature on the correlation between the degree of opinion differences and market liquidity premium. Our research complements the limited number of quantitative research about Japanese corporate bond market and gives some implication for the markets associated with relatively low liquidity (e.g., ABS, CDO, and/or realty market).

To conclude, we list several future research questions. First, we will consider the refinement of our dynamic panel estimation such as the proper selection of instrument variables and/or imposing an appropriate structure to the distribution of error term in MLE. It would be also interesting to construct a static measure representing the price stickiness (e.g., ILLIQ-type measure and/or the difference of GAP measure). Second, it is necessary to use our estimated results to motivate theoretical models. The recent "differences in opinion (DO)" literature surveyed in Section 2 constructs market microstructure model considering the heterogeneous views among market makers. What we need to construct is the model where market maker continuously revises its evaluation about bond spreads and still exhibits the heterogeneity of their evaluations. Studying the price and trade volume dynamics through such a model is one promising way to understand the markets with low liquidity. It also allows us to understand the distributional dynamics of market maker’s reporting contents from theoretical perspectives. Third, our analysis could be refined as in the consistent way with the CAPM literature with liquidity risk (e.g., Acharya and Pedersen (2005)). Fourth, it is important to incorporate the unused data in our original sample with a proper treatment for missing values. One idea is to apply Tobit-type framework to the original data. Fifth, the determination of GAP and further empirical analysis of the distribution of reported spreads would be informative research objects. Doubtlessly, we are far away from the full understanding on the sources of belief/evaluation heterogeneity among market makers and/or investors. One potential candidate generating dispersed reported prices, we are guessing, is the heterogeneity of investor classes and the market makers having tight connections with those investors in each class. To illustrate, the investors taking "Buy & Hold" strategy would not have urgent needs to commit fire-sales even when the quoted prices plunge.[47] Reflecting this feature, the market makers mainly dealing with those investors are somehow allowed to be insensitive with the price changes. On the other hand, the "value-based" investors such as hedge funds are conjectured to be very keen on the price change since it affects the fair-value of their assets. This keenness could be more sounding in CDS markets where hedging motif is the main driver. Along this line, we are planning to document the quoted price dynamics in CDS markets and compare it with our current analysis for corporate bond markets. Trough such an analysis, we aim at establishing the relation between the types of investors and price dynamics. We believe all of these extensions provide further guides for better understanding of corporate bond as well as securitized products in very low liquid markets.

[47] Many corporate bond investors in Japan could be categorized in this group.

<Table and Figure>

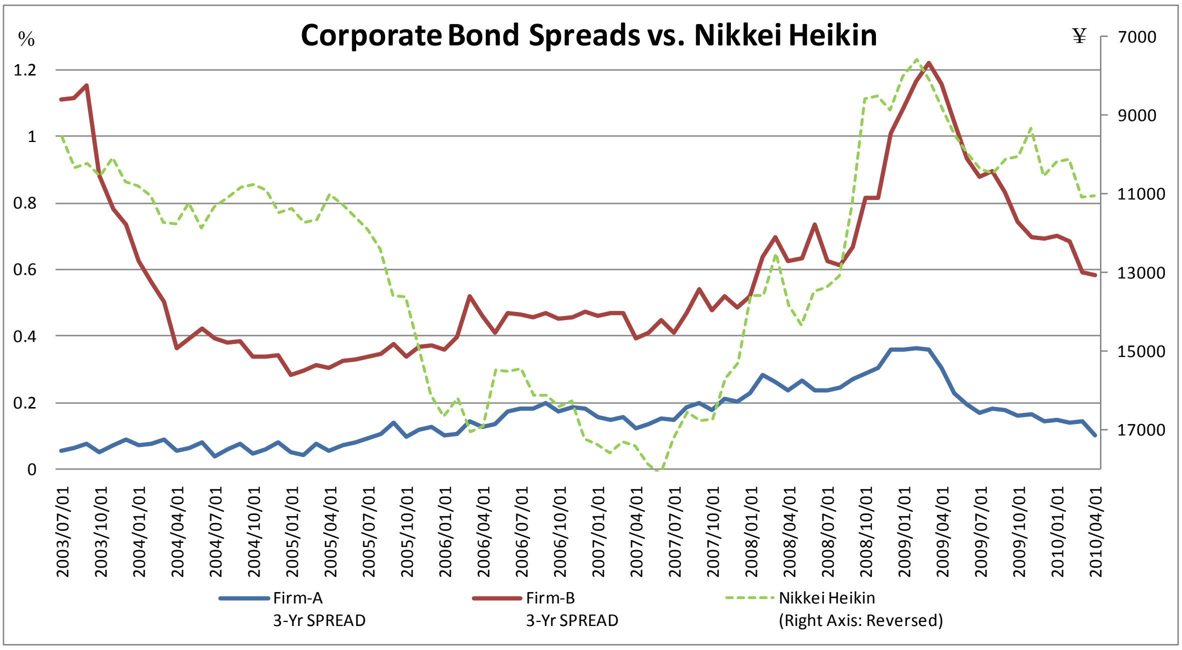

Figure-1 (1): Corporate Bond Spreads and Stock Index

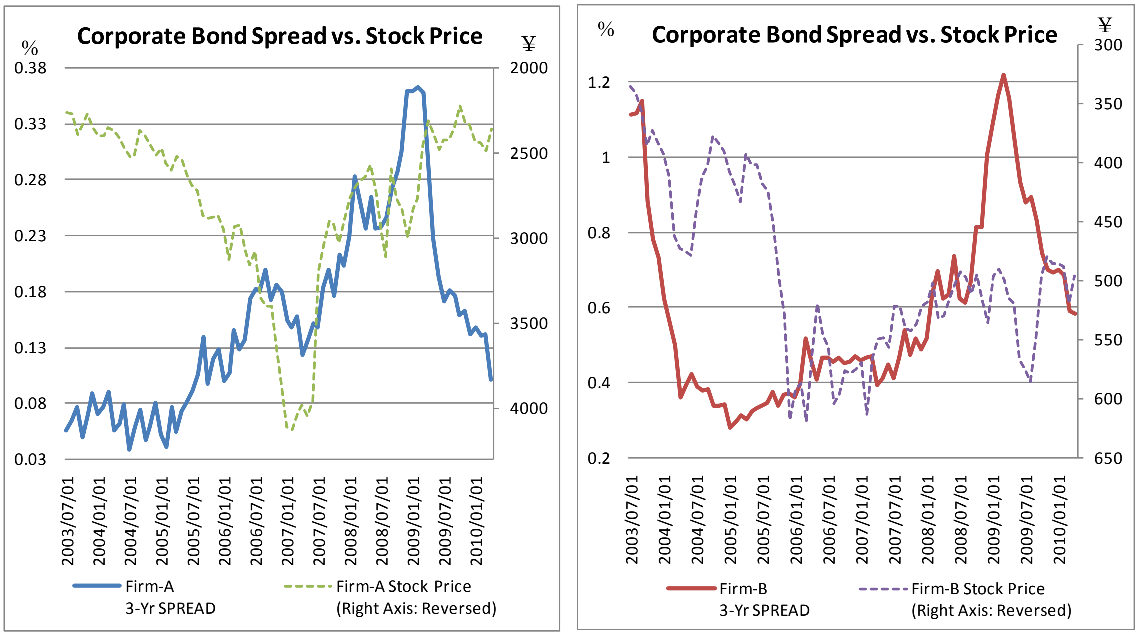

Figure-1 (2): Corporate Bond Spreads and Individual Stock Prices

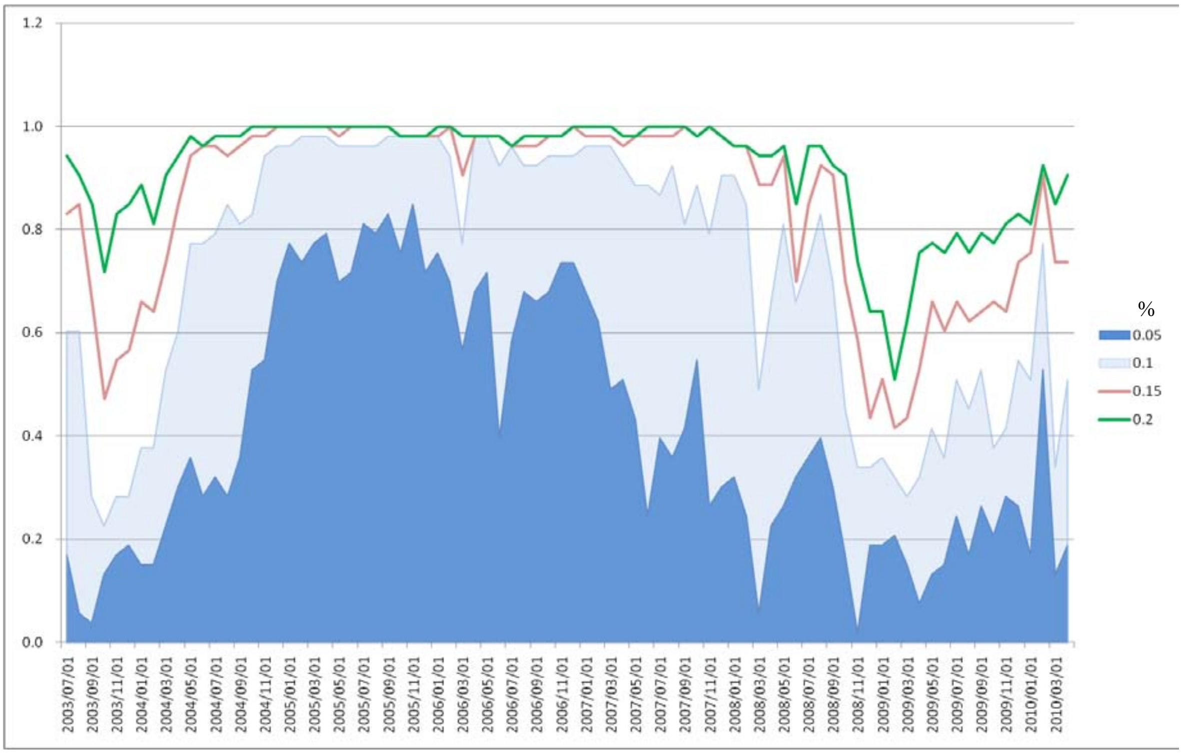

Figure-2 (1): The distribution of GAP measure

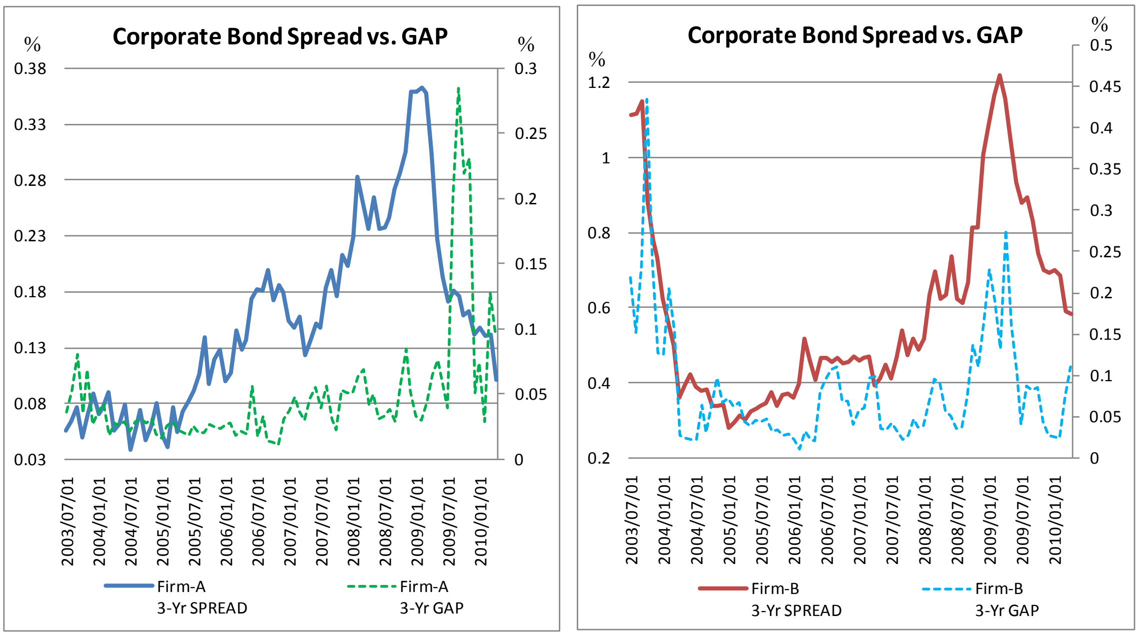

Figure-2 (2): Individual Corporate Bond Spreads and GAP measures

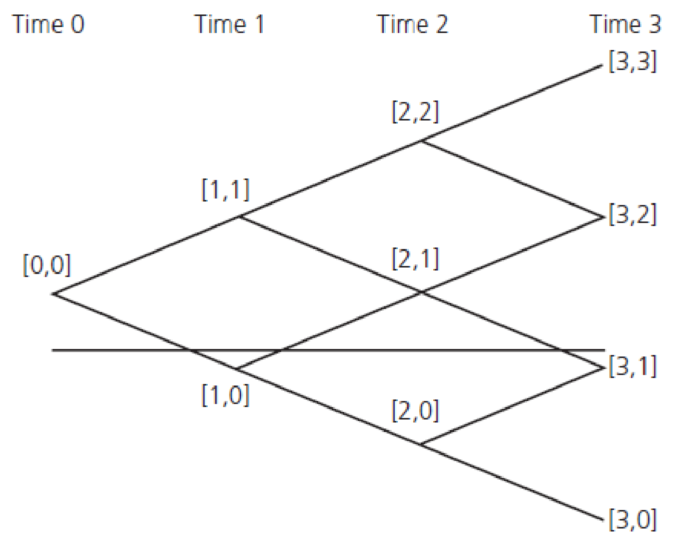

Figure-3 (1): Binomial Tree in Tychon and Vannetelbosch (2005)

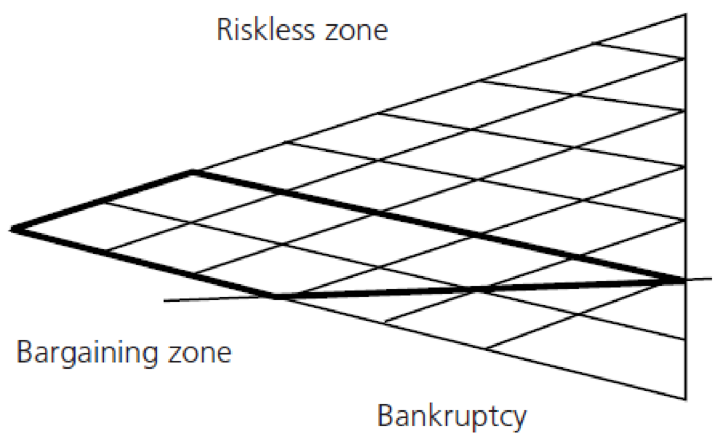

Figure-3 (2): Necessary Nodes for Price Computation in

Binomial Tree in Tychon and Vannetelbosch (2005)

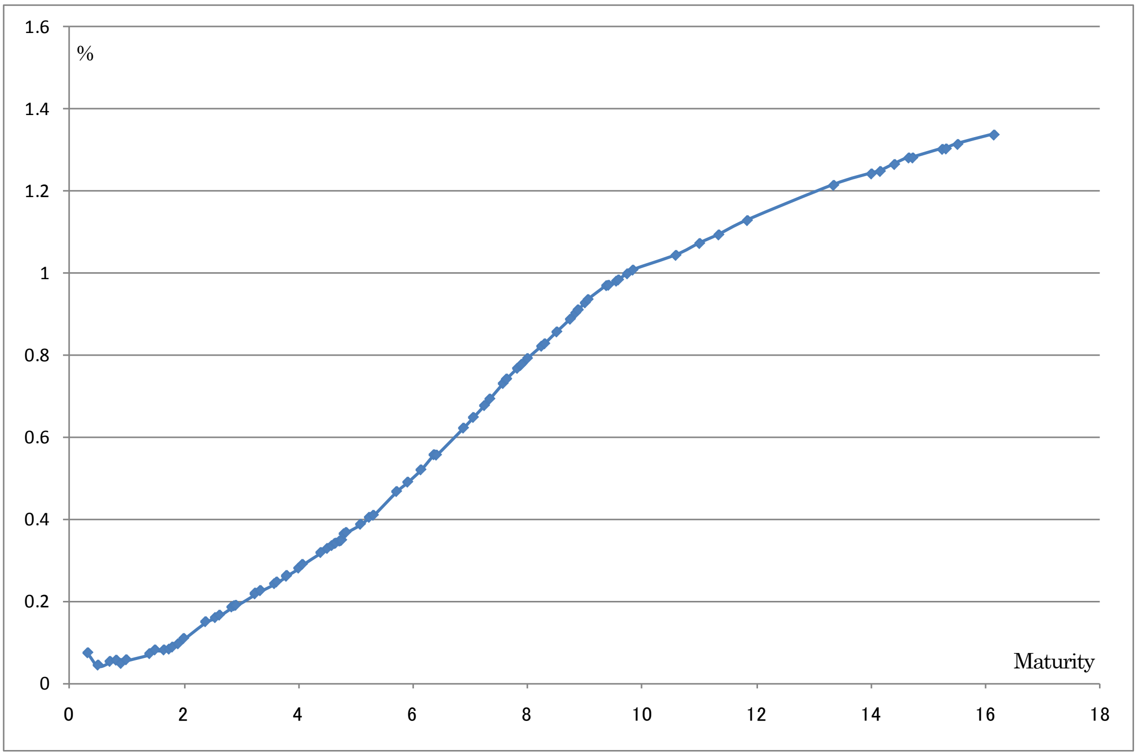

Figure-4(1) Interpolated Yield Curve for Firm-A (July 31st 2003)

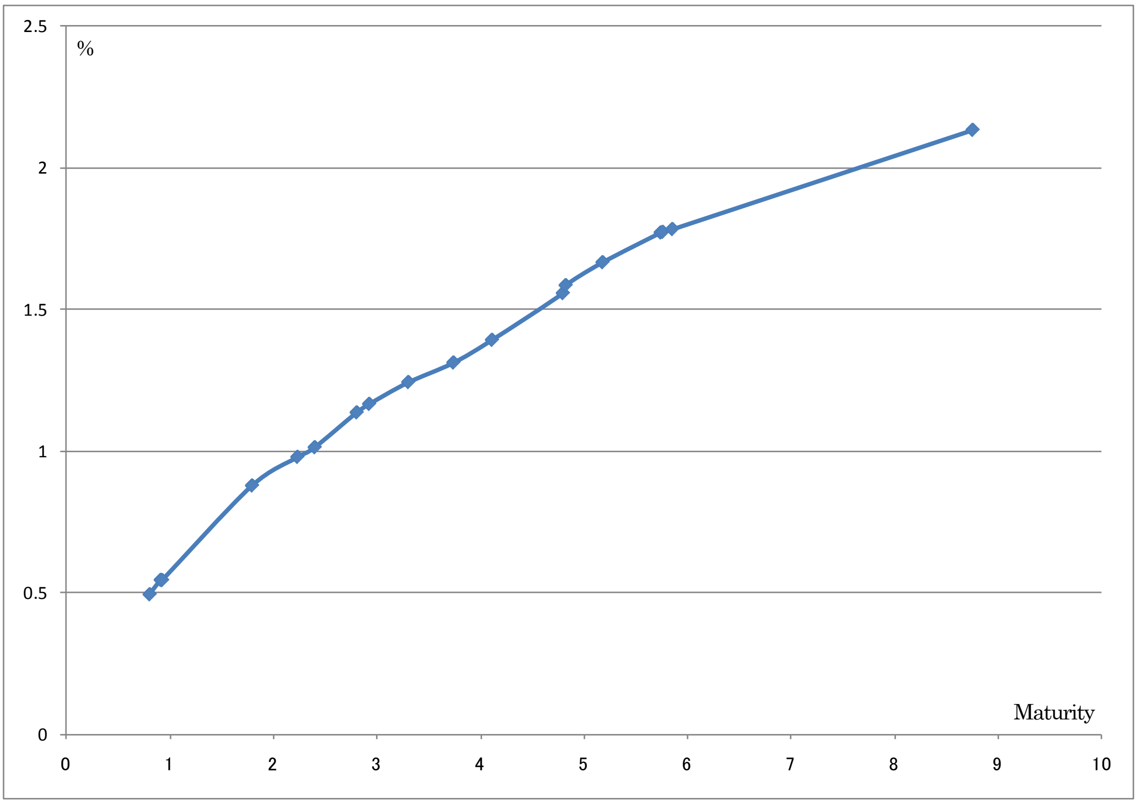

Figure-4(2) Interpolated Yield Curve for Firm-B (July 31st 2003)

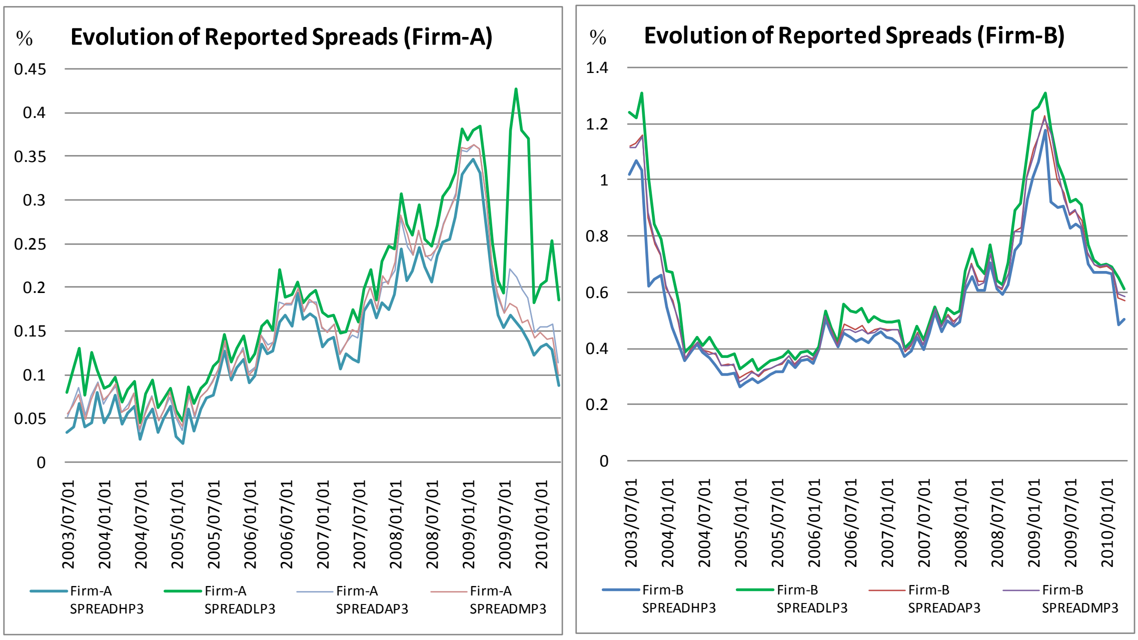

Figure-5 Interpolated Spreads (Highest, Lowest, Average, Median)

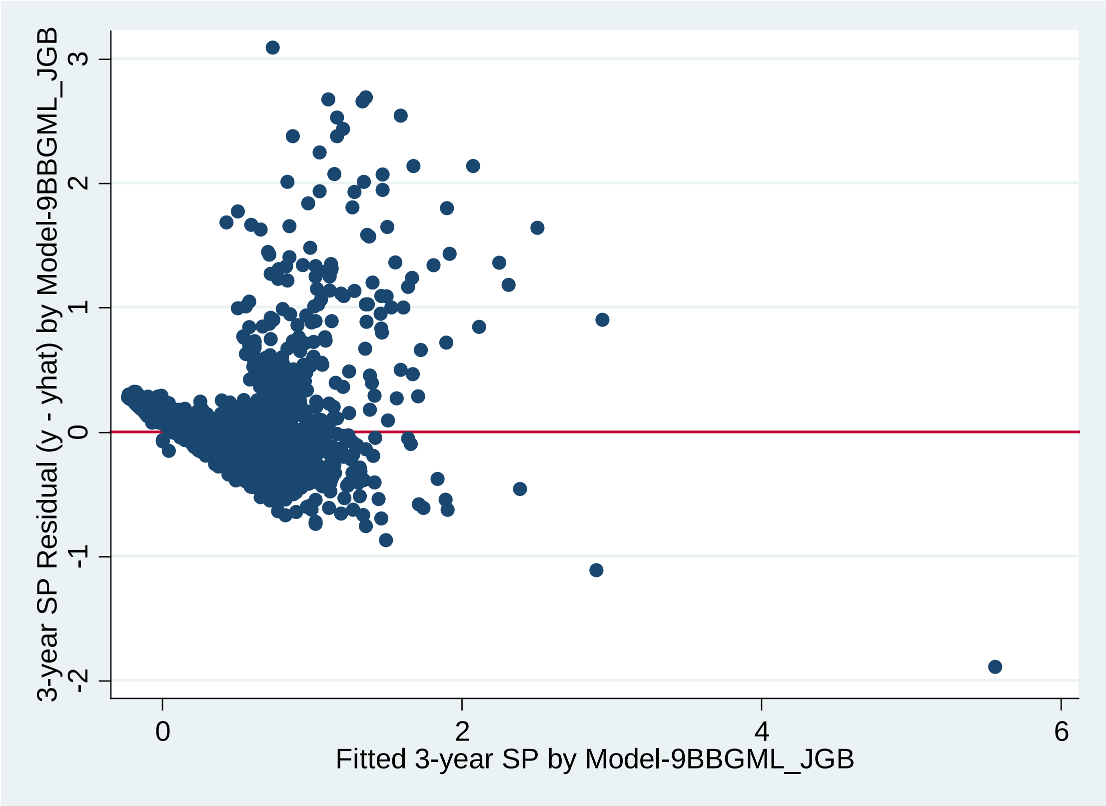

Figure-6 (1): Residual Plot of Static Panel Estimation (Random-Effect)

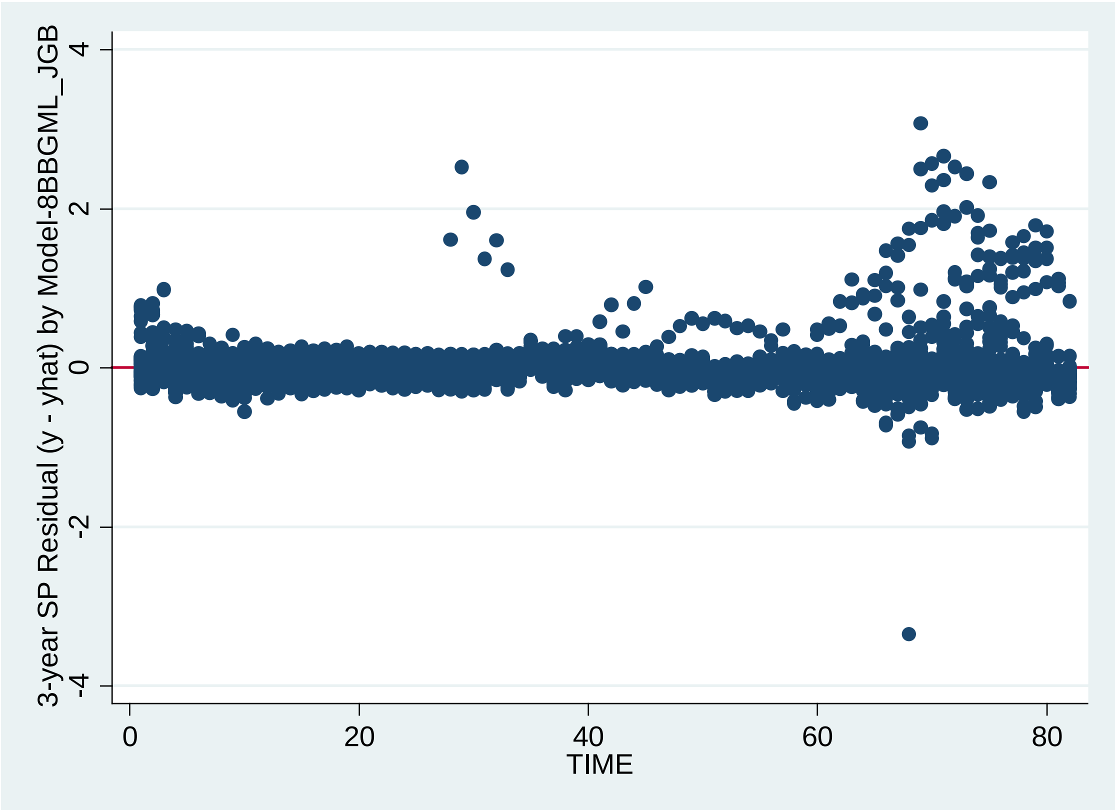

Figure-6 (2): Residual Plot of Static Panel Estimation (Random-Effect)

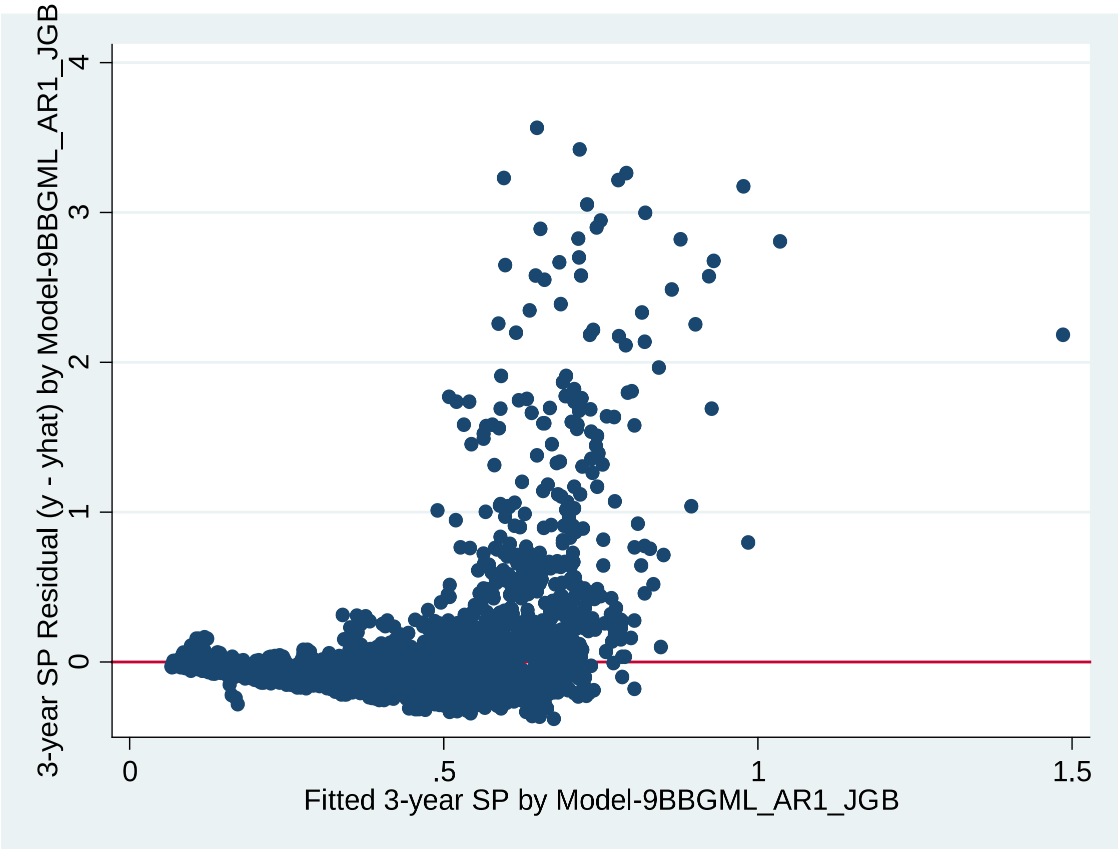

Figure-7(1): Residual Plot of Dynamic Panel Estimation (AR(1) on Disturbance)

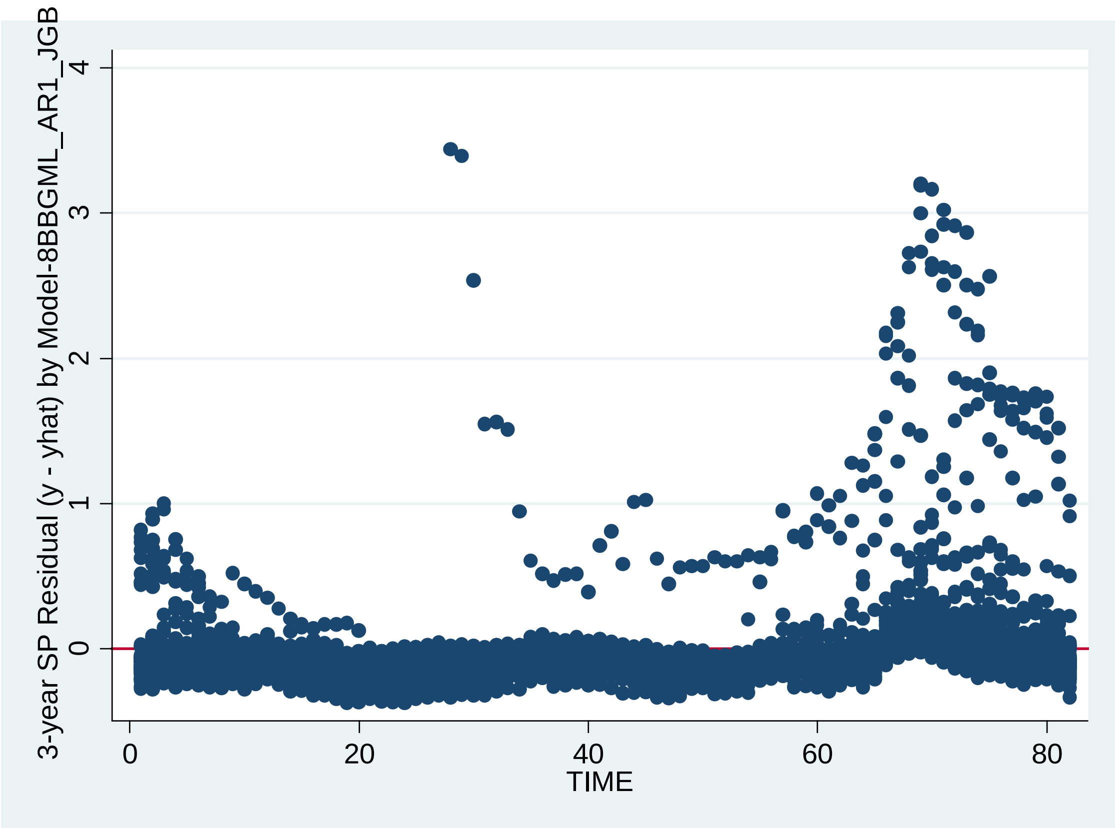

Figure-7(2): Residual Plot of Dynamic Panel Estimation (AR(1) on Disturbance)

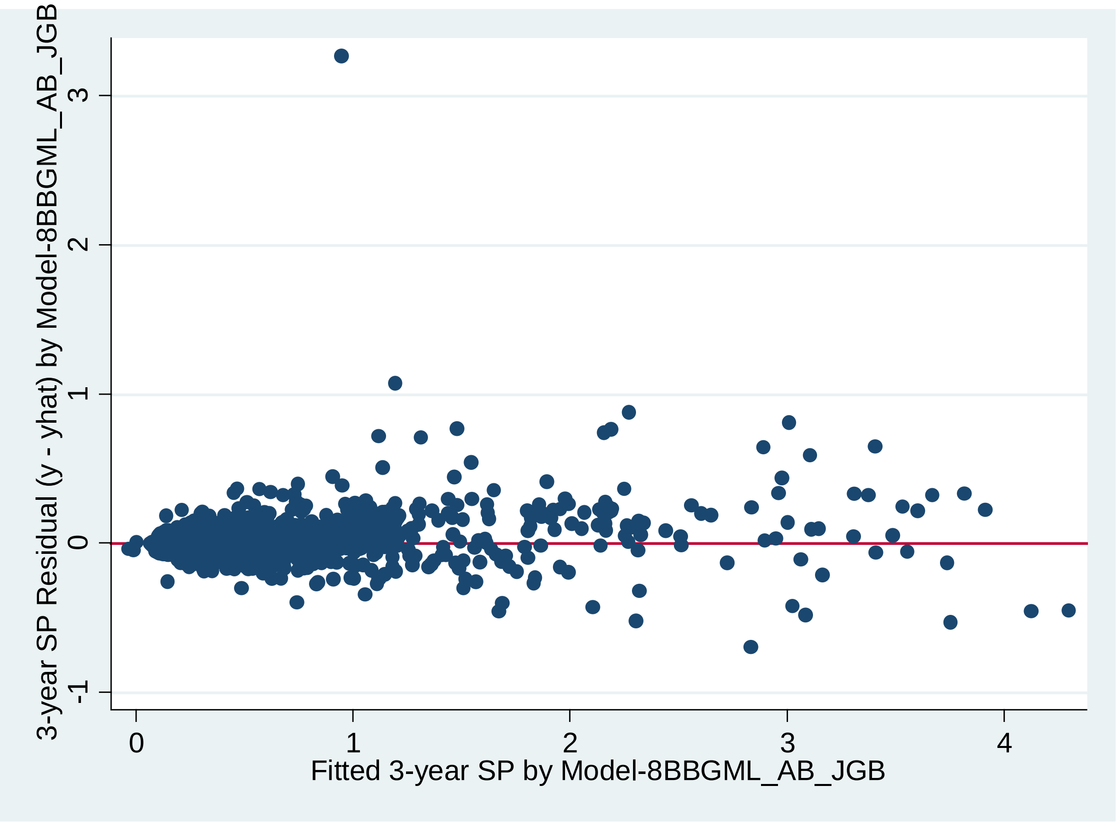

Figure-8(1): Residual Plot of Dynamic Panel Estimation (Arellano=Bond)

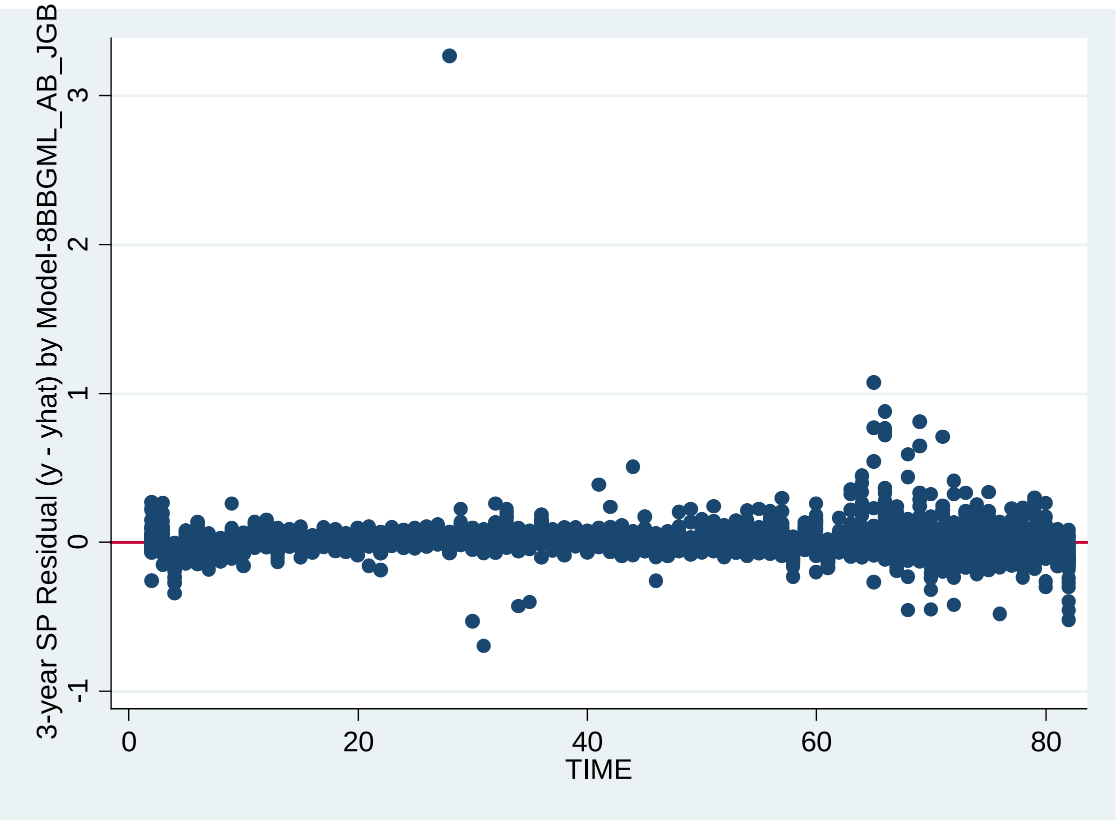

Figure-8(2): Residual Plot of Dynamic Panel Estimation (Arellano=Bond)

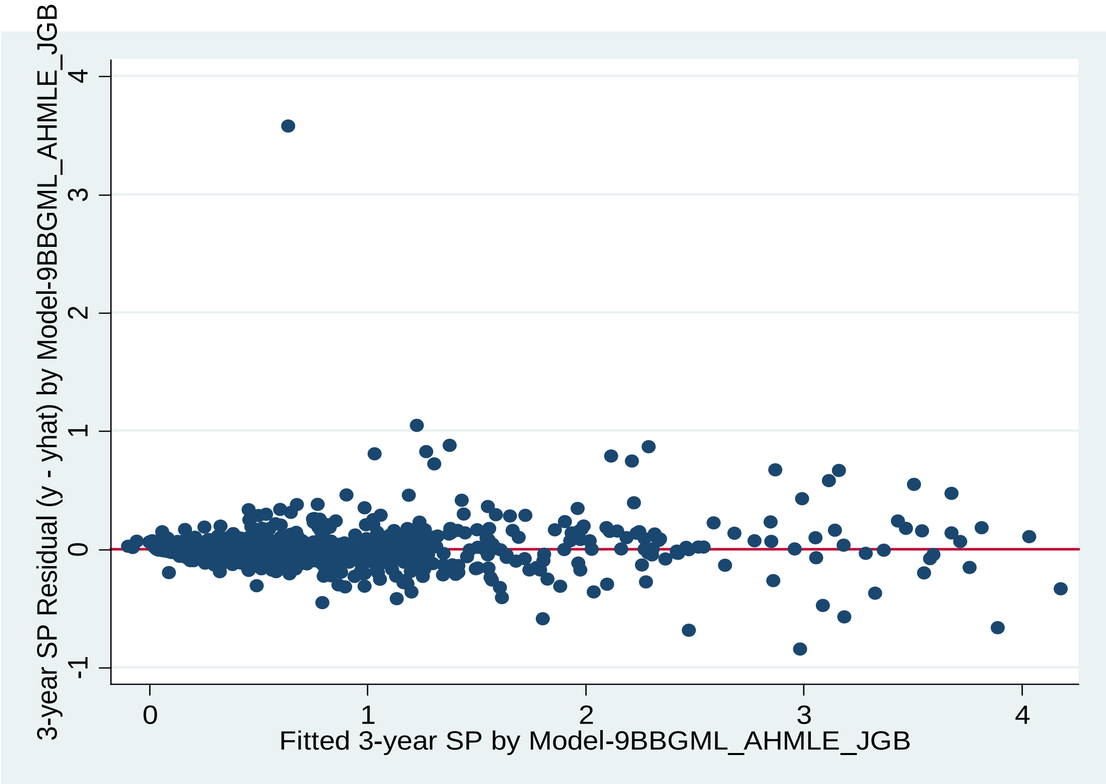

Figure-9(1): Residual Plot of Dynamic Panel Estimation (Anderson=Hsio)

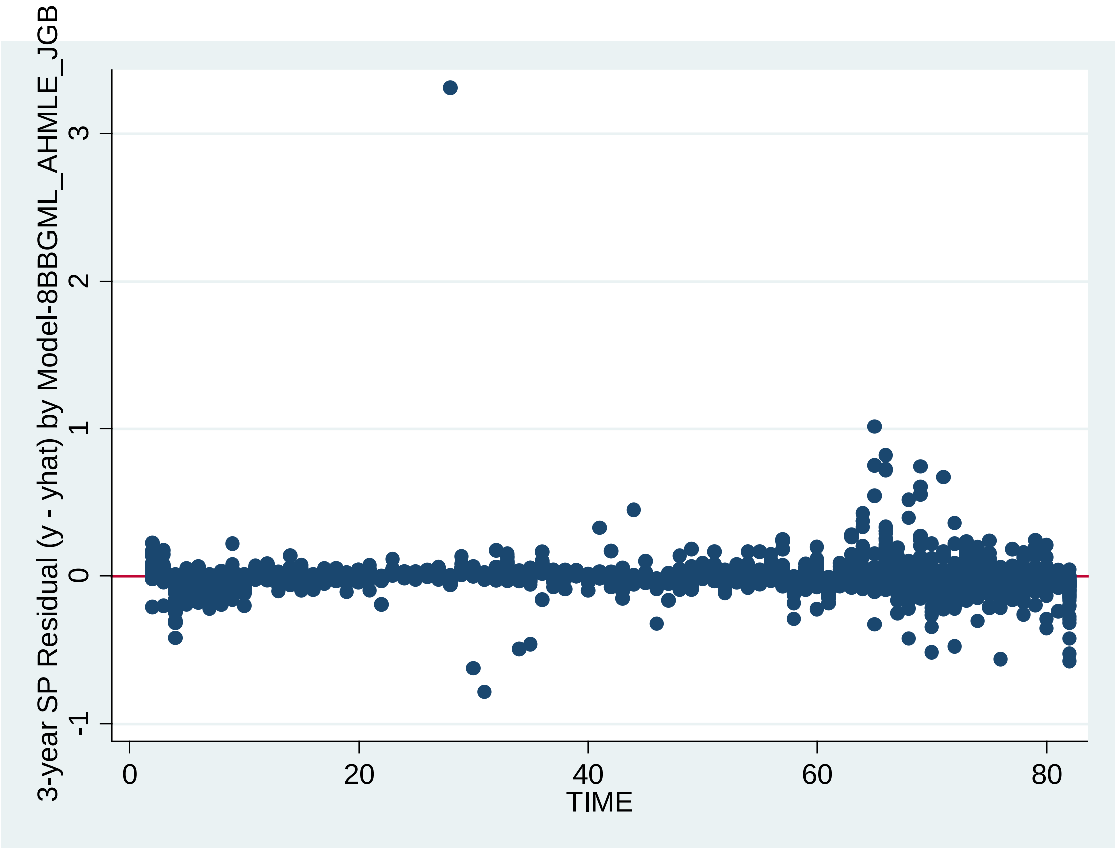

Figure-9(2): Residual Plot of Dynamic Panel Estimation (Anderson=Hsio)

Variable		Defininition	Expected Sign	Obs	Mean	Std.	Min	Max
SP_t	3-Yr SPREAD	Coorporate bond yield minus JGB yield		4173	0.40	0.45	-0.11	4.21
L_t	T_JGBGAP	3-month Tibor minus 3-month JGB yield	+	4264	0.19	0.14	-0.03	0.54
F_t	JGBSLOPE (10Y-2Y)	10-year JGB yield minus 2-year JGB yield	−/+	4264	1.06	0.22	0.69	1.64
F_t	JGB10Y	10-year JGB yield	−/+	4264	1.49	0.20	0.95	1.93
F_t	NKYGROWTH	Growth rata of Nikkei stock index	−/+	4264	0.00	0.06	-0.24	0.13
f_{it}	eHV	20-day historical volatility of individual stock minus estimated historical volatility of each individual	+	4264	0.00	13.69	-76.03	83.84
f_{it}	RATE_RI	R&I credit ratings	+	4264	5.63	2.53	2.00	11.00
l_{it}	GAP3_1DLAG	Highest reported yield minus lowest reported yield in the previous day of 3-Yr SPREAD	+	4172	0.09	0.13	0.00	3.95
l_{it}	GAP3_1DLAG_Adj	GAP3_1DLAG divided by concurrent JGB yield	+	4172	0.25	0.34	0.01	8.51

Table-1 (1): Summary Stat for All Samples

Variable		Defininition	Expected Sign	Obs	Mean	Std.	Min	Max
SP_t	3-Yr SPREAD	Coorporate bond yield minus JGB yield		2029	0.25	0.28	-0.11	4.21
f_{it}	eHV	20-day historical volatility of individual stock minus estimated historical volatility of each individual	+	2050	-3.81	12.77	-76.03	82.44
f_{it}	RATE_RI	R&I credit ratings	+	2050	3.56	1.71	2.00	9.00
l_{it}	GAP3_1DLAG	Highest reported yield minus lowest reported yield in the previous day of 3-Yr SPREAD	+	2029	0.07	0.08	0.01	1.51
l_{it}	GAP3_1DLAG_Adj	GAP3_1DLAG divided by concurrent JGB yield	+	2029	0.18	0.22	0.01	3.35

Table-1 (2): Summary Stat for Initially Hi-Rate

Variable		Defininition	Expected Sign	Obs	Mean	Std.	Min	Max
SP_t	3-Yr SPREAD	Coorporate bond yield minus JGB yield		2144	0.54	0.52	0.13	4.15
f_{it}	eHV	20-day historical volatility of individual stock minus estimated historical volatility of each individual	+	2214	3.53	13.58	-55.67	83.84
f_{it}	RATE_RI	R&I credit ratings	+	2214	7.54	1.41	4.00	11.00
l_{it}	GAP3_1DLAG	Highest reported yield minus lowest reported yield in the previous day of 3-Yr SPREAD	+	2143	0.12	0.16	0.00	3.95
l_{it}	GAP3_1DLAG_Adj	GAP3_1DLAG divided by concurrent JGB yield	+	2143	0.31	0.41	0.01	8.51

Table-1 (3): Summary Stat for Initially Low-Rate

Variable		Defininition	Expected Sign	Obs	Mean	Std.	Min	Max
SP_t	3-Yr SPREAD	Coorporate bond yield minus JGB yield		2499	0.28	0.24	0.03	4.21
L_t	T_JGBGAP	3-month Tibor minus 3-month JGB yield	+	2548	0.13	0.09	-0.03	0.32
F_t	JGBSLOPE (10Y-2Y)	10-year JGB yield minus 2-year JGB yield	−/+	2548	1.07	0.24	0.69	1.64
F_t	JGB10Y	10-year JGB yield	−/+	2548	1.58	0.19	1.17	1.93
F_t	NKYGROWTH	Growth rata of Nikkei stock index	−/+	2548	0.00	0.04	-0.11	0.09
f_{it}	eHV	20-day historical volatility of individual stock minus estimated historical volatility of each individual	+	2548	-0.86	10.72	-38.16	74.70
f_{it}	RATE_RI	R&I credit ratings	+	2548	5.67	2.56	2.00	11.00
l_{it}	GAP3_1DLAG	Highest reported yield minus lowest reported yield in the previous day of 3-Yr SPREAD	+	2498	0.06	0.06	0.01	1.51
l_{it}	GAP3_1DLAG_Adj	GAP3_1DLAG divided by concurrent JGB yield	+	2498	0.12	0.15	0.01	3.35

Table-1 (4): Summary Stat for Good-State

Variable		Defininition	Expected Sign	Obs	Mean	Std.	Min	Max
SP_t	3-Yr SPREAD	Coorporate bond yield minus JGB yield		1674	0.57	0.60	-0.11	4.15
L_t	T_JGBGAP	3-month Tibor minus 3-month JGB yield	+	1716	0.29	0.15	0.07	0.54
F_t	JGBSLOPE (10Y-2Y)	10-year JGB yield minus 2-year JGB yield	−/+	1716	1.04	0.19	0.71	1.39
F_t	JGB10Y	10-year JGB yield	−/+	1716	1.37	0.13	0.95	1.60
F_t	NKYGROWTH	Growth rata of Nikkei stock index	−/+	1716	0.00	0.08	-0.24	0.13
f_{it}	eHV	20-day historical volatility of individual stock minus estimated historical volatility of each individual	+	1716	1.27	17.11	-76.03	83.84
f_{it}	RATE_RI	R&I credit ratings	+	1716	5.56	2.49	2.00	11.00
l_{it}	GAP3_1DLAG	Highest reported yield minus lowest reported yield in the previous day of 3-Yr SPREAD	+	1674	0.15	0.17	0.00	3.95
l_{it}	GAP3_1DLAG_Adj	GAP3_1DLAG divided by concurrent JGB yield	+	1674	0.43	0.45	0.01	8.51

Table-1 (5): Summary Stat for Bad-State

Variable		Defininition	Expected Sign	Obs	Mean	Std.	Min	Max
SP_t	3-Yr SPREAD	Coorporate bond yield minus JGB yield		1213	0.21	0.27	0.03	4.21
L_t	T_JGBGAP	3-month Tibor minus 3-month JGB yield	+	1225	0.13	0.09	-0.03	0.32
F_t	JGBSLOPE (10Y-2Y)	10-year JGB yield minus 2-year JGB yield	−/+	1225	1.07	0.24	0.69	1.64
F_t	JGB10Y	10-year JGB yield	−/+	1225	1.58	0.19	1.17	1.93
F_t	NKYGROWTH	Growth rata of Nikkei stock index	−/+	1225	0.00	0.04	-0.11	0.09
f_{it}	eHV	20-day historical volatility of individual stock minus estimated historical volatility of each individual	+	1225	-3.97	10.09	-32.98	74.70
f_{it}	RATE_RI	R&I credit ratings	+	1225	3.56	1.71	2.00	9.00
l_{it}	GAP3_1DLAG	Highest reported yield minus lowest reported yield in the previous day of 3-Yr SPREAD	+	1213	0.05	0.07	0.01	1.51
l_{it}	GAP3_1DLAG_Adj	GAP3_1DLAG divided by concurrent JGB yield	+	1213	0.10	0.14	0.01	3.35

Table-1 (6): Summary Stat for Initially Hi-Rate & Good-State

Variable		Defininition	Expected Sign	Obs	Mean	Std.	Min	Max
SP_t	3-Yr SPREAD	Coorporate bond yield minus JGB yield		858	0.83	0.70	0.17	4.15
L_t	T_JGBGAP	3-month Tibor minus 3-month JGB yield	+	891	0.29	0.15	0.07	0.54
F_t	JGBSLOPE (10Y-2Y)	10-year JGB yield minus 2-year JGB yield	−/+	891	1.04	0.19	0.71	1.39
F_t	JGB10Y	10-year JGB yield	−/+	891	1.37	0.13	0.95	1.60
F_t	NKYGROWTH	Growth rata of Nikkei stock index	−/+	891	0.00	0.08	-0.24	0.13
f_{it}	eHV	20-day historical volatility of individual stock minus estimated historical volatility of each individual	+	891	5.77	16.93	-55.67	83.84
f_{it}	RATE_RI	R&I credit ratings	+	891	7.42	1.41	4.00	11.00
l_{it}	GAP3_1DLAG	Highest reported yield minus lowest reported yield in the previous day of 3-Yr SPREAD	+	858	0.19	0.22	0.00	3.95
l_{it}	GAP3_1DLAG_Adj	GAP3_1DLAG divided by concurrent JGB yield	+	858	0.54	0.55	0.01	8.51

Table-1 (7): Summary Stat for Initially Low-Rate & Bad-State

	3-Yr SPREAD	3-Yr SPREAD (Lagged)	T_JGBGAP	JGBSLOPE (10Y-2Y)	JGB10Y	NKY GROWTH	eHV	RATE_RI	GAP3_ 1DLAG	GAP3_ 1DLAG_ Adj
3-Yr SPREAD	1.00									
3-Yr SPREAD(Lagged)	0.97	1.00								
T_JGBGAP	0.42	0.40	1.00							
JGBSLOPE (10Y-2Y)	-0.15	-0.12	-0.44	1.00						
JGB10Y	-0.17	-0.16	-0.42	-0.07	1.00					
NKYGROWTH	0.00	0.02	-0.19	0.28	-0.01	1.00				
eHV	0.32	0.31	0.09	-0.07	-0.03	0.04	1.00			
RATE_RI	0.44	0.45	-0.05	0.03	0.01	0.01	0.33	1.00		
GAP3_1DLAG	0.68	0.63	0.31	-0.06	-0.19	0.00	0.26	0.25	1.00	
GAP3_1DLAG_Adj	0.59	0.57	0.22	0.16	-0.38	0.07	0.21	0.25	0.89	1.00

Table-2 (1): Correlation Table for All Samples

	3-Yr SPREAD	3-Yr SPREAD (Lagged)	T_JGBGAP	JGBSLOPE (10Y-2Y)	JGB10Y	NKY GROWTH	eHV	RATE_RI	GAP3_ 1DLAG	GAP3_ 1DLAG_ Adj
3-Yr SPREAD	1.00									
3-Yr SPREAD(Lagged)	0.93	1.00								
T_JGBGAP	0.34	0.34	1.00							
JGBSLOPE (10Y-2Y)	-0.25	-0.23	-0.44	1.00						
JGB10Y	-0.05	-0.04	-0.42	-0.07	1.00					
NKYGROWTH	-0.03	-0.01	-0.18	0.28	-0.01	1.00				
eHV	0.40	0.41	0.06	-0.09	0.00	0.08	1.00			
RATE_RI	0.58	0.60	0.02	-0.02	0.00	0.00	0.53	1.00		
GAP3_1DLAG	0.72	0.62	0.30	-0.07	-0.14	-0.01	0.31	0.47	1.00	
GAP3_1DLAG_Adj	0.48	0.40	0.22	0.19	-0.39	0.09	0.24	0.37	0.85	1.00

Table-2 (2): Correlation Table for Initially Hi-Rate

	3-Yr SPREAD	3-Yr SPREAD (Lagged)	T_JGBGAP	JGBSLOPE (10Y-2Y)	JGB10Y	NKY GROWTH	eHV	RATE_RI	GAP3_ 1DLAG	GAP3_ 1DLAG_ Adj
3-Yr SPREAD	1.00									
3-Yr SPREAD(Lagged)	0.98	1.00								
T_JGBGAP	0.53	0.50	1.00							
JGBSLOPE (10Y-2Y)	-0.12	-0.08	-0.44	1.00						
JGB10Y	-0.26	-0.25	-0.42	-0.07	1.00					
NKYGROWTH	0.03	0.04	-0.19	0.28	-0.01	1.00				
eHV	0.21	0.19	0.13	-0.06	-0.06	0.01	1.00			
RATE_RI	0.20	0.21	-0.17	0.14	0.02	0.04	-0.13	1.00		
GAP3_1DLAG	0.66	0.62	0.35	-0.06	-0.24	0.00	0.20	0.06	1.00	
GAP3_1DLAG_Adj	0.59	0.59	0.25	0.16	-0.42	0.08	0.15	0.10	0.90	1.00

Table-2 (3): Correlation Table for Initially Low-Rate

	3-Yr SPREAD	3-Yr SPREAD (Lagged)	T_JGBGAP	JGBSLOPE (10Y-2Y)	JGB10Y	NKY GROWTH	eHV	RATE_RI	GAP3_ 1DLAG	GAP3_ 1DLAG_ Adj
3-Yr SPREAD	1.00									
3-Yr SPREAD(Lagged)	0.93	1.00								
T_JGBGAP	0.24	0.22	1.00							
JGBSLOPE (10Y-2Y)	-0.20	-0.17	-0.50	1.00						
JGB10Y	0.07	0.08	-0.22	-0.14	1.00					
NKYGROWTH	-0.04	-0.05	-0.23	0.21	-0.05	1.00				
eHV	0.30	0.31	0.02	-0.09	0.03	0.10	1.00			
RATE_RI	0.49	0.50	-0.03	0.03	0.00	0.01	0.36	1.00		
GAP3_1DLAG	0.71	0.57	0.13	-0.05	0.08	-0.08	0.19	0.28	1.00	
GAP3_1DLAG_Adj	0.50	0.39	0.00	0.31	-0.33	0.00	0.11	0.27	0.74	1.00

Table-2 (4): Correlation Table for Good-State

	3-Yr SPREAD	3-Yr SPREAD (Lagged)	T_JGBGAP	JGBSLOPE (10Y-2Y)	JGB10Y	NKY GROWTH	eHV	RATE_RI	GAP3_ 1DLAG	GAP3_ 1DLAG_ Adj
3-Yr SPREAD	1.00									
3-Yr SPREAD(Lagged)	0.98	1.00								
T_JGBGAP	0.32	0.29	1.00							
JGBSLOPE (10Y-2Y)	-0.14	-0.08	-0.58	1.00						
JGB10Y	-0.10	-0.07	-0.22	-0.01	1.00					
NKYGROWTH	0.03	0.05	-0.21	0.41	0.04	1.00				
eHV	0.33	0.31	0.08	-0.04	-0.03	0.01	1.00			
RATE_RI	0.55	0.55	-0.05	0.03	0.00	0.01	0.33	1.00		
GAP3_1DLAG	0.63	0.58	0.14	-0.05	-0.12	0.03	0.28	0.34	1.00	
GAP3_1DLAG_Adj	0.53	0.52	-0.05	0.21	-0.27	0.12	0.23	0.37	0.89	1.00

Table-2 (5): Correlation Table for Initially Bad-State

	3-Yr SPREAD	3-Yr SPREAD (Lagged)	T_JGBGAP	JGBSLOPE (10Y-2Y)	JGB10Y	NKY GROWTH	eHV	RATE_RI	GAP3_ 1DLAG	GAP3_ 1DLAG_ Adj
3-Yr SPREAD	1.00									
3-Yr SPREAD(Lagged)	0.90	1.00								
T_JGBGAP	0.14	0.13	1.00							
JGBSLOPE (10Y-2Y)	-0.19	-0.18	-0.50	1.00						
JGB10Y	0.08	0.10	-0.21	-0.14	1.00					
NKYGROWTH	0.00	-0.01	-0.24	0.21	-0.05	1.00				
eHV	0.37	0.39	0.01	-0.13	0.04	0.13	1.00			
RATE_RI	0.53	0.54	0.01	-0.01	0.01	0.00	0.51	1.00		
GAP3_1DLAG	0.81	0.61	0.10	-0.08	0.11	-0.07	0.25	0.42	1.00	
GAP3_1DLAG_Adj	0.65	0.43	0.00	0.21	-0.22	0.00	0.20	0.35	0.84	1.00

Table-2 (6): Correlation Table for Initially Hi-Rate & Good-State

	3-Yr SPREAD	3-Yr SPREAD (Lagged)	T_JGBGAP	JGBSLOPE (10Y-2Y)	JGB10Y	NKY GROWTH	eHV	RATE_RI	GAP3_ 1DLAG	GAP3_ 1DLAG_ Adj
3-Yr SPREAD	1.00									
3-Yr SPREAD(Lagged)	0.98	1.00								
T_JGBGAP	0.37	0.32	1.00							
JGBSLOPE (10Y-2Y)	-0.10	-0.03	-0.59	1.00						
JGB10Y	-0.14	-0.11	-0.21	0.00	1.00					
NKYGROWTH	0.07	0.10	-0.22	0.41	0.04	1.00				
eHV	0.20	0.17	0.08	-0.04	-0.01	-0.02	1.00			
RATE_RI	0.30	0.32	-0.20	0.14	0.02	0.03	-0.18	1.00		
GAP3_1DLAG	0.59	0.54	0.17	-0.07	-0.14	0.03	0.20	0.14	1.00	
GAP3_1DLAG_Adj	0.51	0.49	-0.04	0.19	-0.30	0.12	0.14	0.21	0.90	1.00

Table-2 (7): Correlation Table for Initially Low-Rate & Bad-State

	(2) Model 1		(3) Model 2		(4) Model 3 Pooling		(4) Model 3 FE		(4) Model 3 RE		(4) Model 3 MLE	
3-Yr SPREAD	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.
T_JGBGAP	1.4094	0.2414 ***	1.4493	0.2390 ***	0.9239	0.0861 ***	0.9837	0.1670 ***	0.9686	0.1687 ***	1.1903	0.0365 ***
JGBSLOPE (10Y-2Y)	0.0530	0.0542	0.0415	0.0518	-0.0325	0.0212	-0.0223	0.0473	-0.0204	0.0446	-0.1311	0.0217 ***
JGB10Y	0.0167	0.0363	0.0297	0.0294	0.0962	0.0196 ***	0.0877	0.0205 ***	0.0876	0.0202 ***	0.3363	0.0240 ***
NKYGROWTH	0.6515	0.1106 ***	0.5901	0.1102 ***	0.4698	0.0944 ***	0.4754	0.0941 ***	0.4737	0.0942 ***	0.4247	0.0733 ***
e_HV			0.0039	0.0010 ***	0.0021	0.0005 ***	0.0020	0.0007 ***	0.0020	0.0007 ***	0.0025	0.0004 ***
RATE_RI			0.0926	0.0248 ***	0.0542	0.0029 ***	0.0763	0.0327 **	0.0628	0.0130 ***	0.0720	0.0057 ***
GAP3_1DLAG					1.7743	0.2907 ***	1.5833	0.2066 ***	1.6064	0.2073 ***	0.5638	0.0145 ***
GAP3_1DLAG_Adj												
3-Yr SPREAD (Lagged)												
_cons	0.0484	0.0623	-0.4874	0.1729 ***	-0.3611	0.0449 ***	-0.4758	0.1963 **	-0.4009	0.1054 ***	-0.7368	0.0614 ***
# Obs	4173		4173		4172		4172		4172		4172	
# Group	52		52		52		52		52		52	
R-sq:												
within	0.2673		0.3069				0.5273		0.5269			
between	0.0320		0.6124				0.7518		0.7719			
overall	0.1793		0.4070		0.6151		0.6029		0.6120			
sigma_alpha							0.0288		0.0000		0.1367	
sigma_e							0.0905		0.0905		0.2592	
rho: AR(1) on e											0.2178	

Note: ***:1%, **:5%, *:10%

```
Breusch and Pagan Lagrangian multiplier test for random effects

3-Yr SPREAD[FCODE,t] = Xb + u[FCODE] + e[FCODE,t]

Estimated       results:
                |       Var        sd=sqrt(Var)
----------+-----------------------------
3-Yr SPREAD     |     0.198782    0.44585
e               |     0.062577    0.250154
u               |     0.007534    0.086796

Test:   Var(u) = 0
chi2(1) =   4728.20
Prob > chi2 =       0.0000
```

```
Hausman test                       ----    Coefficient----
                                   |       (b)        (B)         (b-B)       sqrt(diag(V_b-V_B))
                                   |       fixed      .           Difference  S.E.
-------------+----------------------------------------------------------------
        T_JGBGAP                   |    0.983662   0.968578   0.015085   0.002873
        JGBSLOPE (10Y-2Y)          |   -0.02233   -0.02044   -0.00189   .
        JGB10Y                     |    0.087688   0.087634   5.41E-05   .
        NKYGROWTH                  |    0.475361   0.473703   0.001658   .
        e_HV                       |    0.001958   0.001967  -9.14E-06   8.06E-05
        RATE_RI                    |    0.07626    0.062779   0.013481   0.006026
        GAP3_1DLAG                 |    1.583268   1.60639   -0.02312    0.000878
------------------------------------------------------------------------------
        b = consistent under Ho and Ha; obtained from xtreg
        B = inconsistent under Ha, efficient under Ho; obtained from xtreg

        Test:  Ho:  difference in coefficients not systematic

        chi2(7) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                    =  -126.77    chi2<0     ==> model fitted on these
                                   data fails to meet the asymptotic
                                   assumptions of the Hausman test;
                                   see suest for a generalized test
```

Table-3: Static Model

3-Yr SPREAD	(5) Dynamic Model 4 AR1 Coef.	Std.	(5) Dynamic Model 5 Pooling Coef.	Std.	(5) Dynamic Model 5 FE Coef.	Std.	(5) Dynamic Model 5 RE Coef.	Std.	(5) Dynamic Model 5 AB GMM Coef.	Std.	(5) Dynamic Model 5 AH MLE Coef.	Std.
T_JGBGAP	0.4664	0.0409 ***	0.0496	0.0193 ***	0.0634	0.0150 ***	0.0496	0.0146 ***	0.0537	0.0253 **	0.0588	0.0148 ***
JGBSLOPE (10Y-2Y)	-0.1087	0.0273 ***	-0.0633	0.0055 ***	-0.0577	0.0078 ***	-0.0633	0.0078 ***	-0.0530	0.0049 ***	-0.0618	0.0077 ***
JGB10Y	0.0319	0.0218	0.0036	0.0089	0.0043	0.0087	0.0036	0.0088	-0.0016	0.0066	0.0043	0.0087
NKYGROWTH	0.1255	0.0211 ***	-0.0206	0.0247	-0.0136	0.0258	-0.0206	0.0259	-0.0126	0.0212	-0.0171	0.0258
e_HV	0.0002	0.0001	0.0003	0.0001 *	0.0004	0.0001 ***	0.0003	0.0001 **	0.0004	0.0002 *	0.0003	0.0001 ***
RATE_RI	0.0617	0.0078 ***	0.0030	0.0008 ***	-0.0052	0.0028 *	0.0030	0.0007 ***	-0.0126	0.0119	0.0031	0.0009 ***
GAP3_1DLAG	0.2900	0.0163 ***	0.3905	0.1306 ***	0.4096	0.0149 ***	0.3905	0.0146 ***	0.4310	0.1341 ***	0.3989	0.0149 ***
GAP3_1DLAG_Adj												
3-Yr SPREAD (Lagged)			0.8866	0.0249 ***	0.8682	0.0053 ***	0.8866	0.0048 ***	0.8625	0.0367 ***	0.8782	0.0054 ***
_cons	0.0105	0.0540	0.0449	0.0186 **	0.0860	0.0245 ***	0.0449	0.0196 **	0.1337	0.0636 **	0.0424	0.0198 **
# Obs	4172		4116		4116		4116		4059		4116	
# Group	52				52		52		52		52	
R-sq:												
within	0.4261				0.9384		0.9381					
between	0.6335				0.9972		0.9980					
overall	0.4435				0.9565		0.9584					
sigma_alpha					0.0288		0.0000				0.0101	
sigma_e					0.0905		0.0905				0.0906	
rho: AR(1) on e											0.0122	

Note: ***:1%, **:5%, *:10%

Breusch and Pagan Lagrangian multiplier test for random effects

3-Yr SPREAD[FCODE,t] = Xb + u[FCODE] + e[FCODE,t]

Estimated results:

	Var	sd=sqrt(Var)
3-Yr SPREAD	0.199331	0.446465
e	0.008184	0.090466
u	0	0

Test: Var(u) = 0
chi2(1) = 10.74
Prob > chi2 = 0.0010

Hausman test

	---- Coefficient ---- (b) fixed	(B) .	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
T_JGBGAP	0.868186	0.886612	-0.01843	0.00217
JGBSLOPE (10Y-2Y)	0.063394	0.049639	0.013755	0.003667
JGB10Y	-0.05768	-0.06329	0.005606	.
NKYGROWTH	0.004342	0.003565	0.000777	.
e_HV	-0.01361	-0.02063	0.007019	.
RATE_RI	0.000402	0.000274	0.000128	8.56E-05
GAP3_1DLAG	-0.00515	0.002975	-0.00813	0.002671
GAP3_1DLAG	0.409592	0.390487	0.019105	0.003156

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(8) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 110.19
Prob>chi2 = 0.0000
(V_b-V_B is not positive definite)

Table-4: Dynamic Model

	RE Model 3 Hi-Rate		RE Model 3 Low-Rate		RE Model 3 Good-State		RE Model 3 Bad-State		RE Model 3 Hi- & Good-		RE Model 3 Low- & Bad-	
3-Yr SPREAD	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.
T_JGBGAP	0.3968	0.0960 ***	1.6307	0.3182 ***	0.4215	0.0723 ***	1.2911	0.2265 ***	0.1080	0.0469 **	2.0908	0.4433 ***
JGBSLOPE (10Y-2Y)	-0.1466	0.0258 ***	0.1010	0.0713	-0.1096	0.0241 ***	0.0498	0.0773	-0.1475	0.0177 ***	0.3114	0.1287 **
JGB10Y	0.1224	0.0139 ***	0.0470	0.0275 *	0.0615	0.0161 ***	-0.0519	0.0480	0.0071	0.0130	-0.2066	0.0799 ***
NKYGROWTH	0.1522	0.0600 **	0.8234	0.1625 ***	0.2934	0.0842 ***	0.6141	0.1254 ***	0.4694	0.1114 ***	1.0550	0.2173 ***
e_HV	0.0020	0.0009 **	0.0014	0.0009	0.0015	0.0012	0.0006	0.0010	0.0018	0.0020	0.0009	0.0019
RATE_RI	0.1049	0.0297 ***	0.0830	0.0228 ***	0.0392	0.0093 ***	0.1175	0.0213 ***	0.0516	0.0246 **	0.1788	0.0527 ***
GAP3_1DLAG	1.3678	0.3602 ***	1.4970	0.2287 ***	2.0879	0.3816 ***	1.1167	0.1786 ***	2.4754	0.1378 ***	1.0770	0.2160 ***
GAP3_1DLAG_Adj												
3-Yr SPREAD (Lagged)												
_cons	-0.3211	0.1053 ***	-0.7509	0.2394 ***	-0.0957	0.0412 **	-0.5973	0.1771 ***	0.0409	0.0597	-1.3460	0.4914 ***
# Obs	2029		2143		2498		1674		1213		858	
# Group	25		27		52		52		25		27	
R-sq:												
within	0.6141		0.5761		0.4983		0.4754		0.6302		0.5192	
between	0.7017		0.7305		0.7771		0.6761		0.7787		0.5484	
overall	0.6117		0.5956		0.6301		0.5901		0.7041		0.5213	

Note: ***:1%.**:5%. *:10%

Table-5 (1): Static Model (RE) with Sample Split

	(5) Dynamic Model 5 AH MLE Hi-Rate		(5) Dynamic Model 5 AH MLE Low-Rate		(5) Dynamic Model 5 AH MLE Good-State		(5) Dynamic Model 5 AH MLE Bad-State		(5) Dynamic Model 5 AH MLE Hi- & Good-		(5) Dynamic Model 5 AH MLE Low- & Bad-	
3-Yr SPREAD	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.	Coef.	Std.
T_JGBGAP	-0.0150	0.0199	0.1555	0.0217 ***	0.0603	0.0209 ***	0.0838	0.0247 ***	-0.0385	0.0331	0.2120	0.0470 ***
JGBSLOPE (10Y-2Y)	-0.0800	0.0105 ***	-0.0710	0.0106 ***	-0.0611	0.0072 ***	-0.1286	0.0174 ***	-0.0763	0.0118 ***	-0.1664	0.0317 ***
JGB10Y	0.0129	0.0119	0.0117	0.0118	-0.0096	0.0078	-0.1226	0.0251 ***	-0.0425	0.0127 ***	-0.1524	0.0446 ***
NKYGROWTH	-0.0299	0.0347	0.0229	0.0351	0.2278	0.0348 ***	-0.0345	0.0362	0.2998	0.0572 ***	0.0592	0.0647
e_HV	0.0002	0.0002	0.0007	0.0002 ***	0.0001	0.0002	0.0006	0.0002 ***	0.0001	0.0003	0.0011	0.0003 ***
RATE_RI	0.0050	0.0024 **	0.0082	0.0020 ***	0.0050	0.0009 ***	0.0033	0.0017 **	0.0014	0.0023	0.0129	0.0048 ***
GAP3_1DLAG	0.8356	0.0314 ***	0.2851	0.0161 ***	1.1948	0.0313 ***	0.2848	0.0184 ***	1.7406	0.0436 ***	0.2881	0.0249 ***
GAP3_1DLAG_Adj												
3-Yr SPREAD (Lagged)	0.7352	0.0137 ***	0.8983	0.0060 ***	0.7132	0.0094 ***	0.9095	0.0085 ***	0.6207	0.0150 ***	0.8946	0.0117 ***
_cons	0.0577	0.0268 **	-0.0128	0.0306	0.0586	0.0184 ***	0.2671	0.0468 ***	0.1438	0.0296 ***	0.2525	0.0902 ***
# Obs	2003		2113		2495		1621		1212		830	
# Group	25		27		52		52		25		27	

Note: ***:1%,**:5%, *:10%

Table-5 (2): Dynamic Model with Sample Split

3-Yr SPREAD	RE Model 3 (Robustness Check) Coef.	Std.		Dynamic Model 4 AR1 (Robustness Check) Coef.	Std.		Dynamic Model 5 AB GMM (Robustness Check) Coef.	Std.		Dynamic Model 5 AH MLE (Robustness Check) Coef.	Std.	
T_JGBGAP	1.1859	0.1676	***	0.4514	0.0415	***	0.0943	0.0248	***	0.0851	0.0157	***
JGBSLOPE (10Y-2Y)	-0.1311	0.0393	***	-0.1150	0.0277	***	-0.0772	0.0112	***	-0.0810	0.0083	***
JGB10Y	0.3377	0.0453	***	0.0686	0.0223	***	0.0404	0.0269		0.0370	0.0097	***
NKYGROWTH	0.4237	0.0868	***	0.1212	0.0214	***	-0.0275	0.0228		-0.0338	0.0272	
e_HV	0.0025	0.0007	***	0.0002	0.0001		0.0006	0.0003	**	0.0005	0.0001	***
RATE_RI	0.0672	0.0166	***	0.0593	0.0080	***	-0.0102	0.0113		0.0026	0.0008	***
GAP3_1DLAG												
GAP3_1DLAG_Adj	0.5669	0.0648	***	0.0928	0.0066	***	0.1137	0.0514	**	0.0970	0.0061	***
3-Yr SPREAD (Lagged)							0.8856	0.0368	***	0.9075	0.0058	***
_cons	-0.7120	0.1523	***	-0.0214	0.0554		0.0794	0.0403	**	0.0140	0.0210	
# Obs	4172			4172			4059			4116		
# Group	52			52			52			52		
R-sq:												
within	0.4914			0.4019								
between	0.7314			0.6204								
overall	0.5740			0.4177								

Note: ***:1%. **:5%. *:10%

Table-6: Robustness Check (Adjusted Gap: Relative Distance Measure)

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