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# Impact of ESG Disclosure on Price Discovery Process in the Indian Energy Sector

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**ABSTRACT**

ESG (environmental, social, and governance) framework has importance in investing environment due to its direct relevance with sustainable investments and long-term stock performance. ESG carries implications for all sectors of the economy and energy sector is no exception to that. In case of energy sector, it supports the investments in sustainable energy, carbon reduction, and ethical governance. The present study tries to assess the relative importance of ESG disclosure scores on the price discovery process of energy firms in Indian stock market. The study also examines the pricing efficiency of future contracts in leading the spot prices of energy sector stocks of Indian economy. Using the data from 12 energy firms in Indian stock market, this study deploys the standard time series methodology including test of stationarity, co-integration and error correction mechanism to assess the causality between future and spot prices of energy firms. The findings indicates that ESG disclosure scores do not have an impact on price discovery for most of the energy sector companies, with no long-term causality. BHEL, a low ESG level manufacturing and engineering company in the energy sector, shows slightly different results, indicating reverse causality. Similarly, insignificant short-term causal relationships are exhibited by most of the firms, except NTPC and TTPW (Tata Power) show significant short term causality.

**Keywords:** Environmental, Social, and Governance Factors, Causality, Price Discovery, Sustainability, Lead-lag Relationship, Energy Sector
**JEL Classifications:** C01, C22, D53, G13, G14

## 1. INTRODUCTION

The global shift to sustainable and renewable energy sources is making the energy sector attractive for investors (Falchetta et al., 2021). Traditional fossil fuels continue to dominate investments in this sector, but with the advent of new emerging technologies energy sourced from solar, wind, biofuels etc. are becoming increasingly attractive due to their potential for sustainable growth and lower environmental impact (Liu et al., 2020). Since they serve as viable alternatives to traditional energy sources, promote global sustainability goals, and have long-term economic advantages, therefore new technologies-based energy sources are drawing significant amounts of attention from investors. The same trend can be observed in the stock market, with energy stocks exhibiting significant fluctuations in response to changing regulations, advances in technology, and consumer demand (Falchetta et al., 2021; Liu et al., 2020; Rajavuori and Huhta, 2020; Sharma et al., 2023).

Investor preference has increased for companies that prioritise environmental, social, and governance (ESG) criteria since they are in line with the additional broader goals of sustainability, ethical and social responsibility (Caporale et al., 2022; Gavrilakis and Floros, 2023; Torre et al., 2020). The market participants consider ESG as an indication of financial stability since firms with strong ESG ratings tend to show lesser volatility and higher returns (Torre et al., 2020). ESG is a set of criteria used for evaluating the extent to which a company handles risk and operates in regard to environmental, social and corporate governance while ensuring sustainability and ethics (Kotsantonis and Serafeim, 2019). ESG policies enables companies monitor their impact on the environment, foster social responsibility, and ensure good governance with a view to promote sustainability, long-term growth and positive transition. Depending on investor preferences and market conditions, environmental, social, and governance (ESG) policies have a varying impact on the creation of shareholder value over the short and long term (Rojo-Suárez and Alonso-Conde, 2023).

Investors' awareness of the long-term value and risk management of sustainable practices is becoming evident in price discovery with the consideration of ESG factors in the energy sector (Desai and Lambert, 2024). Price discovery is a process in spot markets where price are decided based on the prices of future market price and the process is important for ensuring market efficiency and transparency, as it reflects the collective sentiment, information, and expectations of market participants (Sharma et al., 2020). Factors such as investor risk attitudes, demand and supply, and economic conditions play significant roles in this process. Investor can make better informed and ethical investment decisions by including ESG factors during the price discovery process (Torre et al., 2020). This is particularly relevant for enterprises that are energy-intensive, pollutant-intensive, or non-state-owned (Zhang et al., 2024). To ensure market efficiency, direct investment choices help maintaining market efficiency by reflecting macroeconomic trends and provide regulatory insights to uphold a fair trading environment (Gavrilakis and Floros, 2023). In order to improve operational efficiency, and resilience against volatility and challenges, energy companies must include ESG strategies to reduce environmental and market risks, with a focus on achieving social equity (Singh and Jaiwani, 2023) and in this light a study on price discovery in energy sector, particularly with special reference to ESG, is essential.

The lead-lag relationship in price discovery between spot and futures markets has recently gained researchers' interest, particularly regarding ESG factors. This study examines this relationship in the energy sector, data from investing.com, to analyse how ESG impacts price discovery for energy firms in Indian stock market.

This study is primarily focused on, to ascertain if price discovery occurs in a ESG compliant energy firms, whether the low ESG score firms have any different price discovery mechanism than that of high ESG score firm. Hence, this study analyses the price discovery mechanism with respect to ESG level of firms in energy sectors, using Indian stock market data from investing.com and the study intends to addresses the following research questions:

- Is price discovery taking place in the energy sector using firm-level data?
- Is there a significant role of ESG disclosure scores in the price discovery process in the energy sector?
- Do firms with high ESG scores have different price discovery mechanism than the firms with low ESG scores?

This study will be useful for researchers, investors, regulators, policymakers, and financial analysts by offering insights into market efficiency and price discovery process for ESG energy stocks.

## 2. LITERATURE REVIEW

There have been several studies on price discovery in the energy sector across various economies. The futures and spot prices of energy sectors are closely linked. For natural gas and heating oil, price discovery mainly takes place in futures markets; for crude oil, it occurs in both futures and spot markets (Shrestha, 2014; Sharma et al., 2022). Using data from 2007-2012 and Hasbrouck's model, Elder et al. (2014) examined price discovery between Brent crude and West Texas Intermediate (WTI) and reveals that WTI is dominant with more than 80% information sharing, irrespective of the Brent - WTI spread inversion. Shao and Hua (2022) uses the Vector error correction model (VECM), permanent-transitory (PT), information share (IS), and modified information share (MIS) models to analyse the pricing efficiency and price discovery of Shanghai Crude Oil Futures (SC). Though SC contributes 50% of price discovery, behind WTI and Brent, the results indicate a long-run equilibrium relationship exist between future and spot prices. Elder et al. (2014) uses Hasbrouck's information sharing model to examine price discovery between WTI and Brent crude oil. Despite Brent price spreads and Cushing inventory movements, WTI typically comprises 65-90% of price discovery. WTI continues to be a crucial international standard. For investments in the energy sector, Cunico et al. (2017) proposes a multiperiod fuzzy optimisation model that addresses uncertainty in demand trends, reserve availability, and fossil resource pricing. In addressing uncertainty in optimistic and pessimistic scenarios, the model outperforms deterministic techniques and offers a strong, strategic strategy when applied to context of Argentina. A study on European investors by Masini and Menichetti (2013), shows the importance of non-financial factors like institutional pressure, belief and technical feasibility in renewable energy investment decisions, offering insights for policy modification and sustainable investment strategies. Renewable energy (RE) technologies face limited adoption due to inadequate private investments and biased perceptions that favours traditional energy production models.

In the energy sector, a conceptual model that links Industry 4.0, ESG, and sustainable development, reveals the contribution of digital transformation to sustainability (Nitlarp and Kiattisin, 2022). Rojo-Suárez and Alonso-Conde (2023) found that while short-run ESG effects on firm value are limit, but long-run performance can reduce value creation due to higher discount rates and substitution effects. Baran et al. (2022) found no consistent ESG-CFP trends in Poland's energy sector, due to state ownership, regulatory challenges, and delayed modernisation as barriers. ESG indices are safe haven avenues in volatile European energy markets, which is focused on risk mitigation, spillover effects, and crisis portfolio strategies (Ahad et al., 2024). More ESG disclosure minimises company risk and improves stock market returns, highlighting the advantages of risk reduction and enhanced market performance for businesses that implement thorough ESG disclosure (Naseer et al., 2024). The evolving role of China's Shanghai International Energy Exchange (INE) crude oil futures in price discovery for

Asian crude oils, are influenced by economic fundamentals, trading characteristics, and disruptions like the COVID-19 pandemic (Yu et al., 2023). ESG strategies have different impacts on the environmental, social, and governance pillars as they improve accounting performance but reduce market performance (Hyusein and Cek, 2024). Moreover, energy and renewable energy firms do not show any sectoral differences. Sarfraz et al. (2023) identifies the primary drivers and mechanisms impacting ESG outcomes and explores into the way the triple transformation of business, people, and technology improves ESG performance in the energy industry. A study by Behl et al. (2022), analysed long-run benefits of ESG investment for Indian energy companies, with negative effects in early lags and positive effects later, but no bidirectional causality. There is marginally negative impact of environmental responsibility and ESG performance on the profitability of energy companies in Europe (Makridou et al., 2024).

According to Zairis et al. (2024), ESG factors have the potential to impact stock price formation by incorporating non-financial information and enabling traditional price discovery processes with an improved sustainability. Higher ESG scores improve information efficiency, which impacts price discovery by reducing stock price synchronicity (Potharla et al., 2023; Sharma et al., 2024). ESG performance also improves market resilience and reduces the risk of geopolitical crashes (Fiorillo et al., 2024). This shows the importance ESG interaction with price discovery process as it maintains stock performance steady during volatile periods. Many researchers have identified different factors that affect stock price discovery, such as Schwartz et al. (2010), Maloney and Mulherin (2003), Patel et al. (2020), Andersen et al. (2007), Gavious and Kedar-Levy (2013) and several others. Singh and Jaiwani (2024) affirm that the price discovery process is related to ESG performance because of investor sensitivity to ESG that affects stock volatility differently in developed and developing economies, hence ultimately influencing market reactions differently. Liang et al. (2024) explain that better corporate governance could enhance company performance in Chinese stock markets, which in turn decreases price volatility. ESG indices could encourage price discovery by integrating sustainable practices into stock performance (Jonwall et al., 2024). Sahu et al. (2024) shows that ESG transparency increases the positive impact of managerial perspectives on price discovery by improving investor decision-making through more reliable and clearer corporate disclosures. Although Yu et al. (2024) argue that ESG factors may attract investor attention, thereby magnifying market reactions and indirectly influencing price discovery, they do not directly cause unpredictable stock price movements.

The energy sector's ESG performance is favourably impacted by triple transformation, which includes people, business, and technology (Ozdurak and Ulusoy, 2020). Despite the fact that it has limitations in its ability to address external factors and investor concerns, context-specific interactions among factors and mechanisms shape outcomes (Ozdurak and Ulusoy, 2020). Using a diversification-consistent DEA model, Bilbao-Terol et al. (2024) analyses price discovery in the energy market, highlighting the financial outperformance and ESG efficiency benefits associated with renewable energy. The study offers a two-step method for striking a balance between financial returns and ESG goals. Singh and Jaiwani (2024) analyses price discovery in the energy sector and shows that multiple ESG factors impact the volatility of stock prices. Due to differences in regulations and developmental aspects, ESG stabilises prices in emerging economies while destabilising them in developed nations. Desai and Lambert (2024) highlighted nuanced effects of ESG risk on valuation by revealing sub-sector valuation asymmetries in the energy sector, showing efficient pricing for securities with high ESG risk but inefficiencies for assets with lesser ESG risk.

## 3. METHODOLOGY

This study considers 12 energy sector companies that have adopted ESG policies and also participate in the futures market within the Indian stock market. The names of the companies are following: Bharat Petroleum Corporation limited (BPCL), Hindustan petroleum corporation limited (HPCL), Indian oil corporation limited (IOCL), Oil and Natural Gas Corporation (ONGC), Gas Authority of India limited (GAIL), Gujarat Gas limited (GGAS), Indraprastha Gas limited (IGAS), Mahanagar Gas Limited (MGAS), National Thermal Power Corporation (NTPC), Tata Power Company Limited (TTPW), Bharat Heavy Electricals Limited (BHEL), and Coal India Limited (COAL). BPCL, HPCL, IOCL, and ONGC primarily deal in oil products; GAIL, GGAS, IGAS, and MGAS are firms specialising in gas related energy supply; while NTPC, TTPW, BHEL, and COAL are other Indian companies operating in the energy sector. These companies are listed on the Bombay stock exchange (BSE) in India, and the daily closing prices of spot and futures markets were collected for these 12 ESG-compliant companies. The sample period the study is from April 1, 2020 to February 2, 2025 except in case of GGAS where the data was available from March 1, 2021. The data for this study was obtained from a web-based financial database called Investing.com. These selected ESG compliant companies were further divided into high and low ESG levels based on their ESG score for 2020, with scores above median ESG score 50 considered high and scores below 50 considered low.

There is a problem of unit root often encountered in time series data that makes the results of analysis spurious (Sharma and Chotia, 2019; Sharma et al., 2020). To detect the presence of a unit root, also known as non-stationarity, the Augmented Dickey-Fuller (ADF) test was conducted (Dickey and Fuller, 1981). The ADF test formulates the null hypothesis that the time series has a unit root (i.e., it is non-stationary), which is rejected if the test results are statistically significant. In the next step, to analyse the long-run relationship between the spot and futures prices of the selected companies, the Johansen co-integration test was conducted. The mathematical equation for the test is given in Equation (1):

$$\Delta Y_t = \mu + Y_{t-1} + \sum_{j=1}^{p} \alpha_j \Delta Y_{t-1} - \beta t + \omega_t \quad (1)$$

The closing prices of the time series variables (spot and futures market prices of the selected companies) are denoted as $Y_t$ in Equation (1). Here, $Y_{t-1}$ represents the first lag of, μ indicates the drift term, t depicts the time trend, and p indicates the longest lag length used. Finding the order of integration for the spot and futures market price series data is the primary intent to apply

Johansen co-integration test. The maximum likelihood method is used in this test, and the results are drawn in two ways: Trace statistics and maximum eigenvalues. The null hypothesis for this test, states that there is no co-integrating relationship between the spot and futures prices of the selected companies, is tested using the Johansen co-integration method. This method is essentially a multivariate version of the ADF test by assuming the reduced form of the VAR framework, as shown in Equation (2).

$$\Delta y_t = B_1 y_{t-1} + \cdots + B_n y_{t-n} + Cx_t + \mu_t \quad (2)$$

Here, $x_t$ is an n-vector of deterministic trends, $\mu_t$ is a vector of shocks, and $y_t$ is a k-vector of I (1) variables. The VAR model may thus be rewritten as shown in Equation (3). This equation represents the dynamic interaction between the variables, with the effect of deterministic trends represented by *Cxt*, the sum taking into account short-term adjustments, the first term of the equation (3) $\prod y_{(t-1)}$ captures the long-run relationship (co-integration) and $\mu_t$ takes up the remaining shock.

$$\Delta y_t = \prod y_{t-1} + \sum_{i=1}^{n-1} \Gamma_i \ \Delta y_{t-1} + Cx_t + \mu_t \quad (3)$$

The long-term causality between the spot and future market prices of the selected firms, was analysed by employing vector error correction model (VECM) (Hasbrouck, 1995). This method is particularly useful for understanding the relationship between non-stationary time series data. A key component of the VECM is the error correction term (ECT), which captures the adjustment mechanism towards long-term equilibrium. The ECT is calculated based on Equations 4 and 5 shown below, that provide insights of deviations from equilibrium are corrected over time.

$$\Delta \left(Company\_S\right)_t = \alpha_1 + \sum_{i=1}^{i=n} \beta_{S,i} \Delta(Company\_S)_{t-1} + \sum_{i=1}^{i=m} \gamma_{S,i} \Delta(Company\_F)_{t-1} + \lambda_1 e_{t-1} + \nu_{1t} \quad (4)$$

$$\Delta \left(Company\_F\right)_t = \alpha_1 + \sum_{i=1}^{i=n} \beta_{F,i} \Delta(Company\_F)_{t-1} + \sum_{i=1}^{i=m} \gamma_{F,i} \Delta(Company\_S)_{t-1} + \lambda_1 e_{t-1} + \nu_{1t} \quad (5)$$

Equations (4 and 5) depicts the dynamic relationships between the changes in spot market prices (Company_S) and futures market prices (Company_F). The first difference between the spot market and futures market prices is denoted by Δ, while $e_{t-1}$ represents the lag of the error correction term (ECT). Causality from the futures market to the spot market is suggested when the coefficients in Equation (4) are both negative and statistically significant, indicating that the futures market leads in price discovery. On the contrary, if the coefficients in Equation (5) are negative and significant, it suggests causality from the spot market to the futures market. In this context, β reflects the speed of adjustment coefficient. The VAR model was used to determine the optimal lag length, based on minimum of the Akaike information criterion (AIC) and Schwarz Information Criteria (SIC) values criteria. A negative and significant ECT in Equation (4) supports the presence of price discovery and long-term causality between the futures and spot markets for the companies studied.

## 4. RESULTS AND DISCUSSION

The following results for ADF test, reported in Table 1, show the presence of a unit root in the time series data of spot and futures

**Table 1: Unit root test**

| Stock | Variable | t-statistics at level | P-value at level | t-statistics at first difference | P-value at first difference | Lag length |
|---|---|---|---|---|---|---|
| BPCL | Spot | −1.485 | 0.541 | −8.138*** | 0.000 | 1 |
| | Future | 0.889 | 0.995 | −8.685*** | 0.000 | |
| HPCL | Spot | −0.654 | 0.856 | −23.235*** | 0.000 | 5 |
| | Future | −2.378 | 0.148 | −22.480*** | 0.000 | |
| IOCL | Spot | −0.821 | 0.811 | −5.524*** | 0.000 | 1 |
| | Future | −1.547 | 0.509 | −32.969*** | 0.000 | |
| ONGC | Spot | −1.189 | 0.681 | −35.022*** | 0.000 | 2 |
| | Future | −1.228 | 0.664 | −35.022*** | 0.000 | |
| GAIL | Spot | −1.106 | 0.716 | −35.725*** | 0.000 | 3 |
| | Future | −1.558 | 0.504 | −34.825*** | 0.000 | |
| GGAS | Spot | −2.034 | 0.272 | −30.994*** | 0.000 | 2 |
| | Future | −2.063 | 0.260 | −31.754*** | 0.000 | |
| IGAS | Spot | −3.035 | 0.032 | −32.118*** | 0.000 | 1 |
| | Future | −1.934 | 0.317 | −26.940*** | 0.000 | |
| MGAS | Spot | −1.678 | 0.442 | −33.655*** | 0.000 | 6 |
| | Future | −1.659 | 0.452 | −34.035*** | 0.000 | |
| NTPC | Spot | −0.663 | 0.854 | −18.790*** | 0.000 | 5 |
| | Future | −0.680 | 0.854 | −18.941*** | 0.000 | |
| TTPW | Spot | −1.478 | 0.545 | −33.690*** | 0.000 | 5 |
| | Future | −1.493 | 0.537 | −33.969*** | 0.000 | |
| BHEL | Spot | −1.191 | 0.680 | −34.491*** | 0.000 | 10 |
| | Future | −1.240 | 0.659 | −7.922*** | 0.000 | |
| COAL | Spot | −0.890 | 0.792 | −34.491*** | 0.000 | 9 |
| | Future | −1.240 | 0.659 | −7.922*** | 0.000 | |

BPCL: Bharat petroleum corporation limited, HPCL: Hindustan petroleum corporation limited, IOCL: Indian oil corporation limited, ONGC: Oil and natural gas corporation, GAIL: Gas authority of India limited, GGAS : Gujarat gas limited, IGAS: Indraprastha gas limited, MGAS: Mahanagar gas limited, NTPC: National thermal power corporation, TTPW: Tata power company limited, BHEL: Bharat heavy Electricals limited, COAL: Coal India limited market prices for all selected companies at the level. All the absolute t-statistics values are less than the critical t value, and the P > 0.05 significance level. Therefore, the null hypothesis of the ADF test, which states that the series has a unit root, cannot be rejected at the level. The ADF test was applied again to the same time series data of the selected companies at the first difference. The results show that the absolute t-statistic value is greater than the critical t-value, and the P < 0.05 significance level. Hence, the null hypothesis of the ADF test is rejected, shows that there is no unit root problem at the first difference.

In the Johansen cointegration test, the null hypothesis of r = < 1 (i.e., at most one co-integrating relationship) and the second null hypothesis of r = 0 (i.e., no co-integrating relationship) among the time series data of the selected companies are tested. As the P-value of trace statistics (Table 2) is lower than 0.05 in case of null hypothesis (r = 0), thus the null hypothesis of no-cointegrating relationship will be rejected. Similarly, in case of null hypothesis (r = 1), the study fail to reject the null as the P > 0.05. This confirms that in case of all sample firms except IOCL and ONGC, there is long-term cointegrating relationship between the spot and future prices of the energy sector stocks.

The long run causality between spot and future price of sample firms is tested using vector error correction mechanism. From the results mentioned in Table 3, it is clear that the error correction terms for IGAS is negative and significant (−0.399284***). This confirms the future prices of IGAS are leading the spot prices in the sample period of the study. This confirms that there is significance evidence of price discovery taking place in case of IGAS. On the other hand, the error correction of BPCL futures is −0.0068 and significant. This confirms that spot prices of BPCL are significantly causing the BPCL future prices in the sample period selected for the study. This confirms the case of reverse price discovery as the price discovery is considered when the future prices are leading the spot prices.

In case of other 10 sample firms, there are no evidences of causality from future to spot or spot to future as all the error correction

**Table 2: Trace statistics**

| Stock | No. of lags (SPOT) | Hypothesized No. of CE (s) | Trace statistic | Prob.** |
|---|---|---|---|---|
| BPCL | 1 | r=0 | 11.373 | 0.019 |
| | | r≤1 | 0.394 | 0.530 |
| HPCL | 5 | r=0 | 6.009 | 0.048 |
| | | r≤1 | 0.071 | 0.790 |
| IOCL | 1 | r=0 | 3.541 | 0.937 |
| | | r≤1 | 0.453 | 0.501 |
| ONGC | 2 | r=0 | 46.954 | 0.000 |
| | | r≤1 | 0.469 | 0.493 |
| GAIL | 3 | r=0 | 2.130 | 0.993 |
| | | r≤1 | 0.581 | 0.446 |
| GGAS | 2 | r=0 | 75.947 | 0.000 |
| | | r≤1 | 2.812 | 0.094 |
| IGAS | 1 | r=0 | 17.023 | 0.029 |
| | | r≤1 | 0.695 | 0.404 |
| MGAS | 6 | r=0 | 30.024 | 0.000 |
| | | r≤1 | 1.504 | 0.220 |
| NTPC | 5 | r=0 | 89.497 | 0.000 |
| | | r≤1 | 0.084 | 0.772 |
| TTPW | 5 | r=0 | 88.545 | 0.000 |
| | | r≤1 | 0.948 | 0.330 |
| BHEL | 10 | r=0 | 87.205 | 0.000 |
| | | r≤1 | 0.042 | 0.838 |
| COAL | 9 | r=0 | 25.396 | 0.001 |
| | | r≤1 | 2.457 | 0.110 |

BPCL: Bharat petroleum corporation limited, HPCL: Hindustan petroleum corporation limited, IOCL: Indian oil corporation limited, ONGC: Oil and natural gas corporation, GAIL: Gas authority of India limited, GGAS : Gujarat gas limited, IGAS: Indraprastha gas limited, MGAS: Mahanagar gas limited, NTPC: National thermal power corporation, TTPW: Tata power company limited, BHEL: Bharat heavy Electricals limited, COAL: Coal India limited

**Table 3: Results of error correction mechanism corresponding to ESG score**

| Company | Spot | Future | ESG disclosure (2020) |
|---|---|---|---|
| BPCL | −0.000761 | −0.006808*** | High |
| | (−1.00094) | (−3.04310) | |
| HPCL | −0.000427 | −0.001573 | High |
| | (−0.08751) | (−0.23422) | |
| IOCL | 0.003942 | 0.005992 | High |
| | (1.43193) | (1.74795) | |
| ONGC | −0.178376 | −0.033476 | Low |
| | (−1.04928) | (−0.19795) | |
| GAIL | 0.005147 | 0.005385 | High |
| | (1.20207) | (1.11057) | |
| GGAS | −0.03667 | 0.249572 | Low |
| | (−0.22433) | (1.48063) | |
| IGAS | −0.399284*** | −0.465578 | Low |
| | (−3.56310) | (−1.72819) | |
| MGAS | −0.188393 | −0.034652 | Low |
| | (−1.43690) | (−0.27051) | |
| NTPC | 0.051976 | 0.330614 | High |
| | (0.24662) | (1.57123) | |
| TTPW | 0.763751** | 1.08614** | High |
| | (1.99340) | (2.73941) | |
| BHEL | 0.058145 | 0.707548 | Low |
| | (0.05796) | (0.69273) | |
| COAL | 0.274991 | 0.355812** | Low |
| | (1.72260) | (2.19843) | |

ESG: Environmental, social, and governance, BPCL: Bharat petroleum corporation limited, HPCL: Hindustan petroleum corporation limited, IOCL: Indian oil corporation limited, ONGC: Oil and natural gas corporation, GAIL: Gas authority of India limited, GGAS: Gujarat gas limited, IGAS: Indraprastha gas limited, MGAS: Mahanagar gas limited, NTPC: National thermal power corporation, TTPW: Tata power company limited, BHEL: Bharat heavy Electricals limited, COAL: Coal India limited

**Table 4: Wald test statistics**

| Company | Chi-square test statistics | P-value | ESG disclosure score |
|---|---|---|---|
| BPCL | 0.272148 | 0.6019 | High |
| HPCL | 3.757023 | 0.5849 | High |
| IOCL | 0.817317 | 0.366 | High |
| ONGC | 6.03897 | 0.0488 | Low |
| GAIL | 1.215617 | 0.7493 | High |
| GGAS | 0.432018 | 0.8057 | Low |
| IGAS | 0.653969 | 0.4187 | Low |
| MGAS | 4.729387 | 0.579 | Low |
| NTPC | 21.1434*** | 0.0008 | High |
| TTPW | 20.58074*** | 0.001 | High |
| BHEL | 12.7767 | 0.3082 | Low |
| COAL | 17.31056** | 0.0441 | Low |

ESG: Environmental, social, and governance, BPCL: Bharat petroleum corporation limited, HPCL: Hindustan petroleum corporation limited, IOCL: Indian oil corporation limited, ONGC: Oil and natural gas corporation, GAIL: Gas authority of India limited, GGAS: Gujarat gas limited, IGAS: Indraprastha gas limited, MGAS: Mahanagar gas limited, NTPC: National thermal power corporation, TTPW: Tata power company limited, BHEL: Bharat heavy Electricals limited, COAL: Coal India limited terms are neither negative nor significant. The coefficients of firms future prices as dependent variable of BPCL (−0.000761), HPCL (−0.000427), ONGC (−0.178376), GGAS (−0.03667) and MGAS (−0.188393) are negative but insignificant. Similarly in case of IOCL (0.003942), GAIL (0.005147), NTPC (0.051976), TTPW (0.763751), BHEL (0.058145) and COAL (0.274991), the coefficients are neither negative nor significant. This confirms in case of these 10 sample firms, there no evidences of price discovery.

The study also tries to assess the impact of ESG disclosure scores on the price discovery mechanism and found that majority of the companies show no significant effect of ESG (environmental, social, and governance) scores on price discovery in the spot market. This is primarily due to insignificant error correction term in case of 10 sample firms out of 12. The only exception is IGAS, which indicates a significant causal relationship in the spot market and BPCL in case of future prices as dependent factors. This confirms that, ESG is not affecting the spot market prices for the companies in energy sectors. Similarly, the future market also shows no significant impact of ESG scores on price discovery for the majority of companies. For companies with high ESG levels (e.g., BPCL, HPCL, IOCL, GAIL, NTPC), their strong ESG scores do not translate into any noticeable effect on price discovery in either the spot or future markets prices. On the other hand, companies with low ESG levels (ONGC, COAL, and BHEL, MGAS) also show no significant impact.

The short-run causality between the spot and future prices is tested using the Wald test (Table 4). The results of Chi-square test statistics applied to assess whether the lagged values of future prices are affecting the current prices of spot market of sample firms suggest that the test statistics is significant in case of NTPC, TTPW and COAL while it is insignificant in case of BPCL, HPCL, IOCL, ONGC, GAIL, GGAS, IGAS, MGAS and BHEL This shows that there are statistical significant evidences of short-run causality from future to spot prices of following firms NTPC, TTPW and COAL while there are no significant evidences of short-run causality from future to spot prices in case of BPCL, HPCL, IOCL, ONGC, GAIL, GGAS, IGAS, MGAS and BHEL. The study also tried to explore the impact of ESG disclosure scores on price discovery process of Indian energy firms using in short-run causal framework. The results are providing mixed evidences. In case of three firms where the short-run causality is significant (NTPC, TTPW and COAL), the two firms NTPC and TTPW carries higher ESG disclosure scores while in case of COAL, the ESG score is low. On the contrary, irrespective of high or low ESG scores, there no statistical significant evidences of short-run causality from future to spot prices of nine sample firms including BPCL, HPCL, IOCL, ONGC, GAIL, GGAS, IGAS, MGAS and BHEL. The results of the analysis highlight that firms' ESG levels have not directly impacted price discovery for the majority of companies. The oil and gas sub-sector (comprising BPCL, HPCL, IOCL, and GAIL) shows insignificant lead-lag relationships in the price discovery process in both spot and future markets, despite high ESG scores for some companies. Similarly, the power sub-sector (NTPC and COAL) also exhibits insignificant lead-lag relationships in both markets.

## 5. CONCLUSION

The present study analysed the impact of ESG disclosure scores on price discovery process in Indian stock market using data of energy firms. This study examines the daily closing prices of spot and futures markets for 12 ESG-compliant companies in Indian stock markets. This considers the sample period from post-covid time and applied VECM framework to assess the long-run causal relationship and Wald test for short-run causal relationship.

The results of this study show that ESG scores do not have impact on price discovery, with exceptions of IGAS in long-run causal framework. In case of short-run causal framework, the future prices are leading the spot prices in case of three sample firms NTPC, TTPW and COAL. With respect the impact of ESG disclosure scores on price discovery process, the study found that the ESG scores do not impact the price discovery process as in case of majority of sample firms with their high or low ESG scores, the price discovery evidences are either insignificant or mixed evidences are reported.

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