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DOI:

[10.1016/j.irfa.2023.102811](https://doi.org/10.1016/j.irfa.2023.102811)

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Document Version

Publisher's PDF, also known as Version of record

Citation for published version (Harvard):

Zhang, Q, Ding, R, Chen, D & Zhang, X 2023, 'The effects of mandatory ESG disclosure on price discovery efficiency around the world', *International Review of Financial Analysis*, vol. 89, 102811. <https://doi.org/10.1016/j.irfa.2023.102811>

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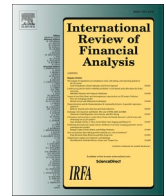
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The effects of mandatory ESG disclosure on price discovery efficiency around the world

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ARTICLE INFO

JEL classification:

G14
G15
G18
G28
G30

Keywords:

Mandatory ESG disclosure
Price efficiency
Governance

ABSTRACT

We examine the effect of mandatory environmental, social and governance (ESG) disclosure on firms' price discovery efficiency around the world. Using data from 45 countries between 2000 and 2020 and a difference-in-differences method, we find that mandatory ESG disclosure increases firm-level stock price non-synchronicity and timeliness of price discovery, suggesting more firm-specific information is incorporated into stock prices in a more timely manner. Mandatory ESG disclosure improves price discovery efficiency more in countries with strong demands for ESG information and in firms with poor disclosure incentives. Mandatory ESG disclosure also leads to other real market changes, such as lower stock returns, greater changes in institutional ownership and higher firm valuation.

1. Introduction

In recent years, growing social and environmental challenges (e.g., climate change, child labour and social inequality) have prompted companies to embrace a more systematic approach towards sustainability reporting, also known as corporate social responsibility (CSR) reporting or environmental, social and governance (ESG) reporting (Ioannou & Serafeim, 2019). Since the later 1990s, a growing number of countries have implemented ESG disclosure mandates, either through laws and regulations or through stock exchange listing requirements. Furthermore, an increasing number of investors are tending to make investment decisions based not only on expected returns but also on non-monetary criteria and social norms (Hong & Kostovetsky, 2012).¹ Concurrent with this trend, the Global Reporting Initiative (GRI) was launched in 1997 with the goal of developing and establishing rigorous and credible reporting guidelines for the “triple bottom line” (accounting, environmental and social performance) of corporations. GRI aimed to gradually evolve sustainability reporting to a point such that it would be on a par with financial reporting in terms of credibility and comparability. The Sustainability Accounting Standards Board (SASB), a non-

profit organization, with a focus on investors' demand for non-financial information, was founded in 2012 to develop and disseminate an industry-specific sustainability reporting standard and encourage companies to disclose financially material sustainability issues, in compliance with the Security and Exchange Commission (SEC)'s requirement in the U.S.

Previous research suggests that better financial disclosure can lead to tangible capital market benefits, including improved liquidity and a lower cost of capital, as well as higher asset prices (or firm value) and better corporate decisions (e.g., Christensen, Hail, & Leuz, 2021). However, ESG disclosure may be fundamentally different from financial disclosure. Financial reporting informs equity investors on firms' operations and cash flows (Biddle, Hilary, & Verdi, 2009), while ESG information not only informs shareholders on the estimation of future cash flows or evaluation of firms' potential risk (Grewal, Riedl, & Serafeim, 2019) but also stakeholders without a direct financial claim on the firm, such as customers or society at large (Bénabou & Tirole, 2010; Christensen, Floyd, Liu, & Maffett, 2017). In addition, ESG reporting generally deals with strategic activities with a long-term horizon (Bénabou & Tirole, 2010) and is multi-dimensional in nature, encompassing a

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¹ For example, socially responsible investors implement a “negative screening” approach that excludes firms operating in “sin” industries such as alcohol and tobacco, which creates an additional demand for firms to disclose ESG information.

diversity of topics, policies and activities (Amel-Zadeh & Serafeim, 2018). Given the fundamental differences between ESG and financial disclosure, and the potential divergent effects on stock markets, there is high risk in relying on prior research on mandatory financial reporting to predict the consequences of mandatory ESG reporting (Bénabou & Tirole, 2010; Christensen et al., 2017; Grewal et al., 2019).

Motivated by the fundamental difference between ESG disclosure and financial disclosure, and the limited empirical evidence on the impacts of ESG disclosure on stock markets, we focus on mandatory ESG disclosure and its economic consequences for share price discovery efficiency around the world. Share price discovery efficiency, which measures the extent to which the stock price incorporates all available public and private information in a timely manner, is crucial to realising the benefits of an efficient capital market (Easley & O'Hara, 2004). Price discovery efficiency is collectively influenced by all market participants (Easley & O'Hara, 2004; Piotroski & Roulstone, 2004; Verrecchia, 2001) and varies in terms of different amounts of information being incorporated into share prices within different time horizons (Back, Cao, & Willard, 2000; Chen, Kelly, & Wu, 2020; Holden & Subrahmanyam, 1992; Kyle, 1985; Qian, Sorensen, & Hua, 2007; Yan & Zhang, 2009). ESG information has been found to be value-relevant (Bolton & Kacperczyk, 2021; Pedersen, Fitzgibbons, & Pomorski, 2021) and mandatory ESG disclosure, by increasing the amount of information available to all market participants, may improve information environments for sophisticated information users such as analysts and institutional investors (Bolton & Kacperczyk, 2021; Krueger, Sautner, Tang, & Zhong, 2021; Pedersen et al., 2021; Schieman & Tietmeyer, 2022). However, it may not necessarily improve information environments for other information users, leading to unclear information asymmetry outcomes between informed and uninformed investors (Brown, Hillegeist, & Lo, 2004; Easley & O'Hara, 2004), and unclear trading tactics being adopted by sophisticated information users to influence price discovery processes (Back et al., 2000; Chen et al., 2020; Holden & Subrahmanyam, 1992; Kyle, 1985; Piotroski & Roulstone, 2004; Qian et al., 2007; Verrecchia, 2001; Yan & Zhang, 2009). Therefore, whether mandatory ESG disclosure regulations improve firm-level share price discovery efficiency remains unresolved, suggesting that identifying the relative magnitudes of the various benefits and costs arising from such regulations is largely an empirical issue that deserves investigation.

To capture the dynamic share price discovery process and its efficiency, we use two measures. The first measure is stock price non-synchronicity (*PSI*), capturing the proportion of variation in the firm-level stock return that cannot be explained by market and industry-wide information but is driven by firm-specific information (Bennett, Stulz, & Wang, 2020; Chen, Goldstein, & Jiang, 2007; Chen, Huang, Li, & Yuan, 2022; Crawford, Roulstone, & So, 2012; Durnev, Morck, Yeung, & Zarowin, 2003; Fernandes & Ferreira, 2008, 2009; Gul, Kim, & Qiu, 2010; Gul, Srinidhi, & Ng, 2011; Kacperczyk, Sundaresan, & Wang, 2021; Morck, Yeung, & Yu, 2000; Roll, 1988). Greater values of *PSI* suggest more efficient stock prices incorporating more firm-specific public and private information, which reveals a stronger capability of this more efficient price discovery process to incorporate larger amounts of information into share prices. Our second measure is the intra-year timeliness of price discovery (*TIMELINESS*), capturing the timeliness with which forward-looking information is incorporated into the stock price throughout a fiscal year (Alford, Jones, Leftwich, & Zmijewski, 1993; Ball & Brown, 1968; Beekes & Brown, 2006; Beekes, Brown, Zhan, & Zhang, 2016; Beekes, Brown, & Zhang, 2015; Haß, Vergauwe, & Zhang, 2014; Zhang, Zhang, Chen, & Gu, 2019; Zhang, Zhang, Chen, & Strange, 2022). Greater values of *TIMELINESS* suggest that the market is slower in incorporating forward-looking value-relevant public and private information into the current share price.

Using data collected from 45 countries between 2000 and 2020, we find that, in countries where the mandatory ESG disclosure becomes effective, stock price non-synchronicity increases, suggesting a higher price discovery efficiency outcome, with more firm-specific information

incorporated into the stock price, and improved timeliness of price discovery, with forward-looking value-relevant information being incorporated into the stock price in a more timely manner. We further identify the conditions under which a mandatory ESG requirement could impact share price discovery efficiency. A mandatory ESG disclosure policy is expected to generate more capital market benefits when the demand for ESG information is stronger. We find that the net benefits of mandatory ESG disclosure on price discovery efficiency are more pronounced in countries with a strong demand for ESG information (countries making environmental protection a high priority, or with poor-quality investor protection) and in firms with poorer disclosure incentives (firms with poorer ESG information disclosure records, poorer ESG performance or poorer corporate governance quality). Our difference-in-differences (DID) test strengthens the causal inference of our results. Our findings are robust to our use of an alternative mandate-effective event window, exclusion of countries with other institutional reforms in the event window of the ESG disclosure mandate, exclusion of observations from Japan and the U.S. (representing >55% of the entire sample), a policy timing analysis, exclusion of ESG-sensitive industries, placebo tests using pseudo effective years of mandates, and estimation of pooled OLS regressions. Finally, we further reveal that mandatory ESG disclosure leads to real stock market changes in terms of reduced firm-level future stock returns, improved institutional investor participation and improved firm valuation outcomes.

Our study makes important contributions to the ESG disclosure and corporate governance literature, in a few ways. First, we respond to the call by Christensen et al. (2021) for more research on whether mandatory non-financial reporting generates market-wide benefits and costs. Our study is the first to identify the capital market impacts of mandatory ESG disclosure on stock price discovery efficiency, measured by price non-synchronicity and timeliness. More specifically, our research is related to, but differs significantly from, Krueger et al. (2021) and Schieman and Tietmeyer (2022), who focus on the impacts of mandatory ESG disclosure on analysts' forecast quality. This is because mandatory ESG disclosure may improve analysts' forecast quality but not necessarily the capabilities of all market participants to incorporate ESG information into share prices (Chen et al., 2020; Easley & O'Hara, 2004; Piotroski & Roulstone, 2004). In addition, our focus on a dynamic price discovery process, in which all market participants participate, not only reveals its capabilities in terms of incorporating different amounts of ESG information from all market participants into share prices, but also its capabilities in terms of shortening the time horizon needed for a more efficient share price (Beekes et al., 2016; Beekes & Brown, 2006; Fama, 1965; Holden & Subrahmanyam, 1992; Qian et al., 2007; Zhang et al., 2022). Thus, our analysis can help us understand this dynamic price discovery process, as a crucial transmission mechanism linking mandatory ESG disclosure to its tangible capital market benefits (Brown et al., 2004; Christensen et al., 2021; Easley & O'Hara, 2004).

Second, we reveal potential spill-over effects (Admati & Pfleiderer, 2000; Baginski & Hinson, 2016; Shroff, Verdi, & Yost, 2017) of mandatory ESG disclosure in countries where firms have flexibility in complying with these mandates. This extends previous literature focusing on the economic consequences of voluntary ESG or CSR disclosure (see Christensen et al., 2021 for a comprehensive review). Our analysis suggests market participants may infer information about non-complying or non-disclosing firms from their complying or disclosing peers, leading to such non-disclosed but inferred firm information ultimately being incorporated into share prices, but in a less timely manner.

Third, the empirical literature exhibits a heavy focus on disclosure regulation in the United States, while a global setting could provide opportunity for tighter research designs to strengthen the causal inferences of mandatory ESG disclosure policy that are absent in a U.S. setting (Leuz & Wysocki, 2016). We respond to the call from Leuz and Wysocki (2016) and focus on the country-level mandatory ESG disclosure policy in a global setting. Our analysis, using data from 45

countries, allows us to construct a robust control group from countries without mandatory ESG disclosure policies, which is less likely to be affected directly or indirectly by mandatory ESG disclosure policies adopted by other countries, and thus helps mitigate identification issues in our DID method used to reveal the real impacts of mandatory ESG disclosure. What is more, our analysis not only reveals the various impacts related to different firm-level factors that moderate the impacts of ESG disclosure on price discovery efficiency, but also those related to different country-level factors. Our analysis should have useful implications for regulators, helping them to evaluate the benefits and costs of mandatory ESG disclosure regulation.

Finally, a caveat regarding many of the prior studies is that they tend to concentrate on specific disclosure items (e.g., mine safety records or greenhouse gas emission) in a single country.² Our study looks at mandates regarding ESG disclosure, which comprehensively cover all ESG activities taking place within a firm around the world, and thus should add to the literature more powerful evidence of the trade-off between benefits and costs related to ESG disclosure regulation.

The remainder of the paper is organized as follows. Section 2 reviews the literature and develops the main hypotheses. The sample and research design are described in Section 3. Section 4 presents the results of baseline models, robustness tests, heterogeneous treatment effects and additional tests. The final section concludes.

2. Related literature and hypothesis development

Recent literature has moved away from a static market efficiency view and suggests that market efficiency is dynamic and that an efficient price discovery process, incorporating all available public and/or private information from all market participants in a timely manner, is crucial to strengthening market discipline (Christensen et al., 2021; Edmans, 2009; Grossman & Stiglitz, 1980; Holmström & Tirole, 1993; Zhang et al., 2022; Zhang, Yang, Strange, & Zhang, 2017) and thus reducing the cost of equity capital (Brown et al., 2004; Easley & O'Hara, 2004; Verrecchia, 2001).

One perspective suggests that making ESG disclosure mandatory mitigates the long-lived private information available in the market (Back et al., 2000; Holden & Subrahmanyam, 1992; Kyle, 1985), incentivizes competitive informed trading (Chen et al., 2020; Qian et al., 2007; Yan & Zhang, 2009), and thus should improve share price discovery efficiency. First of all, ESG information is value-relevant. Bolton and Kacperczyk (2021) show that carbon emissions have a significant

impact on stock returns. Pedersen et al. (2021) propose the ESG-efficient frontier and show how required returns are related to the ESG performance of firms. Second, mandatory ESG disclosure can address the selective disclosure issues related to voluntary ESG disclosure (Dhaliwal, Li, Tsang, & Yang, 2011; Dhaliwal, Radhakrishnan, Tsang, & Yang, 2012; Lins, Servaes, & Tamayo, 2017) and force firms to release previously unavailable information to the market. As a result, stock prices are likely to become more informative after ESG disclosure mandates come into force. Third, mandatory ESG disclosure can improve information environments for sophisticated information users such as analysts and institutional investors, by increasing the volume and quality of ESG information (Ioannou & Serafeim, 2019; Krueger et al., 2021) and reducing the costs of private searching, collection and verification of ESG information (Christensen et al., 2021).³ When more sophisticated information users become informed through this disclosed ESG information, competition among informed investors leads to aggressive trading, which incorporates their superior insights on this value-relevant ESG information into prices (Bushman & Smith, 2001; Chen et al., 2020; Fishman & Hagerty, 1992; Kyle, 1985; Massa, Zhang, & Zhang, 2015; Qian et al., 2007; Yan & Zhang, 2009; Zhang et al., 2022). Thus, mandatory ESG disclosure may shorten informed investors' private information horizon (Back et al., 2000; Holden & Subrahmanyam, 1992; Kyle, 1985) and improve share price discovery efficiency by leading to firm-specific information being incorporated into the share price in a more timely manner. Based on the above discussion, we propose our hypotheses H1a and H1b as follows:

H1a. Mandatory ESG disclosure increases share price informativeness.

H1b. Mandatory ESG disclosure increases share price timeliness.

Another strand of literature suggests that ESG reporting is hard for investors to process (Bingler, Senni, & Monnin, 2022; Park & Raveln, 2013), thereby increasing long private information horizons among differently informed investors (Back et al., 2000; Choi, Larsen, & Seppi, 2019; Ferreira, Ferreira, & Raposo, 2011; Grossman & Stiglitz, 1980; Holden & Subrahmanyam, 1992; Zhang et al., 2017), which may ultimately dampen share price discovery efficiency. Without clear guidance on the metrics of ESG information disclosure that firms have to provide, it is difficult to standardize and regulate the disclosure of ESG information, which provides managers with the flexibility to manipulate it (see Hermalin & Weisbach, 2012 for a review). Consequently, mandatory ESG disclosure may improve the information environment for a limited number of sophisticated and capable information users, but is unlikely to contribute to the information processing and verification of unsophisticated investors (Bingler et al., 2022; Park & Raveln, 2013). Thus, mandatory ESG disclosure may attract the attention of many uninformed investors but enlarge the information asymmetries between them and informed investors (Brown et al., 2004; Easley & O'Hara, 2004; Merton, 1987), stimulating informed investors to engage in more discreet trading tactics so as to extend their long private information horizon and extract rents through liquidity support from uninformed investors (Back et al., 2000; Choi et al., 2019; Ferreira et al., 2011; Fishman & Hagerty, 1992; Grossman & Stiglitz, 1980; Holden & Subrahmanyam, 1992; Zhang et al., 2017). The discreet trading tactics used

² For example, Christensen et al. (2017) examine the real effect of the mine safety disclosure required by the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 in the U.S., and find that the safety of coal mines improves but productivity declines. Chen, Hung, and Wang (2018) exploit the CSR disclosure mandate issued by the Shanghai and Shenzhen Stock Exchanges in China, which took effect for fiscal years ending on or after 31st December 2008. They find a decrease in overall industrial wastewater and CO₂ emissions in cities with more regulated firms. They further document that firms subject to the mandate experience a deterioration in profitability. Grewal et al. (2019) focus on short-window returns to events leading to the passing of an EU directive making the disclosure of non-financial CSR information mandatory (EU Corporate Social Responsibility Directive: NFRD 2014/95/EU). They show, on average, a negative market reaction but positive returns for firms with more CSR disclosure and better CSR performance before the mandate came into force. Downar, Ernstberger, Reichelstein, Schwenen, and Zaklan (2021) investigate whether a mandate regarding greenhouse gas emissions introduced by the UK government generates pressure for firms to decrease their emissions. They show that firms affected by the mandate reduce their emissions by about 8%, which is accompanied by a significant increase in production costs. Finally, Fiechter, Hitz, and Lehmann (2022) also examine the EU Corporate Social Responsibility Directive (NFRD 2014/95/EU) that requires qualifying firms to disclose non-financial information from the fiscal year 2017 onwards. They report that firms increase their CSR activities and did so even before the mandate took effect.

³ For example, Ioannou and Serafeim (2019), who compare firms from four countries with CSR disclosure mandates before 2011 (China, Denmark, Malaysia and South Africa), find that firms in countries with the mandates increase their volume and quality of CSR disclosure in the post-mandate period. Krueger et al. (2021) explore the effect of mandatory ESG disclosure on firms' information environments. They find that mandatory ESG disclosure increases the accuracy of analysts' earnings forecasts, and lowers analyst forecast dispersion. In addition, mandatory disclosure has regular disclosure frequency, transparency and comparability arising from standardization, which reduces the costs of obtaining, processing and comparing ESG information (Christensen et al., 2021).

by informed investors, based on their superior information collection and processing ability, may further compromise market discipline regarding managerial ESG disclosure (Edmans, 2009; Grossman & Stiglitz, 1980; Holmström & Tirole, 1993; Zhang et al., 2017, 2022), leading to poor price discovery efficiency (Ferreira et al., 2011; Grossman & Stiglitz, 1980; Zhang et al., 2017).⁴ Based on the above discussion, we propose H2a and H2b as follows:

H2a. Mandatory ESG disclosure decreases share price informativeness.

H2b. Mandatory ESG disclosure decreases share price timeliness.

In our empirical testing, if the main impact of mandatory ESG disclosure on the price discovery process is to mitigate the long-lived private information available in the market, and incentivize competitive informed trading so that more information is incorporated in the share price in a more timely manner, H1a and H1b will be supported. If the main impact of mandatory ESG disclosure is to increase uncertainty and opportunistic trading by informed investors, H2a and H2b will be supported.

3. Research methods

3.1. Sample and data

Our sample includes public firms from 45 countries for the period from 2000 to 2020. The sample countries are the constituents of the MSCI World Index and the MSCI Emerging Markets Index. The MSCI indices include major developed and emerging countries around the world. The selected countries must have data/information available for all country-level variables.⁵ We include companies delisted during the sample period. We exclude firm-year observations with missing data on the dependent or explanatory variables. We exclude firm-year observations with negative book value of equity or negative sales. We also exclude firms in the financial and utilities sectors, with standard industrial classification (SIC) codes 6011–6799 and 4900–4949, because these two sectors have unique business models and regulatory requirements.⁶ To ensure that our analysis does not suffer from selection bias, our sample includes 27 countries that have enacted ESG disclosure mandates (i.e., the treatment group) and 18 countries without any ESG disclosure mandates (i.e., the control group). Because a mandatory ESG disclosure policy is likely to occur around the same time as other institutional reforms, we restrict the window of the treatment group (i.e., countries with the implementation of mandatory ESG disclosure) to the two years before the policy effective year, the policy effective year, and the three years after the policy effective year.⁷ The full sample period (i.e., 2000–2020) is used as the window for countries in the control group. The above procedure results in a final sample of 78,815 firm-year

observations for the price non-synchronicity sample, and 79,689 firm-year observations for the price timeliness sample. Table 1 reports the sample distribution by country. As shown in the table, China has the largest number of observations in the treatment group, with mandatory ESG disclosure reforms (3005 and 3029), and the United States has the largest number of observations in the control group, without mandatory ESG disclosure reforms (27,299 and 27,700). Japan and the U.S. contribute >55% of observations in the full samples.

We obtain share price and financial data for public firms from the Refinitiv Datastream and Refinitiv Worldscope. Data on analyst following is collected from the Institutional Brokers Estimate System (I/B/E/S). Annual CO₂ emissions (metric tons per capita) are collected from the Emissions Database for Global Atmospheric Research (EDGAR).⁸ The effective years of mandatory ESG disclosure reform are collected from the study of Krueger et al. (2021).⁹ Major corporate governance reform years are collected from the study of Fauver, Hung, Li, and Taboada (2017). Firm-level corporate governance data come from Refinitiv Eikon. Institutional ownership data are obtained from the Refinitiv Ownership Database. The status of firm-level ESG reporting is collected from the Refinitiv ESG Database. Data on legal institution quality and other country-level financial and macroeconomic variables are collected from the World Bank. The anti-self-dealing index is from Djankov, La Porta, Lopez-de-Silanes, and Shleifer (2008). Data with respect to country-level attitudes on environmental protection are collected from the World Values Survey (WVS).

3.2. Measuring price discovery efficiency

An efficient price discovery process, incorporating all available public and/or private information in a timely manner, is crucial for dynamic market efficiency (Brown et al., 2004; Easley & O'Hara, 2004; Grossman & Stiglitz, 1980; Verrecchia, 2001). We measure price discovery efficiency using two proxies, including stock price non-synchronicity, to capture the extent to which the price discovery process incorporates firm-level information into the price, and the timeliness of price discovery, to capture to what extent forward-looking information is incorporated into the share price in a timely manner.¹⁰

Stock price non-synchronicity has been widely used as a measure of stock price informativeness in the literature (Bennett et al., 2020; Chen et al., 2007; Crawford et al., 2012; Durnev et al., 2003; Fernandes & Ferreira, 2008, 2009; Gul et al., 2010, 2011; Kacperczyk et al., 2021; Morck et al., 2000; Roll, 1988).¹¹ Price non-synchronicity measures the amount of firm-specific information incorporated into stock prices, based on the R^2 obtained from asset pricing regressions. Higher levels of price non-synchronicity signal more information-laden stock prices and more efficient stock markets (Durnev et al., 2003).

We construct the stock price non-synchronicity measure based on the

⁴ In addition, making ESG disclosure mandatory may not change firms' disclosure behaviour. Instead, they may continue at the same level of ESG disclosure if their prior voluntary disclosure satisfies the mandatory regulatory requirements. Fiechter et al. (2022) examine the EU Corporate Social Responsibility Directive (NFRD 2014/95/EU) that has required qualifying firms to disclose non-financial information since fiscal year 2017. They report that firms increase their CSR activities and did so even before the mandate took effect.

⁵ Some constituent countries are excluded from our sample due to the lack of data. For example, Kuwait, Qatar, Saudi Arabia and United Arab Emirates are not covered by the anti-self-dealing index of Djankov et al. (2008).

⁶ For example, Fama and French (1992) indicate that the high leverage that is normal for financial firms probably does not have the same meaning as for non-financial firms, where high leverage more likely indicates distress.

⁷ Fauver et al. (2017) restrict their sample period to five years before and after corporate governance reform to mitigate the impact of confounding events. We selected this sample period (two years before the ESG mandatory disclosure policy effective year and three years after the policy effective year) in order to ensure that mandatory ESG disclosure was the only major institutional reform during this period for a given country.

⁸ The EDGAR database can be accessed through the website https://edgar.jrc.ec.europa.eu/report_2022.

⁹ Krueger et al. (2021) analyse ESG disclosure policies around the world and create a list of effective years of ESG disclosure mandates. For example, the UK released amendments to the Companies Act 2006 in 2013. According to this regulation, all public companies are required to produce reports on matters such as strategy and business model, levels of greenhouse gas emissions, human rights and diversity in the company.

¹⁰ We do not use private information risk measurement or PIN here as it only reflects the information asymmetries among differently informed investors, while our focus is on the efficiency of the price discovery process, namely, to what extent and in how timely a manner the share price incorporates all available public and/or private firm-level information.

¹¹ For example, stock price non-synchronicity is related to firm productivity (Bennett et al., 2020), sensitivity of corporate investment to the stock price (Chen et al., 2007), analyst initiations of coverage (Crawford et al., 2012), ownership concentration (Gul et al., 2010) and property rights (Morck et al., 2000).

Table 1
Number of firm-year observations by country and effective years of mandatory ESG disclosure policies.

Country	Number of observations		Mandatory ESG disclosure policy year	Comply-or-explain regulation?	All-at-once disclosure?
	PSI sample	TIMELINESS sample			
	(1)	(2)	(3)	(4)	(5)
Argentina	31	31	2008	No	Yes
Australia	555	647	2003	No	No
Austria	151	152	2016	No	No
Belgium	837	843	–	–	–
Brazil	1010	1007	–	–	–
Canada	761	829	2004	No	Yes
Chile	100	104	2015	Yes	No
China	3005	3029	2008	No	Yes
Colombia	65	65	–	–	–
Czech	54	50	–	–	–
Denmark	776	737	–	–	–
Egypt	274	250	–	–	–
Finland	1351	1400	–	–	–
France	660	547	2001	No	Yes
Germany	1372	1412	2016	Yes	Yes
Greece	167	163	2006	No	Yes
Hungary	27	27	2016	Yes	Yes
India	2432	2425	2015	No	No
Indonesia	486	478	2012	No	No
Ireland	78	80	2016	Yes	Yes
Israel	270	253	–	–	–
Italy	581	588	2016	Yes	Yes
Japan	18,165	18,353	–	–	–
Jordan	45	46	–	–	–
Korea	4311	4037	–	–	–
Malaysia	881	917	2007	Yes	No
Mexico	768	801	–	–	–
Netherlands	287	285	2016	Yes	No
New Zealand	576	595	–	–	–
Norway	375	395	2013	No	No
Pakistan	56	56	2009	No	Yes
Peru	22	23	2016	No	Yes
Philippines	391	358	2011	No	Yes
Poland	413	452	2016	No	Yes
Portugal	107	109	2010	No	No
Russia	306	296	–	–	–
Singapore	349	358	2016	Yes	No
South Africa	407	416	2010	Yes	Yes
Spain	317	324	2012	Yes	No
Sweden	2394	2424	–	–	–
Switzerland	1686	1700	–	–	–
Thailand	2040	2056	–	–	–
Turkey	277	277	2014	No	No
United Kingdom	2300	2594	2013	No	No
United States	27,299	27,700	–	–	–
Total	78,815	79,689			

Columns 1 and 2 show the number of firm-year observations by country based on the regression models as shown in Eq. (5). The effective years of mandatory ESG disclosure policies by country are given in column 3. Columns 4 and 5 indicate the reform approaches. The data on effective years of mandatory ESG disclosure reform and reform approaches are collected from Krueger et al. (2021).

proportion of return variation that cannot be explained by the returns on the market and the sector in which the firm resides. For each firm i and year y in our sample, we run the following time-series regression:

$$r_{i,y,t} = \beta_{0,i,y} + \beta_{1,i,y} r_{m,y,t} + \beta_{2,i} r_{n,y,t} + \varepsilon_{i,y,t}, \tag{1}$$

where $r_{i,y,t}$ denotes the daily return time-series of firm i in year y , and $r_{m,y,t}$ and $r_{n,y,t}$ are the day t value-weighted return indices of the country and sector in which firm i operates. In the empirical analysis, the market index is constructed using the value-weighted average return of all the constituent firms within a market. Similarly, we construct sector indices as the value-weighted average return of all firms in a sector, specified by the two-digit SIC code.

This bi-index model leads to a natural decomposition of the stock

return variation, into a systematic part that is synchronous to other firms, and a firm-specific part that is informative about the firm itself. We use the log-transformed $R_{i,y}^2$, adjusted for degrees of freedom, to capture the informativeness of the stock for the firm:

$$PSI_{i,y} = \ln \left(\frac{1 - R_{i,y}^2}{R_{i,y}^2} \right) \tag{2}$$

$$R_{i,y}^2 = 1 - \frac{T_{i,y} - 1}{T_{i,y} - k_{i,y} - 1} \frac{s^2(\varepsilon_{i,y})}{s^2(r_{i,y})} \tag{3}$$

where $T_{i,y}$ and $k_{i,y}$ are the number of daily return observations and number of explanatory variables in the index model respectively and $s(x_{i,y})$ denotes the sample standard deviation of x for firm i in year y . A

firm has a large *PSI* when its stock price moves less synchronously with the market and sector index, and therefore contains a larger idiosyncratic component and more firm-specific information.

To measure the timeliness of price discovery, we adopt [Beekes and Brown \(2006\)](#)'s methodology to examine the process whereby value-relevant, private information becomes impounded into a stock's market price over a fiscal year. The timeliness of price discovery refers to how quickly that process takes effect. The [Beekes and Brown \(2006\)](#) metric is adapted in subsequent studies to accommodate international comparisons ([Beekes et al., 2016, 2015](#); [Haß et al., 2014](#); [Zhang et al., 2019](#)).¹² The genesis of the timeliness measure lies in the seminal work of [Ball and Brown \(1968\)](#) and [Alford et al. \(1993\)](#). The measure assesses how accurately a firm's daily share price (P_t), observed throughout the year, approximates its terminal value (P_0). [Ball and Brown \(1968\)](#) suggest that the annual financial report is not a highly timely venue for the provision of value-relevant information, since most of the information has been reported on traditional and social media before the earnings announcement day. This justifies the calculation of the differences between the "final" price (P_0) 14 days after the earnings announcement day and the market-adjusted price from 365 days to 1 day before the earnings announcement day for year t (P_t).

For each fiscal year, the timeliness measure traces the share price over 365 calendar days ending 14 days after the firm's annual earnings announcement day, which is an important event and common to all firms in all countries. The measure captures the speed with which forward-looking information contained in the forthcoming annual earnings report is reflected in the stock price up to the day of the annual earnings announcement. Specifically, the timeliness of price discovery (*TIMELINESS*) is calculated as:

$$TIMELINESS = \left(\left(\sum_{t=-365}^{t=-1} |\ln(P_0) - \ln(P_t)| \right) - 0.5 \right) / 365 \quad (4)$$

where P_t is the daily market-adjusted stock price of a firm from 365 calendar days before the annual earnings announcement day until 1 day before the annual earnings announcement day. P_0 is the price 14 days after the annual earnings announcement day, which reflects the intrinsic value of the year. In order to reduce the impact of volatility, we deflate the measure by one plus the absolute rate of return on the share over the time window used to calculate the timeliness metric. We forward-fill prices on days when there is no trading. We set the end date to be 14 days after the earnings release date, which allows the market to gradually absorb information within a reasonable price discovery process ([Beaver, 1968](#)). The 0.5 adjustment is included to recognize that the flow of information is reflected in returns over the day ([Beekes et al., 2016](#); [Haß et al., 2014](#)). The larger the value of *TIMELINESS*, the longer it takes a firm's share price to capture information and converge to P_0 , suggesting slower price timeliness.

3.3. Control variables

According to prior research, our regression models control for other country-level and firm-level variables to explain market efficiency (e.g., [Beekes et al., 2016](#); [Bennett et al., 2020](#); [Bolton & Kacperczyk, 2021](#); [Gul et al., 2010](#); [Kacperczyk et al., 2021](#); [Lim, Brooks, & Kim, 2008](#); [Piotroski & Roulstone, 2004](#)). We control the following country-level variables:

¹² The timeliness measure was first proposed by [Beekes and Brown \(2006\)](#). The paper estimates the price timeliness of Australian public firms and associates it with corporate governance quality. The adapted metric is used in subsequent studies which re-examine the effect of corporate governance on price timeliness ([Beekes et al., 2015, 2016](#); [Haß et al., 2014](#)). [Zhang et al. \(2019\)](#) distinguish between the timeliness of good news and that of bad news. The authors find that financial integration affects good and bad information timeliness asymmetrically.

GSHOCK is a dummy variable for global shocks that equals one if the year is 2008 or 2020, and zero otherwise.¹³ *CO2* is CO2 emissions in metric tons per capita. *CGRF* is a dummy variable that equals one if a country-year is after the year when a major corporate governance reform becomes effective in that country, and zero otherwise. We obtain the information on corporate governance reforms from the work of [Fauver et al. \(2017\)](#). *LIQ* is the sum of three World Governance Indicators (WGI; government effectiveness, regulatory quality, and the rule of law) and the anti-self-dealing index from [Djankov et al. \(2008\)](#). The WGI and anti-self-dealing indices are rescaled to be between 0 and 1. *MKTCAP* is the market capitalisation of listed domestic companies divided by GDP. *GDPG* is the annual percentage growth rate of GDP. We control the following firm-level variables: *SIZE*, the natural logarithm of total assets of a firm in U.S. dollars; *IO*, the number of shares held by institutional investors divided by the total number of shares outstanding; *PROFIT*, earnings before interest, taxes and depreciation divided by total assets; *LEV*, total debt divided by total assets; *BM*, the book value of equity divided by the market value of equity; *CASH*, cash and short-term investments divided by total assets; *CAPEX*, capital expenditure divided by total assets; *TURN*, the share trading volume divided by adjusted shares outstanding; *NUMEST*, the natural logarithm of the number of analysts following a firm in a year; *VOLTY*, the standard deviation of daily stock returns over the 365 calendar days prior to the fiscal year end date. Detailed definitions of all variables and data resources are provided in [Table A1](#) in Appendix A.

[Table 2](#) provides descriptive statistics for the variables used in the main tests. All time-varying variables are winsorized at the top and bottom 1% to control for outliers. We only report the statistics of the variables used in our baseline models and the statistics of the explanatory variables are based on the price non-synchronicity (*PSI*) model. Price non-synchronicity (*PSI*) ranges from -1.751 to 5.988 , with a mean and median of 1.466 and 1.263 , and a standard deviation of 1.457 . Price timeliness (*TIMELINESS*) ranges from 0.029 to 0.409 , with a mean and median of 0.136 and 0.117 , and a standard deviation of 0.079 . The main explanatory variable of interest, *ESGPOST*, is an indicator variable that is equal to one for all years after the mandatory ESG disclosure policy becomes effective in a country, and zero otherwise. *ESGPOST* has 9568 observations with a value of one, about 12.14% of all observations (78,815), in the *PSI* model. *ESGPOST* has 9895 observations with a value of one, about 12.42% of all observations (79,689), in the *TIMELINESS* model. [Table 3](#) provides the Pearson correlation coefficients of the main variables. The correlation between *PSI* and *ESGPOST* is significant and positive, suggesting that stock prices become more informative after the implementation of mandatory ESG disclosure reform. The correlation between *TIMELINESS* and *ESGPOST* is significant and negative, suggesting that price timeliness improves after the implementation of ESG disclosure reform.¹⁴ In the following sections, we test our hypotheses using multivariate regressions, controlling for other variables that could affect market efficiency.

4. Regression results

We begin our regression analysis by estimating the baseline model that examines the effects of mandatory ESG disclosure on *PSI* and *TIMELINESS* respectively. Robustness of the main results is then checked using alternative mandate effective windows, restricted sample analysis, exclusion of treatment countries with simultaneous reforms, exclusion of observations from Japan and the United States (representing >55% of the entire sample), policy timing analysis, exclusion of ESG-sensitive

¹³ We consider the subprime mortgage crisis of 2008 and the COVID-19 pandemic of 2020 as global shocks. We also use the years 2007–2008, 2008–2009, and 2007–2009 as the subprime mortgage crisis period, and the results remain stable and robust.

¹⁴ Note that greater values of *TIMELINESS* suggest slower price timeliness.

Table 2
Summary statistics.

Variables	Mean	Median	SD	Min	Max	p10	p25	p75	p90
<i>PSI</i>	1.466	1.263	1.457	-1.751	5.988	-0.151	0.466	2.257	3.431
<i>TIMELINESS</i>	0.136	0.117	0.079	0.029	0.409	0.052	0.076	0.175	0.245
<i>ESGPOST</i>	0.121	0.000	0.327	0.000	1.000	0.000	0.000	0.000	1.000
<i>GSHOCK</i>	0.134	0.000	0.340	0.000	1.000	0.000	0.000	0.000	1.000
<i>CO2</i>	11.347	9.978	5.301	1.629	21.293	4.199	7.558	15.811	18.985
<i>CGRF</i>	0.872	1.000	0.334	0.000	1.000	0.000	1.000	1.000	1.000
<i>LIQ</i>	2.544	2.712	0.590	0.292	3.841	1.476	2.400	2.921	3.011
<i>MKTCAP</i>	1.041	1.030	0.435	0.231	2.293	0.475	0.681	1.374	1.581
<i>GDPG (%)</i>	2.182	2.161	2.893	-5.693	10.636	-1.224	1.086	3.076	5.585
<i>SIZE</i>	13.786	13.733	1.804	9.726	18.253	11.492	12.518	14.980	16.198
<i>IO</i>	0.408	0.297	0.327	0.003	1.122	0.051	0.132	0.696	0.926
<i>PROFIT</i>	0.094	0.108	0.149	-0.681	0.406	-0.007	0.064	0.160	0.223
<i>LEV</i>	0.218	0.201	0.177	0.000	0.697	0.000	0.055	0.339	0.466
<i>BM</i>	0.677	0.510	0.578	0.038	3.198	0.157	0.283	0.882	1.396
<i>CASH</i>	0.182	0.122	0.185	0.002	0.903	0.022	0.054	0.240	0.429
<i>CAPEX</i>	0.048	0.034	0.047	0.001	0.255	0.007	0.016	0.063	0.106
<i>TURN</i>	1.525	0.960	1.699	0.010	9.407	0.156	0.405	2.001	3.565
<i>NUMEST</i>	3.972	4.043	1.061	1.386	5.948	2.485	3.178	4.804	5.342
<i>VOLTY</i>	0.022	0.019	0.010	0.008	0.063	0.012	0.015	0.026	0.035

The summary statistics of the variables are based on the *PSI* sample, except in the case of *TIMELINESS*. *PSI* is the price non-synchronicity, which is estimated using Eqs. (2) and (3). *TIMELINESS* is the price timeliness, which is calculated using Eq. (4). *ESGPOST* is an indicator variable that is equal to one for all years after the mandatory ESG disclosure policy becomes effective in a country, and zero otherwise. *CO2* is CO2 emissions in metric tons per capita. *CGRF* is an indicator variable equal to one for all years after a major corporate governance reform became effective in the country, and zero otherwise. *LIQ* is the legal institution quality of a country, which is measured based on rule of law, regulatory quality, government effectiveness, and protection against self-dealing. *MKTCAP* is the annual market capitalisation of listed domestic companies divided by GDP. *GDPG* is GDP growth (annual %). *SIZE* is the natural logarithm of the total assets of a firm in U.S. dollars. *IO* is the number of shares held by all types of institutions divided by the total number of shares outstanding. *PROFIT* is earnings before interest, taxes and depreciation divided by total assets. *LEV* is total debt divided by total assets. *BM* is the book value of equity divided by market capitalisation. *CASH* is cash and short-term investments divided by total assets. *CAPEX* is capital expenditure divided by total assets. *TURN* is the annual share trading volume divided by adjusted shares outstanding. *NUMEST* is the natural logarithm of the number of analysts following a firm in a fiscal year. *VOLTY* is the standard deviation of daily stock returns over the 365 days prior to the fiscal year end date. All continuous variables are winsorized at the top and bottom 1%. Table A1 provides details on data and variables.

industries, placebo tests using pseudo effective years of mandates, and OLS estimation controlling for industry, country and year effects. In order to further strengthen our causal inferences regarding mandatory ESG disclosure policy, we conduct two additional sets of tests. First, we investigate the heterogeneous treatment effects based on important country and firm characteristics which affect the demand for ESG disclosure. Second, we confirm the real stock market changes due to ESG disclosure, by looking at cross-sectional patterns of future stock returns, institutional ownership change and firm valuation.

4.1. The effects of mandatory ESG disclosure on price informativeness and timeliness

We first estimate the baseline regression models shown in Eq. (5). The dependent variables are price non-synchronicity (*PSI*) and timeliness of price discovery (*TIMELINESS*) respectively. The main independent variable of interest is the implementation of a policy of mandatory ESG disclosure (*ESGPOST*). Among the 45 sample countries, 27 countries launched ESG disclosure reforms in different years during the sample period and 18 countries did not make such a change. This allows us to adopt a DID design with multiple treatment groups and multiple time periods (Imbens & Wooldridge, 2009). Our DID approach compares changes in market efficiency after the ESG disclosure reforms with changes in market efficiency for countries without disclosure reforms during the sample years. The approach is commonly used in the literature to mitigate endogeneity issues and thereby strengthen the causal inferences of the empirical investigation (Bertrand & Mullainathan, 2003; Fauver et al., 2017; Gao & Zhang, 2017). The baseline model specification is as follows:

$$PSI_{i,t} \text{ or } TIMELINESS_{i,t} = \alpha + \beta_1(ESGPOST) + \sum \beta_m CONTROLS + FIRM FE + YEAR FE + \varepsilon_{i,t} \tag{5}$$

where *i* and *t* stand for firm and year respectively. *ESGPOST* is an indicator variable equal to one starting in the first year after the mandatory ESG disclosure policy became effective in the country, and for all subsequent years, and zero otherwise. *CONTROLS* includes firm- and country-level control variables. *FE* stands for firm and year fixed effects. Based on hypothesis 1, we expect ESG disclosure to be associated with more firm-specific information being incorporated into stock prices in a more timely manner, and thus we expect β_1 to be positive in the *PSI* baseline model and negative in the *TIMELINESS* baseline model. In all regression estimations, we use robust standard errors clustered at the country level, because the ESG disclosure policy is a country-level decision.¹⁵

Columns 1 and 4 of Table 4 present the results of the baseline models. The coefficient on *ESGPOST* is significantly positive in the *PSI* model ($\beta_1=0.118, p < 0.01$) and significantly negative in the *TIMELINESS* model ($\beta_1 = -0.009, p < 0.01$). The results suggest that the share price incorporates more firm-specific information in a more timely manner following the ESG disclosure reforms. Our hypotheses H1a and H1b are therefore supported. The effects are also economically significant. Column 1 shows that price informativeness increases by 8.05% relative to the mean following the reforms.¹⁶ Column 4 shows that price timeliness increases by 6.62% relative to the mean following the reforms.¹⁷ Columns 2 and 5 estimate the baseline models after inclusion of an

¹⁵ We also estimate all regression models with robust standard errors clustered at the firm level as a robustness check. The results are unchanged.

¹⁶ The magnitude of the impact of *ESGPOST* on *PSI* is calculated as 0.118 (coefficient on *ESGPOST* in column 1 of Table 4) ÷ 1.466 (the sample mean of *PSI* in Table 2) = 8.05%.

¹⁷ The magnitude of the impact of *ESGPOST* on *TIMELINESS* is calculated as 0.009 (absolute value of coefficient on *ESGPOST* in column 4 of Table 4) ÷ 0.136 (the sample mean of *TIMELINESS* in Table 2) = 6.62%.

Table 3
Correlation matrix.

	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]	[14]	[15]	[16]	[17]	[18]	[19]
<i>PSI</i>	0.19*	0.03*	-0.12*	0.06*	-0.15*	0.13*	0.09*	0.04*	-0.54*	-0.13*	-0.21*	-0.08*	0.08*	0.13*	-0.06*	-0.16*	-0.37*	0.14*
<i>TIMELINESS</i>		-0.03*	0.15*	0.07*	-0.04*	-0.01	0.05*	0.01	-0.27*	-0.01*	-0.28*	0.03*	0.07*	0.18*	0.02*	0.22*	-0.14*	0.54*
<i>ESGPOST</i>			-0.12*	-0.30*	0.07*	-0.26*	-0.18*	0.38*	-0.06*	-0.18*	0.06*	0.01	-0.07*	-0.05*	0.08*	-0.06*	-0.02*	-0.08*
<i>GSHOCK</i>				0.01*	-0.15*	0.01	0.05*	-0.40*	-0.02*	0.01	-0.07*	0.03*	0.09*	0.03*	-0.02*	0.05*	-0.05*	0.36*
<i>CO2</i>					-0.16*	0.62*	0.44*	-0.17*	0.05*	0.60*	-0.12*	-0.04*	-0.11*	0.10*	-0.02*	0.31*	0.15*	0.19*
<i>CGRF</i>						-0.07*	0.09*	0.01	0.04*	0.08*	-0.02*	-0.03*	-0.06*	0.06*	-0.04*	0.13*	0.02*	-0.10*
<i>LIQ</i>							0.52*	-0.36*	-0.01	0.46*	-0.11*	-0.08*	-0.07*	0.07*	-0.10*	0.06*	0.11*	0.04*
<i>MKTCAP</i>								-0.16*	0.03*	0.50*	-0.11*	-0.04*	-0.22*	0.12*	-0.08*	0.19*	0.14*	0.08*
<i>GDPG</i>									-0.09*	-0.15*	0.11*	0.01*	-0.15*	-0.06*	0.16*	0.06*	-0.02*	-0.15*
<i>IO</i>									0.24*	0.24*	0.23*	0.31*	0.04*	-0.35*	0.03*	0.33*	0.63*	0.34*
<i>PROFIT</i>											-0.01	0.03*	-0.24*	0.02*	-0.07*	0.33*	0.40*	0.03*
<i>LEV</i>													-0.14*	-0.37*	-0.21*	-0.11*	0.16*	0.45*
<i>BM</i>													0.06*	-0.40*	0.11*	0.04*	0.08*	-0.01*
<i>CASH</i>														-0.19*	-0.05*	-0.14*	-0.27*	0.30*
<i>CAPEX</i>															-0.21*	0.16*	-0.08*	0.30*
<i>TURN</i>																0.04*	0.07*	-0.03*
<i>NUMEST</i>																	0.16*	0.37*
<i>VOLTY</i>																		0.16*

This table reports the Pearson correlations among the variables. All continuous variables are winsorized at the top and bottom 1%. * indicates that the correlation is significant at least at the 5% level (two-tailed test).

interaction term between *ESGPOST* and a comply-or-explain approach (*COE*). Columns 3 and 6 estimate the baseline models after inclusion of an interaction term between *ESGPOST* and an all-at-once approach (*ATO*). Mandatory ESG disclosure provides flexibility under the *COE* approach for firms in disclosing ESG information allowing them to explain why they did not comply, and this is expected to provide incentives for some firms to withhold information. However, market participants could potentially infer this withheld information by making a comparison with the ESG data from those firms which do comply or disclose (Admati & Pfleiderer, 2000; Baginski & Hinson, 2016; Shroff et al., 2017). If so, this potential spill-over effect of mandatory ESG disclosure should be evidenced by a partially compromised price discovery efficiency, with unaffected price informativeness measured by *PSI* but a reduced timeliness of price discovery (*TIMELINESS*). This slower speed with which the share price incorporates withheld information is due to the effort and time that needs to be spent by market participants to infer the withheld information, in deriving it from the data supplied by complying or disclosing firms. As predicted, column 2 shows that the coefficient on *ESGPOST*×*COE* is insignificant, suggesting that changes in *PSI* are similar across the comply-or-explain disclosure approach and rule-based disclosure mandates. Column 5 shows that the coefficient on *ESGPOST*×*COE* is significantly positive, suggesting that the effect of ESG disclosure mandates on *TIMELINESS* is less pronounced for countries that adopt a comply-or-explain disclosure approach.

Column 3 shows that the coefficient on *ESGPOST* is positive but insignificant, while that on *ESGPOST*×*ATO* is significantly positive. These findings suggest that *PSI* is not necessarily improved, compared to *PSI* without ESG disclosure mandates, after the implementation of more flexible ESG disclosure mandates that allow gradual disclosure, but only after the implementation of strict, all-at-once ESG disclosure mandates.¹⁸ Column 6 shows that the coefficients on both *ESGPOST* and *ESGPOST*×*ATO* are significantly negative, suggesting that ESG disclosure mandates are effective when it comes to *TIMELINESS*, regardless of whether they are all-at-once mandates or not. However, the effect is more pronounced for those countries that introduce the mandatory ESG disclosure all at once. These results reinforce our hypotheses H1a and H1b, suggesting that stricter ESG disclosure mandates help the market to incorporate more value-relevant information in a more timely manner into the share price.

With respect to the control variables, stock price informativeness and timeliness are significantly related to global shocks (*GSHOCK*), legal institution quality (*LIQ*), GDP growth (*GDPG*), firm size (*SIZE*), profitability (*PROFIT*), financial leverage (*LEV*), the book-to-market ratio (*BM*), cash holding (*CASH*) and capital expenditure (*CAPEX*). The findings are consistent with previously documented evidence (e.g., Beekes et al., 2016; Bennett et al., 2020; Lim et al., 2008) and indicate that economic conditions and firm fundamentals can affect price discovery efficiency.

4.2. Robustness checks

Table 5 presents robustness checks of the findings from the baseline regression models. Panel A of Table 5 shows the results using a [-1, +1] sample, which restricts the period of the treatment group to one year before the policy effective year, the effective year itself and one year after the policy effective year. The narrower event window further reduces the potential impact of other reforms implemented in the sample countries around the same time. Moreover, we create a restricted [-3, +3] sample that requires a treatment firm to appear in at least one year of the pre-reform period and one year of the post-reform period. The results of using these two alternative samples are similar to those reported in columns 1 and 4 of Table 4.

¹⁸ The all-at-once disclosure approach refers to environmental, social and governance disclosure all being introduced at once.

Table 4
The effects of mandatory ESG disclosure on price informativeness and timeliness: Baseline results.

Dependent variable	PSI			TIMELINESS		
	(1)	(2)	(3)	(4)	(5)	(6)
<i>ESGPOST</i>	0.118*** (2.62)	0.096** (2.02)	0.023 (0.29)	-0.009*** (-3.10)	-0.011*** (-3.11)	-0.006*** (-2.85)
<i>ESGPOST</i> × <i>COE</i>		0.072 (0.63)			0.007** (2.05)	
<i>ESGPOST</i> × <i>ATO</i>			0.209* (1.74)			-0.008* (-1.92)
Country-level controls						
<i>GSHOCK</i>	-1.863*** (-6.10)	-1.864*** (-6.11)	-1.867*** (-6.14)	-0.019* (-1.91)	-0.019* (-1.91)	-0.019* (-1.91)
<i>CO2</i>	0.053 (1.36)	0.053 (1.35)	0.049 (1.26)	0.001 (1.33)	0.001 (1.27)	0.001* (1.85)
<i>CGRF</i>	-0.329* (-1.65)	-0.328* (-1.65)	-0.338* (-1.69)	0.003 (1.22)	0.003 (1.30)	0.003 (1.42)
<i>LIQ</i>	-1.242*** (-3.20)	-1.232*** (-3.10)	-1.209*** (-2.99)	-0.016*** (-3.91)	-0.015*** (-3.47)	-0.018*** (-4.30)
<i>MKTCAP</i>	0.490** (2.45)	0.487** (2.46)	0.479** (2.37)	-0.001 (-0.01)	-0.001 (-0.04)	-0.001 (-0.03)
<i>GDPG</i>	-0.052*** (-3.54)	-0.052*** (-3.53)	-0.052*** (-3.52)	0.001** (2.43)	0.001** (2.40)	0.001** (2.43)
Firm-level controls						
<i>SIZE</i>	-0.344*** (-20.65)	-0.343*** (-21.07)	-0.346*** (-21.32)	-0.005*** (-7.50)	-0.005*** (-7.98)	-0.005*** (-7.98)
<i>IO</i>	-0.395 (-1.29)	-0.398 (-1.30)	-0.392 (-1.29)	0.015*** (7.60)	0.014*** (7.22)	0.015*** (7.48)
<i>PROFIT</i>	-0.280** (-2.18)	-0.281** (-2.18)	-0.278** (-2.15)	-0.020*** (9.39)	-0.021*** (-9.46)	-0.021*** (-9.69)
<i>LEV</i>	0.742*** (10.15)	0.741*** (10.16)	0.739*** (10.07)	0.032*** (11.53)	0.032*** (11.49)	0.032 (11.40)
<i>BM</i>	0.335*** (4.47)	0.335*** (4.47)	0.335*** (4.49)	0.009*** (3.36)	0.009*** (3.36)	0.009*** (3.35)
<i>CASH</i>	-0.378*** (-5.66)	-0.378*** (-5.64)	-0.379*** (-5.68)	-0.011*** (-3.66)	-0.011*** (-3.66)	-0.011*** (-3.67)
<i>CAPEX</i>	-0.641*** (-3.76)	-0.644*** (-3.73)	-0.656*** (-3.83)	0.016*** (2.70)	0.016** (2.63)	0.017*** (2.81)
<i>TURN</i>	-0.041* (-1.94)	-0.041* (-1.94)	-0.042* (-1.97)	-0.001 (-0.51)	-0.001 (-0.50)	-0.001 (-0.47)
<i>NUMEST</i>	-0.062* (-1.69)	-0.061* (-1.69)	-0.064* (-1.71)	-0.001 (-1.13)	-0.001 (-1.09)	-0.001 (-1.10)
<i>VOLTY</i>	-0.554 (-0.11)	-0.560 (-0.11)	-0.480 (-0.10)	3.230*** (46.09)	3.229*** (47.38)	3.225*** (47.59)
Number of observations	78,815	78,815	78,815	79,689	79,689	79,689
Adjusted R-squared	0.333	0.333	0.333	0.170	0.170	0.170
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes

This table presents the regression results for the impact of mandatory ESG disclosure on price informativeness and timeliness. The dependent variables are price non-synchronicity (*PSI*) in columns 1–3, and price timeliness (*TIMELINESS*) in columns 4–6. *ESGPOST* is an indicator variable that is equal to one for all years after the mandatory ESG disclosure policy becomes effective in a country, and zero otherwise. *COE* is an indicator variable that is equal to one for all years after the mandatory ESG disclosure policy becomes effective in a country if the comply-or-explain ESG disclosure approach is adopted, and zero otherwise. *ATO* is an indicator variable that is equal to one for all years after the mandatory ESG disclosure policy becomes effective in a country if mandatory environmental, social and governance disclosure are introduced all at once, or zero if the country implements mandatory disclosure gradually. *GSHOCK* is a dummy variable that is equal to one for the years 2001, 2008 and 2020, and zero otherwise. *CO2* is the natural logarithm of CO2 emissions in metric tons per capita. *CGRF* is an indicator variable equal to one for all years after a major corporate governance reform became effective in the country, and zero otherwise. *LIQ* is the legal institution quality of a country, which is measured based on rule of law, regulatory quality, government effectiveness, and protection against self-dealing. *MKTCAP* is the annual market capitalisation of listed domestic companies divided by GDP. *GDPG* is GDP growth (annual %). *SIZE* is the natural logarithm of the market capitalisation of a firm in U.S. dollars. *IO* is the number of shares held by all types of institutions divided by the total number of shares outstanding. *PROFIT* is earnings before interest, taxes and depreciation divided by total sales. *LEV* is total debt divided by total assets. *BM* is the book value of equity divided by market capitalisation. *CASH* is cash and short-term investments divided by total assets. *CAPEX* is capital expenditure divided by total assets. *TURN* is the share trading volume divided by adjusted shares outstanding. *NUMEST* is the natural logarithm of the number of analysts following a firm in a fiscal year. *VOLTY* is the standard deviation of daily stock returns over the 365 days prior to the fiscal year end date. All continuous variables are winsorized at the top and bottom 1%. Standard errors are clustered at the country level. The t-statistics are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively (two-tailed tests).

Columns 1 and 2 of Panel B of Table 5 present the results of excluding treatment countries with simultaneous reforms. Australia, Canada and France launched major corporate governance reforms in 2004, 2004 and

2003 respectively. The governance reforms took place within the event windows of the ESG disclosure mandates in those countries. To rule out the impact of confounding events, we exclude firms from those three

Table 5
The effects of mandatory ESG disclosure on price informativeness and timeliness: Robustness checks.

Panel A: Alternative event window and restricted sample				
Dependent variable	[-1, +1] sample		Restricted sample	
	<i>PSI</i>	<i>TIMELINESS</i>	<i>PSI</i>	<i>TIMELINESS</i>
	(1)	(2)	(3)	(4)
<i>ESGPOST</i>	0.138** (2.40)	-0.008*** (-2.64)	0.117** (2.36)	-0.009*** (-3.13)
Number of observations	70,215	70,756	75,676	76,425
Adjusted R-squared	0.354	0.174	0.336	0.173
Control variables	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Panel B: Alternative samples				
Dependent variable	Excluding treatment countries with simultaneous reforms		Excluding Japanese & U.S. firms	
	<i>PSI</i>	<i>TIMELINESS</i>	<i>PSI</i>	<i>TIMELINESS</i>
	(1)	(2)	(3)	(4)
<i>ESGPOST</i>	0.123** (2.30)	-0.009*** (-2.94)	0.131** (2.28)	-0.007*** (-3.39)
Number of observations	76,839	77,666	33,351	33,636
Adjusted R-squared	0.339	0.170	0.262	0.135
Control variables	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Panel C: Policy timing analysis and ESG-sensitive industries				
Dependent variable	Pre- and post-ESG disclosure		Excluding ESG-sensitive industries	
	<i>PSI</i>	<i>TIMELINESS</i>	<i>PSI</i>	<i>TIMELINESS</i>
	(1)	(2)	(3)	(4)
<i>ESGPOST</i>			0.127*** (3.02)	-0.009*** (-3.74)
<i>Pre-ESG disclosure years</i>	0.111 (1.23)	0.006 (1.52)		
<i>First effective year</i>	0.163** (2.22)	-0.007** (-2.46)		
<i>Year 2+</i>	0.191** (2.05)	-0.004 (-1.07)		
Number of observations	78,815	79,689	69,340	70,204
Adjusted R-squared	0.333	0.170	0.336	0.165
Control variables	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Panel D: Placebo tests				
Dependent variable	3 years pre-reform		3 years post-reform	
	<i>PSI</i>	<i>TIMELINESS</i>	<i>PSI</i>	<i>TIMELINESS</i>
	(1)	(2)	(3)	(4)
<i>ESGPOST</i>	-0.002 (-0.02)	0.002 (0.85)	-0.085 (-0.91)	-0.002 (-0.82)
Number of observations	74,675	75,304	80,949	82,062
Adjusted R-squared	0.342	0.169	0.335	0.165
Control variables	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Panel E: Pooled OLS estimation with industry, country and year effects				
Dependent variable	<i>PSI</i>		<i>TIMELINESS</i>	
	(1)	(2)	(3)	(4)
<i>ESGPOST</i>	0.112***		-0.008***	

(continued on next page)

Table 5 (continued)

Panel A: Alternative event window and restricted sample				
Dependent variable	[-1, +1] sample		Restricted sample	
	<i>PSI</i>	<i>TIMELINESS</i>	<i>PSI</i>	<i>TIMELINESS</i>
	(1)	(2)	(3)	(4)
	(3.20)		(-3.26)	
Number of observations	78,815		79,689	
Adjusted R-squared	0.539		0.344	
Control variables	Yes		Yes	
Industry fixed effects	Yes		Yes	
Country fixed effects	Yes		Yes	
Year fixed effects	Yes		Yes	

Panel A reports the robustness checks using two alternative samples: a [-1, +1] sample and a restrictive [-3, +3] sample that requires a firm to appear at least one year before the first effective year and one year after the effective year. Panel B presents the results excluding treatment countries with simultaneous reforms and excluding U.S. firms. Panel C presents results of a policy timing analysis and excluding ESG-sensitive industries. Panel D reports results of placebo tests using pseudo effective years. Panel E presents results using pooled OLS estimation with industry, country and year effects. All the control variables used in Table 4 are included. All continuous variables are winsorized at the top and bottom 1%. The results for the control variables and fixed effects are not reported for brevity. Standard errors are clustered at the country level. The t-statistics are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively (two-tailed tests).

countries as a robust check. Columns 3 and 4 of Panel B present the results of excluding Japanese and U.S. firms. It is likely that our results are driven by the Japanese and U.S. firms, which make up over 55% of our sample. We therefore re-estimate the baseline models without them. The results in Panel B show that the effects of *ESGPOST* remain unchanged.

Panel C of Table 5 presents a policy timing analysis and the results of excluding ESG-sensitive industries. In columns 1 and 2 of Panel C, *ESGPOST* is replaced by three reform timing indicator variables: *Pre-ESG disclosure years*, which equals one for the two years before the policy effective year; *First effective year*, which is equal to one for the first year after the policy effective year; and *Year 2+*, which is equal to one for the second and third years after the reform becomes effective and zero otherwise. To confirm the impact of ESG disclosure reform, we would expect to see insignificant effects of *Pre-ESG disclosure years* and significant effects of the post-reform indicator variables. For both the *PSI* and *TIMELINESS* models, the results show insignificant coefficients on the *Pre-ESG disclosure years* indicator variable and significant coefficients on the *First effective year* indicator variable. The coefficient on *Year 2+* indicator variable is significantly positive in the *PSI* model. These results suggest that the improvement in price efficiency materializes after the ESG disclosure reform becomes effective.

Bolton and Kacperczyk (2021) indicate that only a few salient industries produce a large fraction of carbon emissions. There might be designated regulations or by-laws in place for these salient industries before the ESG disclosure policy is implemented. It is therefore likely that the existence of salient industries in our samples prevents us from analysing marginal effects of the new policy on an average firm. Columns 3 and 4 of Panel C of Table 5 present the analysis excluding salient industries, which we define as mining ($SIC \geq 1000$ and $SIC \leq 1499$), oil & gas ($SIC \geq 1311$ and $SIC \leq 1389$), and chemicals ($SIC \geq 2800$ and

SIC \leq 2890).¹⁹ Regarding the effects of the ESG disclosure reform on informativeness and timeliness, our previous conclusions are unchanged.

Panel D of Table 5 presents the results of placebo tests, which verify the parallel trend assumption underlying our DID estimation. Specifically, we aim to show that, in the absence of the ESG disclosure reforms, the average changes in price informativeness and timeliness would have been the same in the treatment group as in the benchmark group. In the first placebo test, we set the pseudo effective year as three years before the actual effective year of the reform. In the second placebo test, we set the pseudo effective year as three years after the actual effective year of the reform. Panel C shows that the coefficients on *ESGPOST* are insignificant in all models, suggesting that, in the absence of treatment, our treatment and benchmark samples exhibit similar trends in price efficiency.

Panel E of Table 5 presents the results of pooled OLS estimation in which we control for industry, country and year effects. Our baseline model estimation with firm fixed effects does not allow for the inclusion of industry or country fixed effects due to multicollinearity. The concern is that uncontrolled industry and country fixed effects may cause biased coefficient estimation. Bolton and Kacperczyk (2021) find that including industry effects changes both the significance and magnitude of the effects of carbon emissions on stock returns. We construct industry, country and year dummy variables and include them in the baseline regression models.²⁰ As shown in columns 1 and 2 of Panel E, the results remain unchanged after we control for industry, country and year effects.

4.3. Heterogeneous treatment effects

To provide further evidence that the mandatory ESG disclosure reforms indeed cause the change in market efficiency, we create interaction terms to examine the heterogeneous treatment effects. The motivation is twofold. First, using interaction terms can help to alleviate the endogeneity concerns due to omitted explanatory variables because it is less likely for an omitted control variable to be correlated with the interaction term than with linear terms (Claessens & Laeven, 2003; Gao & Zhang, 2017; Raddatz, 2006). Second, examining heterogeneous treatment effects can tease out the effect of the mandate of interest from those of other concurrent mandates and therefore provide causal evidence (Chhaochharia & Grinstein, 2007; Fauver et al., 2017). We compare the effects of the ESG disclosure mandate on firms that are expected to be more impacted by the mandate, to the effects on firms that are expected to be less impacted by the mandate. If the ESG rules have a significant effect on price discovery efficiency, the effect should be more pronounced for more impacted firms than for less impacted firms.

We design five sets of tests to explore the heterogeneous treatment effects of the ESG disclosure policies. First, if the improved efficiency after the reforms is indeed due to increased disclosure of ESG information, the treatment effect should be stronger in countries in which priority is given to environmental protection over economic growth. Moreover, it is more likely for ESG disclosure reforms to be introduced in a country that prioritizes environmental issues. We obtain the information on attitudes on environmental protection from the WVS database. We select four waves of the WVS covering the period from 1999 to

¹⁹ ESG-sensitive industries include firms from utility, mining, oil & gas, and chemicals industries (Bolton & Kacperczyk, 2021), which produce a significantly larger fraction of carbon emissions, compared to other industries. Because we have already removed utility firms from our initial sample, we further remove ESG-sensitive industries such as mining, oil & gas, and chemicals.

²⁰ The industry dummy variables are based on the Fama-French 48 industry groups.

Table 6

Heterogeneous treatment effects based on attitudes on environmental protection and status of ESG reporting.

Panel A: Heterogeneous effects based on attitudes on environmental protection		
Dependent variable	PSI	TIMELINESS
	(1)	(2)
<i>ESGPOST</i> × <i>Environment first</i>	0.122** (2.01)	-0.010*** (-3.20)
<i>ESGPOST</i> × <i>Not environment first</i>	0.105 (1.36)	-0.004* (-1.87)
Number of observations	78,815	79,698
Adjusted R-squared	0.333	0.170
Control variables	Yes	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Panel B: Heterogeneous effects based on the status of ESG reporting		
Dependent variable	PSI	TIMELINESS
	(1)	(2)
<i>ESGPOST</i> × <i>ESG reporting firms</i>	0.102 (1.51)	-0.003 (-1.34)
<i>ESGPOST</i> × <i>Non ESG reporting firms</i>	0.124** (2.21)	-0.011*** (-3.68)
Number of observations	78,815	79,689
Adjusted R-squared	0.333	0.170
Control variables	Yes	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes
Panel C: Heterogeneous effects based on ESG performance		
Dependent variable	PSI	TIMELINESS
	(1)	(2)
<i>ESGPOST</i> × <i>High ESG score</i>	0.112 (1.61)	-0.002 (-0.85)
<i>ESGPOST</i> × <i>Low ESG score</i>	0.120** (2.17)	-0.011*** (-3.67)
Number of observations	78,815	79,689
Adjusted R-squared	0.333	0.170
Control variables	Yes	Yes
Firm fixed effects	Yes	Yes
Year fixed effects	Yes	Yes

Panel A reports the results of examining the relative effects of ESG disclosure reform on market efficiency in different countries based on the attitude on the priority of environmental protection. *Environment first* is an indicator variable that takes the value one for countries where people agree that environmental protection should be given priority over economic growth, and zero otherwise. *Not environment first* is (1 - *Environment first*). Panel B reports the results of examining the relative effects of ESG disclosure reform on market efficiency for different firms based on the status of ESG reporting. *ESG reporting firms* is an indicator variable that takes the value one if a firm has ESG reports uploaded in the Refinitiv ESG database in a year, and zero otherwise. *Non ESG reporting firms* is (1 - *ESG reporting firms*). Panel C reports the results of examining the relative effects of ESG disclosure reform on market efficiency for different firms based on ESG performance. *High ESG score* is an indicator variable that takes the value one if a firm has an ESG performance score above the sample median, and zero otherwise. *Low ESG score* is (1 - *High ESG score*). All the control variables used in Table 4 are also included. All continuous variables are winsorized at the top and bottom 1%. The results for the control variables and fixed effects are not reported for brevity. Standard errors are clustered at the country level. The t-statistics are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively (two-tailed tests).

2020. We create an indicator variable, *Environment first*, that takes the value one for countries where more of the population agree that environmental protection should be given priority over economic growth and zero otherwise. *Environment first* is estimated based on responses to the WVS question: "Which of the following comes closer to your own point of view? 1. Protecting the environment should be given priority,

even if it causes slower economic growth and some loss of jobs. 2. Economic growth and creating jobs should be the top priority, even if the environment suffers to some extent.” We recode the response to this question to one if a survey participant chose statement 1 and zero otherwise. We then calculate the mean score of the responses for each country-wave. Within a wave, the score is calculated once and applies to all country-years covered by the wave. An average score is finally calculated for each country across the waves of the WVS. Higher scores suggest that more people put environmental protection ahead of economic growth. We create an indicator variable, *Environment first*, that takes the value one if the score is above the sample median and zero otherwise. We re-estimate Eq. (5), replacing the *ESGPOST* indicator with $ESGPOST \times Environment\ first$ and $ESGPOST \times Not\ environment\ first$. The *Not environment first* indicator is defined as $(1 - Environment\ first)$. Panel A of Table 6 presents the results. The coefficients on $ESGPOST \times Environment\ first$ are significant at the 1% or 5% level, whereas the coefficients on $ESGPOST \times Not\ environment\ first$ are either insignificant or significant at the 10% level. This result indicates that the effect of ESG disclosure reform is more pronounced in countries where the value of putting the environment first prevails.

Second, the effects of ESG disclosure reform may depend on firms' status of ESG reporting. If it is the first time a firm produces and/or submits ESG-related reports due to mandatory ESG disclosure regulations, the impact of the mandatory ESG disclosure should lead to a completely new set of information being available to market participants, and thus its impacts on price discovery should be more pronounced for the firm. We create an indicator variable, *ESG reporting firms*, that takes the value one if a firm has ESG reports uploaded in the Refinitiv ESG database (formerly known as ASSET4) in a year and zero otherwise. In the regression estimation, we replace the *ESGPOST* indicator with $ESGPOST \times ESG\ reporting\ firms$ and $ESGPOST \times Non\ ESG\ reporting\ firms$. The *Non ESG reporting firms* indicator is defined as $(1 - ESG\ reporting\ firms)$. Panel B of Table 6 presents the results. The coefficients on $ESGPOST \times Non\ ESG\ reporting\ firms$ are significant at the 1% or 5% level. The coefficients on $ESGPOST \times ESG\ reporting\ firms$ are not significant. This result indicates that the effect of ESG disclosure reform is more pronounced for firms without a previous ESG information disclosure practice.

Third, it is likely that firms with good ESG performance are more forthcoming with ESG-related news, regardless of the launch of ESG disclosure mandates. Thus, the effects of ESG disclosure mandates should be more pronounced for firms with poor ESG performance. We use the ESG score from the Refinitiv ESG database to measure ESG performance. We create an indicator variable, *High ESG score*, that takes the value one if a firm has an ESG performance score above the sample median in a year, and zero otherwise. In the regression estimation, we replace the *ESGPOST* indicator with $ESGPOST \times High\ ESG\ score$ and $ESGPOST \times Low\ ESG\ score$. The *Low ESG score* indicator is defined as $(1 - High\ ESG\ score)$. Panel C of Table 6 presents the results. The coefficients on $ESGPOST \times Low\ ESG\ score$ are significant at the 1% or 5% level. The coefficients on $ESGPOST \times High\ ESG\ score$ are not significant. This result indicates that the effect of ESG disclosure reform is more pronounced for firms with low ESG performance scores.

Fourth, prior research documents that good corporate governance improves disclosure and price efficiency (Beekes et al., 2016; Beekes & Brown, 2006; Kacperczyk et al., 2021). The mandatory ESG disclosure reforms are likely to play a governance role if firms lack sound internal governance. Thus poorly governed firms are expected to be more affected by the new rules than well-governed firms. To test the conjecture, we create an indicator variable, *High corporate governance quality*, that takes the value one for firms whose average corporate governance score is above the sample median, and zero otherwise. We adopt the approach of Chung, Elder, and Kim (2010) and construct a firm-level

Table 7

Heterogeneous effects based on corporate governance and institutional quality.

Panel A: Heterogeneous effects based on corporate governance quality			
Dependent variable	PSI		TIMELINESS
	(1)	-	(2)
$ESGPOST \times High\ corporate\ governance\ quality$	0.037 (0.56)	-	-0.006* (-1.92)
$ESGPOST \times Low\ corporate\ governance\ quality$	0.174*** (2.89)	-	-0.011*** (-3.73)
Number of observations	78,815	-	79,689
Adjusted R-squared	0.333	-	0.170
Control variables	Yes	-	Yes
Firm fixed effects	Yes	-	Yes
Year fixed effects	Yes	-	Yes
Panel B: Heterogeneous effects based on legal institution quality			
Dependent variable	PSI		TIMELINESS
	(1)	-	(2)
$ESGPOST \times High\ legal\ institution\ quality$	-0.013 (-0.14)	-	-0.005* (-1.77)
$ESGPOST \times Low\ legal\ institution\ quality$	0.169*** (2.72)	-	-0.010*** (-3.12)
Number of observations	78,815	-	79,689
Adjusted R-squared	0.333	-	0.170
Control variables	Yes	-	Yes
Firm fixed effects	Yes	-	Yes
Year fixed effects	Yes	-	Yes

Panel A reports the results of examining the relative effects of ESG disclosure reform on market efficiency for different firms based on corporate governance quality. *High corporate governance quality* is an indicator variable that takes the value one for firms whose average corporate governance score is above the sample median, and zero otherwise. *Low corporate governance quality* is $(1 - High\ corporate\ governance\ quality)$. Panel B reports the results of examining the relative effects of ESG disclosure reform on market efficiency in different countries based on institutional quality. *High legal institution quality* is an indicator variable that takes the value one for countries whose legal institution quality index (*LIQ*) is above the sample median, and zero otherwise. *Low legal institution quality* is $(1 - High\ legal\ institution\ quality)$. All the control variables used in Table 4 are also included. All continuous variables are winsorized at the top and bottom 1%. The results for the control variables and fixed effects are not reported for brevity. Standard errors are clustered at the country level. The t-statistics are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively (two-tailed tests).

index of corporate governance quality (*CGQ*) with 22 underlying governance characteristics. Appendix B gives details of the governance items and criteria. If a firm meets a characteristic successfully in a given year, it will score one point and zero otherwise. We weight all characteristics equally to obtain the total *CGQ* index for a year. The average *CGQ* index is then calculated to represent the overall corporate governance quality of a firm during the sample period. In the regression estimation, we replace the *ESGPOST* indicator with $ESGPOST \times High\ corporate\ governance\ quality$ and $ESGPOST \times Low\ corporate\ governance\ quality$. The *Low corporate governance quality* indicator is defined as $(1 - High\ corporate\ governance\ quality)$. Panel A of Table 7 presents the results. The coefficients on $ESGPOST \times Low\ corporate\ governance\ quality$ are significant at the 1% level for both the *PSI* and *TIMELINESS* models. The coefficient on $ESGPOST \times High\ corporate\ governance\ quality$ is significant at the 10% level for the *TIMELINESS* model. This result shows that the effect of ESG disclosure reform is more pronounced for firms with poorer corporate governance, suggesting that external mandatory ESG reform substitutes for internal corporate governance in enhancing price efficiency.

Lastly, considering that country-level legal institutions influence investor protection, corporate governance and firm value (La Porta, Lopez-De-Silanes, Shleifer, & Vishny, 1997, 1998, 2000, 2002), the

treatment effects are likely to be different across countries with different legal institution quality. On one hand, better legal institutions may help ESG disclosure reform to take effect via stronger enforcement of rules and regulations, and therefore the treatment effect is likely to be more pronounced in countries with better institutional quality. On the other hand, mandatory ESG disclosure reform may substitute for legal institutions in affecting price efficiency because the reforms can be implemented through other channels than legal institutions. To explore the empirical question, we create an indicator variable, *High legal institution quality*, that takes the value one if the legal institution quality index of a country (*LIQ*) is above the sample median, and zero otherwise. We re-estimate the baseline models by replacing the *ESGPOST* indicator with *ESGPOST* × *High legal institution quality* and *ESGPOST* × *Low legal institution quality*. The *Low legal institution quality* indicator is defined as (1 – *High legal institution quality*). Panel B of Table 7 presents the results. The coefficients on *ESGPOST* × *Low legal institution quality* are significant at the 1% level for both the *PSI* and *TIMELINESS* models. The coefficient on *ESGPOST* × *High institutional quality* is significant at the 10% level for the *TIMELINESS* model. This result indicates that the effect of ESG disclosure reform is more pronounced in countries with weak legal institutions.

4.4. Does mandatory ESG disclosure lead to real stock market changes?

The results of our main tests shed some light on the contemporaneous impact of the ESG disclosure policy on market efficiency. We now test whether investors indeed care about the changes due to the new policy and whether mandatory ESG disclosure leads to real stock market change in the longer term. Relevant theories suggest that, if the ESG disclosure reforms help to reduce private information asymmetry, a lower cost of equity capital can be expected (Brown et al., 2004; Easley & O'Hara, 2004). Previous studies have integrated relevant ESG factors into analyses of the pattern of stock returns. For example, Chava (2014) finds that firms that derive substantial revenues from the sale of coal or oil are associated with a higher implied cost of capital. Bolton and Kacperczyk (2021) find that carbon emissions of U.S. firms are significantly positively related to cross-sectional stock returns, suggesting that investors have demanded compensation for their exposure to carbon emission risk. The authors also find that institutional investors indeed divest from firms associated with high carbon emissions. Pedersen et al. (2021) sort stocks into quintiles based on individual ESG proxies and then form portfolios that go long on the best ESG stocks and short on the worst ESG stocks. The authors find that the portfolio based on G (i.e., governance) earns significant abnormal returns. They also find that the ESG proxies are positively associated with institutional holdings in favour of greener firms.

In our first test, we evaluate ESG disclosure reform based on its ability to forecast future stock returns. In addition, we examine the change in institutional ownership after ESG disclosure reform. We calculate annual market-adjusted stock returns using the same estimation window as that defined in the estimation of *TIMELINESS*. The change in institutional ownership is calculated as the absolute value of institutional ownership in year *t* + 1 minus institutional ownership in year *t*.²¹ We estimate the following fixed-effects regression model:

$$RET_{i,t+1} \text{ or } \Delta IO_{i,t+1} = \alpha + \beta_1(ESGPOST) + \sum \beta_m CONTROLS_{i,t} + FIRM FE + YEAR FE + \epsilon_{i,t} \quad (6)$$

where *RET*_{*i,t*+1} refers to the annual stock return of company *i* in year *t* +

²¹ We use the absolute value of the change in institutional ownership because the ESG disclosure mandates can either increase or decrease institutional ownership, and therefore it is their institutional ownership rebalancing activities (including both buying and selling) that matter, which increases price efficiency after the ESG disclosure mandates.

1. $\Delta IO_{i,t+1}$ is the absolute value of institutional ownership in year *t* + 1 minus institutional ownership in year *t*. *ESGPOST* is defined as for Eq. (5). The vector of controls includes all the firm- and country-specific variables controlled in the *PSI* and *TIMELINESS* models. We include firm age (*AGE*) and stock price momentum (*MMI*) as additional control

Table 8
The impact of mandatory ESG disclosure on stock returns.

Dependent variable	<i>RET</i>	ΔIO	<i>TQ</i>
	(1)	(2)	(3)
<i>ESGPOST</i>	-0.071*** (-5.72)	0.004** (2.16)	0.154*** (3.54)
Country-level controls			
<i>GSHOCK</i>	-0.047 (-0.90)	0.009 (1.12)	-0.046 (-0.27)
<i>CO2</i>	0.002 (0.35)	0.002** (2.47)	-0.14 (-0.71)
<i>CGRF</i>	-0.013 (-0.61)	-0.010** (-2.29)	-0.064 (-1.12)
<i>LIQ</i>	-0.043 (-0.70)	0.002 (0.27)	-0.519** (-2.32)
<i>MKTCAP</i>	0.051 (1.02)	0.008** (2.34)	0.474*** (2.94)
<i>GDPG</i>	0.011** (2.40)	0.001** (2.21)	-0.009 (-1.09)
Firm-level controls			
<i>AGE</i>	0.031*** (2.93)	-0.005 (-1.41)	-0.074* (-1.70)
<i>MMI</i>	-0.054*** (-12.22)	0.001** (2.50)	0.355*** (10.24)
<i>SIZE</i>	-0.146*** (-16.63)	-0.005*** (-3.50)	-0.249*** (-7.34)
<i>IO</i>	-0.047*** (-2.83)	0.006 (0.69)	0.280*** (8.04)
<i>PROFIT</i>	-0.080** (-2.42)	-0.002 (-1.04)	0.891*** (3.80)
<i>LEV</i>	0.237*** (9.01)	0.017*** (2.62)	-0.635*** (-7.47)
<i>BM</i>	0.175*** (9.57)	0.003 (1.11)	-0.617*** (-5.99)
<i>CASH</i>	-0.057 (-1.52)	-0.004** (-2.41)	0.800*** (5.83)
<i>CAPEX</i>	-0.413*** (-5.98)	-0.009 (-1.30)	1.553*** (3.85)
<i>TURN</i>	-0.019*** (-4.47)	0.001*** (6.80)	-0.002 (-0.20)
<i>NUMEST</i>	-0.046*** (-7.51)	-0.002 (-1.61)	0.146*** (3.87)
<i>VOLTY</i>	3.009** (2.32)	0.456*** (4.99)	2.468 (0.90)
Number of observations	71,198	74,718	76,787
Adjusted R-squared	0.122	0.048	0.253
Firm fixed effects	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes

This table presents the regression results for the impact of mandatory ESG disclosure on the stock return, change in institutional ownership and firm valuation. In column 1, the dependent variable is the stock return (*RET*), measured as the market-adjusted annual returns of a share in year *t* + 1. In column 2, the dependent variable is the change in institutional ownership (ΔIO), measured as the absolute value of institutional ownership in year *t* + 1 minus institutional ownership in year *t*. In column 3, the dependent variable is Tobin's *q* (*TQ*), measured as total assets minus the book value of equity plus the market value of equity divided by total assets in year *t*. *RET* and ΔIO lead the explanatory variables by one year, and *TQ* is contemporaneous with the explanatory variables. *ESGPOST* is an indicator variable that is equal to one for all years after the mandatory ESG disclosure policy becomes effective in a country, and zero otherwise. *AGE* is the natural logarithm of firm age. *MMI* stands for price momentum, measured as the compounded returns over the previous 12 months. Other control variables are the same as those used in Table 4. Continuous variables are winsorized at the top and bottom 1% to control for outliers. Standard errors are clustered at the country level. The t-statistics are reported in parentheses. ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively (two-tailed tests).

variables (e.g., Fauver et al., 2017; Kacperczyk et al., 2021). Firm fixed effects and year fixed effects are also included. We cluster standard errors at the country level. The coefficient of interest is β_1 . For the return model, the expected sign of β_1 is negative because the ESG disclosure is likely to reduce the risk premium of information asymmetry and ultimately reduce investors' expected return and cost of equity capital. For the institutional ownership model, the expected sign of β_1 is positive, meaning that investors may either increase their investments in firms associated with good ESG performance or divest from firms associated with poor ESG performance after the ESG disclosure reforms become effective.

We are also interested in testing whether the ESG reforms will ultimately influence firm value, given the alleged effects on price efficiency and returns. Firm value is measured by Tobin's q , which is calculated as total assets minus the book value of equity plus the market value of equity divided by total assets. We estimate the following fixed-effects regression model:

$$TQ_{i,t} = \alpha + \beta_1(ESGPOST) + \sum \beta_m CONTROL_{i,c,t} + FIRMFE + YEARFE + \varepsilon_{i,t} \quad (7)$$

where $TQ_{i,t}$ refers to the Tobin's q of company i in year t . The explanatory variables and fixed effects used are the same as those defined for Eq. (6). We cluster standard errors at the country level. The coefficient of interest is β_1 . The expected sign of β_1 is positive because the ESG disclosure reform is likely to increase firm value if the reform reduces the cost of equity capital, all other things being equal.

We report the regression results of the additional tests in Table 8. Columns 1 and 2 show the results for the regression models described in Eq. (6). Column 3 presents the results for the regression model shown in Eq. (7). We find a negative and statistically significant effect of *ESGPOST* on future stock returns (*RET*) ($\beta_1 = -0.071, p < 0.01$) in column 1. This result suggests that mandatory ESG disclosure contributes to the information set, so that risk premiums on ESG factors are reduced after the implementation of new policies. The ESG disclosure reform decreases stock returns by 7.1% annualized. Our finding echoes those of Bolton and Kacperczyk (2021) and Pedersen et al. (2021). For example, Bolton and Kacperczyk (2021) document that a one-standard-deviation increase in firms' carbon emissions can increase stock returns by up to 3.6% per annum. In column 2, the change in institutional ownership (ΔIO) shows a significant increase after the ESG reform ($\beta_1 = 0.004, p < 0.05$), suggesting that institutional investors integrate ESG factors and adjust their portfolios accordingly. The result in column 3 shows that firm value (*TQ*) increases in the post-reform period ($\beta_1 = 0.154, p < 0.01$). With respect to the magnitude of the effects, the mandatory ESG disclosure reforms are associated with a 9.5% increase in the change in institutional ownership, and an 8.11% increase in firm value, relative to their respective means.²²

5. Conclusion

Both scholars such as Nobel Laureate in Economics Oliver Hart and practitioners such as CEO and chairman of BlackRock, the largest asset management firm in the world, Larry Fink argue that the purpose of incorporation goes beyond shareholder value maximization to providing products and solving social problems such as climate change and social inequality. ESG disclosure mandates enable a wide audience to understand the implications of firms' activities and policies on social welfare.

Appendix A. Variable definitions

²² The magnitude of the impact of *ESGPOST* on ΔIO is calculated as 0.004 (coefficient on *ESGPOST* in column 2 of Table 8) \div 0.042 (the unreported sample mean of ΔIO) = 9.5%. The magnitude of the impact of *ESGPOST* on *TQ* is calculated as 0.154 (coefficient on *ESGPOST* in column 3 of Table 8) \div 1.898 (the unreported sample mean of *TQ*) = 8.11%.

How, though, does the stock market respond to the changes in relation to ESG developments and what are the real impacts of mandatory ESG disclosure on price discovery efficiency? These are fundamental questions for the emerging field of ESG and accounting/finance.

This paper examines the impact of mandatory ESG disclosure reforms launched around the world since the early 2000s on price discovery efficiency in 45 countries. We undertake a DID analysis and find robust evidence that the ESG disclosure reform has significantly improved price discovery efficiency. Heterogeneous treatment tests reveal the conditions under which the reforms take effect. The effects of the ESG reforms are stronger for firms in countries that value and prioritize environmental protection, for firms in countries with low institutional quality, for firms that do not release ESG-related documents, for firms with poor ESG performance, and for firms that lack complete corporate governance mechanisms. We find that institutional investors care about the reforms, such that the real impacts of mandatory ESG disclosure lead to reduced future stock returns (cost of equity capital), improved institutional ownership and higher firm valuations in the post-reform period.

Our research has a few implications for policy makers. First, stock exchanges now face global competition in attracting high-quality companies to list and in raising equity capital from investors. In order to strengthen their competitiveness in the global financial market, it is crucial to prioritize mandatory ESG disclosure regulations, which can improve price discovery efficiency and reduce the cost of equity capital. Second, flexibility in mandatory ESG regulation, such as a comply-or-explain (COE) or step-by-step style, is not as effective as the strictly mandatory approach in promoting price discovery efficiency. However, it is better than no mandatory disclosure regulation at all, because it could still generate spill-over benefits and improve the overall information environment and price discovery efficiency. Finally, despite mandatory disclosure having net benefits in promoting price discovery efficiency, the challenges remain in creating standardized reporting standards for ESG disclosure (Christensen et al., 2021), which could further reduce the cost of information collection, processing and verification, and maximize its benefits in promoting stock market development. Our analysis also has valuable implications for corporate managers, board directors and investors. For management and board directors, ESG disclosure practice could be perceived as a quality signal by investors, and thus a way for companies to differentiate themselves from their competitors. Although institutional investors may be able to gain insights from ESG disclosure, retail investors may need to be mindful in trading shares with a low level of ESG disclosure compliance.

Further study could extend our analysis in a couple of ways. We focus on the effect of market-level ESG disclosure regulation on overall price discovery efficiency in terms of the incorporation of both financial and non-financial information. Further studies could extend this to investigate how firm-level financial disclosure quality and ESG disclosure quality are affected by ESG disclosure regulation and via which channels price discovery efficiency is promoted more. Second, we find some evidence of spill-over effects of mandatory ESG disclosure with compliance flexibilities. Further research could extend ours by looking at the channels through which such spill-over effects are realized.

Data availability

Data will be made available on request.

Table A1

Variable	Acronym	Description	Data source
Stock price non-synchronicity	<i>PSI</i>	PSI is a measure of stock price informativeness based on the R^2 from asset pricing regressions, as shown in Eqs. (1)–(3).	Refinitiv Datastream Authors' own calculation
Stock price timeliness	<i>TIMELINESS</i>	The price timeliness of value-relevant news, based on daily market-adjusted share prices, as estimated in Eq. (4). The measure is deflated by one plus the absolute rate of return on the share over the period.	Refinitiv Datastream & Worldscope Authors' own calculation
Mandatory ESG disclosure	<i>ESGPOST</i>	An indicator variable that is equal to one for all years after the mandatory ESG disclosure policy becomes effective in a country, and zero otherwise.	Krueger et al. (2021)
Comply-or-explain	<i>COE</i>	An indicator variable that is equal to one for all years after the mandatory ESG disclosure policy becomes effective in a country if the comply-or-explain ESG disclosure approach is adopted, and zero otherwise.	Krueger et al. (2021)
All-at-once	<i>ATO</i>	An indicator variable that is equal to one for all years after the mandatory ESG disclosure policy becomes effective in a country if mandatory environmental, social and governance disclosure are introduced all at once, or zero if the country implements mandatory disclosure gradually.	Krueger et al. (2021)
Global shocks	<i>GSHOCK</i>	An indicator variable for global shocks that equals one if the year is 2008 or 2020, and zero otherwise.	Authors' own calculation
Carbon emissions	<i>CO2</i>	<i>CO2</i> is CO2 emissions in metric tons per capita.	Emissions Database for Global Atmospheric Research (EDGAR) https://edgar.jrc.ec.europa.eu/report_2022 Fauver et al. (2017)
Corporate governance reform	<i>CGRF</i>	An indicator variable equal to one for all years after a major corporate governance reform became effective in the country, and zero otherwise.	
Legal institution quality	<i>LIQ</i>	Sum of three World Governance Indicators (government effectiveness, regulatory quality and the rule of law) and the anti-self-dealing index from Djankov et al. (2008) . The WGI and anti-self-dealing indices are rescaled to be between 0 and 1.	World Governance Indicators Djankov et al. (2008)
Stock market capitalisation	<i>MKTCAP</i>	Market capitalisation of listed domestic companies divided by GDP.	World Development Indicators
GDP growth	<i>GDPG</i>	Annual percentage growth rate of GDP.	World Development Indicators
Environment first	–	The environment first score of a country is estimated based on responses to the WVS question: "Which of the following comes closer to your own point of view? 1. Protecting the environment should be given priority, even if it causes slower economic growth and some loss of jobs. 2. Economic growth and creating jobs should be the top priority, even if the environment suffers to some extent." We recode the response to this question to one if a survey participant chose statement 1, and zero otherwise. We then calculate the mean of the response for each country-wave. The score is calculated for each wave of the WVS. Within a wave, the score is calculated once and applies to all country-years covered by the wave. An average score is calculated for each country. Higher scores suggest that people put environmental protection first.	Four waves of the World Values Survey (WVS) in 1999–2004, 2005–2009, 2010–2014 and 2017–2020.
ESG-reporting firms	–	An indicator variable that takes the value one if a firm has ESG reports uploaded in the Refinitiv ESG database in a year, and zero otherwise. Missing information in a year is coded as zero.	Refinitiv ESG Database
High ESG score	–	An indicator variable that takes the value one if a firm has an ESG performance score above the sample median in a year, and zero otherwise. Missing information in a year is coded as zero.	Refinitiv ESG Database
Corporate governance quality	<i>CGQ</i>	Refer to Appendix B for our corporate governance standards relating to financial and operating transparency, following Chung et al. (2010) . CGQ is the annual ratio of their CG scores according to these 22 CG standards, divided by the full score of 22. Missing information in a year is coded as zero.	Refinitiv Eikon
Firm size	<i>SIZE</i>	The natural logarithm of the total assets of a firm in U.S. dollars (Worldscope item 02999).	Refinitiv Worldscope
Institutional ownership	<i>IO</i>	Number of shares held by all types of institutions divided by total number of shares outstanding.	Refinitiv Ownership Database
Profitability	<i>PROFIT</i>	Earnings before interest, taxes and depreciation (Worldscope item 18,198) divided by total assets (Worldscope item 02999).	Refinitiv Worldscope
Leverage	<i>LEV</i>	Total debt (Worldscope item 03255) divided by total assets (Worldscope item 02999).	Refinitiv Worldscope
Book-to-market ratio	<i>BM</i>	Book value of equity (Worldscope item 03501) divided by market value of equity (Worldscope item 08001).	Refinitiv Worldscope
Cash holding	<i>CASH</i>	Cash and short-term investments (Worldscope item 02001) divided by total assets (Worldscope item 02999).	Refinitiv Worldscope
Capital expenditure	<i>CAPEX</i>	Capital expenditures (Worldscope item 04601) divided by total assets (Worldscope item 02999).	Refinitiv Worldscope
Stock trading volume	<i>TURN</i>	Share trading volume (Datastream item VO) divided by adjusted shares outstanding (Datastream items NOSH/AF).	Refinitiv Datastream
Analyst following	<i>NUMEST</i>	The natural logarithm of the number of analysts following a firm in a fiscal year.	I/B/E/S
Stock return volatility	<i>VOLTY</i>	The standard deviation of daily stock returns over the 365 calendar days prior to the fiscal year end date.	Refinitiv Datastream Authors' own calculation
Firm age	<i>AGE</i>	The natural logarithm of the number of years since the firm was incorporated.	Refinitiv Worldscope
Stock price momentum	<i>MM1</i>	Compounded stock returns over the previous 12 months.	Refinitiv Datastream Authors' own calculation
Stock return	<i>RET</i>	Market-adjusted annual returns of a share in year $t + 1$	Refinitiv Datastream Authors' own calculation

(continued on next page)

Table A1 (continued)

Variable	Acronym	Description	Data source
Change in institutional ownership	ΔIO	The absolute value of institutional ownership in year $t + 1$ minus institutional ownership in year t .	Refinitiv Ownership Database
Tobin's q	TQ	Total assets (Worldscope item 02999) minus book value of equity (Worldscope item 03501) plus market value of equity (Worldscope item 08001) divided by total assets.	Refinitiv Worldscope

Appendix B. Construction of corporate governance index

Table B1

Corporate Governance Categories and Standards	
<i>Audit</i>	
1	Audit committee independence is true.
<i>Board</i>	
2	Strictly independent board members are >50% of the board directors.
3	Nomination committee independence is true.
4	Compensation committee is comprised solely of independent outside directors.
5	Committee meeting attendance average is greater than zero (i.e., meets at least once during the year).
6	Staggered Board Structure is false.
7	Size of board of directors is at least 6 but not >15 members.
8	Shareholders have cumulative voting rights to elect directors.
9	CEO serves on no more than two additional boards of other public companies.
10	Chairman is not ex-CEO.
11	CEO and Chairman is separated.
12	Any of the following policies is available publicly.
	<ul style="list-style-type: none"> • Board Independence • Board Diversity • Board Experience • Executive Compensation Performance • Executive Compensation ESG Performance • Executive Retention
<i>Charter</i>	
13	There is no poison pill provision.
14	Supermajority Vote Requirement is false.
15	Shareholder Approval Significant Transactions is true.
16	Written Consent Requirements is true.
17	Limited Shareholder Rights to Call Meetings is false.
18	Unlimited Authorized Capital or Blank Check is false.
<i>Compensation</i>	
19	Board Member Long Term Compensation Incentives is greater than zero.
<i>Ownership</i>	
20	Executive Compensation Long Term Objectives is true.
21	Shareholders Approval Stock Compensation Plan is true.
<i>Anti-Takeover Devices</i>	
22	There is no anti-takeover device.

This table shows the construction method for the corporate governance quality index. Following Chung et al. (2010), we adopt 22 CG standards relating to financial and operating transparency. The CG standards are taken from data compiled by Refinitiv Eikon.

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