Business Environmental Innovation and Waste Recycling

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Abstract:

Waste recycling is an important means to build the circular economy and combat climate change and environmental degradation. This paper examines the impact of business environmental innovation on waste recycling at the firm level. Using a large sample of publicly listed firms from 41 countries during 2007-2022, we find that a firm's commitment to environmental innovation can help improve its waste recycling ratio. Three alternative measures of business environmental innovation are used in the analysis, and they provide consistent results. Moreover, the findings are robust to various endogeneity tests and subsample analysis.

Keywords:

Business environmental innovation, Waste recycling, Circular economy

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"Lego plans to make half the plastic in its bricks from renewable or recycled material rather than fossil fuels by 2026, in its latest effort to ensure its toys are more environmentally friendly."[2]

"Behind the scenes our committed colleagues have been testing over 600 materials in our mission to make our products more sustainable. Some materials will work, others won't – that's the nature of innovation."[3]

1. Introduction

Environmental concerns continue to grow globally. In combating climate change and environmental degradation, the importance of waste management has gradually gained attention. UNFCCC COP27 in 2022 arranged a special event, titled "Unmanaged Waste: a hidden cause of climate change", to raise public awareness about the importance of waste management. It pointed out that "failure to safely manage waste affects health, the environment and contributes to GHG emissions (black carbon aerosols may have as much as 5,000 times global warming potential of CO2)." [4] Waste is defined as the unintended by-product from the process of consumption and production (United Nation, 2024). Poor waste management can trigger climate change through the leak of adverse GHGs to the environment. Take the United States as an example, the solid waste landfill is ranked the third as a source of methane emissions, releasing 15% of annual methane emissions, equivalent to emissions of 21.6 million cars in 2019 (Clifford, 2021). Additionally, waste is one of the causes for the potential illness and the degradation of the human health, due to inhalation of emissions from incinerators and landfills, ingestion of contaminated water from landfill leachate, and consumption of food contaminated by bacteria, viruses, or persistent organic

[2] "Lego plans to make half the plastic in bricks from renewable materials by 2026", *Sarah Butler*, The Guardian, 28 August 2024

[3] https://www.lego.com/en-us/sustainability/sustainable-materials?locale=en-us Retrieved on September 04, 2024

[4] https://www.unodc.org/unodc/en/environment-climate/cop27-unmanaged-waste.html

chemicals from land spreading of emissions (Giusti, 2009). Hence, the waste management is an urgent mission of the society in this era of industrialization.

Noticing the European Union produces more than 2.2 billion tonnes of waste every year, the European Parliament decides to update its legislation on waste management to "promote a shift to a more sustainable model known as the circular economy".[5] It defines the circular economy as "a model of production and consumption, which involves sharing, leasing, reusing, repairing, refurbishing and recycling existing materials and products as long as possible." Reusing and recycling are essential means to build the circular economy. Moreover, they are part of the 3Rs of sustainable waste management framework (Reduce, Reuse, and Recycle). By recycling and reusing, businesses can cut down the volume of waste that could have ended up in landfills and incinerators, and therefore decreases pollution to the environment. Further, waste recycling can help businesses reduce their demand for raw materials and natural resources, which can reduce costs of business operations and enhance competitiveness while contribute to the ecosystem preservation and recovery (Raghupathy & Chaturvedi, 2013; Agovino et al. 2020). Moreover, the recycling process can produce a variety of new materials and opportunities for innovative design (Rahimi & García, 2017). Finally, reusing and recycling can help extend the usage of materials and products and promote sustainability (Gorman et al. 2022).

The news about Lego offers one example on how businesses can use recycled materials to help build the circular economy and shows the essential role of innovation for the recycling and reusing. In this study, we aim to examine, with a large sample of firms in the global setting, the relation between business environmental innovation and waste recycling at the firm-level.

[5] https://www.europarl.europa.eu/topics/en/article/20151201STO05603/circular-economy-definition-importance-and-benefits Retrieved on September 04, 2024

Business environmental innovation may have positive impacts on waste recycling for two reasons. First, business environmental innovation aims to develop the technological know-hows and business strategies that can stimulate sustainability in business operations. Past studies have shown that business environmental innovation can help improve companies' environmental performance, such as carbon emissions reduction (Fethi & Rahuma, 2020), renewable energy use promotion (Su, Umar, & Khan, 2021), and recycled product performance (Fernando et al. 2021). Recent study by Albitar et al. (2024) shows that in the advanced economies of G-7 countries firms with higher eco-innovation score produce less waste and recycle more. Second, waste recycling requires companies to find innovative ways and adopt innovative technologies to effectively and efficiently separate waste and put it back to the production process. Besides the example from the Lego Group illustrating the importance of innovation for recycling, past scientific studies have examined how adopting and designing innovative technologies can help specific waste get transformed to usable materials and energy for other manufacturing process. The examples include but are not limited to agro-industrial wastes (Freitas et al. 2021), glass fibres (Oliveux et al. 2012) and solid plastic waste (Ragaert et al. 2017).

Using a large sample of publicly listed firms from 41 countries around the world, we find that a firm's commitment to environmental innovation can help improve its environmental performance by increasing its waste recycling ratio. Due to the complexity of business environmental innovation, we use three alternative measures that have been developed and used in recent studies, including the overall Environment Innovation Score provided by the Refinitiv ESG, as well as Product Innovation Measure and Process Innovation Measure developed by Nadeem et al. (2020), and find consistent results. Our finding of the positive relationship between business environmental innovation and waste recycling is robust to various endogeneity tests, and holds for both developed and developing countries, environmental sensitive and non-sensitive industries, and pre- and post-COVID subperiods.

Overall, our paper contributes to the emerging literature studying waste management at firm level. Several recent papers have examined the determinants and impacts of waste management. Studies have shown that a firm's waste management is influenced by its board gender composition (Gull et al. 2023), the presence and composition of sustainability committee (Gull et al. 2024), corporate governance mechanisms (Shahab et al. 2022), audit quality (Saeed et al. 2024), climate governance quality (Ahsan et al. 2024), foreign directors (Uyar et al. 2024), and eco-innovation (Albitar et al. 2024). On the impact side, recent studies show that waste management can help improve firms' financial performance by reducing their operating costs (Gull et al. 2022) and can boost the competitiveness of firms operating in sectors related to the circular economy (Agovino et al. 2020). Compared with substantial number of published studies on greenhouse gas emissions, there is only limited amount of empirical research on waste management practices at firm level so further research is needed in this area.

More specifically, this paper is closely related to the pioneer work by Albitar et al. (2024) which explores the impact of eco-innovation on corporate waste management among firms in G7 countries during 2016-2020. Using Refinitiv eco-innovation score as the proxy for business environmental innovation, they find that firms with higher eco-innovation scores produce less waste and recycle more of the waste. Compared to their work, our study help advances the research in three aspects. First, we extend the investigation to a broader context globally, by covering 41 developed and developing countries over a much longer sample period of 2007-2022. Our findings show that the positive impact of business environmental innovation on waste recycling holds for not just more advanced economies like G7 countries but also less developed countries, and this impact works both before and after the COVID crisis. Second, besides using Refinitiv eco-innovation score, we also use the process innovation and product innovation measures constructed from the relevant raw datapoints identified by Nadeem et al. (2020) as alternative measures of business environmental innovation. This is in response a recent call by Berg et al. (2022) to explore and use verifiable raw data provided by rating agencies, instead of just relying on aggregated scores like ESG score or sub-category score like eco-innovation score. Last but more importantly, we choose to focus on waste recycling due to its importance for waste management and the circular economy, and the less conclusive finding in prior research. More specifically, Albitar et al. (2024) shows that the coefficient estimate of EIS for waste recycling is about zero despite its statistical significance, so it requires further examination on the economic significance of the impact of environmental innovation on waste recycling. Our study finds solid evidence that environmental innovation has positive impact on waste recycling.

The remainder of the paper proceeds as follows. Section 2 develops the testing hypothesis. Section 3 describes the data and empirical methodology and presents descriptive statistics. The empirical findings are presented in Section 4. Section 5 concludes the paper.

2. Hypothesis Development

The impact of business environmental innovation on waste recycling can be analyzed from two perspectives.

First, the Natural Resource-based View (NRBV) proposed by Hart (1995) has been used as the theoretical framework to analyze the relationship between business environmental innovation and environmental performance at firm level (Lee and Min, 2015), and waste recycling is an important part of environmental performance. More specifically, besides emphasizing the importance of holding unique resources that are valuable, scarce, and not easy to be imitated by competitors or substituted by others, the NRBV argues that businesses should consider the constraints and opportunities associated with the natural environment in their decision-making and aim to create a long-term sustainable competitive advantage, instead of just focusing on short-term profits at the expense of the environment. Meanwhile, it emphasizes the importance of business strategy because firms must put effort to build capabilities that can help them use the resources. As Lee and Min (2015) point out, business environmental innovation, in the framework of the NRBV, can be "viewed as the cultivation of distinctive, long-term focused green capabilities" (Page 535), so it can be regarded as an important part of business environmental strategies. Therefore, business environmental innovation can help a firm use its unique resources and achieve a sustainable competitive advantage with both environmental benefits and economic benefits. Previous studies have documented the impacts of business environmental innovation on different aspects of environmental performance, such as carbon emissions reduction (Lee and Min, 2015; Alam et al, 2019; Fethi & Rahuma, 2020; Albitar et al. 2022), renewable energy use promotion (Su et al. 2021), recycled product performance (Fernando et al. 2021) and waste management (Albitar et al. 2024). Overall, researchers have found a firm's business environmental innovation can enhance its environmental performance. Since waste recycling is part of a firm's environmental management and is important for combating climate change and building the circular economy, business environmental innovation may have positive influence on waste recycling.

Another way to analyze the relationship between business environmental innovation and waste recycling is through the technologies needed. Waste recycling requires companies to find innovative ways and modern technologies to effectively and efficiently separate waste and put it back to the production process. The innovative technologies used in waste recycling activities have been discussed in scientific papers. For example, Ragaert et al. (2017) show that innovation in mechanical and chemical recycling technologies can improve the efficiency of sorting, cleaning, and processing solid plastic waste, leading to better recycling outcome. Studying chemical recycling of glass fibre, Oliveux et al. (2012) show that the hydrolysis process can decompose the complex materials into their basic components, enabling the recycling of materials that were previously non-recyclable. Freitas et al. (2021) find that innovations in biological recycling use micro-organisms to break down organic waste, transforming it into useful products like biofuels and fertilizers. Hence, firms more engaged in business environmental innovation may be equipped with better technologies and design better production process to enhance their waste recycling ratios.

Based on these two perspectives, we develop the following hypothesis.

Hypothesis: Business environmental innovations is positively associated with waste recycling.

3. Data and Methodology

3.1 Sample

To construct the sample used for this study, we require sample firms to have available data to measure waste recycling and business environmental innovation. Annual accounting data are retrieved from the Worldscope database. Data on waste recycling and environmental innovation are retrieved from the Refinitiv ESG database[6]. Our period of study is 2007-2022. Financial firms and observations with missing data are removed from the sample. Further, we remove countries or economies with fewer than 60 observations. The final sample includes 19,277 observations of

[6] In further tests, we also consider additional control variables like board characteristics and CSR governance measures. These data also come from the Refinitiv ESG database.

3,543 firms from 41 countries/economies. The distributions of our sample by year, country/economy, and industry are reported respectively in Table 1.

[Table 1 about here]

3.2 Empirical Model

To examine the impact of corporate environmental innovation on waste recycling, we estimate the following empirical model.

$$R\_Waste_{i,t} = \alpha + \beta \times Eco\_Innovation_{i,t} + \gamma \times X_{i,t} + FEs + \epsilon_{i,t}$$

The dependent variable is the Waste Recycling Ratio ($R\_Waste_{i,t}$), defined as the total recycled and reused waste produced by a firm i divided by the total waste it produced during year t.

The main explanatory variable of interest for our study is environmental innovation. We use three alternative measures of environmental innovation that have been used in recent studies. The first measure is the Environmental Innovation Score (EIS) provided by the Refinitiv ESG database. It shows "a company's capacity to reduce the environmental costs and burdens for its customers, and thereby creating new market opportunities through new environmental technologies and processes or eco designed products" (Refinitiv, 2022). This variable has been used to examine the determinants of environmental innovation or its impacts on firms' financial or environmental performance (Arena et al. 2018, Quintana García et al. 2022; Dicuonzo et al. 2022; Fiorillo et al. 2022; Albitar et al. 2023; Albitar et al. 2024).

Recent research has documented divergence of ESG ratings, at the aggregate level and in specific sub-categories, across different rating agencies (Chatterji et al. 2016). Berg et al. (2022) conduct a thorough examination of the divergence of ESG scores among rating agencies and recommend researchers to "work with raw data that can be independently verified". (page 1343). Based on this suggestion, we also use two alternative measures of environmental innovation, product innovation (PRD_ INNV) and process innovation (PRC_ INNV), developed by Nadeem et al. (2020). Both measures are constructed from relevant data points in the Refinitiv ESG database, following the definitions of process innovation and production innovation provided by Cuerva et al. (2014) and Tseng et al. (2013).

Process innovation (PRC_ INNV) measures the efforts of a firm to adopt environmental technologies that promote the sustainable use of natural resources and energy efficiency, while motivating the reduction and recycling of waste and other emissions. Hence, Nadeem et al. (2020) suggests the measure of process innovation (PRC_ INNV) by aggregating six indicators, including Energy Efficiency Targets, Water Efficiency Targets, Eco-Design Products, Emissions Reduction Policy, Resource Reduction Policy, and Waste Management Initiatives. Product innovation (PRD_INNV) measures a firm's willingness to design and produce ecological products and commit to products' environment management system. Nadeem et al. (2020) suggests the measure of product innovation (PRD_INNV) by aggregating five indicators, including Product Environmental Responsible Use, Sustainable Building Products, Organic Products Initiatives, Product Access Low Price, and Product Responsibility Monitoring. Those indicators are binary variables, which are assigned the value of 1 if companies have disclosed the required information, and 0 otherwise. Therefore, the PRC_ INNV is the equal sum of six indicators and is scored 0 (no disclosure for any indicator) to 6 (disclose all indicators). Similarly, the PRD_INNV is the equal sum of five indicators, which is scored 0 (no disclosure for any indicator) to 5 (disclose all indicators). These two measures have been used in several recent studies (Iqbal et al. 2022; Nadeem et al. 2021).

Further, we follow Alam et al. (2019) and Lee and Min, (2015) to include financial characteristics such as firm size (Size), financial leverage (Leverage), profitability (ROA), market-to-book ratio (MTB), and capital expenditure (CapEx/Sales) as control variables in the regression.

Variable definitions are provided in Appendix 1. All the financial characteristics are winsorized at the 1st and 99th percentiles to mitigate the potential impacts of outliers. Industry, year, and country fixed effects are included in all regressions, and standard errors are clustered at firm level.

4. Empirical Results

4.1 Description Statistics

[Table 2 about here]

Summary statistics and pairwise correlations of the variables used in our regression analysis are reported in Table 2. The mean value of waste recycling ratio is 0.618 and its median is 0.693. The summary statistics of three measures of environmental innovation show that business engagement in environmental innovation varies across firms. Panel B of Table 2 reports the correlation matrix. The three alternative measures of business environmental innovation are positively correlated with statistical significance at 1% level. EIS is positively correlated with both PRD_INNV (0.340) and PRC_INNV (0.610), while the correlation coefficient between PRD_INNV and PRC_INNV is 0.354. These findings show some levels of overlap among these three measures of business environmental innovation, but they also indicate that the extent of the overlap is limited, suggesting that they reflect different aspects of a firm's environmental innovation. More importantly, the correlation coefficients between waste recycling ratio and environmental innovation measures are all positive and statistically significant, indicating that firms with more engagement into environmental innovation tend to have higher portion of total waste being recycled or reused.

4.2 Baseline Regression Results

[Table 3 about here]

Table 3 presents the main results of our regression model that analyzes the impact of business environmental innovation on waste recycling. The dependent variable is waste recycling ratio. We use each of three alternative measures of business environmental innovation, Environmental Innovation Score (EIS), product innovation (PRD_ INNV) and process innovation (PRC_ INNV), in the regression model and report their results in three columns, respectively. Country, year and industry fixed effects are included in the regressions, and standard errors are clustered at firm level.

The coefficient estimates on alternative measures of environmental innovation are all positive, 0.083 for EIS, 0.020 for PRC_INNV, and 0.022 for PRD_INNV in respective regressions, and are all statistically significant at 1% level. In terms of economic significance, an increase in EIS by one sample standard deviation (reported in Table 2 Panel A) can add another 2.70% increase in waste recycling ratio (0.325×0.083=2.70%). Similarly, an increase in PRC_INNV by one sample standard deviation can add another 2.30% increase in waste recycling ratio (1.151 ×0.020=2.30%), and an increase in PRD_INNV by one sample standard deviation can add another 2.02% increase in waste recycling ratio (0.916 ×0.022=2.02%). These indicate that firms with stronger commitment to environmental innovation tend to have higher portion of total wastes recycled or reused.

Meanwhile, coefficient estimates of ROA and MTB are positive and statistically significant, indicating that more profitable firms and firms with more growth opportunities would have higher portion of their total wastes recycled or reused. The coefficient estimate of CapEx/Sales is negative and statistically significant, indicating that firms with more investment in fixed assets, as measured by higher capital expenditure to sales ratio, would engage less in waste recycling as they have lower portion of their total wastes recycled or reused.

4.3 Identification

4.3.1 Additional Control Variables

[Table 4 about here]

To mitigate the endogeneity concern related to omitted variables, we include several additional control variables into the regression. Following existing studies (Gull et al. 2023; Gull et al. 2024), we include CSR compensation, CSR committee, board size (BDsize), board independence (BDIndep), CEO-chair duality (Separate) and board gender diversity (BDdiversity). We present the regression results in Table 4. Even after controlling for these additional controls, the relationship between business environmental innovation and waste recycling remains positive and statistically significant at 1% level.

4.3.2 Lagged Explanatory Variable

[Table 5 about here]

Our baseline analysis is based on a contemporaneous regression. One concern is that the findings may capture the correlation instead of causation. Another concern is the waste data may suffer from some reporting delay. To address these concerns, we follow Alam et al. (2019), Shahab et al. (2022) to use the lagged explanatory variable approach by using the lagged measures of business environmental innovation in the regression model. The results reported in Table 5 reaffirm the strong relationship between business environmental innovation and waste recycling.

4.3.3 Two-stage Least-squares(2SLS) Regression

[Table 6 about here]

In this section, we use the instrumental variable approach to address the concern of reverse causality that waste recycling may affect business environmental innovation. For a given measure of business environmental innovation, we follow Shahab et al. (2022) and Gull et al. (2024) to use its industry average and one-year lagged value as the instrumental variables (IVs) in the first stage estimations. A firm is motivated to engage in environmental innovation when it sees its peers in the same industry are improving their eco-innovation and a firm's commitment to environmental innovation in the prior year can affect its engagement this year as well. For example, in the 2SLS analysis for using the Environmental Innovation Score as the measure of business environmental innovation, the IVs are the industry average Environmental Innovation Score (IndAverage(EIS)) and one-year lagged value of EIS (lag_EIS). The results of first stage estimation are reported in Column (1) of Table 6 and it shows that a firm's lagged EIS and industry-average EIS have significant impacts on its EIS. Using fitted EIS from the first stage regression as the explanatory variable in the second stage regression, the results reported in Column 2 shows that business environmental innovation as measured by EIS has positive impacts on waste recycling, consistent with the findings in our baseline regressions.

Overall, Table 6 reports the results from both stages of three sets of 2SLS analysis for the three alternative proxies of business environmental innovations used in our study. The second-stage regressions results show that coefficient estimates for all three alternative measures of the environmental innovation are positive and statistically significant at 1% level, consistent with the baseline results. The Kleibergen-Paap (2006) rk LM statistics for underidentification test are highly significant. The Craggg-Donald F-statistic for weak identification tests are much higher than the Stock-Yogo critical value.

4.4 Additional Analysis

The findings in previous sections are based on the full sample. In this section, we consider several additional subsample analyses to further test the robustness of our findings.

[Table 7 about here]

4.4.1 G7 vs. Non-G7 countries

Albitar et al. (2024) examine the impact in G7 countries because they represent more advanced economy and emphasize waste management more. As waste management should be a global endeavour to combat climate change, it would be interesting to check whether environmental innovation can help improve waste recycling in less developed countries. Therefore, we run the regressions for subsamples of firms from developed countries (G7 countries) and less developed countries (non-G7 countries) and report the results in Table 7 Panel A. The findings on the relationship between business environmental innovation and waste recycling are positive and statistically significant in both subsamples, like our baseline findings reported earlier. In both developed countries and less developed countries, firms more engaged in environmental innovation tend to have higher part of waste recycled or reused.

4.4.2 Pre and Post COVID subperiods

Further, the COVID-19 crisis has escalated public attentions and concerns to waste management due to the significant increase in waste from workplace and household, especially due to the use of various single-use plastics for safety measures. It has triggered more discussion to modernize waste management policies and infrastructure and attract more investment in waste management (Forlani and Njie, 2022; Jayasinghe et al. 2023). To explore whether the impact of environmental innovation on waste recycling has been changed by the COVID-19 crisis, we divide the sample into pre-COVID and post-COVID subsamples, the later includes observations in 2020, 2021 and 2022. We conduct the regression analysis for two subsamples and report the results in Table 7 Panel B. The positive relationship between environmental innovation and waste recycling holds in both pre-COVID subperiod and post-COVID subperiod. In both subperiods, firms more engaged in environmental innovation tend to have higher portion of waste recycled or reused.

4.4.3 Environmentally Sensitive vs. Non-sensitive Sectors

We further examine whether the impact of business environmental innovation on waste recycling varies across industries, because firms operating in industries that are more sensitive to environmental concerns tend to face more oversight from various stakeholders. We follow Nadeem et al. (2020) and Gull et al. (2022) to consider the agricultural, chemical, construction, fishing, forestry, metal, mining, and petroleum industries as environmentally sensitive industries, and the rest as environmental non-sensitive industries. We conduct the regression analysis for two subsamples and report the results in Table 7 Panel C. The positive relationship between environmental innovation and waste recycling holds in both environmental sensitive industries and environmental non-sensitive industries. In both subsamples, firms more engaged in environmental innovation tend to have higher portion of waste recycled or reused.

5. Conclusion

Waste recycling and using, as part of the sustainable waste management framework, plays a vital role in building the circular economy to combat climate change and environmental degradation. In this paper, we examine the impact of business environmental innovation on waste recycling activities by firms in a global setting. Using a large sample of publicly listed firms from 41 countries, we find clear evidence that a firm's commitment to environmental innovation can help increase its waste recycling ratio. We find strong and consistent results by using alternative measures of business environmental innovation. Our findings are robust to various endogeneity tests and hold for different subsamples.

Examining the impacts of business environmental innovation on waste recycling has important policy implications. In recent years, policymakers, researchers and various organizations have called for the transition from the traditional linear model of economic activity to the circular economy. While the traditional model of economic activity transforms raw materials into products and generate waste, the new model of circular economy requires innovative designs and practices throughout the entire production and consumption process in the economy to extend the life cycle of existing materials and products (Sehnem et al. 2021). By reusing and recycling, businesses can bring materials that could have ended up as waste back into the production process, which helps cut down waste and pollution, reduce the demand for new materials and natural resources, and promote overall sustainability. It requires businesses to find innovate ways to redesign their production and adopt proper technologies to achieve better waste reusing and recycling. The empirical evidence from our paper shows the importance of business environmental innovation to help achieve higher waste recycling which contributes to the circular economy.

We acknowledge several limitations of our study and believe that these will be the areas for future research. We only examine the impact of business environmental innovation on waste recycling due to its importance for the circular economy and the less conclusive finding in prior research. Future research can consider examining the impact of business environmental innovation on other aspects of waste management in both developed and less developed countries. Moreover, it may be interesting to examine whether country-level factors like national culture and economic development or other firm-level factors may moderate the relationship between business environmental innovation and waste recycling.

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Appendix 1. Variable definitions

R_Waste	Waste Recycling Ratio (R_Waste) is defined as the total recycled and reused waste produced by a firm divided by the total waste it produced during year t
EIS	Environmental innovation score (EIS) is defined as the Environmental innovation score scaled by 100
PRC_INNV	Process innovation score (PRC_ INNV) is aggregated from six indicators, including Energy Efficiency Targets, Water Efficiency Targets, Eco-Design Products, Emissions Reduction Policy, Resource Reduction Policy, and Waste Management Initiatives.
PRD INNV	Product innovation score (PRD_INNV) is aggregated from five indicators, including Product Environmental Responsible Use, Sustainable Building Products, Organic Products Initiatives, Product Access Low Price, and Product Responsibility Monitoring.
Size	Natural logarithm of total assets in U.S. dollars
Leverage	Ratio of total debt to total assets
ROA	Net income scaled by total assets
MTB	Market-to-book ratio
CapEx/Sales	Capital expenditure scaled by total sales

Table 1: Sample Distribution

This table presents the sample distribution by year (Panel A), industries (Panel B), country/economy (Panel C).

Panel A: Sample distribution by year

	Freq.	Percent
2007	305	1.58
2008	488	2.53
2009	573	2.97
2010	687	3.56
2011	759	3.94
2012	823	4.27
2013	883	4.58
2014	946	4.91
2015	997	5.17
2016	1088	5.64
2017	1235	6.41
2018	1506	7.81
2019	1774	9.20
2020	2092	10.85
2021	2428	12.60
2022	2693	13.97
Total	19277	100.00

Panel B: Sample distribution by the Fama-French 12 industries

Fama-French industry code (12 industries)	Freq.	Percent
Consumer Non-Durables	1734	9.00
Consumer Durables	934	4.85
Manufacturing	3648	18.92
Energy	903	4.68
Chemicals	1517	7.87
Business Equipment	2499	12.96
Telecommunication	626	3.25
Utilities	1352	7.01
Wholesale and Retail	1549	8.04
Healthcare	1227	6.37
Other	3288	17.06
Total	19277	100.00

Panel C: Sample distribution by country/economy

	Freq.	Percent
Argentina	93	0.48
Australia	535	2.78
Austria	90	0.47
Belgium	155	0.80
Brazil	507	2.63
Canada	662	3.43
Chile	148	0.77
China	362	1.88
Colombia	93	0.48
Denmark	176	0.91
Finland	366	1.90
France	799	4.14
Germany	685	3.55
Greece	75	0.39
Hong Kong	366	1.90
India	502	2.60
Indonesia	114	0.59
Ireland	62	0.32
Italy	524	2.72
Japan	2947	15.29
Malaysia	279	1.45
Mexico	181	0.94
Netherlands	267	1.39
New Zealand	65	0.34
Norway	187	0.97
Peru	67	0.35
Philippines	82	0.43
Poland	113	0.59
Portugal	110	0.57
Russia	200	1.04
Singapore	176	0.91
South Africa	345	1.79
South Korea	747	3.88
Spain	318	1.65
Sweden	410	2.13
Switzerland	449	2.33
Taiwan	815	4.23
Thailand	346	1.79
Turkey	283	1.47
United Kingdom	1334	6.92
United States	3242	16.82
Total	19277	100.00

Table 2: Summary Statistics

This table presents the summary statistics of variables used in this study (Panel A) and their pairwise correlations (Panel B). Levels of statistical significance are presented as follows: *** p<0.01, ** p<0.05, * p<0.1

Panel A: Summary Statistics

	N	Mean	Median	SD	Min	p25	p75	Max
R Waste	19277	.618	0.693	.309	0	.385	.889	1
EIS	19277	.402	0.397	.325	0	0	.684	.999
PRC INNV	19277	3.909	4.000	1.151	0	3	5	6
PRD INNV	19277	1.239	1.000	.916	0	1	2	5
Size	19277	15.728	15.736	1.477	12.104	14.761	16.725	19.13
Leverage	19277	.269	0.258	.163	0	.15	.371	.721
ROA	19277	.048	0.043	.068	-.198	.017	.078	.264
MTB	19277	1.756	1.323	1.256	.634	1.038	1.943	8.21
CapEx/Sales	19277	.084	0.048	.102	.002	.027	.097	.598

Panel B: Pairwise Correlations

	R_Waste	EIS	PRC_INNV	PRD_INNV	Size	Leverage	ROA	MTB	CapEx/Sales
R_Waste	1.000								
EIS	0.218***	1.000							
PRC_INNV	0.157***	0.340***	1.000						
PRD_INNV	0.171***	0.610***	0.354***	1.000					
Size	0.039***	0.290***	0.278***	0.305***	1.000				
Leverage	-0.050***	0.021***	0.019***	0.006	0.205***	1.000			
ROA	0.045***	-0.036***	0.037***	0.024***	-0.075***	-0.279***	1.000		
MTB	0.026***	-0.095***	-0.027***	-0.011	-0.224***	-0.146***	0.498***	1.000	
CapEx/Sales	-0.189***	-0.122***	-0.070***	-0.141***	0.089***	0.158***	-0.105***	-0.068***	1.000

Table 3: Baseline Regressions

	(1)	(2)	(3)
EIS	0.083***		
	[0.015]		
PRC_INNV		0.020***	
		[0.004]	
PRD_INNV			0.022***
			[0.005]
Size	0.005	0.005	0.006
	[0.004]	[0.004]	[0.004]
Leverage	0.037	0.034	0.038
	[0.030]	[0.030]	[0.030]
ROA	0.148**	0.136**	0.146**
	[0.060]	[0.060]	[0.060]
MTB	0.011***	0.011***	0.010***
	[0.004]	[0.004]	[0.004]
CapEx/Sales	-0.168***	-0.192***	-0.174***
	[0.047]	[0.047]	[0.047]
Constant	0.485***	0.450***	0.475***
	[0.057]	[0.057]	[0.057]
Country FE	YES	YES	YES
Year FE	YES	YES	YES
Industry FE	YES	YES	YES
Adj R-squared	0.253	0.252	0.250
Observations	19,277	19,277	19,277

This table reports the coefficient estimates of regressions used to examine the relationship between business environmental innovation and waste recycling. The dependent variable is the Waste Recycling Ratio (R_Waste). Columns (1) to (3) are the regression results with each of the three different proxies for business environmental innovation as the key explanatory variable, along with control variables. Year fixed effects, Industry fixed effects, Country fixed effects are included in all regressions. Variable definitions are provided in Appendix 1. Standard errors are clustered at firm level. Robust standard errors are reported in brackets. Levels of statistical significance are presented as follows: *** p<0.01, ** p<0.05, * p<0.1.

Table 4: Additional Control Variables

	(1)	(2)	(3)
EIS	0.084***		
	[0.015]		
PRC_INNV		0.022***	
		[0.004]	
PRD_INNV			0.022***
			[0.005]
Size	0.002	0.002	0.003
	[0.004]	[0.004]	[0.004]
Leverage	0.033	0.030	0.034
	[0.029]	[0.029]	[0.030]
ROA	0.157***	0.144**	0.155**
	[0.061]	[0.060]	[0.060]
MTB	0.011***	0.011***	0.010***
	[0.004]	[0.004]	[0.004]
CapEx/Sales	-0.158***	-0.183***	-0.165***
	[0.047]	[0.048]	[0.048]
CSRCompensation	-0.002	-0.003	-0.003
	[0.008]	[0.008]	[0.008]
CSRCommittee	-0.019*	-0.027**	-0.020*
	[0.010]	[0.011]	[0.011]
BDsize	0.054***	0.056***	0.054***
	[0.019]	[0.019]	[0.019]
BDIndep	-0.022	-0.023	-0.024
	[0.025]	[0.025]	[0.025]
Seperate	0.004	0.004	0.003
	[0.009]	[0.009]	[0.009]
BDdiversity	0.062	0.068*	0.063
	[0.039]	[0.039]	[0.040]
Constant	0.412***	0.372***	0.402***
	[0.060]	[0.059]	[0.060]
Observations	18,687	18,687	18,687
Country FE	YES	YES	YES
Year FE	YES	YES	YES
Industry FE	YES	YES	YES
Adj R-squared	0.252	0.251	0.250

This table reports the coefficient estimates of regressions used to examine the relationship between business environmental innovation and waste recycling with additional control variables. The dependent variable is the Waste Recycling Ratio (R_Waste). Columns (1) to (3) are the regression results with each of the three different proxies for business environmental innovation as the key explanatory variable, along with control variables. Year fixed effects, Industry fixed effects, Country fixed effects are included in all regressions. Variable definitions are provided in Appendix 1. Standard errors are clustered at firm level. Robust standard errors are reported in brackets. Levels of statistical significance are presented as follows: *** p<0.01, ** p<0.05, * p<0.1.

Table 5: Lagged Explanatory Variable

	(1)	(2)	(3)
lag_EIS	0.082***		
	[0.015]		
lag_PRC_INN		0.021***	
		[0.003]	
lag_PRD_INN			0.021***
			[0.005]
Size	0.003	0.002	0.004
	[0.004]	[0.004]	[0.004]
Leverage	0.040	0.036	0.041
	[0.031]	[0.031]	[0.031]
ROA	0.185***	0.168***	0.181***
	[0.062]	[0.062]	[0.062]
MTB	0.008*	0.008**	0.008*
	[0.004]	[0.004]	[0.004]
CapEx/Sales	-0.170***	-0.193***	-0.176***
	[0.049]	[0.049]	[0.049]
Constant	0.517***	0.498***	0.507***
	[0.061]	[0.060]	[0.061]
Observations	18,221	18,222	18,199
Country FE	YES	YES	YES
Year FE	YES	YES	YES
Industry FE	YES	YES	YES
Adj R-squared	0.260	0.261	0.257

This table reports the coefficient estimates of regressions used to examine the relationship between business environmental innovation and waste recycling with lagged explanatory variables. The dependent variable is the Waste Recycling Ratio (R_Waste). Columns (1) to (3) are the regression results with each of the three lagged proxies for business environmental innovation as the key explanatory variable, along with control variables. Year fixed effects, Industry fixed effects, Country fixed effects are included in all regressions. Variable definitions are provided in Appendix 1. Standard errors are clustered at firm level. Robust standard errors are reported in brackets. Levels of statistical significance are presented as follows: *** p<0.01, ** p<0.05, * p<0.1.

Table 6: 2SLS regression estimates

	(1) 1st-stage EIS	(2) 2nd-stage R_Waste	(3) 1st-stage PRC_INNV	(4) 2nd-stage R_Waste	(5) 1st-stage PRD_INNV	(6) 2nd-stage R_Waste
EIS		0.104*** (0.017)				
PRC_INNV				0.031*** (0.004)		
PRD_INNV						0.027*** (0.006)
Size	0.005*** (0.001)	0.002 (0.004)	0.029*** (0.005)	0.000 (0.004)	0.014*** (0.003)	0.003 (0.004)
Leverage	0.001 (0.007)	0.040 (0.031)	0.032 (0.037)	0.036 (0.031)	-0.000 (0.020)	0.042 (0.031)
ROA	0.025 (0.018)	0.182*** (0.062)	0.109 (0.093)	0.163*** (0.062)	0.040 (0.051)	0.180*** (0.062)
MTB	-0.002 (0.001)	0.008** (0.004)	-0.000 (0.006)	0.008** (0.004)	0.001 (0.003)	0.007* (0.004)
CapEx/Sales	-0.026** (0.011)	-0.161*** (0.049)	-0.014 (0.054)	-0.192*** (0.049)	-0.106*** (0.029)	-0.169*** (0.049)
IndAverage(EIS)	0.190*** (0.012)					
lag_EIS	0.849*** (0.005)					
IndAverage(PRC_INNV)			0.318*** (0.019)			
lag_PRC_INNV			0.724*** (0.006)			
IndAverage(PRD_INNV)					0.185*** (0.012)	
lag_PRD_INNV					0.866*** (0.005)	
Constant	0.058* (0.031)	0.362*** (0.084)	0.301** (0.136)	0.310*** (0.084)	0.245*** (0.080)	0.340*** (0.085)
N	18221	18221	18222	18222	18199	18199
Country FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Adj R-squared		0.260		0.258		0.257

Underidentification test:			
Kleibergen-Paap rk LM-stat	1034.144	891.465	813.835
P-value (LM-Stat)	0.000	0.000	0.000
Weak identification test:			
Cragg-Donald F-stat	22,534.715	8181.653	21,741.687
Stock-Yogo critical value	19.93	19.93	19.93

This table reports the results of two-stage least-squares estimations of the impact of business environmental innovation on waste recycling. For each measure of business environmental innovation, we use the industry average and one-year lagged value as the instrumental variables. Year fixed effects, Industry fixed effects, Country fixed effects are included in all regressions. Variable definitions are provided in Appendix 1. Standard errors are clustered at firm level. Robust standard errors are reported in brackets. Levels of statistical significance are presented as follows: *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

Table 7: Additional Analysis

Panel A: G7 vs. non-G7 Countries

	(1) G7 countries	(2) G7 countries	(3) G7 countries	(4) non-G7 countries	(5) non-G7 countries	(6) non-G7 countries
EIS	0.105***			0.064***		
	[0.020]			[0.022]		
PRC_INNV		0.018***			0.022***	
		[0.005]			[0.005]	
PRD_INNV			0.029***			0.015*
			[0.007]			[0.008]
Size	-0.002	-0.000	-0.002	0.012**	0.009*	0.013**
	[0.005]	[0.005]	[0.005]	[0.006]	[0.006]	[0.006]
Leverage	0.051	0.047	0.054	0.023	0.020	0.023
	[0.040]	[0.040]	[0.040]	[0.044]	[0.044]	[0.044]
ROA	0.189**	0.176**	0.183**	0.073	0.064	0.073
	[0.077]	[0.078]	[0.077]	[0.094]	[0.092]	[0.093]
MTB	0.003	0.003	0.002	0.019***	0.018***	0.018***
	[0.006]	[0.006]	[0.006]	[0.005]	[0.005]	[0.005]
CapEx/Sales	-0.277***	-0.324***	-0.293***	-0.071	-0.084	-0.073
	[0.076]	[0.078]	[0.077]	[0.058]	[0.058]	[0.058]
Constant	0.636***	0.581***	0.635***	0.340***	0.323***	0.325***
	[0.079]	[0.078]	[0.079]	[0.083]	[0.082]	[0.083]
Observations	10,193	10,193	10,193	9,084	9,084	9,084
Country FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Adj R-squared	0.297	0.291	0.294	0.210	0.212	0.208

This table reports the coefficient estimates of regressions used to examine the relationship between business environmental innovation and waste recycling for subsamples of firms from developed countries (G7 countries, Columns (1) to (3)) and less developed countries (non-G7 countries, Columns (4) to (6)). The dependent variable is the Waste Recycling Ratio (R_Waste). Year fixed effects, Industry fixed effects, Country fixed effects are included in all regressions. Variable definitions are provided in Appendix 1. Standard errors are clustered at firm level. Robust standard errors are reported in brackets. Levels of statistical significance are presented as follows: *** p<0.01, ** p<0.05, * p<0.1

Panel B: Pre-COVID vs. Post-COVID Subperiods

	(1) Pre-COVID	(2) Pre-COVID	(3) Pre-COVID	(4) Post-COVID	(5) Post-COVID	(6) Post-COVID
EIS	0.087***			0.074***		
	[0.017]			[0.018]		
PRC_INNV		0.021***			0.018***	
		[0.004]			[0.005]	
PRD_INNV			0.024***			0.017***
			[0.006]			[0.006]
Size	0.004	0.003	0.005	0.008**	0.009**	0.010**
	[0.005]	[0.005]	[0.005]	[0.004]	[0.004]	[0.004]
Leverage	0.046	0.043	0.048	0.018	0.015	0.019
	[0.038]	[0.038]	[0.038]	[0.033]	[0.033]	[0.033]
ROA	0.291***	0.271***	0.283***	0.017	0.014	0.023
	[0.080]	[0.079]	[0.080]	[0.074]	[0.074]	[0.073]
MTB	0.007	0.008	0.006	0.014***	0.014***	0.014***
	[0.007]	[0.007]	[0.007]	[0.004]	[0.004]	[0.004]
CapEx/Sales	-0.221***	-0.249***	-0.229***	-0.096*	-0.115**	-0.100*
	[0.061]	[0.061]	[0.061]	[0.054]	[0.055]	[0.055]
Constant	0.504***	0.477***	0.497***	0.427***	0.383***	0.413***
	[0.076]	[0.075]	[0.076]	[0.060]	[0.059]	[0.060]
Observations	12,064	12,064	12,064	7,213	7,213	7,213
Country FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Adj R-squared	0.290	0.289	0.288	0.212	0.211	0.210

This table reports the coefficient estimates of regressions used to examine the relationship between business environmental innovation and waste recycling for pre-COVID subperiod (Columns (1) to (3)) and post-COVID subperiod . The dependent variable is the Waste Recycling Ratio (R_Waste). Columns (1) to (3) are the regression results with each of the three different proxies for business environmental innovation as the key explanatory variable, along with control variables for pre-COVID Subperiods. Columns (4) to (5) are the regression results with each of the three different proxies for business environmental innovation as the key explanatory variable, along with control variables for post-COVID Subperiods. Year fixed effects, Industry fixed effects, Country fixed effects are included in all regressions. Variable definitions are provided in Appendix 1. Standard errors are clustered at firm level. Robust standard errors are reported in brackets. Levels of statistical significance are presented as follows: *** p<0.01, ** p<0.05, * p<0.1

Panel C: Environmental sensitive industries vs. Environmental non-sensitive industries

	(1) Environmental sensitive industries	(2) Environmental sensitive industries	(3) Environmental sensitive industries	(4) Environmental non-sensitive industries	(5) Environmental non-sensitive industries	(6) Environmental non-sensitive industries
EIS	0.059***			0.073***		
	[0.022]			[0.017]		
PRC_INNV		0.019***			0.020***	
		[0.005]			[0.004]	
PRD_INNV			0.021***			0.017***
			[0.008]			[0.006]
Size	0.003	0.000	0.002	0.009**	0.009**	0.011**
	[0.005]	[0.005]	[0.005]	[0.005]	[0.005]	[0.005]
Leverage	0.073	0.069	0.078*	-0.077**	-0.085**	-0.081**
	[0.045]	[0.046]	[0.045]	[0.036]	[0.036]	[0.036]
ROA	0.062	0.054	0.063	0.237***	0.232***	0.239***
	[0.079]	[0.079]	[0.079]	[0.079]	[0.078]	[0.079]
MTB	0.020***	0.020***	0.020***	0.002	0.002	0.002
	[0.006]	[0.006]	[0.006]	[0.005]	[0.004]	[0.005]
CapEx/Sales	-0.100*	-0.115*	-0.099*	-0.020	-0.033	-0.026
	[0.060]	[0.060]	[0.060]	[0.069]	[0.070]	[0.070]
Constant	0.461***	0.451***	0.475***	0.487***	0.448***	0.465***
	[0.085]	[0.084]	[0.085]	[0.069]	[0.068]	[0.069]
Observations	9,068	9,068	9,068	10,209	10,209	10,209
Country FE	YES	YES	YES	YES	YES	YES
Year FE	YES	YES	YES	YES	YES	YES
Industry FE	YES	YES	YES	YES	YES	YES
Adj R-squared	0.319	0.320	0.319	0.253	0.253	0.250

This table reports the coefficient estimates of regressions used to examine the relationship between business environmental innovation and waste recycling for environmental sensitive industries (Columns (1) to (3)) and environmental non-sensitive industries (Columns (4) to (6)). The dependent variable is the Waste Recycling Ratio (R_Waste). Environmental sensitive industries include agricultural, chemical, construction, fishing, forestry, metal, mining, and petroleum industries. Year fixed effects, Industry fixed effects, Country fixed effects are included in all regressions. Variable definitions are provided in Appendix 1. Standard errors are clustered at firm level. Robust standard errors are reported in brackets. Levels of statistical significance are presented as follows: *** p<0.01, ** p<0.05, * p<0.1