5-2024

When market forces backfire: Mandatory ESG disclosure and corporate innovation

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SINGAPORE MANAGEMENT UNIVERSITY
2024

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Submitted to School of Accountancy
in partial fulfillment of the requirements for the
Degree of Doctor of Philosophy in Accounting

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2024

I hereby declare that this PhD dissertation is my original work
and it has been written by me in its entirety.
I have duly acknowledged all the sources of information
which have been used in this dissertation.

This PhD dissertation has also not been submitted for any degree
in any university previously.

Andi Zhang
30 April 2024

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Abstract

Mandatory ESG disclosure makes it possible to incorporate ESG information into stock prices, incentivizing firms to "do good". This channel, however, may lead to suboptimal investments, according to disclosure theories. This study investigates the changes in firms' investment in innovation activities following the staggered introduction of mandatory ESG disclosure around the world. Using a sample of corporate patents filed by listed firms across 58 countries from 2000 to 2022, I find that the introduction of mandatory ESG disclosure is associated with less corporate innovation. The effect is mainly driven by countries that mandate ESG disclosure within corporate financial reports, when the market force channel is more likely to work (i.e., when ESG information is more likely to be incorporated into stock prices). To shed light on the underlying mechanism, I document a less sensitive market response to financial information, measured by a reduction in earnings response coefficients (ERCs) and the main effect is mainly driven by countries with a greater reduction in ERCs. In addition, the main effect is partially mitigated in countries with stronger external financing and unlikely to be driven by

proprietary cost. Collectively, this paper suggests that mandatory ESG disclosure leads to an unintended cost for corporate innovation.

Keywords: ESG Disclosure; Market Force; Innovation; Patents.

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1. Introduction

What is the implication for corporate investment and investment efficiency when investors value both financial and Environmental, Social, and Governance (ESG) information? When investors value ESG information, stock prices respond to firms' ESG information, in addition to financial information, incentivizing firms to "do good". This channel is referred to by Fama (2020) as the role of market forces in addressing ESG issues.[1] However, the corporate investment implications are more nuanced. While some empirical studies have documented superior financial performance following the adoption of ESG disclosure mandates (Gibbons, 2023; Krueger et al., 2024), recent analytical studies predict that ESG disclosure may lead to suboptimal investment under certain circumstances (Aghamolla and An, 2021; Jiang et al., 2023; Lu, 2024; Xue, 2023).

Aghamolla and An (2021) model managers' project selection between a sustainable and a traditional project. They find that compared to the voluntary ESG disclosure regime, the mandatory regime compels managers to overinvest in the sustainable project and underinvest in traditional projects, contrary to the preferences of aggregate shareholders. Jiang et al. (2023) show that mandating ESG disclosure without mandatory certification leads to lower investment efficiency compared to mandating neither (i.e., the voluntary disclosure regime). More related to the market force channel, Xue (2023)'s analytical model shows that mandatory ESG disclosure increases price responsiveness to ESG information and decreases

[1] Throughout the paper, the market force channel refers exclusively to the disciplinary effect of stock prices, based on Fama's terminology (Fama, 2020).

price responsiveness to financial information, which incentivizes the firm to underinvest. On the other hand, mandatory ESG disclosure may crowd out investors' proprietary information and dampen managerial learning, which in turn decreases investment efficiency (Goldstein et al., 2023; Lu, 2024). Lu (2024) documents a reduction in investment-q sensitivity following the initiation of Asset 4 ESG ratings, which is consistent with the reduced managerial learning channel. Collectively, the effect of mandatory ESG disclosure on corporate investment is ex ante unclear.

I investigate this research question in the setting of international adoption of mandatory ESG disclosure. Based on Krueger et al. (2023), I identify 34 countries that have adopted ESG disclosure mandates from 2000 to 2022.[2] Leveraging disclosure theories, I first examine the effect of mandatory ESG disclosure on price responsiveness to financial information. In a market with investors who value both financial and ESG information, mandatory ESG disclosure makes it possible to incorporate ESG information into stock prices, leading to increased price responsiveness to ESG information, at the cost of decreased responsiveness to financial information (Xue, 2023). I test this notion by comparing the changes in earnings response coefficients (ERCs) following ESG disclosure mandates.[3] I document smaller ERCs following mandatory ESG disclosure around earnings

[2] I thank the author team for making the dataset publicly available. For more information, please refer to Krueger, P., Z. Sautner, D. Tang, and R. Zhong, 2023, Data for 'Mandatory ESG Disclosure Policies Around the World'. https://osf.io/syn8t/.

[3] Albeit straightforward, a direct investigation of changes in price responsiveness to ESG information is not feasible for the following reasons: 1) provisions of ESG information are voluntary prior to the disclosure mandates, and thus the pre- and post- periods are not comparable and 2) the release dates of ESG information (in both the pre- and post- periods) are largely missing.

announcement dates of annual reports.[4] In terms of the cross-sectional variation, I document that the effect is mainly driven by countries that mandate ESG disclosure within corporate financial reports, rather than in a standalone report. This suggests that only when ESG information is easily accessible (i.e., disclosed in annual reports) can it be fully incorporated into stock prices.

Having established that mandatory ESG disclosure leads to smaller price responsiveness to financial information, I move on to test the effect of mandatory ESG disclosure on corporate investment. I focus on investment in corporate innovation, a long-term intangible investment that determines corporate competitiveness (Corrado and Hulten, 2010) and a key driver of real economy (Solow, 1957). To capture investment efficiency in corporate innovation, I rely on the forward citation of patents, as it reflects the breadth of the patents' influence and value (Griliches et al., 1986), and has been widely used in prior studies as a proxy for innovation quality (Cohen et al., 2022; Skinner and Valentine, 2023; Zhong, 2018). I obtain patent information from PatentsView, a data platform maintained by the United States Patent Citation and Patent Assignment (USPTO) and has been widely used in the accounting, finance and economics literature (Allen et al., 2022; Furman et al., 2021; Skinner and Valentine, 2023).[5]

Using a sample of patent applications by listed firms across 58 countries from

[4] I focus only on annual financial reports instead of quarterly reports as in prior studies (Collins et al., 1998; Livnat and Mendenhall, 2006). This is because I am interested in the heterogeneous treatment effects based on disclosure venues (i.e., within financial reports versus in standalone reports), and the ESG disclosure mandates specify whether or not firms should disclose ESG information in their **annual** financial reports.

[5] PatentsView details up-to-date information for all patents that have been granted by the USPTO. To link each patent application to a listed firm, I rely on two alternative patent databases, the UVA Darden Global Corporate Patent Database (GCPD database), and the WRDS U.S. patent database. The two databases adopt fuzzy name matching strategies to link patent assignees to firm names, respectively. I detail the data processing procedures in Section 3.

2000 to 2022 and difference-in-differences (DiD) estimation, I find that the staggered introduction of mandatory ESG disclosure is associated with less corporate innovation. In terms of economic magnitude, patent citations decrease by 15.5% after a country introduces ESG disclosure mandates, which is a substantial unintended cost. To shed more light on the market force channel, I test and find the main effect is more pronounced in countries that experience a greater decline in ERCs. In addition, I document a significant reduction in corporate profitability subsequent to mandatory ESG disclosure, suggesting that the reduction in corporate innovation activities is indeed inefficient.

Mandatory ESG disclosure is vital to the market force channel as it facilitates incorporation of ESG information into stock prices. However, there are substantial frictions arisen from the awareness, acquisition, and processing costs of ESG disclosure. To test this notion and shed more light on the heterogeneity in the main findings, I leverage variation in ESG disclosure venues and compare countries that require ESG disclosure within corporate financial reports versus those that mandate standalone ESG reports. Financial reports are more standardized and easily accessible, compared to standalone reports. In the cross-sectional analyses, I test and find that the main effects are predominantly driven by countries that mandate ESG disclosure within annual financial reports (i.e., when the market force channel is more likely to take effect).

What is the role of investors' environmental preferences? There is ample evidence indicating that investors care about ESG aspects of firms' operations and are willing to sacrifice financial returns for nonpecuniary benefits (Barber et al.,

2021; Martin and Moser, 2016; Pástor et al., 2022; Riedl and Smeets, 2017). When aggregate investors have stronger environmental preferences, they may attribute a greater portion to ESG information in the formation of market prices. Therefore, when ESG disclosure is mandated, the price responsiveness to financial (ESG) would be even smaller (greater), leading to more severe underinvestment in the innovation activities. To shed more light on the underlying mechanism, I investigate the cross-sectional variation due to investors' environmental preferences. Specifically, I use the Yale University's Environmental Performance Index (EPI) to proxy environmental preferences. EPI captures country-level belief in the importance of environmental issues, and has been used by prior studies to proxy environmental preferences (Dyck et al., 2019; Ilhan et al., 2023; Krueger et al., 2024). A higher EPI reflects stronger environmental preferences. Empirically, I document that the decrease in ERCs is predominantly driven by countries with high EPI. Moreover, the main effect (i.e., decrease in innovation activities) is stronger in countries with high EPI, and the difference is statistically and economically significant. Specifically, mandatory adoption of ESG disclosure decreases corporate innovation by 13.7% in countries with low EPI countries and decreases innovation by 20.2% in high EPI countries.

Next, I examine the moderating role of external financing. Previous studies have documented some beneficial economic consequences for mandatory ESG disclosure. For example, Krueger et al. (2023) document an increase in stock liquidity following mandatory ESG disclosure. More relatedly, Gibbons (2023) documents inflows of institutional investors, especially long-term oriented

institutions, and higher levels of long-term oriented investments. I examine whether and to what extent external financing moderates the main effect. I leverage World Bank credit and equity market development data to investigate the notion. After controlling the credit market and equity market development as a portion of gross domestic production (GDP), I continue to document a significant decrease in innovation activities following ESG disclosure mandates. I further conduct subsample analyses based on countries that have stronger (weaker) credit (equity) markets. The findings suggest that the main effect is mainly driven by countries with weaker credit (equity) markets. Taken together, the findings suggest an asymmetric outcome for countries that adopt mandatory ESG disclosure. In countries with relatively weak credit and equity markets, mandating ESG disclosure decreases innovation activities.

An alternative explanation for the negative relationship between ESG disclosure and corporate innovation is proprietary cost. Specifically, mandatory ESG disclosure may induce substantial proprietary cost to innovating firms, altering the cost-benefit trade-offs for corporate innovation. However, it is unclear whether and how the proprietary cost explanation can affect price responsiveness to financial and ESG information. Nevertheless, I investigate the moderating role of proprietary cost. Following prior studies, I collect data on property rights protection from the Economic Freedom maintained by the Heritage Foundation (Li et al., 2022; Zhong, 2018). Higher (lower) the score for property rights protection, lower (higher) the proprietary cost. The empirical findings show that the main effect continues to hold, regardless of the proprietary cost, suggesting that the

alternative explanation is unlikely.

I perform a battery of robustness tests for the main findings. (1) I restrict the sample period to 2000 till 2017, which is essentially equivalent to that of the GCPD database.[6] (2) I use alternative adjustment methods to adjust patent truncation issues (Dass et al., 2017; Hall et al., 2001). (3) I replace the dependent variable by the logarithm of one plus the number of patent applications. (4) I include for industry * year and industry * country fixed effects to control for innovation breakthroughs (Krueger et al., 2024; Li et al., 2022). (5) I remove observations from the U.S. (and Japan), as they represent the largest portion of the control (treatment) sample. (6) I restrict the sample by removing never-treated countries, to ensure that the treatment effect is not driven by changes in innovation activities in never-treated countries. (7) I collapse the sample by each firm, around the adoption year, to alleviate the concerns that DiD estimates are biased when a large number of observations come from the same firm (Bertrand et al., 2004). (8) Finally, Cohn et al. (2022) highlight the concerns when the dependent variable is a count-based outcome and recommend fixed-effect Poisson models. To this end, I re-estimate all the robustness stated above by Poisson estimation with high-dimensional fixed effects. The main findings are qualitatively similar in all the robustness checks.

Finally, I reconcile the main findings in this paper with Gibbons (2023), who has documented that environmental and social disclosure mandates lead to more institutional holdings and increased long-term investments, including patent

[6] The only difference comes from patents filed by U.S. firms and is only available in the WRDS U.S. patents database. If WRDS identifies certain patents filed by U.S. firms and they are not in the GCPD database, the final sample links them to U.S. firms based on WRDS datasets. The results are qualitatively similar if I restrict the patent sample to GCPD database alone.

applications. First, I have shown that the main effect is predominantly driven by countries with relatively weak equity and credit markets. The overall effect of ESG disclosure mandates on innovation activities depends on the relative magnitude of the financing channel and the market force channel documented in this paper (i.e., mandatory ESG disclosure decreases price responsiveness to financial information, leading to underinvestment problems). In countries with relatively weak equity markets, the market force channel dominates. Second, this paper focuses on a sample of innovative firms while Gibbons (2023) focuses on all firms with non-missing financial data. It is a common sample selection criterion to investigate innovation activities only in innovative firms (Aghion et al., 2013; Geng et al., 2023; Kogan et al., 2017). Following these studies, I define innovative firms as those who have filed at least one patent in the USPTO. Innovative firms have unique financing characteristics than regular firms, due to cost of capital considerations and proprietary information concerns. As Hall and Lerner (2010) point out in *Handbook of the Economics of Innovation*, large established firms appear to prefer internal funds over equity financing, and venture capital is a helpful medium for lowering cost of capital for small innovative firms, had it been available. Additionally, due to proprietary information concerns, innovative firms rely deeply on debt financing and single-lender financing (Griffin et al., 2022; Kerr and Nanda, 2015; Mann, 2018; Nanda and Nicholas, 2014). Overall, debt financing can be a vital channel of funding innovation activities, in addition to equity financing. The subsample analysis based on the development of credit market lends support to this notion.

Finally, the difference between this paper and Gibbons (2023) could arise from

econometrics. Given that Gibbons (2023) covers all firms with non-missing data, including those who have never filed any patents to the patent office (i.e., non-innovative firms), all the observations from such firms would have the outcome variables (i.e., patent applications) being zero. As Cohn et al. (2022) point out, these observations simply contain no information about regression coefficients in a model in which the fixed effects are multiplicative. They also caution against the practice of using the logarithm of one plus the raw outcome variable and recommend Poisson estimation with high-dimensional fixed effects. Empirically, I first show that linear estimation in the full sample (i.e., inclusive of both innovative and non-innovative firms) yields a **positive** coefficient between mandatory ESG disclosure and innovation activities. However, when I restrict a sample to include only innovative firms or use Poisson estimation with high-dimensional fixed effects, the coefficient estimates **flip signs**. Finally, to be more comparable with Gibbons (2023), I limit the sample period to 2000-2017, and find the patterns continue to hold. Taken together, the difference between this paper and Gibbons (2023) likely comes from both economic and econometric reasons: the unique financing characteristics of innovative firms and linear estimation of count-like dependent variables with substantial zeros outcomes both contribute to the discrepancy.

The study makes the following contributions to the literature. First, the findings in this study highlight that reliance on market forces to drive ESG transition can sometimes backfire. Bénabou and Tirole (2010) point out it is more efficient to restrain firms from certain actions than to have shareholders undo the negative consequences. When investors value both financial and ESG information,

their tastes can have disciplinary effect on firms behaviors (Fama, 2020; Fama and French, 2007; Friedman and Heinle, 2016; Pástor et al., 2021). This channel is referred to by Fama (2020) as the market forces to address ESG issues. Specifically, when investors value environmental issues, "clean" firms have high stock prices (i.e., lower expected returns) relative to "dirty" firms, which incentivizes firms to become "clean". Mandatory ESG disclosure facilitates the market forces channel, as it makes it possible to incorporate ESG information into the stock price. Nevertheless, this paper highlights that reliance on market forces to drive ESG transition can lead to suboptimal financial performance. Using forward citations as the proxy for investment efficiency in patent applications, this paper documents underinvestment in innovation activities, and the pattern is driven by stock prices being less responsive to financial information. Therefore, the findings caution against relying on the market force channel alone to drive ESG transition.

This study also contributes to the strand of literature on mandatory ESG disclosure by documenting an unintended cost. ESG disclosure is distinct from financial disclosure and its implications are hard to predict (Christensen et al., 2021). Extensive studies have documented benefits for mandatory ESG disclosure, both in the ESG dimension (Downar et al., 2021; Fiechter et al., 2022; Jouvenot and Krueger, 2019; Tomar, 2023) as well as in the financial dimension (Boulton, 2023; Gibbons, 2023; Krueger et al., 2024). Less studies, however, have investigated the costs. The findings in this paper add to related studies (Chen et al., 2018; Christensen et al., 2022; Rajgopal and Tantri, 2022) by pinning down a market-driven cost. Leveraging disclosure theories, this paper documents a

decreased price responsiveness to financial information, following the adoption of ESG disclosure mandate, which leads to underinvestment in corporate innovation. This is a substantial cost given that corporate innovation is vital in long-term firm competitiveness and a main driver of real economy. Furthermore, the findings can potentially inform regulators when they set up the scope of ESG disclosure, especially for economies with relatively weak equity and credit markets.

Finally, the study adds to the literature on the real effects of corporate disclosure. While jurisdictions around the world are proposing mandatory ESG disclosure, its implications for innovation investment and its efficiency are less investigated. Built on the literature of disclosure theories, some studies have pointed out that mandating ESG disclosure could lead to suboptimal investment efficiency under certain circumstances (Aghamolla and An, 2021; Jiang et al., 2023; Xue, 2023). The findings in this paper add to this strand of literature by providing empirical evidence that shows mandating ESG disclosure leads to suboptimal investments (i.e., underinvestment in innovation activities), consistent with the prediction by Xue (2023). More generally, the findings echo the studies on investment inefficiency due to greater precision in information disclosure (Geng et al., 2023; Kanodia et al., 2005; Kanodia and Sapra, 2016). For example, Geng et al. (2023) provide theoretical and empirical evidence that shows greater financing reporting quality can incentivize myopic investments. This paper adds to this stand of literature by showing increased precision in ESG information disclosure leads to underinvestment.

The remainder of this paper proceeds as follows. Section 2 reviews related

literature and develops main hypotheses. Section 3 describes the research design. Section 4 presents the empirical results. Section 5 presents sensitivity and additional analyses. Finally, Section 6 concludes.

2. Related Literature and Hypothesis Development

Bénabou and Tirole (2010) argue that when a firm imposes negative consequences to the society, it is more efficient to restrain firms from certain actions than to have shareholders undo the negative consequences. Existing literature has shown that when investors value both ESG and financial information, their preferences ("tastes") for ESG information should have a disciplinary effect (Fama, 2020; Fama and French, 2007; Friedman and Heinle, 2016; Pástor et al., 2021). In the spirits of Fama and French (2007), these studies support the notion that "clean" firms with higher stock prices (i.e., lower expected returns) relative to "dirty" firms. This price effect therefore incentives firms to become "clean". This channel is referred to by Fama (2020) as the market forces to address ESG issues.

Mandatory ESG disclosure is a key market force that drives ESG transition. However, without mandatory disclosure, investors can only rely on noisy signals of financial and ESG performance, which contains little information content (Bagwell, 1995; Kanodia et al., 2005). Therefore, mandatory ESG disclosure matters in the sense that it increases ESG information precision and thus it is possible to incorporate ESG information into the stock price.

Mandatory ESG disclosure has benefits beyond the market force channel.

Christensen et al. (2021) argue that "to the extent that mandatory CSR reporting and CSR standards improve the information available to investors, the same theories and many of the prior findings (on the real effects of financial disclosure) should apply". Consistent with this notion, existing studies have documented that mandatory ESG disclosure is associated with superior performance both in the ESG dimension (Downar et al., 2021; Fiechter et al., 2022; Jouvenot and Krueger, 2019; Tomar, 2023) as well as in the financial dimension (Boulton, 2023; Gibbons, 2023; Ilhan et al., 2023; Krueger et al., 2024). For example, Tomar (2023) finds that following mandatory greenhouse gas (GHG) disclosure, affected facilities reduce GHG emissions by 7.9%. Ilhan et al. (2023) find that ESG disclosure facilitates green financing, as sustainable investors respond to green disclosure by increasing investment in green firms.

Benefits notwithstanding, mandatory ESG disclosure is not without costs. As Christensen et al. (2021) point out, similar costs from the financial disclosure can be applied to the ESG setting, including compliance costs, proprietary costs, agency costs, etc. Consistent with this notion, Chen et al. (2018) finds that mandating ESG disclosure can generate positive externalities at the cost of shareholder value, in the Chinese setting. Christensen et al. (2022) find that ESG disclosure is associated with greater ESG rating disagreement. Using a sample of Indian firms, Rajgopal and Tantri (2023) find that mandatory ESG disclosure leads to a reduction in ESG activities since the regulatory change diminishes the signaling value.

Literature on the real effects of corporate disclosure generates similar insights under certain circumstances (Aghamolla and An, 2021; Jiang et al., 2023; Xue,

2023). This strand of literature is based on traditional disclosure theories in the era of ESG and investigates how managers' decision-making is affected due to investors' reaction, following mandatory disclosure (i.e., the market force channel). Jiang et al. (2023) investigate the case where managers can choose between a risky and risk-free project. They find that when the certification cost is relatively high for the ESG information to be disclosed, mandatory disclosure without mandatory certification leads to inefficient investment, compared to the voluntary regime and the regime that requires both mandatory disclosure and certification. More related to the ESG setting, Aghamolla and An (2021) model managers' project selection between a sustainable and a traditional (i.e., non-clean) project. They find that compared to the voluntary ESG disclosure regime, the mandatory regime compels managers to overinvest in the sustainable project and underinvest in the financial dimension (i.e., traditional projects), even though aggregate shareholders may prefer higher financial returns. Xue (2023) investigates a case where managers select an investment level that is endogenously related to ESG impact (e.g., higher investment levels for manufacturing companies lead to more emissions). He finds that mandating ESG disclosure leads to underinvestment problems in the financial dimension, and the effect is increasing in shareholders' preferences in ESG issues, relative to financial returns.

Collectively, it is unclear ex ante what is the corporate investment implication of mandatory ESG disclosure. To investigate this question, I focus on corporate investment in innovation activities. Corporate innovation is a long-term intangible investment that determines corporate competitiveness (Corrado and Hulten, 2010)

and a key driver of real economy (Solow, 1957). To measure investment efficiency in corporate innovation, I rely on the forward citation of patents, as it reflects the breadth of the patents' influence and value (Griliches et al., 1986), and has been widely used in prior studies as a proxy for innovation quality (Cohen et al., 2022; Skinner and Valentine, 2023; Zhong, 2018).

I propose the main hypothesis in the null form:

Hypothesis 1: Mandatory ESG disclosure is not associated with investment efficiency in innovation activities.

3. Research Design

3.1. Data and Sample

3.1.1. Main Sample

To create the main sample, I start with all publicly listed firms in the S&P Compustat database from 2000-2022. I extract from Compustat North America financial information for North American firms and Compustat Global for the rest of firms. I extract stock price data for North American firms from CRSP and Compustat Global for other firms. I rely on analyst forecast to calculate earnings surprise, which is obtained from I/B/E/S. Information on mandatory ESG disclosure around the world is based on Krueger et al. (2023), which is compiled based on the Carrots & Sticks project, the Global Reporting Initiative (GRI) and the Sustainable Stock Exchanges (SSE). I obtain country-level variables from the

World Bank.

Having obtained financial variables and control variables, I then merge in the patent data (See Section 3.1.2. for details). It is a common practice to investigate innovation activities only in innovative firms (Aghion et al., 2013; Geng et al., 2023; Kogan et al., 2017). Following these studies, I define innovative firms as those who have filed at least one patent to the USPTO. Specifically, for firms that have never filed any patents, I exclude observations from such firms from the final sample. After matching the data sources and applying the screening protocol, I obtain a final panel of 218,709 firm-year observations covering from 58 countries for the main tests.

3.1.2. PatentsView Data

To measure innovation activities, I rely on three streams of patent database: (1) The PatentsView database, maintained by USPTO, (2) UVA-GCPD global patent database, following Bena et al. (2017),[7] and (3) WRDS U.S. patent database.[8] All the three databases are based on patents filed to the USPTO, which covers different applicants from 230 countries. I employ the USPTO-based databases to investigate the research question, as they reflect the most important (i.e., economically significant) innovation by firms around the world, and has been

[7] I thank the author team for sharing the database. For more information, please refer to https://patents.darden.virginia.edu/get-data.

[8] The NBER patent database and the KPSS database (Kogan et al., 2017) are two frequently used alternatives. I did not use the NBER patent database as it covers an earlier sample period (till 2010). As to the KPSS database, albeit update-to-date, it lacks detailed information such as assignee names, which is vital to the matching process. Moreover, since KPSS focus on market reaction to capture patent value, the database only covers firms that have non-missing stock prices around patent grant dates, which significantly limits the sample size. I therefore resort to the WRDS U.S. patent database instead.

extensively used previous studies (Bena et al., 2017; Griffin et al., 2021).[9]

I collect data on all patent applications to USPTO from 2000 through 2022 via the PatentsView database as the primary source. I use PatentsView as my primary data source since it covers detailed up-to-date information and has been widely used in the accounting, finance and economics literature (Allen et al., 2022; Furman et al., 2021; Skinner and Valentine, 2023). Another advantage is that it maintains an up-to-date patent classification system (i.e., corporative patent classification) to enable tractable patent truncation adjustment at the patent class level,[10] which is vital in the innovation literature (Dass et al., 2017; Hall et al., 2001).

Since I focus on publicly traded firms, for which there are rich, publicly available measures of firm characteristics, I link each patent assignee in the PatentsView database to a listed firm identifier. To do so, I rely on the GCPD database and WRDS U.S. patent database, which creates a fuzzy name matching algorithm and provides a unique S&P firm identifier (i.e., gvkey), respectively.

To conduct the matching, I have created two matching tables, patent number-identifier and assignee-identifier tables, after merging the GCPD and WRDS patent database. Whenever there is a discrepancy (e.g., the same patent number is linked to two different firm identifiers by the two database), I resort to the GCPD database as it has been widely used in previous studies (Bena et al., 2017; Griffin et al., 2021). With the two matching tables, I first conduct the patent number-identifier matching,

[9] See Bena et al. (2017) for a more extensive discussion.

[10] The USPTO has adopted multiple classification systems in the history, among which the international patent classification (IPC), the U.S. patent classification (USPC), and CPC are three main systems. Earlier data sources, such as the frequently used patent data maintained by Google (see https://www.google.com/googlebooks/uspto-patents.html) feature only **historical** classifications and are subject to changes constantly. Patentsview, however, **retrospectively** assigns a CPC code that is updated in real time. It is therefore more tractable and comparable in a panel dataset.

for U.S. firms till 2019 and all-but-U.S. firms till 2017. For observations afterwards, I resort to assignee-identifier matching with the latest assignee-identifier link.

(Insert Figure 1 here)

3.1.3. Environmental Performance Index (EPI) Data

To proxy for the enforcement strength of ESG-related standards, I use the environmental norm from the environmental performance index (EPI), compiled by the Yale Center for Environmental Law and Policy. The data utilizes a proximity-to-target methodology focused on a core set of environmental outcomes linked to policy goals that facilitate cross-country comparisons among economic and regional peer groups of 180 countries. Specifically, EPI derives a score for each of the 180 countries on 32 performance indicators. My conjecture for the use of the EPI measure is that it captures the country-level emphasis on ESG-related issues, which can be applied to aggregate investors as well.

3.2. Empirical Research Design

For the empirical analyses, I exploit the staggered adoption of mandatory ESG disclosure in different countries, which is based on the mandatory ESG disclosure identification provided in Krueger et al. (2023). To test the effect of mandatory ESG disclosure on ERCs, I estimate the following model using ordinary least squares (OLS):

$$CAR_{i,j,t} = \beta_0 + \beta_1 Post_{j,t} + \beta_2 Surprise_{i,j,t} + \beta_3 Post_{j,t} * Surprise_{i,j,t} + \alpha_i + \alpha_j + \alpha_t + \varepsilon_{i,j,t} \quad (1)$$

where $CAR_{i,j,t}$ measures the market-adjusted cumulative abnormal return in the three-day or five-day window around annual earnings announcement dates. $Surprise_{i,j,t}$ is the standardized earnings surprise, measured by actual earnings per share (EPS) less consensus EPS forecast, divided by the stock prices on earnings announcement dates, where consensus EPS forecast is measured by the average analyst forecast issued within the six-month window prior to earnings announcement dates. $Post_{j,t}$ is a dummy variable that equals one if country *j* has adopted mandatory ESG disclosure in year *t*, and zero otherwise. β_3 is the coefficient of interest, and it captures the change in ERCs around ESG disclosure mandates. I include year and firm fixed effects, denoted as α_i, α_t, respectively. Standard errors are clustered at the firm level.

To test the effect of mandatory ESG disclosure on investment in corporate innovation, I estimate the following model using ordinary least squares (OLS):

$$y_{i,j,t} = \beta_0 + \beta_1 Post_{j,t} + \gamma Controls_{i,j,t} + \alpha_i + \alpha_t + \varepsilon_{i,j,t} \quad (2)$$

where $y_{i,j,t}$ is patent applications, proxied by the logarithm of one plus the number of adjusted forward citations by applied patents for firm *i* from country *j* in year *t*. $Post_{j,t}$ is a dummy variable that equals one if country *j* has adopted mandatory

ESG disclosure in year *t*, and zero otherwise. $Controls_{i,j,t}$ is a series of variables that are associated with innovation activities as in previous studies (Aghion et al., 2013; Amore and Bennedsen, 2016; Li et al., 2022; Mann, 2018), including revenue (*Sale*), capital-labor ratio (*K/L*), leverage (*Lev*), market valuation (*Q*), tangible assets (*Tangibility*), profitability (*ROA*), cash and cash equivalents (*Cash*), etc. I also include country-level variables to control for time-varying macroeconomic conditions that could be associated with innovation performance, including gross domestic product per capita (*GDP*), GDP growth rate (*GDPGrowth*), and economic policy uncertainty (*EPU*) (Baker et al., 2016). To further control for the time trends and time-invariant firm characteristics as well as country characteristics that could impact innovation performance, I include firm, year fixed effects, denoted as α_i, α_t, respectively. Standard errors are clustered at the firm level.

3.3. Summary Statistics

Table 1 provides summary statistics of main variables used in the empirical analyses. Refer to Appendix A for detailed variable definition. The final sample comprises 206,603 firm-year observations, from 58 unique countries. *Patent_No* represents the raw number of patents that a firm files to the USPTO in a given year. On average, each firm files around 12.479 patents, which is comparable to prior literature (Zhong, 2018). *Cit* represents the average number of forward citations for applied patents in a given year.[11] I winsorize all continuous independent and

[11] Forward citations are calculated as of December 31, 2022, the end of sample period.

control variables at 1% and 99% to reduce the influence of outliers.

(Insert Table 1 here)

4. Empirical Findings

4.1. Mandatory ESG Disclosure and Price Responsiveness

I first investigate the changes in ERCs around ESG disclosure mandates. It would be ideal to investigate the changes in price responsiveness to both ESG and financial information simultaneously. Unfortunately, it is not empirically feasible to test the changes in the ESG dimension. Without mandatory ESG disclosure, there is little ESG disclosure in the market and such disclosure is largely voluntary. Such voluntary disclosure is characterized by boilerplates and overstatements (Lyon and Montgomery, 2015). Put differently, the "greenwashing" concerns are high. Therefore, it is hard to compare investors' response around ESG disclosure mandates, as the effect can be attributed to (1) changes in ESG disclosure, (2) changes in the extent of "greenwashing", etc.

Financial information, however, provides a comparable and tractable setting. Annual financial reports are mandated before and after ESG disclosure. The information content is largely unchanged around the ESG disclosure mandates. Moreover, as certification is mandated for financial statements, the misreporting incentive (i.e., parallel to "greenwashing") is relatively small and unchanged around the shock.

I investigate this notion by testing the changes in earnings response coefficients (ERCs) around mandatory ESG disclosure. This accounting measure captures price responsiveness to financial news and has a long history (Collins and Kothari, 1989). Empirically, I estimate ERCs by regressing the market-adjusted CARs to earnings surprise (*Surprise*), which is the standardized earnings per share less most recent consensus analyst forecasts (Livnat and Mendenhall, 2006). Consensus analyst forecast is defined as the average latest analyst forecasts that are issued in the six-month window prior to earnings announcement dates. To investigate the changes of ERCs around ESG disclosure mandates, I include *Post* as in the main test and interact with *Surprise*.

(Insert Table 2 here)

Table 2 reports the empirical findings. Column (1) and (2) report the estimates where the dependent variable is the five-day and three-day market-adjusted CARs, respectively. In both Columns (1) and (2), the coefficients for *Surprise* load positively, consistent with prior studies. More importantly, the interaction term of *Post* and *Surprise* loads negatively. This suggests that following ESG disclosure mandates, the price responsiveness to financial information is reduced.

The empirical findings lend support to the predictions by Xue (2023). Specifically, when market prices incorporate both financial and ESG information, mandatory ESG disclosure decreases price responsiveness to financial information. The findings describe a specific case where the market force can backfire, in

addressing ESG transitions.

Although several disclosure papers have predicted suboptimal investment efficiency following mandatory ESG disclosure, the scenario in Xue (2023) fits this paper the most and is more generalizable. For example, in Jiang et al. (2023), they require managers to choose between a risky and risk-free project and assume that the risk-free project has higher expected payoffs (i.e., the first best investment is to choose the risk-free project). Their set-up is more relevant to fixed assets investment where empire-building is main source of agency concern (Hope and Thomas, 2008; Stein, 2003), and less so for the long-term oriented innovation, which suffers more from underinvestment problems (Holmstrom, 1989). Aghamolla and An (2021) model managers' project selection between a sustainable and a traditional project, where the former has better ESG externalities and lower financial returns. Xue (2023) is more general in the sense that managers choose an investment level, and it endogenously brings ESG externalities.

4.2. Mandatory ESG Disclosure and Corporate Innovation

Table 3 presents the results for the main hypothesis. Specifically, in Columns (1) through (3), I include no control variables, firm-level controls, and firm-level as well as country-level controls. Across all three columns, the coefficient estimates of *Post* load positively and significantly. This supports the notion that on average, mandatory adoption of ESG disclosure leads to less innovation activities. Moreover, given that the outcome variable, forward citations, capture both the quantity and

quality of innovation performance, it suggests a reduction in investment efficient in corporate innovation.

In terms of economic magnitude, following mandatory ESG disclosure, patent citations decrease by 10.6% to 15.5%, depending on specifications. For example, based on coefficient estimates in Column (3), patent citations decrease by 15.5% after a country introduces ESG disclosure mandates. This suggests that the main effect is economically meaningful.

(Insert Table 2 here)

The unique features of innovation activities underscore the implications of less innovation activities. Innovation activities are characterized by high risks and uncertainty, and suffer more from underinvestment problems (Holmstrom, 1989). This is distinct from fixed assets investment, where overinvestment and/or empire-building is a greater concern (Hope and Thomas, 2008; Stein, 2003). Therefore, the empirical findings documented in Table 2 highlight the possibility of underinvestment in innovation activities.

Given that the main test is a staggered DiD estimation, I investigate whether the shock satisfies the parallel trend assumption and investigate the dynamic effect around the mandates. In Figure 2, I plot the differences in outcome variable around the year of adoption. To do so, I replace the *Post* variable in Column (3) (i.e., full control variables) with a series of dummy variables, t_k (where k =1, 2, 3, …) and tj (where j = 0, 1, 2, 3, …), representing k (j) year before (after) the adoption of

mandatory ESG disclosure. Therefore, t0 represents the year the mandatory ESG disclosure is first introduced.

(Insert Figure 2 here)

Figure 2 shows that, in the pre-periods, the treatment and control group do not differ significantly in the outcome variable (except for t_3, whose coefficient is marginally significant with t-statistics equal to 1.69). Starting from the adoption year (i.e., t0), however, the two groups differ significantly. The pattern has two important takeaways: (1) the main analysis is largely consistent with the parallel trend assumption, and (2) the main result is immediately effective.

4.3. Heterogenous Treatment Effects due to Change in ERCs

This paper takes the stand that when stock prices incorporate ESG information, as a result of mandatory ESG disclosure, the financial performance can be worse off (Xue, 2023). Table 2 has shown that following mandatory ESG disclosure, price responsiveness to financial information decreases (i.e., smaller ERCs). This section further corroborates that the change in ERCs is the underlying mechanism for less innovation investment.

Empirically, I construct a change in ERCs in the country level and compare cross-country variation in the treatment effects. Specifically, for each country, I calculate an ERC for the pre- and post- periods, respectively, and gets the change in ERCs. To do so, I restrain the sample to countries that have observations in both

the pre- and post- periods (i.e., removing never-treated countries). I then rank the decline in ERCs by country and create an indicator variable accordingly (denoted as *I(ERC_decline)*). *I(ERC_decline)* equals one if the decline in ERC is greater than the sample median, and zero otherwise. I interact the indicator variable with *Post* and rerun equation (2).

Table 4 presents the regression results. In Table 4, the sample decreases significantly, compared to the main test in Table 3, due to the estimation of country-level change in ERCs (i.e., never-treated countries are removed). In addition, the coefficient for the standalone *I(ERC_decline)* is subsumed and thus not reported in Table 4.

(Insert Table 4 here)

In Table 4, *Post* continues to load negatively, suggesting that mandatory ESG disclosure leads to less investment in innovation activities. Moreover, the interaction term, *Post* * *I(ERC_decline)*, loads negatively and is significant at 1% level. This suggests that countries that experience a greater decline in ERCs suffer more from the reduction in innovation investments. Taken together, the empirical findings suggest that mandatory ESG disclosure leads to an unintended reduction in corporate innovation, as a result of market price being less responsive to financial information.

4.4. Patent Application Reduction and Firm Profitability

The empirical findings thus far have documented a reduction in patent application. Given that the main dependent variable of interest in Table 3 is standardized forward patent citation, a measure that reflects both the quantity and quality of patents' (Griliches et al., 1986) and has been widely used in prior studies (Cohen et al., 2022; Skinner and Valentine, 2023; Zhong, 2018). Therefore, the results can be interpreted as a reduction in efficiency in innovation activities.

To shed more light on the efficiency of innovation activities, this section moves on to test whether there is any impact on financial performance. To do so, I test the effect of mandatory ESG disclosure on corporate profitability, measured by return on assets (ROA). The empirical findings are presented in Table 5.

(Insert Table 5 here)

Table 5 shows that, the variable of interest, *Post*, loads significantly negative, suggesting a reduction in profitability. This corroborates the notion that a reduction in innovation activities are less preferrable in the sense that it affects financial performance.

4.5. Heterogenous Treatment Effects due to Disclosure Venue

This section moves on to test whether there is cross-sectional variation on the main effects. To do so, I leverage the variation in disclosure mandates in terms of

disclosure venues. Specifically, some countries require ESG disclosure in a standalone format (e.g., an ESG report. Such countries include Singapore, China, etc. The "alone" group), other countries require ESG disclosure within annual reports (e.g., France, Germany, etc. The "integrated" group). With the notion that ESG information requires substantial awareness and processing costs, I posit that only when ESG information is readily available (i.e., in annual reports) can it lead to real effects. This is analogous to the investor response in the financial setting (Blankespoor, 2018).

Empirically, I replace the *Post* variable into two dummy variables, *Post_alone* and *Post_annual*. *Post_alone* (*Post_annual*) equals one when a country has mandated ESG disclosure in a standalone format (within annual financial reports), and zero otherwise.[12] The empirical findings are presented in Table 6. Panel A and Panel B of Table 6 present findings for the heterogenous treatment effects on ERCs, measured by five-day CARs and three-day CARs, respectively. Panel C presents findings for the main test, i.e., the effect on innovation activities.

In all three panels, I include the original results (i.e., without decomposition) in the first column, to be more tractable. Column (2) estimates the effect for the "alone" group relative to the "integrated" group and other control countries. Similarly, Column (3) estimates the effect for the "integrated" group relative to the "alone" group and other control countries. Column (4) estimates the effects for the

[12] There are countries, however, require ESG disclosure in both a standalone report and in annual reports. Such countries include Norway, Spain, etc. As the focus in this section is to investigate the variation due to ESG information availability, I treat such countries as high ESG information availability (i.e., as in the "integrated" group). The empirical findings are unchanged if I: (1) remove such countries or (2) treat these countries as low information availability (i.e., as in the "alone" group).

"alone" and "integrated" group simultaneously, relative to control countries.

(Insert Table 6 here)

In Table 6 Panel A, Column (1) replicates the findings in Column (1) of Table 2. Columns (2) through (4) report findings that pin down the heterogeneity due to different disclosure venues. The empirical findings show that a reduction in ERCs is only present in countries that require mandatory ESG disclosure within annual financial reports. This highlights that information availability is an important factor for the market force to take effect. Table 6 Panel B and Panel C report similar patterns. Findings in Columns (2) through (4) again highlight that the market force takes effect only when ESG information is easily accessible.

4.6. The Role of Environmental Preferences

Given that market forces can lead to an unintended reduction in corporate innovation, what is the role of environmental preferences? When the environmental preferences are higher, investors are more likely to play a disciplinary effect on ESG issues. This section further investigates the implications for corporate innovation.

I leverage Yale's EPI environmental norms to test this notion. Empirically, I investigate the effect in subsamples that have relatively high versus low EPI index each year. I first examine the test of the underlying channel (i.e., price responsiveness to financial information) and then show the real effect (i.e.,

innovation activities).

Table 7 reports the empirical findings. In Panel A of Table 7, I show the results for changes in ERCs in high EPI countries versus low EPI countries. Panel A shows that the interaction term of *Post* and *Surprise* is only significant for countries that have relatively high EPI index. This is consistent with the notion that stronger environmental preferences bring about stronger emphasis on ESG information, relative to financial information.

Table 7 Panel B reports the results for innovation activities. The coefficients of *Post* both load significantly and negatively in the two subsamples. However, the difference between the two groups is statistically and economically significant. In countries with relatively high EPI, mandatory ESG disclosure decreases innovation activities by 20.2%, and it decreases corporate innovation by 13.7% in countries with relatively low EPI countries.

Taken together, this section documents that stronger environmental preferences lead to a more salient unintended cost in the financial dimension.

(Insert Table 7 here)

4.7. The Role of External Financing

The external financing constraint is a main driver of the underinvestment problems in innovation activities (Brown et al., 2013; Hall and Lerner, 2010). This section moves on to investigate the moderating role of external financing.

Table 8 reports the empirical findings. Panel A includes country-level

development in terms of the credit and equity markets as control variables. In Column (2) of Panel A, the coefficient of *Post* still loads significantly and negatively, albeit smaller in magnitude. This suggests that external financing alone cannot explain the main findings of decreased innovation activities.

(Insert Table 8 here)

Table 8 Panel B reports the findings of subsample analyses. Columns (1) and (2) compare the heterogeneous treatment effects in countries with relatively weak versus strong equity markets. Columns (3) and (4) compare the cross-sectional variation based on relatively weak versus strong credit markets. The results show that the negative coefficients are present only in countries with limited external financing (i.e., relatively weak equity or credit markets). Moreover, the difference is statistically significant based on 500 times permutation.

Taken together, this section shows that the availability of external financing is an important moderating factor for the main effect. The findings are also relevant for regulators in promoting mandatory ESG disclosure, especially for economies with limited external financing.

4.8. The Role of Proprietary Cost

An alternative explanation for the negative relationship between mandatory ESG disclosure and corporate innovation is proprietary cost. Specifically, mandatory ESG disclosure may induce substantial proprietary cost, particularly for

innovative firms, which is the focus of this study. An increase in proprietary cost can alter the cost-benefit trade-offs for innovation activities, and lead to a reduction in innovation. In this section, I investigate the moderating role of proprietary cost.

Following prior studies, I collect data on property rights protection from the Economic Freedom maintained by the Heritage Foundation (Li et al., 2022; Zhong, 2018). Higher (lower) the score for property rights protection, lower (higher) the proprietary cost. Table 9 reports the empirical findings. Panel A includes country-level proprietary cost as a control variable. In Column (2) of Panel A, the coefficient of *Post* still loads significantly and negatively, albeit smaller in magnitude. This suggests that proprietary cost story alone cannot explain the main findings of decreased innovation activities.

(Insert Table 9 here)

Table 9 Panel B reports the findings of subsample analyses. Columns (1) and (2) compare the heterogeneous treatment effects in countries with low versus high proprietary cost. The results show that the negative coefficients are present in both groups, and they are not significantly different, based on 500 times permutation. Taken together, this section shows that the main findings are unlikely to be driven by proprietary cost.

5. Robustness Checks and Additional Analyses

5.1. Alternative Specifications

I perform a battery of robustness checks and the empirical findings are reported in Table 10.

5.1.1. Alternative Sample Periods

I first include further restrictions in sample periods. Specifically, given that patent applications take around two years to be granted, I restrict the sample period to 2000 till 2020, to further address patent truncation issues (Dass et al., 2017). The findings are reported in Column (1). Second, I restrict the sample period to 2000 till 2017, which is essentially the GCPD patent database (see in Column (2)). The only difference comes from patents filed by U.S. firms and is only available in the WRDS U.S. patents database. If WRDS identifies certain patents filed by U.S. firms and they are not in the GCPD database, the final sample links them to U.S. firms based on WRDS datasets. The results are qualitatively similar if I restrict the patent sample to GCPD database alone. The results are qualitatively similar.

5.1.2. Alternative Dependent Variables

In Column (3), I adjust patent citations by each CPC subclass instead of by CPC class. In Column (4), I replace the dependent variable with the logarithm of one plus patent number, adjusted at the CPC class level. The inferences are

unchanged.

5.1.3. Alternative Fixed Effects Variables

In Columns (5) and (6), I include Industry * Year fixed effects and Industry * Country fixed effects to control technological shocks. The robustness and consistency across all these analyses suggest that my results cannot be explained by changes due to innovation breakthroughs.

5.1.4. Alternative Sample Firms

In Columns (7) and (8), I remove all the observations from the U.S. and from either U.S. or Japan as the two countries account for the largest number of observations. In Columns (9), I remove all the observations from never-treated countries, to alleviate concerns that changes in innovation activities from never-treated countries, instead of treated countries, are driving the main findings. In Column (10), I collapse the sample by each firm to one observation in the pre-period and one in the post-period, to alleviate concerns that having many observations from the same firms may bias DiD estimates (Bertrand et al., 2004). The main findings remain strong and consistent across all these alternative sample selection criteria.

5.1.5. Poisson Estimation with High-Dimensional Fixed Effects

Cohn et al. (2022) caution against estimating count-like outcomes with

logarithm transformation, as it lacks economic interpretation and can be severely biased. According to their suggestions, I re-estimate all the empirical analyses stated in Section 5.1, with Poisson estimation with high-dimensional fixed effects (PPMLHDFE, following Correia et al., 2020).

Panel B of Table 10 reports the findings. The main effects remain consistent across all but one specification, when the patent number is the dependent variable. Collectively, the main findings are robust.

(Insert Table 10 here)

5.2. Reconciliation with Gibbons (2023)

Gibbons (2023) has documented that environmental and social disclosure mandates lead to more institutional holdings and increased long-term investments, including patent applications. I reconcile my findings with his in this section.

First, I have shown in Table 8 that the main effect is predominantly driven by countries with limited external financing. The overall effect of ESG disclosure mandates on innovation activities depends on the relative magnitude of the external financing channel and the market force channel documented in this paper. In countries with relatively weak equity markets, the market force channel dominates.

Second, this paper focuses on a sample of innovative firms while Gibbons (2023) focuses on all firms with non-missing financial data. It is a common sample selection criterion to investigate innovation activities only in innovative firms

(Aghion et al., 2013; Geng et al., 2023; Kogan et al., 2017). Following these studies, I define innovative firms as those who have filed at least one patent in the USPTO. Innovative firms have unique financing characteristics compared to regular firms. Hall and Lerner (2010) argue that large established firms appear to prefer internal funds over equity financing, and venture capital is helpful for lowering cost of capital for small innovative firms. However, there are limits to venture capital as a solution to the funding gap, especially in countries where public equity markets for VC exit are not highly developed.

There has been an increasing attention to the role of debt financing (Hall and Lerner, 2010; Kerr and Nanda, 2015). Consistent with this notion, Nanda and Nicholas (2014) show that bank distress leads to a decrease in the number and quality of innovation, highlighting the role of bank financing in funding innovation. Mann (2018) further finds that not only debt financing is common for innovating firms, but also that patents are often used as collateral. Moreover, Griffin et al. (2022) find that R&D-active firms are more likely to choose single-lender over multi-lender, to protect their proprietary knowledge by communicating it to a single lender while disclosing generic and less sensitive information to the public. Overall, debt financing can be a vital channel of funding innovation activities, in addition to equity financing. In Table 8, the subsample analysis based on the development of credit market lends support to this notion.

Finally, the difference between this paper and Gibbons (2023) could arise from econometric estimation. Given that Gibbons (2023) covers all firms with non-missing data, including those who have never filed any patents to the patent office

(i.e., non-innovative firms), all the observations from such firms would have the outcome variables (i.e., patent applications) being zero. As Cohn et al. (2022) point out, these observations simply contain no information about regression coefficients in a model in which the fixed effects are multiplicative.

I empirically investigate the notion of economic and econometric reasons and report related findings in Table 11. I first show in Column (1) that linear estimation in the full sample (i.e., inclusive of both innovative and non-innovative firms) yields a **positive** coefficient between mandatory ESG disclosure and innovation activities. However, when I restrict a sample to include only innovative firms (Column (2)) or use Poisson estimation with high-dimensional fixed effects (Column (3)), the coefficient estimates **flip signs**.

(Insert Table 11 here)

Finally, to be more comparable with Gibbons (2023), I limit the sample period to 2000-2017, and find the patterns continue to hold. The empirical findings are reported in Columns (4) through (6). Taken together, the difference between this paper and Gibbons (2023) likely comes from both economic and econometric reasons: the unique financing characteristics of innovative firms and linear estimation of count-like dependent variables with substantial zeros outcomes both contribute to the discrepancy.

6. Conclusions

Jurisdictions around the world are proposing ESG disclosure mandates, with the aim to delegate ESG transition to large companies on behalf of shareholders. When investors value ESG information, stock prices incorporate ESG information and incentivize firms to "do good", referred to by Fama (2020) as the channel of market forces in addressing ESG issues. However, the implications of ESG disclosure mandates for corporate investment, are underexplored. This paper fills in the void by estimating the changes in innovation activities around mandatory ESG disclosure.

Using an international sample of patent applications by listed firms from 2000 to 2022, I find that mandatory ESG disclosure is associated with less corporate innovation. Specifically, patent citations decrease by 15.5% after a country introduces ESG disclosure mandates. This is a substantial unintended cost in the financial dimension.

Leveraging disclosure theories, I test and find the effect is mainly driven by countries that mandate ESG disclosure within corporate financial reports, instead of in a standalone ESG report. This suggests that only when ESG information is easily accessible (e.g., disclosed within financial reports) can it be fully incorporated into stock prices, which in turn alters managerial decisions. In terms of the underlying mechanism, I document a decrease in price responsiveness to financial information, following the staggered adoption of mandatory ESG disclosure.

Taken together, this paper documents a specific case where market forces backfire: mandatory ESG disclosure leads to an unintended cost in terms of decreased innovation activities. The findings add to related studies on the cost side of ESG disclosure (Chen et al., 2018; Rajgopal and Tantri, 2022) by pinning down a market-driven channel. The findings also caution against relying on the market forces alone in addressing ESG issues. Finally, this paper can potentially inform regulators when they set up the scope of ESG disclosure, especially for economies with relatively weak equity and credit markets.

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Appendix A. Variable Definition

Variables	Definition
Variables for Corporate Innovation	
Patent_No	= the number of patents applied by a firm in a given year. Source: PatentsView.
Cit	= the number of adjusted forward citations summed across all patents a firm receives in a given year, as of December 31, 2022. Patent citations are adjusted with the "fixed effect" approach following Hall et al. (2001). Source: PatentsView.
Post	= a dummy variable that equals one when a country has adopted mandatory ESG disclosure, and zero otherwise. Source: Krueger et al. (2023).
Sale	= Sales revenue (in million U.S dollars), *sale*. Source: Compustat.
K/L	= The ratio of capital over labor, *ppent*/*emp*. Source: Compustat.
Lev	= The ratio of total debt over total assets, (*dltt*+*dlc*)/*at*. Source: Compustat.
Q	= The ratio of (book value of total assets + market value of equity – book value of equity – deferred taxes) divided by the book value of total assets, (*at*+*mv*-*ceq*-*txdb*)/*at*, where mv represents market value and is calculated based on Compustat NA and Compustat Global by hand. Source: Compustat.
Tangibility	= The ratio of tangible assets (i.e., property, plant and equipment) over total assets, *ppent*/*at*. Source: Compustat.
ROA	= The ratio of net income over total assets, *ni*/*at*. Source: Compustat
Cash	= The ratio of cash and cash equivalents over total assets, *che*/*at*. Source: Compustat.
GDP	= Country-level gross domestic product. Source: The World Bank DataBank.
GDPGrowth	= Country-level gross domestic product growth rate. Source: The World Bank DataBank.
EPU	= Economic policy uncertainty by Baker et al. (2016). Source: https://www.policyuncertainty.com/about.html.
Variables for Earnings Response Coefficients	
CAR[-2,+2]	= Market-adjusted five-day cumulative abnormal returns around earnings announcement dates. Source: Compustat, CRSP, I/B/E/S.
CAR[-1,+1]	= Market-adjusted three-day cumulative abnormal returns around earnings announcement dates. Source: Compustat, CRSP, I/B/E/S.

Surprise	= Standardized earnings surprise, which is the actual earnings per share less consensus analyst forecast, divided by the closing stock prices on earnings announcement dates, where consensus analyst forecast is the median analyst forecasts issued within the six-month window prior to earnings announcement dates. Source: I/B/E/S.
I(ERC_decline)	= a dummy variable that equals one when a country experiences a greater decline in earnings response coefficients, and zero otherwise. Source: Compustat, I/B/E/S.

Other Variables

Post_alone	= a dummy variable that equals one when a country has mandated ESG disclosure in a standalone format, and zero otherwise. Source: Krueger et al. (2023).
Post_annual	= a dummy variable that equals one when a country has mandated ESG disclosure within annual financial reports, and zero otherwise. Source: Krueger et al. (2023).
EPI	= Environmental norms from Yale University's Environmental Performance Index (EPI). Source: https://epi.yale.edu/.
Equity Market / GDP	= Country-level equity market development, deflated by GDP. Source: The World Bank DataBank.
Credit Market / GDP	= Country-level credit market development, deflated by GDP. Source: The World Bank DataBank.
Proprietary	= Country-level proprietary cost, measured by the index for property rights protection from the Economic Freedom maintained by the Heritage Foundation. Source: https://www.heritage.org/index/pages/all-country-scores.

Figure 1. International Patent Application via USPTO PatentsView database

The figure below shows the data procedures of creating an international patent application database. The original patent application information is from PatentsView. To link each patent application to listed firms, I rely on the UVA Darden Global Corporate Patent Database (UVA-GCPD database) and WRDS U.S. patent database. With the two databases, I have created two linking tables that linked patent number and assignee (name of innovators) to S&P firm identifier (i.e., COMPUSTAT gvkey). The assignee matching is only conducted after the coverage of patent number matching (i.e., 2017 for non-U.S. firms and 2019 for U.S. firms).

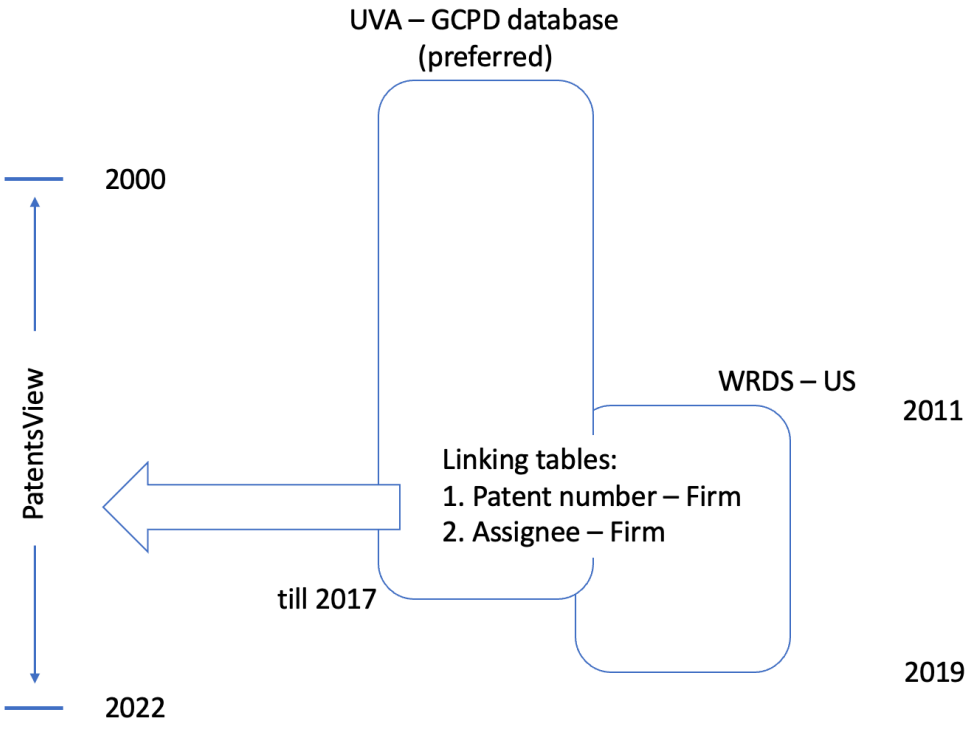

Figure 2. Dynamic Effects of Mandatory ESG Disclosure

The figure below shows dynamic changes of coefficients with respect to the year to mandatory ESG disclosure, which equals the time difference by subtracting the current year from the adoption year of mandatory ESG disclosure. t0 represents the year that introduces the mandatory ESG disclosure, while t_k represents k years prior to the ESG disclosure mandates (where k = 1, 2, 3, …), and tj represents j years after the ESG disclosure mandates (where j = 0, 1, 2, 3, …).

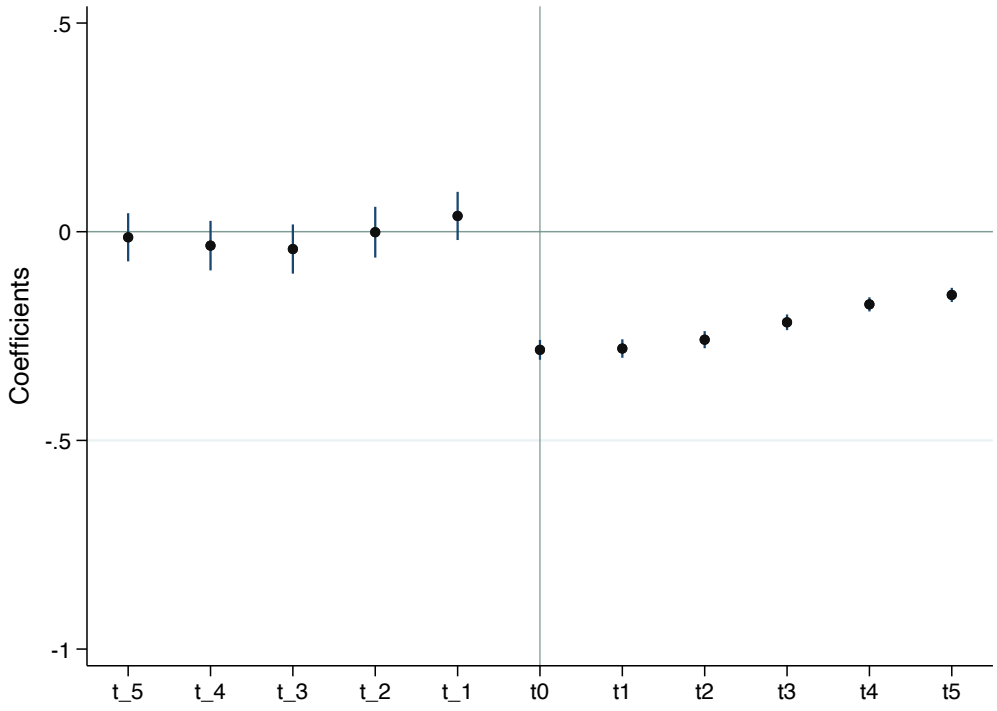

Table 1

Summary Statistics

This table contains summary statistics for the key variables used in subsequent analyses. Definitions of variables are in Appendix A.

VarName	Obs	Mean	SD	P5	P25	Median	P75	P95
Patent_No	206603	12.479	116.482	0.000	0.000	0.000	1.000	31.000
Cit	206603	97.833	1289.801	0.000	0.000	0.000	0.000	175.000
Log*(Sale)*	206603	6.666	3.318	0.265	4.505	6.776	8.892	12.112
Log*(K/L)*	206603	5.439	2.620	1.762	3.499	5.016	7.199	9.917
Lev	206603	0.229	0.291	0.000	0.029	0.170	0.327	0.618
Q	206603	2.654	17.133	0.000	0.000	0.284	1.047	4.611
Tangibility	206603	0.257	0.219	0.010	0.080	0.204	0.375	0.716
ROA	206603	-0.082	0.477	-0.621	-0.034	0.025	0.064	0.150
Cash	206603	0.207	0.215	0.006	0.052	0.133	0.285	0.704
GDP	206603	29.023	1.341	26.489	28.141	29.206	30.290	30.600
GDPGrowth	206603	2.858	3.151	-2.768	1.550	2.579	4.548	8.447
EPU	206603	0.210	0.165	0.000	0.084	0.184	0.287	0.528

Table 2

Mandatory ESG Disclosure and Price Responsiveness to Financial Information

This table reports regression results for the effect of mandatory ESG disclosure on price responsiveness to financial information. The dependent variable in Column (1) (Column(2)) is five-day (three-day) market-adjusted cumulated abnormal returns around the annual earnings announcement dates. For the main independent variables, *Surprise* is defined as the actual EPS less consensus analyst forecast, divided by the stock prices of earnings announcement dates, where consensus analyst forecast is the average analyst forecasts issued within the six-month window prior to earnings announcement dates. *Post* is a dummy variable that equals one if a country has mandated ESG disclosure, and zero otherwise. Appendix A defines all variables. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

	(1) CAR[-2,+2]	(1) CAR[-1,+1]
Surprise	0.007**	0.005**
	(2.02)	(2.06)
*Post * Surprise*	-1.291**	-0.881*
	(-2.41)	(-1.81)
Post	10.271***	7.494***
	(3.23)	(2.71)
Firm F.E.	Yes	Yes
Year F.E.	Yes	Yes
N	94968	94972
Adj. R^2	0.082	-0.009

Table 3

Mandatory ESG Disclosure and Patent Applications

This table reports regression results for the impact of mandatory ESG disclosure on patent applications. The dependent variable is the logarithm of one plus the number of citations for patent applications. The main independent variable, *Post*, is a dummy variable that equals one if a mandated disclosure policy has been introduced, and zero otherwise. Appendix A defines all variables. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

	(1)	(2)	(3)
Dpt Var =	Log(1+*Cit*)	Log(1+*Cit*)	Log(1+*Cit*)
Post	-0.124***	-0.106***	-0.155***
	(-7.12)	(-3.38)	(-4.48)
Log(*Sale*)		0.027***	0.029***
		(7.29)	(7.16)
Log(*K*/*L*)		0.009**	0.004
		(2.44)	(0.98)
Lev		-0.029**	-0.039***
		(-2.37)	(-3.07)
Q		-0.001***	-0.001***
		(-6.16)	(-3.41)
Tangibility		0.097***	0.127***
		(3.36)	(4.17)
ROA		-0.015***	-0.012**
		(-2.65)	(-2.02)
Cash		0.110***	0.150***
		(5.37)	(6.92)
GDP			0.200***
			(7.56)
GDPGrowth			-0.019***
			(-18.75)
EPU			0.145***
			(11.01)
Firm F.E.	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes
N	390372	221386	206603
Adj. R^2	0.728	0.735	0.735

Table 4

Heterogenous Treatment Effects due to Change in ERCs

This table reports regression results for the cross-sectional variation based on country-level changes in earnings response coefficients (ERCs). The dependent variable is the logarithm of one plus the number of citations for patent applications. *Post* is a dummy variable that equals one if a country has introduced mandatory ESG disclosure, and zero otherwise. *I(ERC_decline)* in Column (1) (Column (2)), is an indicator that equals one when a country (firm-year) experiences a greater decline in ERCs relative to sample medians, and zero otherwise. Appendix A defines all variables. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

	(1)	(2)
Dpt Var =	Log(1+*Cit*)	Log(1+*Cit*)
*Post * I(ERC_decline)*	-0.168**	-0.319***
	(-2.40)	(-4.99)
Post	-0.273***	-0.150***
	(-5.16)	(-3.21)
Log(Sale)	0.018***	0.018***
	(4.52)	(4.39)
Log(K/L)	-0.006*	-0.007**
	(-1.94)	(-2.00)
Lev	0.001	0.001
	(0.04)	(0.05)
Q	-0.000	-0.000
	(-1.30)	(-1.37)
Tangibility	0.072***	0.071***
	(2.59)	(2.59)
ROA	0.004	0.005
	(0.88)	(0.99)
Cash	0.039*	0.034
	(1.79)	(1.57)
GDP	0.155***	0.129***
	(4.03)	(3.20)
GDPGrowth	-0.005***	-0.005***
	(-4.64)	(-4.14)
EPU	0.041***	0.048***
	(2.83)	(3.37)
Firm F.E.	Yes	Yes
Year F.E.	Yes	Yes
N	92163	92163
Adj. R^2	0.709	0.710

Table 5

Patent Application Decrease and Firm Profitability

This table reports results for the effect of patent application decrease on firm profitability, driven by mandatory ESG disclosure. The main independent variable, *Post* is a dummy variable that equals one if a country has mandated ESG disclosure, and zero otherwise. *Size* equals the logarithm of one plus book value of assets. FCF measures free cash flows and is equal to operating income before depreciation and amortization (COMPUSTAT item: oibdp) less interest expense (COMPUSTAT item: xint) less total income taxes (COMPUSTAT item: txt) less dividend distribution (COMPUSTAT item: dvc), deflated by book value of total assets (i.e., (oibdp−xint−txt−dvc)/at). Appendix A defines all remaining variables. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

	(1)	(2)
Dpt Var =	*ROA*	*ROA*
Post	-0.033***	-0.020**
	(-4.55)	(-2.21)
Size	0.181***	0.195***
	(34.99)	(35.36)
Q	0.001	0.001**
	(0.98)	(2.23)
Lev	-0.630***	-0.625***
	(-36.13)	(-35.64)
Tangibility	0.218***	0.206***
	(7.69)	(7.06)
FCF	0.001***	0.001***
	(3.01)	(3.02)
GDP		-0.125***
		(-16.68)
GDPGrowth		0.008***
		(13.52)
EPU		-0.023***
		(-3.25)
Firm F.E.	Yes	Yes
Year F.E.	Yes	Yes
N	183368	169937
Adj. R^2	0.682	0.684

Table 6

Heterogenous Treatment Effects due to Disclosure Venue

This table reports regression results for the cross-sectional variation based on disclosure venue, i.e., mandatory ESG disclosure in in a standalone report versus in annual reports. The dependent variable is the logarithm of one plus the number of citations for patent applications. The main independent variables are *Post_alone* and *Post_annual*, where *Post_alone* (*Post_annual*), is a dummy variable that equals one if a country has introduced mandatory ESG disclosure in a standalone ESG and/or CSR report (annual reports), and zero otherwise. Appendix A defines all variables. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

Panel A: ERC based on [-2, +2] window around earnings announcements

	(1)	(2)	(3)	(4)
	CAR[-2,+2]	CAR[-2,+2]	CAR[-2,+2]	CAR[-2,+2]
Surprise	0.007**	0.002	0.005*	0.005*
	(2.02)	(1.28)	(1.74)	(1.74)
*Post * Surprise*	-1.291**			
	(-2.41)			
*Post_alone * Surprise*		37.669		-36.936
		(1.17)		(-0.40)
*Post_annual * Surprise*			-1.371**	-1.391**
			(-2.50)	(-2.49)
Post	10.271***			
	(3.23)			
Post_alone		-0.511***		0.304
		(-3.46)		(1.62)
Post_annual			23.445***	23.458***
			(3.31)	(3.31)
Firm F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
N	94968	94968	94968	94968
Adj. R^2	0.082	0.079	0.085	0.085

Panel B: ERC based on [-1, +1] window around earnings announcements

	(1)	(2)	(3)	(4)
	CAR[-1,+1]	CAR[-1,+1]	CAR[-1,+1]	CAR[-1,+1]
Surprise	0.005**	0.002*	0.004*	0.004*
	(2.06)	(1.72)	(1.87)	(1.86)
*Post * Surprise*	-0.881*			
	(-1.81)			
*Post_alone * Surprise*		31.455		-22.692
		(1.31)		(-0.33)
*Post_annual * Surprise*			-0.935*	-0.954*
			(-1.88)	(-1.88)
Post	7.494***			
	(2.71)			
Post_alone		-0.310***		0.282
		(-3.08)		(1.57)
Post_annual			17.025***	17.038***
			(2.77)	(2.77)

Firm F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
N	94972	94972	94972	94972
Adj R^2	-0.009	-0.011	-0.005	-0.005

Panel C: Change of Innovation Activities

	(1)	(2)	(3)	(4)
Dpt Var =	Log(1+*Cit*)	Log(1+*Cit*)	Log(1+*Cit*)	Log(1+*Cit*)
Post	-0.155***			
	(-4.48)			
Post_alone		-0.080*		-0.090*
		(-1.70)		(-1.90)
Post_annual			-0.207***	-0.211***
			(-4.22)	(-4.29)
Log*(Sale)*	0.029***	0.029***	0.029***	0.029***
	(7.16)	(7.19)	(7.16)	(7.15)
Log*(K/L)*	0.004	0.004	0.004	0.004
	(0.98)	(1.00)	(0.98)	(0.98)
Lev	-0.039***	-0.037***	-0.038***	-0.039***
	(-3.07)	(-2.98)	(-3.03)	(-3.07)
Q	-0.001***	-0.001***	-0.001***	-0.001***
	(-3.41)	(-3.28)	(-3.59)	(-3.52)
Tangibility	0.127***	0.129***	0.129***	0.128***
	(4.17)	(4.21)	(4.23)	(4.19)
ROA	-0.012**	-0.012**	-0.012**	-0.012**
	(-2.02)	(-2.04)	(-1.98)	(-2.00)
Cash	0.150***	0.151***	0.148***	0.149***
	(6.92)	(6.99)	(6.84)	(6.87)
GDP	0.200***	0.190***	0.179***	0.191***
	(7.56)	(7.20)	(6.73)	(7.22)
GDPGrowth	-0.019***	-0.020***	-0.019***	-0.019***
	(-18.75)	(-19.03)	(-18.62)	(-18.74)
EPU	0.145***	0.144***	0.146***	0.146***
	(11.01)	(10.88)	(11.03)	(11.04)
p-value of F-test *Post_alone* = *Post_annual*				0.002***
Firm F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
N	206603	206603	206603	206603
Adj. R^2	0.735	0.735	0.735	0.735

Table 7

Mechanism: Moderating Role of Environmental Preferences

This table reports results for the moderating effect of environmental preferences in each country. I use Yale's EPI index to capture country-level environmental preferences and conduct the analyses in subsamples that have higher-than-median / lower-than-median EPI index in each year. In Panel A, the dependent variable is three-day market-adjusted cumulated abnormal returns around the annual earnings announcement dates. For the main independent variables, *Surprise* is defined as the actual EPS less consensus analyst forecast, divided by stock prices, where consensus analyst forecast is the median analyst forecasts issued within the six-month window prior to earnings announcement dates. *Post* is a dummy variable that equals one if a country has mandated ESG disclosure, and zero otherwise. In Panel B, the dependent variable is the logarithm of one plus forward citations of patent applications. The main independent variable, *Post*, is defined the same way as in Panel A. The p-value is based on 500 times permutation for testing whether the coefficient estimates in the two subsamples are statistically different. Appendix A defines all variables. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

Panel A: cross-sectional variation of E-preference on ERC

	(1) CAR[-2,+2]	(2) CAR[-2,+2]	(3) CAR[-1,+1]	(4) CAR[-1,+1]
Surprise	0.103	0.007*	0.048	0.006*
	(0.38)	(1.67)	(0.36)	(1.75)
*Post * Surprise*	-78.337	-2.324**	-16.646	-1.743**
	(-0.95)	(-2.48)	(-0.43)	(-2.04)
Post	6.778	12.888***	2.615	10.186**
	(1.42)	(2.93)	(1.05)	(2.55)
p-value for β(1) = β(2)	0.248		0.314	
Sample	Lower E-preference based on Yale EPI index	Higher E-preference based on Yale EPI index	Lower E-preference based on Yale EPI index	Higher E-preference based on Yale EPI index
Firm F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
N	40600	52623	40600	52625
Adj R2	-0.096	0.145	-0.085	-0.004

Panel B: cross-sectional variation of E-preference on innovation activity

	(1) Log(1+*Cit*)	(2) Log(1+*Cit*)
Post	-0.137***	-0.202***
	(-2.89)	(-4.92)
p-value for β(1) = β(2)	0.036**	
Sample	Lower E-preference based on Yale EPI index	Higher E-preference based on Yale EPI index
Controls	Yes	Yes
Firm F.E.	Yes	Yes
Year F.E.	Yes	Yes
N	108884	99644
Adj R2	0.869	0.728

Table 8

Moderating Role of External Financing

This table reports results for the moderating effect of external financing. I use the World Bank credit (equity) market development index to measure accessibility to external credit (equity) market, each of which equals the portion of credit (equity) market with respect to GDP. In Panel A, the dependent variable is the logarithm of one plus forward citations of patent applications. The main independent variable, *Post* is a dummy variable that equals one if a country has mandated ESG disclosure, and zero otherwise. In Panel B, I conduct analyses based on subsamples that have higher-than-median or lower-than-median equity (credit) market development index in each year. The p-value in Panel B is based on 500 times permutation for testing whether the coefficient estimates in the two subsamples are statistically different. Appendix A defines all variables. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

Panel A: control for equity/credit market development

	(1)	(2)
Dpt Var =	Log(1+*Cit*)	Log(1+*Cit*)
Post	-0.155***	-0.139***
	(-4.48)	(-4.18)
Equity Market / GDP		-0.282***
		(-13.29)
Credit Market / GDP		0.275***
		(-10.13)
Controls	Yes	Yes
Firm F.E.	Yes	Yes
Year F.E.	Yes	Yes
N	206603	152670
Adj. R^2	0.735	0.799

Panel B: subsample analyses based on strong/weak markets

	(1)	(2)	(3)	(4)
	Log(1+*Cit*)	Log(1+*Cit*)	Log(1+*Cit*)	Log(1+*Cit*)
Post	-0.231***	-0.005	-0.327***	0.017
	(-6.00)	(-0.08)	(-9.03)	(0.14)
p-value for β(1) = β(2)	0.000***		0.000***	
Sample	weak equity market	strong equity market	weak credit market	strong credit market
Controls	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
N	73973	87423	68619	110033
Adj. R^2	0.864	0.782	0.714	0.756

Table 9

Moderating Role of Proprietary Cost

This table reports results for the moderating effect of proprietary cost. I use the property rights protection index by Economic Freedom from Heritage Foundation to proxy proprietary cost. A higher (lower) value of property rights protection index indicates smaller (larger) proprietary cost. In Panel A, the dependent variable is the logarithm of one plus forward citations of patent applications. The main independent variable, *Post* is a dummy variable that equals one if a country has mandated ESG disclosure, and zero otherwise. In Panel B, I conduct analyses based on subsamples that have higher-than-median or lower-than-median property rights protection index in each year. The p-value in Panel B is based on 500 times permutation for testing whether the coefficient estimates in the two subsamples are statistically different. Appendix A defines all variables. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

Panel A: control for proprietary cost

	(1)	(2)
Dpt Var =	Log(1+*Cit*)	Log(1+*Cit*)
Post	-0.155***	-0.072**
	(-4.48)	(-2.25)
Proprietary		0.004***
		(14.21)
Controls	Yes	Yes
Firm F.E.	Yes	Yes
Year F.E.	Yes	Yes
N	206603	206603
Adj. R^2	0.735	0.736

Panel B: subsample analyses based on proprietary cost

	(1)	(2)
Dpt Var =	Log(1+*Cit*)	Log(1+*Cit*)
Post	-0.126***	-0.102**
	(-3.09)	(-2.36)
Sample	low proprietary cost	high proprietary cost
p-value for $\beta(1) = \beta(2)$	0.176	
Controls	Yes	Yes
Firm F.E.	Yes	Yes
Year F.E.	Yes	Yes
N	76276	129578
Adj. R^2	0.843	0.760

Table 10

Robustness Checks

This table reports results for a battery of robustness checks. The main independent variable across all specifications, *Post*, is a dummy variable that equals one if a country has mandated ESG disclosure, and zero otherwise. Panel A reports regression results for linear estimation while Panel B reports the results based on Poisson estimation with high-dimensional fixed effects (using PPMLHDFE, following Cohn et al., 2022 and Correia et al., 2020). In Column (1), I restrict the sample period to address patent truncation issues (Dass et al., 2017). In Column (2), I restrict the sample period to 2000 till 2017, which matches the coverage of the GCPD patent database. In Column (3), I adjust patent citations by each CPC subclass instead of by CPC class. In Column (4), I replace the dependent variable with the logarithm of one plus patent number, adjusted at the CPC class level. In Columns (5) and (6), I include Industry * Year fixed effects, and Industry * Country fixed effects to control innovation breakthroughs. In Columns (7) and (8), I remove all the observations from the U.S. and from either U.S. or Japan as the two countries account for the largest number of observations. In Columns (9), I remove all the observations from never-treated countries, to alleviate concerns that changes in innovation activities from never-treated countries are driving the main findings. In Column (10), I collapse the sample by each firm to one observation in the pre-period and one in the post-period, to alleviate concerns that having many observations from the same firms may bias DiD estimates (Bertrand et al., 2004). Appendix A defines all variables. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

Panel A: alternative measures and specifications

Dpt Var =	(1) Log(1+*Cit*)	(2) Log(1+*Cit*)	(3) Log(1+*Cit*)	(4) Log(1+*Patent_No*)	(5) Log(1+*Cit*)	(6) Log(1+*Cit*)	(7) Log(1+*Cit*)	(8) Log(1+*Cit*)	(9) Log(1+*Cit*)	(10) Log(1+*Cit*)
Post	-0.112***	-0.079***	-0.168***	-0.187***	-0.155***	-0.084**	-0.299***	-0.326***	-0.379***	-0.470***
	(-3.76)	(-2.92)	(-4.83)	(-6.10)	(-4.46)	(-2.46)	(-8.75)	(-9.53)	(-11.34)	(-9.56)
Sample	Till 2020	Till2017	Different adjustment	Full	Full	Full	Remove USA	Remove USA & JPN	Remove never treated	Collapsed sample
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
IndxYear F.E.	No	No	No	No	No	Yes	No	No	No	No
IndxCountry F.E.	No	No	No	No	Yes	No	No	No	No	No
N	172365	128104	206603	206603	206603	206579	152396	126591	117381	1824
Adj. R^2	0.791	0.835	0.733	0.818	0.733	0.742	0.730	0.705	0.697	0.771

Panel B: alternative measures and specifications with Poisson estimator (Cohn et al., 2022; Correia et al., 2020)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)

Dpt Var =	*Cit*	*Cit*	*Cit*	*Patent_No*	*Cit*	*Cit*	*Cit*	*Cit*	*Cit*	Log(1+*Cit*)
Post	-0.400*** (-2.79)	-0.380*** (-3.03)	-0.364*** (-3.22)	-0.160* (-1.84)	-0.404*** (-2.83)	-0.420*** (-3.14)	-0.407*** (-3.02)	-0.390*** (-2.64)	-0.384*** (-2.69)	-0.774*** (-11.45)
Sample	Till 2020	Till2017	Different adjustment	Full	Full	Full	Remove USA	Remove USA & JPN	Remove never treated	Collapsed sample
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No
IndxYear F.E.	No	No	No	No	No	Yes	No	No	No	No
IndxCountry F.E.	No	No	No	No	Yes	No	No	No	No	No
N	88032	76667	91525	108350	91525	89429	43479	21996	15166	88032
Pseudo R^2	0.910	0.925	0.909	0.941	0.910	0.916	0.912	0.897	0.897	0.910

Table 11

Reconciliation with Gibbons (2023)

This table reconciles the main findings with Gibbons (2023). The main independent variable across all specifications, Post, is a dummy variable that equals one if a country has mandated ESG disclosure, and zero otherwise. In Column (1), I report the regression results when allowing non-innovative firms to enter the main sample, consistent with Gibbons (2023). In Column (2), I restrict the sample to innovative firms (i.e., same coefficient estimates as in the main test). In Column (3), I report Poisson estimates with raw count-like outcome as the dependent variable (i.e., forward citations) (Cohn et al., 2022). Columns (4) through (6) parallel the specifications in Columns (1) through (3), but is restricted to a sample ending in 2017 (inclusive), the same in Gibbons (2023). Appendix A defines all variables. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Dpt Var =	Log(1+*Cit*)	Log(1+*Cit*)	*Cit*	Log(1+*Cit*)	Log(1+*Cit*)	*Cit*
Post	0.082***	-0.155***	-0.394***	0.038***	-0.079***	-0.367***
	(8.21)	(-4.48)	(-2.77)	(3.38)	(-2.92)	(-2.94)
Sample	All firms	Innovative Firms	All firms	All firms till 2017	Innovative Firms till 2017	All firms till 2017
Estimation	OLS	OLS	Poisson	OLS	OLS	Poisson
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes
N	343155	206603	91762	239510	128104	76904
Adj. R^2	0.743	0.735	-	0.853	0.835	-
Pseudo R^2	-	-	0.910	-	-	0.925

Table A1

Alternative Investment Outcomes

This table reports results for alternative investment outcomes. Columns (1) and (2) report empirical findings for capital expenditure (*CAPEX*) and Columns (3) and (4) report findings for intangible investments (*Intang*). *CAPEX* is measured by capital expenditure (COMPUSTAT item: capx) deflated by book value of total assets. Following Geng et al. (2023), *Intang* is equal to R&D expenditure (COMPUSTAT item: xrd) plus 30% of selling, general and administrative expense (COMPUSTAT item: xsga), deflated by book value of total assets. The main independent variable, *Post* is a dummy variable that equals one if a country has mandated ESG disclosure, and zero otherwise. Appendix A defines all variables. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

	(1)	(1)	(1)	(2)
Dpt Var =	*CAPEX*	*CAPEX*	*Intang*	*Intang*
Post	-0.002*	-0.036	-0.027	-0.036
	(-1.94)	(-0.58)	(-0.60)	(-0.58)
Log(*Sale*)	0.002*	0.031**	0.032**	0.031**
	(1.84)	(1.97)	(2.17)	(1.97)
Log(*K*/*L*)	-0.001	-0.169***	-0.151***	-0.169***
	(-0.98)	(-4.82)	(-4.97)	(-4.82)
Lev	-0.014**	0.883***	0.832***	0.883***
	(-2.21)	(3.28)	(3.28)	(3.28)
Q	0.000**	-0.001	-0.000	-0.001
	(2.22)	(-1.23)	(-0.88)	(-1.23)
Tangibility	0.100***	0.554*	0.480*	0.554*
	(11.88)	(1.77)	(1.72)	(1.77)
ROA	-0.025***	-0.626***	-0.623***	-0.626***
	(-3.41)	(-5.91)	(-6.12)	(-5.91)
Cash	0.005	0.615	0.566	0.615
	(0.99)	(1.14)	(1.15)	(1.14)
GDP		0.030		0.030
		(0.32)		(0.32)
GDPGrowth		0.000		0.000
		(0.12)		(0.12)
EPU		0.179		0.179
		(1.13)		(1.13)
Firm F.E.	Yes	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes	Yes
N	215576	206603	221386	206603
Adj. R^2	0.244	0.032	0.029	0.032

Table A2

Green Patents versus Non-Green Patents

This table reports regression results for the impact of mandatory ESG disclosure on patent applications. The dependent variable is the logarithm of one plus the number of citations for green (non-green) patent applications in Panel A (Panel B). I rely on OECD guidelines to identify green versus non-green patents based on their classes, subclasses and groups, according to their corporate patent classification codes (CPC). CPC information of each patent is obtained from the PatentsView database. The main independent variable, *Post*, is a dummy variable that equals one if a mandated disclosure policy has been introduced, and zero otherwise. Appendix A defines all variables. Standard errors, reported in parentheses, are clustered at the firm level. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

Panel A: Applications for Green Patents

	(1)	(2)	(3)
Dpt Var =	Log(1+*Cit*)	Log(1+*Cit*)	Log(1+*Cit*)
Post	-0.009**	-0.009**	-0.010**
	(-2.31)	(-2.31)	(-2.48)
Controls	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes
N	206603	206603	206603
Adj. R^2	0.271	0.271	0.271

Panel B: Applications for Non-Green Patents

	(1)	(2)	(3)
Dpt Var =	Log(1+*Cit*)	Log(1+*Cit*)	Log(1+*Cit*)
Post	-0.125***	-0.125***	-0.154***
	(-3.57)	(-3.60)	(-4.46)
Controls	Yes	Yes	Yes
Firm F.E.	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes
N	206603	206603	206603
Adj. R^2	0.734	0.734	0.735