GX Future Lab No.2

Assessing the Greenium of Transition Bonds in Japanese Electric Power Bonds: Evidence from Japan's Electric Utilities

Working Paper

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March 2026

GX Acceleration Agency

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[Abstract]

For Japan to achieve carbon neutrality by 2050, the country's largest CO_2 emitter, that is, the energy transition sector, must promote green transformation (GX). GX includes shifting from CO_2-emitting coal, oil, and gas-fired power generation to CO_2-free power generation, such as renewable energy and nuclear power generation (low-carbon energy sources). Electric utilities issue green bonds for capital investment in renewable energy power generation facilities. However, they have been issuing transition bonds recently to restart and build new nuclear power plants, and the issuance is expected to increase in the future.

This study aims to show that, like green bonds, transition bonds issued by electric utilities exhibit a "greenium" (green premium), that is, they have lower yields than straight bonds issued by the same issuer with the same maturity date. Panel data based on secondary market data were quantitatively analyzed. Results revealed that (1) the greenium becomes more pronounced as the remaining maturity increases and that (2) it is more pronounced for smaller issuance amounts.

Keywords: Electric Power bonds, Transition Bonds, Green Bonds, Greenium, Panel Data Analysis
JEL Classification: G11, G12, G14, Q5

[†] The author gratefully acknowledges valuable comments and suggestions from Professor Hiroshi Ishijima (Chuo University), Professor Yasunori Ouchida (Hiroshima University), Professor Kazuhiko Ohashi (Hitotsubashi University Graduate School), Associate Professor Kentaro Kikuchi (Shiga University), Professor Yoshihiro Zenno (Fukuyama University), Akane Enatsu (Nomura Capital Markets Institute), the Finance Group of Chugoku Electric Power Company, and Hideki Takada (GX Acceleration Agency). We would like to express our gratitude to them here. Any remaining errors are solely the responsibility of the author. The views expressed in this paper are those of the author and do not necessarily reflect the official views or policies of the GX Acceleration Agency.

1. Introduction

In October 2020, the Japanese government declared its aim to achieve carbon neutrality (net zero) by 2050.[1] Accordingly, in April 2021, it announced plans to reduce greenhouse gas (GHG) emissions by 46% compared with the 2013 levels by 2030 and further aspire to a 50% reduction target. The government also approved the "Plan for Global Warming Countermeasures" by Cabinet decision on February 18, 2025. This plan sets targets toward achieving carbon neutrality by 2050: a 60% reduction by 2035 and a 73% reduction by 2040. The Japanese government has submitted the new "Japan's Nationally Determined Contribution (NDC)" to the United Nations Framework Convention on Climate Change (UNFCCC) Secretariat.

The energy transition sector (e.g., electric utilities) is the largest CO_2 emitter and accounts for 40.1% of Japan's total CO_2 emissions in 2023. Therefore, the country must promote green transformation (GX), such as shifting from coal, oil, and gas-fired power generation, which emits CO_2, to non-CO_2 emitting power generation, such as renewable energy and nuclear power generation (low-carbon energy sources).[2]

The Seventh Strategic Energy Plan, approved by the Cabinet on February 18, 2025, aims to increase the share of renewable and nuclear energy in total power generation from their current levels of approximately 20% and 10% only to 40–50% and 20%, respectively, by 2040.

Against this background, electric utilities have begun issuing green bonds to finance their capital investment in renewable energy generation facilities. Ministry of the Environment (2024) cites the environmental and social benefits of issuing and investing in green bonds, including "global environmental conservation" through direct investment in green projects and "resolving social and economic issues through the promotion of green projects."

Ministry of the Environment (2024) also cites the following financial technology advantages: issuers can (1) "strengthen a funding base by acquiring new investors," such as investors who highly value investment targets that contribute to solving environmental

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[1] Prime Minister Suga declared in his policy address on October 26, 2020, that Japan aims to achieve carbon neutrality by 2050. Furthermore, at the Headquarters for Global Warming Prevention Policy and the U.S.-hosted Climate Summit in April 2021, Prime Minister Suga stated, "We aim to reduce greenhouse gas emissions by 46% from fiscal year 2013 levels by fiscal year 2030, as an ambitious target consistent with the 2050 goal. We will continue to strive toward the higher target of 50%." Carbon neutrality refers to the concept of balancing greenhouse gas emissions, such as CO_2, with absorption, thereby reducing net emissions to zero.

[2] For details, see Amatatsu (2025), "Understanding the Decline in Japan's CO_2 Emissions: Evidence from Factor Decomposition," *GX Future Lab*, No. 1. In addition to promoting energy conservation, the study suggests that it will be necessary to further shift from CO_2-emitting thermal power generation to CO_2-free solar, wind, and nuclear power generation and to further promote fuel and raw material conversion, including in the manufacturing sector.

problems, including global warming, and (2) "gain pricing benefits" due to high investor demand.[3] Furthermore, it states that green bonds have lower volatility than straight bonds due to this high demand and because they are often held to maturity. Thus, they are "an effective investment for those who seek to control the risk of price fluctuations."

Hisada (2022) stated that "investors purchase green bonds to maintain stable cash flow, contribute to the realization of a sustainable society, and gain high social recognition."[4] For example, Japan Post Insurance Co., Ltd. (2023) held that "investments considering ESG and other non-financial information enhance the sustainability of society and improve long-term investment outcomes (reduce risks). In addition, there is a correlation between financial conditions and non-financial information over the long term, and we believe considering ESG contributes to the strengthening of portfolio risk management and the selection of investees that are expected to grow over the medium to long term, thus leading to improved investment outcomes."

Under the green standards for green bonds, hydrogen and ammonia co-firing and dedicated combustion power generation using nuclear and thermal power may be excluded from the eligible uses of funds.[5] Thus, electric utilities have been issuing transition bonds recently rather than green bonds to invest in these exclusions as part of their GX promotion efforts. The "Basic Guidelines on Climate Transition Finance" formulated by the Financial Services Agency, the Ministry of Economy, Trade and Industry (METI), and the Ministry of the Environment defines transition bonds as "a financing means to promote long-term, strategic GHG emissions reduction initiatives that are taken by a company considering to tackle climate change for the achievement of a decarbonized society."[6]

A "greenium" (a portmanteau of "green" and "premium") refers to the excess of straight

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[3] Enatsu (2017) states that "green bonds contribute to the diversification of the investor base because, in addition to diversifying financing methods, they are attractive to investors who include environmental issues in their investment criteria."

[4] Green bond investors often publicly announce and promote their purchases of green bonds, while green bond issuers publicly disclose lists of investor commitments and the names of investors who have purchased the bonds.

[5] The "Green Bond Principles" and the "Green Bond Guidelines" do not include hydrogen and ammonia co-firing or dedicated firing power generation using nuclear or thermal power within their definitions of green projects. In Europe, the EU Taxonomy, which classifies economic activities as green or otherwise, designates nuclear power and gas- or oil-fired power generation as "Transitional Activities" rather than "Green Activities." However, against the backdrop of the global energy crisis and heightened security concerns, there has been a shift toward a more permissive view of nuclear power, and some power companies in Canada, France, and other countries have issued green bonds with nuclear power designated as the use of funds.

[6] The "Basic Guidelines on Climate Transition Finance" state that "the purpose of these Guidelines is to strengthen the position of climate transition finance as a means of financing transitions, especially in hard-to-abate sectors, and to introduce additional funds in order to contribute to achieving the 2050 carbon-neutral goals and the Paris Agreement, by popularizing transition finance, which is in its startup phase, and ensuring the credibility of financing labeled as transition finance."

bond yield over green bond yield, where both bonds are issued by the same issuer and with the same maturity date. Therefore, green bonds are priced higher than straight bonds. This difference is due to institutional investors' active investments in green bonds in response to the United Nations' 2006 presentation of the Principles for Responsible Investment (PRI) as a code of conduct for investors. This guideline advocates investing from an environmental, social, and governance (ESG) perspective. In Japan, many institutional investors, such as the Government Pension Investment Fund (GPIF), have signed the PRI, leading to the growing popularity of green bonds and their lower yields compared with straight bonds.[7]

Many previous studies analyzed greenium in overseas markets. Zerbib (2019) analyzed 110 green bonds for which data were available in the global secondary bond market up to 2017 and reported a greenium of approximately −2 bps. Furthermore, the author found that greenium was particularly pronounced in the low-rated and financial sectors. MacAskill et al. (2021) reviewed 15 studies published between 2007 and 2019 and confirmed that greenium existed in 70% of the studies in the secondary market. They reported that most of the previous studies showed a greenium ranging from −1 to −9 bps. Kanemura (2025) analyzed the price difference between the straight bond and green bond indices using US and EU bond indices and reported the existence of greening. In contrast, Larcker and Watts (2020) analyzed the secondary market for US municipal bonds and reported that no greenium existed. Furthermore, they reported that (1) greenium, (2) issuance amount, and (3) Climate Bonds Initiative (CBI) certification have no clear relationship. A CBI certification confirms that bonds meet the CBI standards.

In previous green bond studies in Japan, Hisada (2023) reported greeniums ranging from −6 to −7 bps and from −1 to −2 bps in the Japanese issuance market and secondary market, respectively, although the explanatory power was weak. GPIF and ICE (2024) reported that a greenium ranging from −1 to −4 bps existed for green bonds in the secondary market until February 2023, though it has been virtually non-existent since then.

The key point of discussion is whether transition bonds will generate a greenium like green bonds. Institutional investors who invest based on green standards may not invest in transition bonds, raising concerns that transition bonds will be less popular than green bonds. Thus, transition bond yields are expected to be higher than green and straight bond yields.

Regarding the analysis of greenium for transition bonds, no prior research has been conducted, either in Japan or globally, due to the novelty of the concept of transition bonds.

Accordingly, this present study analyzes greenium in the secondary market for green and transition bonds in electric utilities. Transition bonds in electric utilities account for

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[7] Bank of Japan, Financial Markets Department (2024), reports that 60% of investors who invested in the most recent year consider interest rates on ESG bonds to be "lower" than those on ordinary bonds.

approximately half of the total outstanding amount in Japan, excluding government bonds. They are also issued frequently, making them suitable for greenium analysis. Based on our experience in bond issuance management in the public sector and bond investment at financial institutions, we analyzed green and transition bonds in Japan's electric power bonds from the perspective of financial market participants. Our analysis is grounded in our understanding of asset–liability management (ALM) practices, market participant characteristics, and the credit market environment. This study is the first to analyze transition bond greenium and thus provides financial market participants and academia with new insights by comparing green and transition bonds in electric power bonds.

2. Green Bonds and Transition Bonds in Electric Power Bonds

Green bonds are used to finance projects whose environmental improvements are expected to exceed the environmental impact of their implementation (Table 1). In Japan, green bonds are issued and managed in accordance with the Ministry of the Environment's "Green Bond Guidelines." These guidelines are consistent with the globally recognized "Green Bond Principles" of the International Capital Market Association (ICMA). The guidelines list 10 types of projects as eligible uses of green bond proceeds, including renewable energy, energy conservation, and green buildings.

In contrast, investors invest in transition bonds based on their judgment as to whether the issuer's strategy can achieve long-term goals consistent with the Paris Agreement. They need to determine whether the issuer will implement projects in line with a long-term transition strategy toward achieving carbon neutrality. Transition bonds are issued and managed in accordance with the "Basic Guidelines on Climate Transition Finance." These guidelines are in line with the globally recognized "Climate Transition Finance Handbook" of ICMA. It states that "the focus should not be solely on the intended use of funds, but rather on a comprehensive assessment of the company's 'transition strategy' toward decarbonization and the reliability and transparency of its implementation" and does not specify classifications for the use of funds.[8] To determine whether a company's decarbonization strategy and initiatives

[8] The "Basic Guidelines on Climate Transition Finance" require disclosure of four elements: (1) the funder's climate transition strategy and governance, (2) environmental materiality within the business model, (3) a science-based climate transition strategy, including targets and pathways, and (4) transparency in implementation. Specifically, entities raising funds through transition finance are defined as (a) entities that have set decarbonization goals, formulated strategies and plans to achieve them, and are raising funds to implement initiatives aligned with those strategies and plans, and (b) entities raising funds for activities, including investments and financing, that enable the decarbonization transitions of other companies. Furthermore, the Guidelines emphasize that transition finance must be assessed not only based on the intended use of the raised funds but also by overlaying

are eligible for transition finance, financial institutions refer to METI's "Technology Roadmap for Transition Finance." It shows specific transition directions for eight high-emission sectors, including steel and chemicals, and effectively requires financial institutions to refer to it.[9]

Table 1: Overview and Principles and Guidelines for Green Bonds and Transition Bonds

	Green bonds	Transition bonds
Overview	These fund-specific bonds are issued to raise funds for green projects that contribute to solving environmental issues, including global warming.	These bonds are divided into two types: with specified and with unspecified use. Bonds with specified use require the issuer to formulate a long-term transition strategy for reducing greenhouse gas emissions.
Principles and guidelines	・ "Green Bond Principles" (ICMA) ・ "Green Bond Guidelines" (Ministry of the Environment)	・ "Climate Transition Finance Handbook" (ICMA) ・ "Basic Guidelines on Climate Transition Finance" (Financial Services Agency, Ministry of Economy, Trade and Industry [METI], Ministry of the Environment) ・ Refer to the "Technology Roadmap for Transition Finance" (METI)

Source: Japan Securities Dealers Association

Green and transition bonds differ from straight bonds in that issuers commit to decarbonization efforts, with green bonds specifying the use of funds for green projects and transition bonds specifying projects in line with transition strategies toward carbon neutrality.

Figure 1 illustrates the trends in the issuance amounts of green and transition bonds in electric utilities. It shows that green bonds expanded to 167 billion yen in 2022 after Tohoku

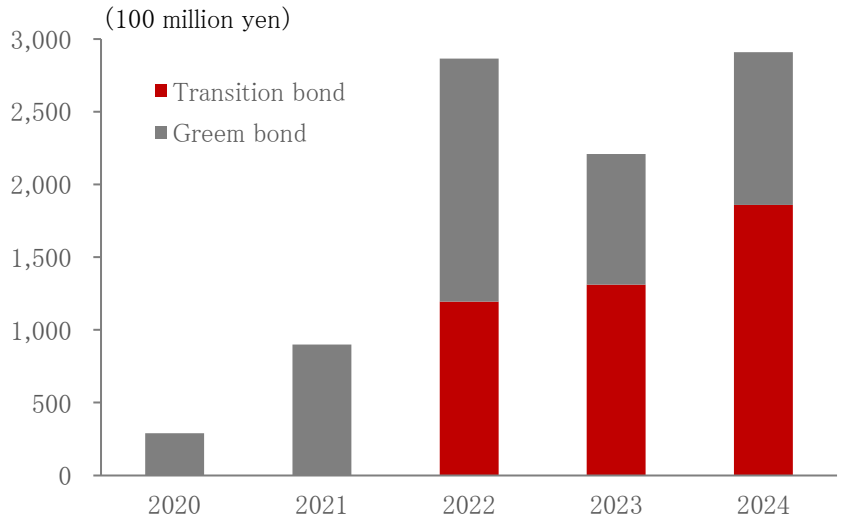
an assessment of the credibility of the fundraisers' strategies and practices.

[9] The "Basic Guidelines on Climate Transition Finance" further state that "referencing this roadmap will help fundraisers formulate transition strategies consistent with the Paris Agreement and help fund providers assess the credibility and effectiveness of individual companies' transition strategies, as well as the transition eligibility of assets."

Electric Power Company began issuing 5 billion yen in 10-year bonds in February 2020. However, the issuance amount shrank to 105 billion yen in 2024. In contrast, after Kyushu Electric Power Company began issuing 30 billion yen in 5-year bonds and 25 billion yen in 10-year bonds in May 2022 and JERA began issuing 12 billion yen in 5-year bonds, the issuance amount of transition bonds expanded to 186 billion yen in 2024.

The outstanding amount of electric power bonds, including those issued in March 2025, is 481 and 465.6 billion yen for green and transition bonds, respectively. Financing will increase for the restart and construction of new nuclear power plants, as well as capital investment in hydrogen and ammonia co-firing and dedicated firing power generation utilizing thermal power. Thus, the outstanding amount of transition bonds is expected to exceed that of green bonds in the electric utilities bond market.

Figure 1: Issuance amounts of green bonds and transition bonds in electric utilities



Source: Bloomberg

3. Calculation Method and Data Statistics for Greenium

(1) The matching method for greenium calculation considering redemption month differences

Green and transition bond greenium is calculated by comparing them with the yield curve for straight bonds (electric power bonds other than green and transition bonds, referred to as “non-labeled”). In this paper, the difference between the compound yield of a green or transition bond and that of the yield curve for straight bonds is referred to as the greenium. When the figure is negative, a greenium exists and is generated, whereas it does not exist and is not generated when the figure is positive; rather, a premium is generated.

Figure 2(a) explains the calculation method for greenium in this paper. If straight bonds with the same remaining maturity are issued by the same electric power company, greenium can be calculated by subtracting the compound yield of the straight bonds from the compound yield of the green or transition bonds. In Figure 2(a), the greenium is −6.8 bps, calculated by subtracting the compound yield of Chugoku Electric Power Company's straight bond with a remaining maturity of 9.7 years (#438) from the compound yield of its transition bond with a remaining maturity of 9.7 years (#457).

In contrast, in Figure 2(b), if no straight bonds with the same remaining maturity as that of the green or transition bond are issued by the same electric power company, then the yield curve's compound yield must be subtracted from the compound yield of the green or transition bond. The difference in redemption months must be considered in the calculation. Accordingly, the yield curve's compound yield for straight bonds with the same remaining maturity as transition bond #556 is calculated by linearly interpolating the compound yields for Tohoku Electric Power Company's straight bonds #550 and #554. Then, by subtracting the calculated compound yield of the straight bond yield curve from that of transition bond #556, a greenium of −0.5 bps is calculated.

The issuance frequency varies between power companies. Thus, three linear interpolation methods are used when considering the redemption month difference: (1) The first method is shown in Figure 2(b). (2) The second method is shown in Figure 2(c) and used for two straight bonds with longer remaining maturities than transition bonds. (3) The third method refers to straight bonds with shorter and longer remaining maturities than transition bonds. First, two straight bonds with maturities close to those of green or transition bonds are selected. Next, using the three linear interpolation methods, the yield curve for straight bonds is calculated. Finally, the greenium is calculated.[10]

Previous studies calculated greenium using a similar approach. The method of calculating greenium that considers redemption month differences is referred to as the matching method (Zerbib, 2019; Hisada, 2023).

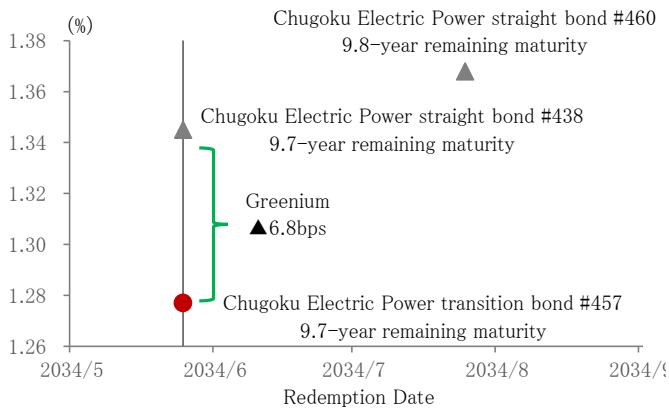
In addition to the methods described in this paper, another method for calculating greenium involves using spline interpolation rather than linear interpolation. When calculating the compound yield of the yield curve that considers the maturity spread, spline interpolation considers the continuity of slope and curvature, whereas linear interpolation considers only the slope between two points. Spline interpolation smoothly connects multiple segments using high-order polynomials. Coefficients are determined to satisfy first- and second-order

[10] If there was a significant difference, generally six months or more, between the remaining maturity of a green bond or transition bond and that of the two benchmark conventional bonds, the bond was excluded from the dataset, on the grounds that the compound yield derived from a linearly interpolated yield curve would differ materially from the actual yield.

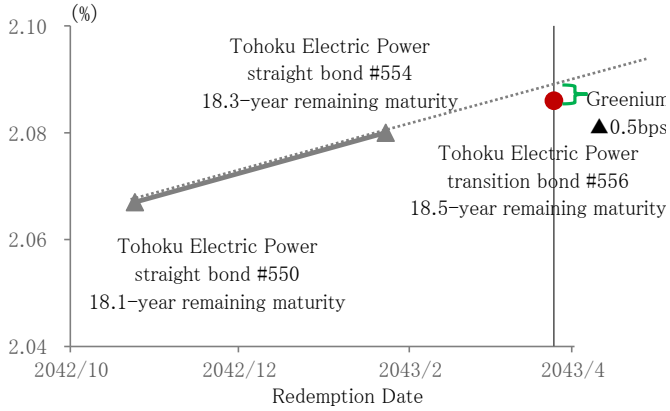
differentiation conditions. At least four observation points are required, making the calculation complex and difficult to apply in bond trading practice compared with linear interpolation.

Figure 2: Calculation methods for greenium

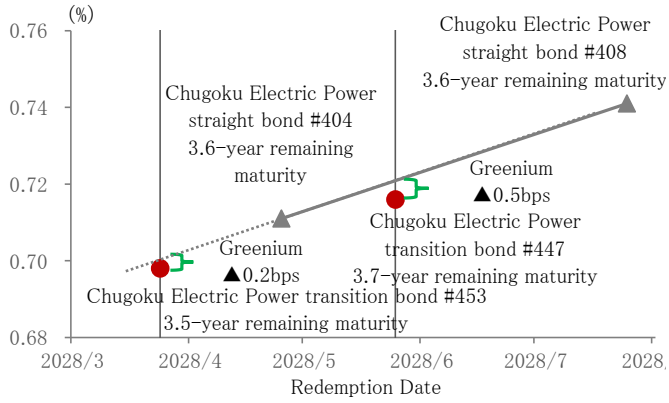
(a) Greenium calculation method using straight bonds with the same remaining maturity



(b) Greenium calculation method considering redemption month differences (1)



(c) Greenium calculation method considering redemption month differences (2)



Source: Bloomberg

Note: Data are as of September 30, 2024.

(2) Data

Greenium is calculated by subtracting the compound yield of the yield curve for straight bonds of the same electric power company (calculated using method 3.(1)) from that of the green and transition bonds issued to date.[11]

[11] This category covers electric power bonds issued by the former general electric utilities, namely

The data utilize Bloomberg's secondary market compound yields. This approach is used because bond transactions in Japan's secondary market typically rely on prices and yields quoted by a broker's broker (BB), namely, Japan Bond Trading Company. However, because BB prices and yields are intended for professional dealers, the data are not always systematically organized. In contrast, Bloomberg provides market participants and research institutions with data on market prices and yields that are almost identical to BB prices and yields. These data are based on prices and yields quoted by major securities companies in the secondary market.[12] In addition, Bloomberg's data are easily accessible to users.

Monthly data were used (month-end values) to analyze trends in green and transition bond greenium. In addition, the month-end values were further smoothed using a three-month moving average (3MA) for analysis.

The data period covers January–December 2024. Green and transition bonds in electric utilities have been issued since 2020 and 2022, respectively. However, from 2022 to 2023, the Japanese government bond (JGB) yield curve significantly distorted downward, mainly around the 7-year remaining maturity used for settling long-term government bond futures transactions. The yield curves for JGBs and electric power bonds diverged significantly (with spreads against JGBs widening substantially). Consequently, the functioning of the credit derivatives market, including electric power bonds, deteriorated significantly.[13] Therefore, the analysis period was set to 2024 onward.

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the 10 electric power companies that held regional monopolies due to entry restrictions under the Electric Utility Act prior to the liberalization of the electricity market in April 2016. However, Tokyo Electric Power Company (TEPCO) transferred its operations to three subsidiaries: Tokyo Electric Power Grid for transmission and distribution, Tokyo Energy Partner for retail electricity, and Tokyo CAFEL Power for fuel procurement and thermal power generation. As a result, Tokyo Electric Power Grid, the transmission and distribution operator, is the primary issuer of bonds. Tokyo Electric Power Grid's electric power bonds were excluded from the analysis because its business structure differs from that of other former general electric utilities. Okinawa Electric Power was also excluded because its business scale and outstanding electric power bond balance are significantly smaller than those of the other former general electric utilities. In addition, Shikoku Electric Power was excluded because it issues ordinary bonds infrequently and because the remaining maturity of its green bonds differs too greatly from that of the ordinary bonds used as benchmarks.

[12] In the secondary market for foreign bonds, trading is generally based on prices and yields quoted by Bloomberg. Based on practical bond trading experience, there is a difference of approximately 0.1 to 0.2 basis points between yields quoted by Bloomberg's real-time data and those quoted by BB for Japanese government bonds. Moreover, yields reported in the trading reference statistics published by the Japan Securities Dealers Association, which are sometimes used in prior research, are calculated as averages based on bid–ask quotes reported by 5 to 8 securities firms (as of end-September 2024) for electric power bonds. As a result, quotes from securities firms that are not major participants in the secondary market are also included, and the statistics may not always reflect actual market conditions. Based on bond trading practice, these reference statistics tend to lag behind actual market developments.

[13] For details, see Ochi and Osada (2024).

(3) Data statistics

Table 2 shows the statistics for green and transition bond greenium in electric utilities. The average greenium for the entire data set is −0.4 bps, indicating that a greenium exists. Particularly, transition bond data show that the average greenium is −0.9 bps, and the third quartile (75th percentile) is 0.0 bps. Therefore, a greenium is generated in most of the transition bond data. In contrast, although green bonds show a greenium of −0.1 bps in the first quartile (25th percentile), the average is 0.1 bps. Therefore, most green bond data do not show a greenium.

Table 2: Statistics of green and transition bond greenium in electric utilities

(Unit: bps)

	Number of issues	Sample size	Average	First quartile	Second quartile	Third quartile	Standard deviation
Overall	34	324	−0.364	−0.250	−0.021	0.070	1.363
Green bond	15	167	0.145	−0.081	0.031	0.169	0.815
Transition bond	19	157	−0.905	−1.133	−0.149	0.000	1.603

Source: Bloomberg

4. Time Series Trends and Cross-Sectional Analysis

(1) Time series trends

The transition bond greenium in electric utilities was negative for Chugoku Electric Power Company, as shown in Figure 3(a). Therefore, a greenium exists and is generated. Under the favorable credit market environment in the first half of 2024 (described later), the greenium widened to a negative range of 2–6 bps.[14]

In contrast, Figure 3(b) shows that Kyushu Electric Power Company's transition and green bonds remained around zero. In the second half of 2024, the greenium for certain transition and green bonds turned negative, indicating the existence of a greenium. Kyushu Electric Power Company's transition bond #527 became popular because it limited the use of funds to capital investment in nuclear power plants, and the negative greenium has expanded relatively.

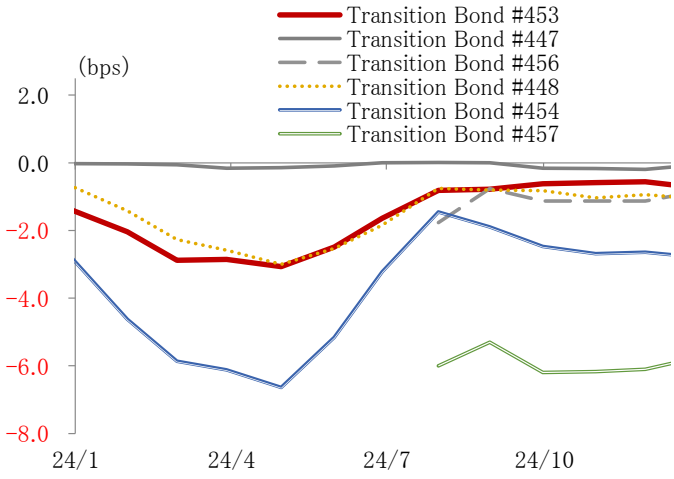
Therefore, the level of greenium varies between electric utilities. Particularly, Chugoku

[14] In the first half of 2024, spreads against government bonds narrowed across the credit market.

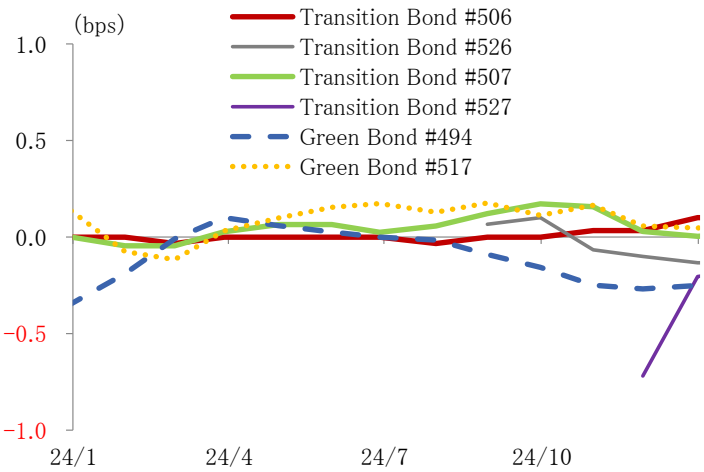
Electric Power Company's transition bond greenium is more negative than that of other electric power bonds.

Figure 3: Transition and green bond greenium in electric utilities

(a) Greenium of Chugoku Electric Power bonds



(b) Greenium of Kyushu Electric Power bonds



Source: Bloomberg

Note: Greenium is smoothed using a three-month moving average (3MA) of month-end values.

(2) Cross-sectional analysis

We conducted a cross-sectional analysis of green and transition bond greenium in electric utilities using data from September 2024 (smoothed using 3MA of month-end values). We treated Chugoku Electric Power bonds separately because their transition bonds have a relatively large negative greenium.

Figure 4(a) indicates a negative correlation between greenium and remaining maturity. Therefore, the longer the remaining maturity, the larger the negative greenium.

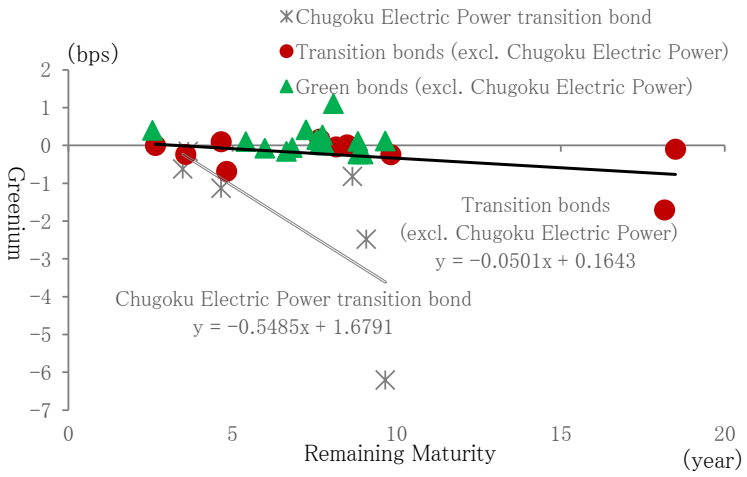
Investors often invest in bonds with maturities that match the remaining maturity of their liabilities from an ALM perspective. Thus, investor characteristics differ depending on the remaining maturity. Investors in long-term zones (e.g., 10 years) and ultra-long-term zones (e.g., 20 years) are mostly institutional investors. They include life insurance companies and pension funds that hold bonds for long periods or until maturity. Such investors are likely to invest in green and transition bonds actively with the intention of holding them until maturity and are unlikely to sell them easily. This behavior tends to widen the negative spread of greenium.

In contrast, the medium-term zone (e.g., bonds with a remaining maturity of 5 years) is dominated by investors such as banks that repeatedly buy and sell bonds in the short term. Their investment in green and transition bonds has low liquidity and is not particularly large.

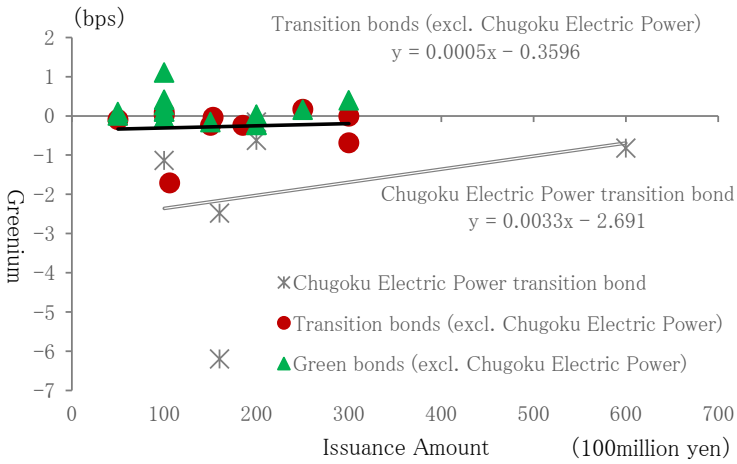
In addition, because they prefer price over the significance of investing in green and transition bonds, they are expected to sell when yields fall and bond prices rise, allowing the negative greenium to narrow easily.[15]

Figure 4: Relationship between greenium and remaining maturity

(a) Distribution of greenium and remaining maturity



(b) Distribution of greenium and issuance amount



Source: Bloomberg

Note: Data are as of September 2024. Greenium is smoothed using the 3MA of month-end values.

Figure 4(b) illustrates a weak but positive correlation between greenium and issuance amount, with the negative greenium becoming smaller as the issuance amount increases. When supply (issuance amount) is small relative to investor demand, bond prices are high and yields are low, and vice versa. Therefore, supply and demand determine bond prices and yields, albeit with a weak correlation to greenium levels.

Moreover, green and transition bonds with long remaining maturities and small issuance amounts are likely to have a greenium as their scarcity in the secondary market is valued.

[15] The "market segmentation hypothesis," one theory explaining the structure of interest rates, assumes that markets are segmented by bond maturity. This segmentation arises because investors and fund-raising entities have differing preferences with respect to investment and funding horizons. Consequently, interest rates are determined independently for each maturity segment based on its specific supply and demand conditions.

5. Panel Data Analysis of Greenium in Electric Power Bonds

(1) Panel data analysis model

Panel data analysis is applied to the same subject over multiple timepoints using a combination of time series and cross-sectional data. Based on the above characteristics, we controlled for maturity, issuance amount, and market valuation of electric power companies. Then, we performed panel data analysis on the greenium of green and transition bonds issued by electric power companies as follows:

$$Greenium_{i,t} = \alpha + \beta \cdot Term_{i,t} + \gamma \cdot Amount_{i,t} + \delta \cdot TransitionDummy_{i,t} + Company_i + \varepsilon_t + \epsilon_{i,t}$$

where *Greenium* is the dependent variable for each issue, and (1) *Term* (the remaining maturity for each issue), (2) *Amount* (the amount for each issuance), and (3) *TransitionDummy* are the explanatory variables. *TransitionDummy* is a dummy variable set to 1 for transition bonds and 0 for green bonds for each issue. In addition, fixed effects (*Company*) for each electric power company and time fixed effects (ε) are added. α is the constant term, and ϵ is the error term.[16]

In this analysis, white cross-section and period standard errors were applied to perform a robust estimation by considering the error variance (heterogeneous variance) for each issue and timepoint when performing panel data regression analysis.

(2) Estimation results

Table 3 presents the estimation results from the panel data analysis. First, all coefficients are significant at the 5% level, consistent with the theory presented in the cross-sectional analysis. (1) A longer remaining maturity indicates a larger negative greenium. For example, the negative greenium increases by 0.4, 0.8, and 1.7 bps for 5-, 10-, and 20-year bonds, respectively. (2) The negative spread of greenium narrows as the issuance amount increases. For example, the negative spread of greenium narrows by 0.2, 0.4, and 1.0 bps for 10-, 20-, and 50-billion yen issuances, respectively. (3) Transition bonds have a slightly larger negative greenium spread than green bonds, at −0.2 bps.[17] Regarding this point, (a) transition bonds have only recently begun issuance in 2022, attracting high attention from investors; (b) amid

[16] Zerbib (2019) and Hisada (2023) included credit ratings as explanatory variables. However, because there is little variation in the credit ratings of electric power bonds, credit ratings were excluded from this analysis. Rating and Investment Information, Inc. (R&I) rates Kansai Electric Power Company and Chubu Electric Power Company as AA–, while other companies are rated A+.

[17] Given this minimal difference, green bonds and transition bonds can be regarded as practically equivalent.

this high attention, power companies are actively conducting investor relations (IR) activities; and (c) transition bonds contribute to reducing overall GHG emissions in society in the medium to long term through the emission reduction efforts of their investment targets. Investors do not differentiate between green and transition bonds in their investment stance.

Second, fixed effects indicate that Chugoku Electric Power Company and Kansai Electric Power Company have a large negative greenium. Therefore, market participants have different evaluations of each electric power company (described later).

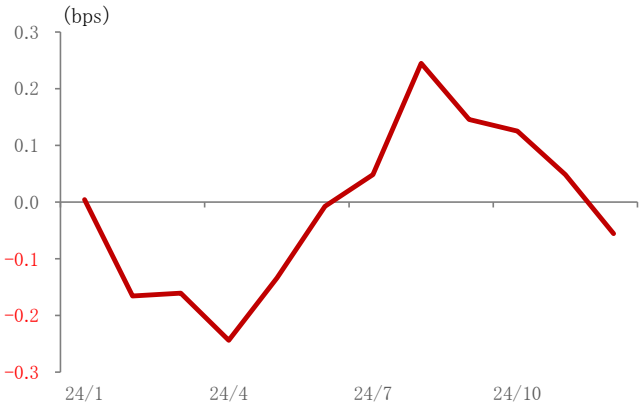
Third, time fixed effects show that the negative greenium widened in the first half of 2024 and narrowed in the second half of the year. Although the credit market environment improved overall in the first half of 2024, it deteriorated in the second half due to factors such as the Nikkei Stock Average temporarily plummeting from the 42,000- to 33,000-yen range on a closing basis from late July to early August. For example, in the electricity bond issuance market, ordinary electricity bonds were issued at an average spread of 37.3 bps against government bonds in the first half of the year. However, in the second half, they were issued at a spread of 48.5 bps against government bonds (Figure 6). Therefore, the credit market environment could have deteriorated, and the negative greenium narrowed.[18]

[18] The credit market environment is strongly influenced by uncertainty in the broader financial economy and by changes in investor risk tolerance. When uncertainty increases rapidly, as during the Lehman shock, the European sovereign debt crisis, or the COVID-19 shock, financial institutions and investors become more risk-averse, leading to a deterioration in credit market conditions through widening spreads against government bonds (credit spreads) and rising funding costs. During such periods, price declines become pronounced not only in the credit market but also in other risk asset markets, such as equities. Conversely, when market risk tolerance improves due to factors such as monetary easing, expectations of economic recovery, or reduced concerns about credit risk, spreads against government bonds narrow and credit market conditions improve. In such phases, other risk asset markets, including equities, also tend to experience price increases. Amatatsu (2013) describes the mechanism of volatility transmission across financial instruments and national markets, taking into account risk management practices among market participants.

Table 3: Estimation results (sample period: January–December 2024; *n* = 324)

Explanatory variables	Coefficient	p-value
α	1.734	0.000
Term(years)	−0.084	0.000
Amount (100 million yen)	0.002	0.017
TransitionDummy	−0.236	0.009
Fixed effects		
Chugoku Electric Power	−3.463	0.000
Kansai Electric Power	−1.599	0.001
Chubu Electric Power	−1.365	0.005
Kyushu Electric Power	−1.344	0.005
Hokuriku Electric Power	−1.186	0.013
Tohoku Electric Power	−0.875	0.067
Time fixed effects		
As shown in Figure 5		
Adjusted R^2	0.461	

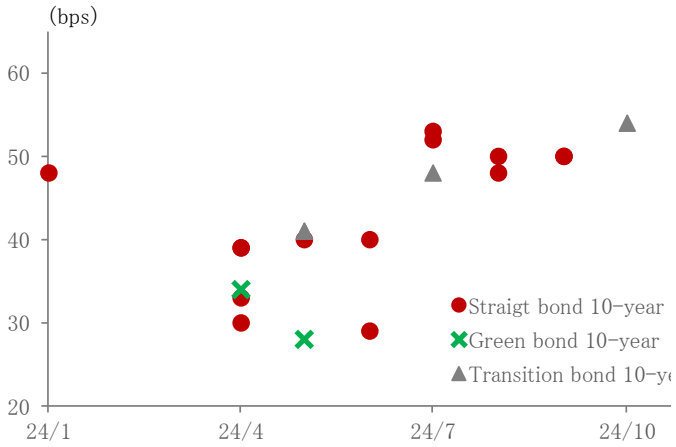
Figure 5: Time fixed effects



Source: Bloomberg

Note: To achieve robust estimates, White cross-sectional and period standard errors were applied.

Figure 6: Spread between 10-year electric power bonds and government bonds (issuance market)



Source: Mizuho Securities

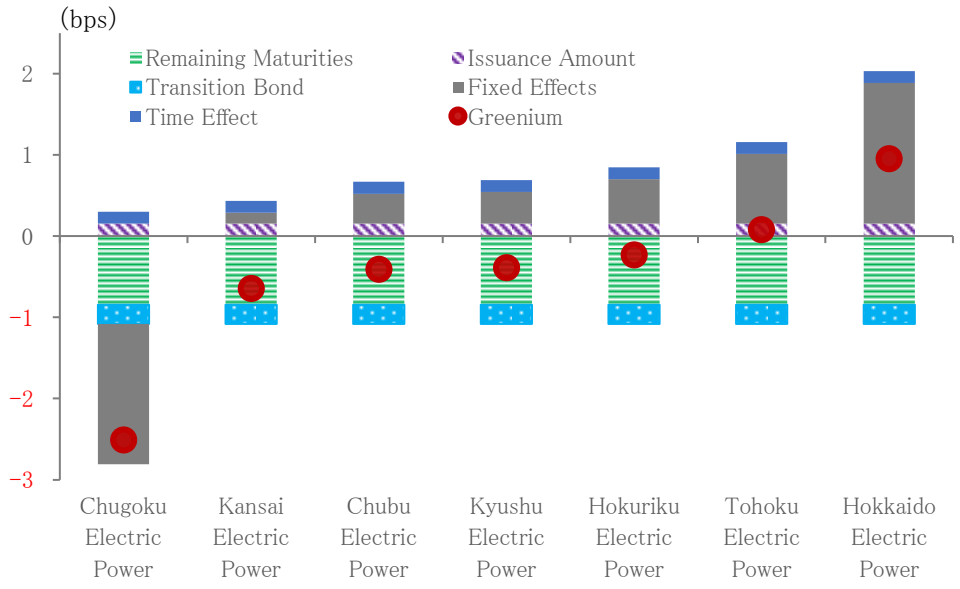
Finally, the panel data analysis's adjusted R-squared is 0.461, indicating an appropriate fit for the estimated model. The adjusted R-squared values in Zerbib's (2019) and Hisada's (2023) models range from 0.023 to 0.056 and from 0.018 to 0.122, respectively. Therefore, the model in this paper has high explanatory power. Zerbib's (2019) and Hisada's (2023) models may not fully capture the different characteristics between industries because they analyzed green bonds across diverse industries. Electric power bonds are issued frequently, have a large outstanding balance, and are well recognized by financial market participants. The model in this paper focuses on analyzing these electric power bonds and therefore has high explanatory power.

(3) Greenium values for transition bonds in standard bonds

Figure 7 shows estimates of the greenium for each electric power company using the estimated coefficients. A 10-billion yen (a standard bond in the credit market) transition bond with a remaining maturity of 10 years was assumed in the estimates.

The results show that transition bonds issued by Chugoku Electric Power Company, Kansai Electric Power Company, Chubu Electric Power Company, Kyushu Electric Power Company, and Hokuriku Electric Power Company have a greenium between −2.5 bps and −0.2 bps. These results also indicate that Chugoku Electric Power Company, Kansai Electric Power Company, Chubu Electric Power Company, and Kyushu Electric Power Company have a greenium between −2.3 bps and −0.2 bps for their green bonds.

Figure 7: Estimated greenium for 10-year transition bonds with a 10-billion yen issue



Source: Bloomberg

Note: Fixed effects are the sum of the constant term and the fixed effect for each power company.

Time fixed effects are the figure for September 2024.

(4) Consideration of the background of the differences in greenium among electric power companies

Figure 7 shows differences in greenium levels due to differences in fixed effects for each electric power company. The background of these differences is difficult to analyze quantitatively due to data constraints covering seven electric utilities. Nevertheless, we will examine this issue with reference to interviews with financial market participants (securities companies, life insurance companies, and electric utilities).

First, institutional investors who actively invest in ESG are likely to consider ESG scores, which quantify the ESG initiatives of their investment targets. Bloomberg's ESG scores rank companies within their industry sectors on a scale of 1–10. This ranking is based on relative comparisons of hundreds of qualitative and quantitative data points deemed financially material by sustainable disclosure standard-setting bodies, such as the Sustainability Accounting Standards Board, and industry associations.[19,20] Bloomberg's 2023 ESG scores and the fixed effects of each electric power company in Figure 7 are negatively correlated. Electric utilities with active decarbonization efforts and a high degree of sustainable information disclosure are evaluated positively, and those with high ESG scores have a large negative greenium (Figure 8[a]).

Second, institutional investors who actively invest in ESG are expected to consider the CO_2 emissions of their investment targets. Nippon Life (2024) summarizes specific evaluation criteria for transition finance, its rationale, and the evaluation process. It evaluates GHG reduction plans in transition strategies using the Scope 1 GHG emission factor (Scope 1 GHG emissions <gCO_2>/electricity <kWh>). The fixed effects of each power company in Figure 7 and the Scope 1 GHG emission factor in 2023 are positively correlated. When the Scope 1 GHG emission factor is small, the negative greenium is large (Figure 8[b]).

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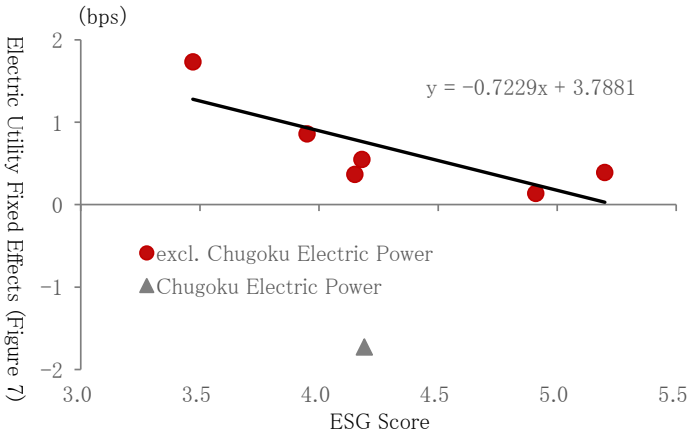
[19] The Sustainability Accounting Standards Board (SASB) Standards, one set of international guidelines, have established and published disclosure standards covering 11 sectors and 77 industries.

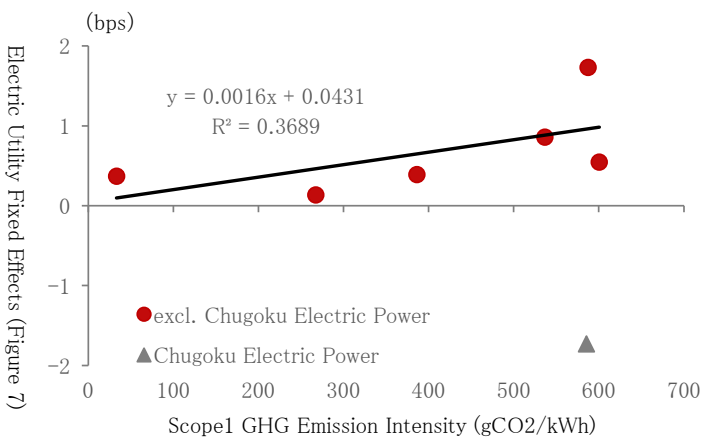
[20] The "Bloomberg ESG Disclosure Score" analyzed by Yuyama, Shirasu, and Morihira (2020) differs from the "ESG Score." The Bloomberg ESG Disclosure Score is calculated based on the volume of sustainability-related disclosures in securities reports and similar documents. MSCI, Sustainalytics, and other providers also offer ESG scores. However, market participants note that "the Bloomberg ESG Score is more convenient to use because the data usage fees for MSCI and other providers are high."

Figure 8: Fixed effects

(a) Fixed effects and 2023 ESG scores for each power company in Figure 7



(b) Fixed effects and Scope 1 GHG emission factors (2023) for each power company in Figure 7



Source: Bloomberg

Finally, financial market participants pointed out the reasons for the exceptionally large negative greenium on Chugoku Electric Power Company's transition bonds in Figure 7. They are (1) the large number of transition bond issuances, (2) Chugoku Electric Power Company's proactive investor visits (127 and 122 in 2023 and 2024, respectively) (Chugoku Electric Power Company, 2025), and (3) the high level of recognition and popularity of Chugoku Electric Power bonds as the primary targets of these investor visits, including financial institutions and corporate bond investors. Data on the number of visits made by issuers to investors and the awareness level of issuers among investors are not available. Thus, they cannot be quantified. However, many companies actively engage in IR activities, providing information on their management and financial status to shareholders, investors, customers, and others to enhance corporate trust and lead to improved fundraising and corporate value. Thus, it can be assumed that the efforts of the Chugoku Electric Power Company, Finance Group, are appreciated by financial market participants.

Many financial market participants also mentioned that although Chugoku Electric Power Company's three bonds are transition-linked, they do not affect greenium. Transition-linked bonds do not specify the use of funds, but rather set sustainability-related key performance indicators, such as environmental and social issues, and specific-performance targets (SPTs). The coupon interest rate received by investors fluctuates depending on the achievement of the SPTs. Thus, these bonds motivate issuers to achieve ambitious, preset targets. Although Chugoku Electric Power Company's numerical target for its transition-linked bonds is to "halve CO_2 emissions from its retail electricity business in 2030 compared with 2013," it has

already achieved a 46.1% reduction as of 2023 and is progressing steadily. The company states that if it fails to achieve its target, then it will "support the reduction of environmental impact in another form by donating an amount equivalent to 0.2% of the issue amount to organizations engaged in environmental conservation activities." However, certain financial market participants emphasized that "the effectiveness of donations to organizations is unclear, and concerns about greenwashing are not raised depending on the organizations receiving the donations." Accordingly, financial market participants specified that "transition-linked bonds are not as popular as transition bonds."

This qualitative analysis suggests that greenium differs between electric utilities due to financial market participants' evaluation of each company's ESG and decarbonization initiatives.[21]

(5) Panel data qualitative analysis

Based on the qualitative analysis, we performed a panel data analysis on the greenium of green and transition bonds issued by electric utilities, adding ESG scores and a dummy variable for Chugoku Electric Power as explanatory variables.

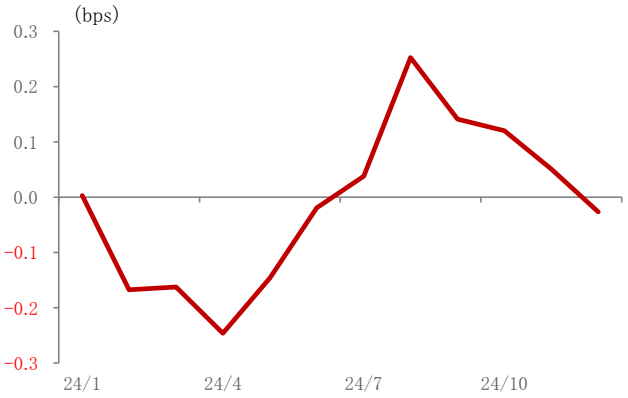
Table 4 shows that the ESG score and Chugoku Power dummy variable exhibited significant and theoretically expected signs. The coefficients and p-values for the other explanatory variables (*Term*, *Amount*, and *TransitionDummy*) analyzed in Table 3 remain unchanged. Furthermore, the adjusted R-squared value remains largely unchanged at 0.45. Thus, this model can be considered appropriate.

[21] GPIF and ICE (2024) analyzed the relationship between greenhouse gas emission reductions based on the use of funds (impact assessment) and greenium, concluding that in Japan, disclosure of information, including the use of funds, does not necessarily lead to greenium and that "there is no clear universal pattern." With respect to bond trading practices, some market participants note that "only a limited number of major life insurance companies invest based on the use of funds."

Table 4: Estimation results (sample period: January–December 2024; *n* = 324)

Explanatory variables	Coefficient	p-value
α	3.298	0.000
Term (years)	−0.088	0.000
Amount (100 million yen)	0.001	0.044
TransitionDummy	−0.266	0.006
ESG score	−0.547	0.000
Chugoku Electric Power dummy	−1.992	0.000
Time fixed effects		
As shown in Figure 9		
Adjusted R^2	0.448	

Figure 9: Time fixed effects



Source: Bloomberg

Note: To achieve a robust estimation, white cross-section and period standard errors were applied.

6. Conclusion

Unlike previous studies, this study analyzes greenium in the secondary market for green bonds and transition bonds in electric utilities. Particularly, based on our experience in bond issuance and bond investment, we analyzed bond trading practices, including ALM practices, market participant characteristics, and the credit market environment. Furthermore, this study is the first to analyze transition bond greenium worldwide. Its comparison of the differences between the greenium of green bonds and transition bonds contributes to financial market participants and academia.

Our results confirmed that, in addition to green bonds, transition bonds also generate a greenium in the secondary market.

The panel data analysis quantitatively derived the following results: (1) the longer the remaining maturity, the greater the negative greenium; (2) the smaller the issuance amount, the greater the negative greenium; and (3) transition bonds have a slightly larger negative greenium than green bonds, by 0.2 bps. Furthermore, (4) market participants evaluate each electric power company differently, and (5) greenium is affected by the credit market environment.

Qualitative analysis suggests that (a) high ESG scores, (b) low Scope 1 GHG emission

factors, and (c) active IR activities are likely to increase negative greenium. To achieve carbon neutrality in Japan, the energy transition sector must further shift from CO_2-emitting thermal power generation to CO_2-free solar, wind, and nuclear power generation and fuel conversion, such as hydrogen and ammonia co-firing and dedicated firing power generation utilizing thermal power generation. Therefore, transition bond issuance is expected to increase. The results of this study suggest that electric utilities should manage bond issuance based on the characteristics of investors' time horizons in ALM and the increase in negative greenium when the credit market environment is favorable.[22] Electric utilities are also expected to raise their ESG scores and reduce their Scope 1 GHG emission factors.

Furthermore, IR activities can contribute to increasing negative greenium as demonstrated by Chugoku Electric Power Company's bonds with a larger negative greenium than other electric power bonds due to the company's proactive IR activities. Issuers must clearly explain the significance of transition bonds to investors to gain their understanding. For Japan, promoting sustainable finance is necessary to expand the investor base in green and transition bonds.

[22] In periods when credit market conditions deteriorate, such as during the Lehman shock or the COVID-19 crisis, it is possible that "a greenium does not exist and is not generated."

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