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Culture and Corporate Decarbonization Efforts: A Time-Varying Analysis and Topology Approach

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Abstract: This study examines the influence of culture on corporate responses to climate change. Given the inherent uncertainty associated with climate change, cultural values, as a non-market force, are expected to impact corporate's decision making regarding decarbonization.To investigate this, a sample of large firms from 23 societies participating in the Carbon Disclosure Project (CDP) survey was analyzed, along with cultural measures assessed by the Global Leadership and Organizational Behavior Effectiveness (GLOBE) study. The findings of this study reveal that cultural values have diverse effects on corporate decarbonization efforts. Specifically, a preference for avoiding uncertainty and a future-oriented perspective tend to foster decarbonization, while a strong focus on performance appears to hinder such efforts. Additionally, the relationship between culture and decarbonization demonstrates a time-varying characteristic, indicating the influence of culture on carbon performance is contingent upon the evolution of carbon-related institutions over the study period.

Keywords: climate change; national culture; decarbonization performance; time-varying coefficients feature; local linear smoother; topology

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1. Introduction

Corporations have been identified as major contributors to global greenhouse gas (GHG) emissions, which are a primary driver of climate change. As a result, corporate decarbonization has become a critical component of environmental, social, and governance (ESG) performance. A growing body of literature has focused on the importance of carbon information transparency, including carbon disclosure policies, which are viewed as essential for increasing climate awareness and reducing excessive carbon emissions. Previous studies (Freedman and Jaggi 2005; Kolk et al. 2008; Stanny and Ely 2008; Pinkse and Kolk 2009; Prado-Lorenzo et al. 2009; Cotter and Najah 2012) have emphasized the significance of carbon disclosure policies for corporate decarbonization efforts. Luo and Tang (2015) argue that ethical managers are more likely to disclose their company's true decarbonization performance, which aligns with the assumptions of voluntary disclosure theory. This theory suggests a positive relationship between environmental performance and climate change disclosure, as demonstrated by previous research conducted by Verrecchia (1983), Dye (1985), Deegan and Rankin (1996), and Hopwood (2009). Other empirical works have applied legitimacy theory, which predicts a negative relationship between carbon performance and climate change disclosure, as demonstrated by the findings of Al-Tuwaijri et al. (2004) and Luo and Tang (2014). Overall, these theoretical and empirical studies highlight the importance of understanding the drivers of corporate decarbonization strategies and the role of disclosure policies in promoting decarbonization efforts.

Previous studies have indicated that external social, economic, regulatory, and institutional pressures (Freedman and Jaggi 2005, 2009, 2011; Prado-Lorenzo et al. 2009; Luo

et al. 2012) and the internal conditions of the firm, including its financial resources (Luo et al. 2013; Ioannou et al. 2015; Timo et al. 2022), have an impact on a firm's decisions regarding carbon and climate change. However, the importance and relevance of these factors are subject to the individual manager's interpretation and judgment. Managers' judgments, green aspirations, and attitudes are influenced by national culture (Chui and Kwok 2008), as it manifests itself in business decisions and social institutions, particularly in uncertain conditions (Leung et al. 2005). Climate change is a complex issue with high inherent uncertainty and managers are likely to respond based on their cultural prescriptions. Nation culture also influences ethical decision making (Vitell et al. 1993) and stakeholder expectations (Carroll 1979), leading companies to adopt sustainable behaviors that shape their standards of transparency and environmental practices. As a result, systematic heterogeneity in firms' decarbonization actions is expected to be associated with national culture. However, despite the potential significance of this relationship, few studies have explored it to date.

Culture can be defined as a set of values and beliefs that are expressed through social norms, behaviors, and artifacts shared by the members of a society (Rokeach 1973; Hofstede 1980; Trice and Beyer 1993; Vaske and Donnelly 1999; Leung et al. 2011). Cultural dimensions have been measured to characterize national culture (Hofstede 1980; House et al. 2004). Previous research provides substantial empirical evidence of the significant relationship between national cultural values and managers' social, economic, and environmental decisions. For instance, Van der Laan Smith et al. (2005) reveal that a society with feminine-coded values places greater emphasis on social goals, such as environmental protection, in contrast to masculine societies that prioritize power and economic status. Husted (2005) suggests that power distance, individualism, and masculinity have a positive impact on a country's social and institutional capacity for sustainability. Williams (1999) demonstrates that uncertainty avoidance (UASV) and masculinity are associated with environmental disclosure. Buhr and Freedman (2001) find that corporations in Canadian society, which has highly collectivistic cultural values, tend to exhibit higher levels of voluntary environmental disclosure than U.S. society, with more individualistic values. In recent years, much research has been conducted on voluntary corporate carbon disclosure (Freedman and Jaggi 2005; Kolk et al. 2008; Stanny and Ely 2008; Pinkse and Kolk 2009; Prado-Lorenzo et al. 2009; Stanny and Ely 2008; Stanny 2013; Cotter and Najah 2012). Notably, Luo and Tang (2022) explore, for the first time, the impact of culture on corporate carbon performance. Their study utilizes the GLOBE model to analyze the data and finds that the dimensions of future orientation, uncertainty avoidance, performance orientation, gender egalitarianism, and power distance stimulate corporate carbon reduction, while the dimension of in-group collectivism inhibits corporate carbon reduction. However, as Husted (2005) suggests, the relationship between cultural value and environmental sustainability is likely to be a variable associated with time, which underscores the need for an in-depth analysis of the time-varying impact of cultural contexts on corporate decarbonization.

The objective of our study is to enhance our understanding of how culture affects the carbon performance of corporations. To achieve this, we select three out of the nine recognized national cultural dimensions from the GLOBE indices (House et al. 2004). Specifically, we focus on the future orientation society value (FOSV), performance orientation society value (POSV), and uncertainty avoidance society value (UASV) dimensions, as we believe that they are the most relevant to climate decisions. Our measurement of decarbonization involves the reduction in carbon emissions intensity, which reflects a company's carbon policies and actions aimed at reducing carbon emissions, and is indicative of the company's corporate carbon performance. We formulate the hypothesis that the carbon decisions of corporations in response to the climate crisis are influenced by relevant carbon institutions and that this relationship varies across time. Therefore, we employ an innovative time-varying model, incorporating a local linear smoother to capture these effects. Our findings reveal a positive relationship between FOSV and UASV and decarbonization, whereas the association between POSV and decarbonization is negative. This suggests that

firms operating in countries with higher FOSV and UASV exhibit better decarbonization outcomes. Conversely, the level of POSV in national culture has a negative impact on the degree of decarbonization in firms. As anticipated, our empirical results also indicate that the relationship between culture and decarbonization is subject to fluctuations over time. This is due to changes in the perception of the importance of climate change and variations in the stringency of carbon institutions.

The current study makes several significant contributions to the existing literature. Firstly, it focuses on a new research area of decarbonization, whereas previous literature has emphasized other hazardous and toxic chemicals, such as waste and SO_2, which cause air or water pollution. However, given the detrimental impact of high carbon emissions on temperature, sea level, and the frequency of extreme weather events, our research topic gains crucial importance in addressing long-term and irreversible damage to the climate. This justifies the importance of our research topic. Additionally, previous research has predominantly focused on a national scale. In contrast, our study examines a sample of large firms operating in multiple countries that are actively engaged in combating climate change. The global scope of our study allows us to analyze influential factors at a country level, including the European Union Emissions Trading System (ETS), the stringency of national climate regulations, and the varying effects of national legal systems on firm carbon performance. Consequently, our study provides novel insights into this critical issue.

Secondly, to the best of our knowledge, our study is the first to explore the dynamic relationship between cultural dimensions and corporate carbon performance over time. Through our empirical analysis, we uncover how the influence of cultural dimensions on decarbonization changes over time. Specifically, we find that the performance orientation dimension has a negative effect, which contradicts the positive association observed by Luo and Tang (2022). However, our model exhibits greater flexibility and robustness compared to theirs. Therefore, our work offers new insights into the influence of cultural values on environmental practices withinorganizations. Furthermore, the time-varying model utilized in this paper proves to be an effective tool for investigating dynamic relationships. Researchers interested in studying the dynamic links between cultural values and outcomes, as suggested by Husted (1999, 2000, 2005), may find this approach valuable. Finally, our findings align with those of Vitell et al. (1993), Pucheta-Martínez and Gallego-Álvarez (2020), and Luo and Tang (2022), who also suggest that the cultural context of companies significantly influences their environmental performance.

The remainder of the paper is organized as follows: In Section 2 we present a literature review. In Section 3 we develop our hypotheses. In Section 4, we introduce our research design, which includes our proposed models with variable measurement and sample selection. In Section 5, we show the empirical results. Section 6 providesa discussion, and Section 7 includes conclusions and policy implications.

2. Literature Review

In recent years, there has been a notable shift in attention toward the issue of climate change (Kolk et al. 2008; Stanny and Ely 2008), This global concern has prompted governments worldwide to implement various measures, such as carbon pricing (e.g., the EU ETS), carbon charges, fees, or taxes (Matsumura et al. 2013; Chapple et al. 2013), aimed at reducing greenhouse gas (GHG) emissions. Consequently, companies that emit GHGs are now internalizing the costs of carbon emissions, and directors are facing increasing regulatory and institutional pressures due to the adverse impact of carbon emissions on climate change. According to institutional theory, these stringent regulations and pressures can stimulate firms, each with their distinct institutional orientation, to make different climate-related decisions and undertake projects that minimize energy expenses and reduce their carbon footprint (DiMaggio and Powell 1983; Tang and Luo 2016).

To investigate how companies respond to external pressures and translate motivations into actions, Tang and Luo (2014) propose the concept of a carbon management system (CMS). In their study, Luo and Tang (2015) demonstrate that corporate incentives to adopt

CMSs are associated with factors such as ETS, peer competition, legal system, and carbon risk exposure. Ioannou et al. (2015) argue that firms that set more challenging targets for carbon reduction are more likely to achieve a higher percentage of such targets. In research conducted by Luo et al. (2012), it is revealed that corporate carbon disclosure is primarily driven by the general public and government actions. Moreover, firms in GHG-intensive sectors tend to disclose more ecological information (Luo and Tang 2016). He et al. (2013) suggest a negative relationship between the cost of capital and carbon disclosure. Matsumura et al. (2013) and Griffin et al. (2017) find that U.S. firms, in their sample, experienced a significant market value loss of USD 212 per ton of GHG emissions. Similar results are reported by Chapple et al. (2013) for Australian firms and by Clarkson et al. (2015) for EU markets. Furthermore, some scholars have focused on the impact of corporate governance on proactive strategies and carbon transparency (Liao et al. 2015; Elsayih et al. 2018).

Regarding cultural factors, while there is a large body of literature on the influence of culture on business, little attention has been paid to the impact of culture on corporate response to climate change. Luo and Tang (2015) show that cultural dimensions such as masculinity, power distance, and UASV are strongly associated with a propensity to carbon disclosure. Further, Luo et al. (2018) argue that power distance moderates the negative relationship between carbon disclosure and carbon emissions. However, Pucheta-Martínez and Gallego-Álvarez (2020) contend that the power distance dimension does not affect environmental reporting. Additionally, Pucheta-Martínez and Gallego-Álvarez (2020) also unexpectedly find that uncertainty avoidance and long-term orientation encourage and discourage environmental disclosure, respectively, which contradicts most of the previous literature. Given the lack of consensus on the relationship between culture and environmental disclosure, an important question arises regarding how culture affects corporate carbon performance.

In the current context, there is a widespread consensus on the importance of operational decarbonization as a crucial step toward promoting cleaner production and facilitating the transition to a carbon-neutral economy in the corporate world. This agreement has been supported by several studies, including those conducted by Xia and Niu (2020), Alsaifi et al. (2020), Ashraf et al. (2020), Penz and Polsa (2018), Velte et al. (2020), and Zhang et al. (2020). In this study, our aim is to explore how cultural factors can influence the gap between corporate managers and the goal of decarbonization, taking into account the various nuanced understandings of the concept of distance. By gaining this knowledge, we can not only comprehend the differences in responses to climate change across countries but also facilitate efforts to close the gap between corporate actors and policymakers. This, in turn, will promote the transition toward a low-carbon future.

3. Hypothesis Development

The issue of global warming and its consequences is widely recognized as a global problem that transcends national boundaries. However, there are significant variations in the levels of decarbonization observed among different countries (Luo and Tang 2016). Although economic theories, such as agency theory and signal theory, and social theories, such as legitimacy theory and institutional theory, offer some explanation for the heterogeneity in corporate environmental and carbon policies and performance, they only provide a partial understanding (Hambrick and Mason 1984; Schneider and De Meyer 1991). Given the inherently uncertain nature of climate change, the corporate carbon response to carbon reduction is particularly influenced by national culture, more so than other business decisions (Luo and Tang 2015). Managers are likely to adopt the prevailing cultural values to rationalize their choices regarding carbon reduction.

3.1. Uncertainty Avoidance Society Value

The cultural dimension UASV, or uncertainty avoidance society value, refers to the extent to which a society, organization, or group relies on social norms, rules, and pro-

cedures to mitigate the unpredictability of future events (House et al. 2004, p. 30). High UASV is associated with discomfort with ambiguity and a preference for a more predictable environment, often resisting change (Hofstede et al. 2010). In contrast, weak UASV cultures are more tolerant of uncertainty and accepting of risk (Offermann and Hellmann 1997). Given the high degree of uncertainty associated with climate change (Stern 2007; Nordhaus 1992, 2017), a strong positive relationship is expected between UASV and carbon performance. Decarbonization projects are viewed as a way to mitigate the damage and uncertainty caused by global warming. Therefore, a strong UASV culture would likely align with a proactive decarbonization strategy, leading companies in such cultures to prioritize carbon-reduction investments and achieve higher carbon performance. Based on these premises, we propose the following hypothesis:

H1. *The UASV of a national culture is positively related to corporate decarbonization. That is, the higher the UASV is, the more carbon reduction will be. Moreover, this positive relationship is varied in magnitude over time.*

3.2. Future Orientation Society Value

In the realm of culture, FOSV, or future orientation society value, refers to the extent to which a community promotes and rewards future-oriented conduct, such as planning and delaying gratification (House et al. 2004, p. 282). A high-FOSV society is characterized by a tendency to save for the future, enabling the development of sustainable business strategies and long-term performance capabilities (Hofstede et al. 2010). On the other hand, a low-FOSV culture is more likely to prioritize the immediate satisfaction of needs (Freeman et al. 2010; Trotman and Bradley 1981). In this context, a society with high FOSV values may demonstrate a preference and inclination toward long-term green policies, driven by the belief that humans can eventually exert control over nature (Luo and Tang 2015). An FOSV culture is expected to be associated with environmentally conscious organizations, emphasizing long-range planning and investments. Therefore, we formulate our second hypothesis as follows:

H2. *The FOSV of a national culture is positively related to corporate decarbonization. And the magnitude of this promoting effect is also time-varied.*

3.3. Performance Orientation Society Value

The cultural construct known as performance orientation/social valuation (POSV) refers to the degree to which members of a society endorse and reward achievement and excellence (House et al. 2004). In cultures characterized by high POSV, individuals prioritize competitiveness, materialism, and economic success over social and familial relationships as well as environmental preservation. This emphasis on economic performance often leads organizations to prioritize financial outcomes over environmental and carbon performance (Luo and Tang 2016; Tang and Luo 2014). Based on these observations, we posit the following hypothesis.

H3. *The POSV of a national culture is negatively associated with corporate decarbonization. And the extent of this negative effect is contingent upon changes in time as well.*

4. Research Methodology

4.1. Sample Selection

The sample for this study was extracted from the CDP database. Our initial sample included 1626 companies from around the world that voluntarily disclosed their carbon-related data in response to a standardized questionnaire administered by CDP. The data were collected over the period of 2008–2014.

CDP is an independent non-profit organization that collects information on GHG emissions from the largest listed companies globally. The organization uses a standardized questionnaire to gather data on carbon emissions, climate-related risks, and opportunities. Participation in the survey is voluntary, and the organization publishes the responses of

the participating companies on its website. The CDP database is used by many researchers (Kolk et al. 2008; Matsumura et al. 2013; Stanny 2013; Stanny and Ely 2008) because it is comprehensive and consistent, which is especially important for this subject, in regard to the diversity of places where carbon disclosures are currently made.

The use of the CDP database offers several advantages for our study. Firstly, participating companies adhere to a standardized format and set of requirements outlined in the CDP survey guidelines. This ensures consistency in reporting across companies. Secondly, the data collection, reporting, and rating procedures are consistent for all reporting companies, enabling meaningful comparisons to be made across firms and over time. Lastly, the CDP database provides comprehensive information compared to other voluntary disclosure channels and the CDP disclosure index is regarded as credible and consistent in the field (Tang and Luo 2016). Thus, the use of CDP data enhances the statistical power of the tests employed in our study, allowing for robust analysis and reliable findings. The comprehensive and consistent nature of the CDP database makes it particularly suitable for examining the relationship between cultural dimensions and corporate carbon performance.

4.2. Time-Varying Coefficients Model

We use carbon emissions data for the 1626 companies in our sample over the period 2008–2014 to measure corporate decarbonization, here referring to reduced levels of carbon emissions intensity. This measure is more appropriate than other measures because it is more objective. Decarbonization levels are measured by DeCo2, the negative natural logarithm of the ratio of total Scope 1 and Scope 2 GHG emissions to total sales. There are 10 independent variables (k = 10) in which the explanatory variable is one of the three dimensions of GLOBE national culture, that is, FOSV, UASV, and POSV. The remaining nine independent variables are control variables, which we use previous work (Tang and Luo 2016) to determine as follows: firm size (SIZE), leverage (LEV), return on asset (ROA), Tobin's Q (TOBINQ), capital intensity (CAPINT), newness (NEW), legal system (LEGAL), primary climate change policy (ETS), and economic development (GDPCC). The variables SIZE, LEV, ROA, TOBINQ, CAPINT, and NEW are firm-level measurements, and the variables GDPCC, LEGAL, and ETS are country-level measurements.

To test our hypotheses, we run the following models:

$$\begin{aligned} DeCo2_{ij} = \beta_0(t) &+ \beta_1(t)UASV + \beta_2(t)GDPCC + \beta_3(t)LEGAL + \beta_4(t)ETS \\ &+ \beta_5(t)SIZE + \beta_6(t)LEV + \beta_7(t)ROA + \beta_8(t)TOBINQ \\ &+ \beta_9(t)CAPINT + \beta_{10}(t)NEW + u_t; \end{aligned}$$

$$\begin{aligned} DeCo2_{ij} = \beta_0(t) &+ \beta_1(t)FOSV + \beta_2(t)GDPCC + \beta_3(t)LEGAL + \beta_4(t)ETS \\ &+ \beta_5(t)SIZE + \beta_6(t)LEV + \beta_7(t)ROA + \beta_8(t)TOBINQ \\ &+ \beta_9(t)CAPINT + \beta_{10}(t)NEW + v_t; \end{aligned}$$

$$\begin{aligned} DeCo2_{ij} = \beta_0(t) &+ \beta_1(t)POSV + \beta_2(t)GDPCC + \beta_3(t)LEGAL + \beta_4(t)ETS \\ &+ \beta_5(t)SIZE + \beta_6(t)LEV + \beta_7(t)ROA + \beta_8(t)TOBINQ \\ &+ \beta_9(t)CAPINT + \beta_{10}(t)NEW + \varepsilon_t. \end{aligned}$$

5. Empirical Analysis

5.1. Descriptive Statistics

After removing observations with missing values for financial variables and those countries with fewer than 30 observations, the resulting dataset consists of 6723 observations from a total of 23 countries. Figure 1 shows that the USA (1711), the United Kingdom (917), and Japan (732) have the most observations, while Portugal has the least at 35 observations.

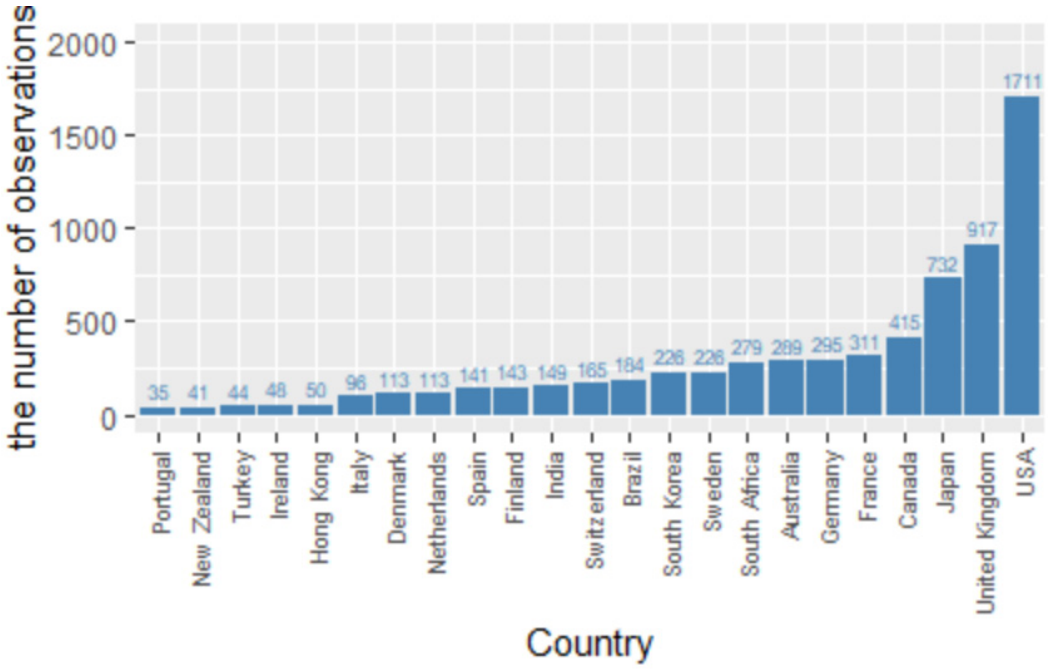

Figure 1. The distribution of the samples.

By examining the boxplots of Figures 2–9, we can observe that the distributions of DeCo2, LEV, ROA, TOBINQ, CAPINT, NEW, GDPCC, and SIZE differ across the investigated countries. Specifically, the outliers, for example, in Figure 3, represent those corporations that outperform, in leverage, the other corporations of the same country. We can also learn from Figure 8 that the GDPs of these countries remained relatively stable during the period under investigation.

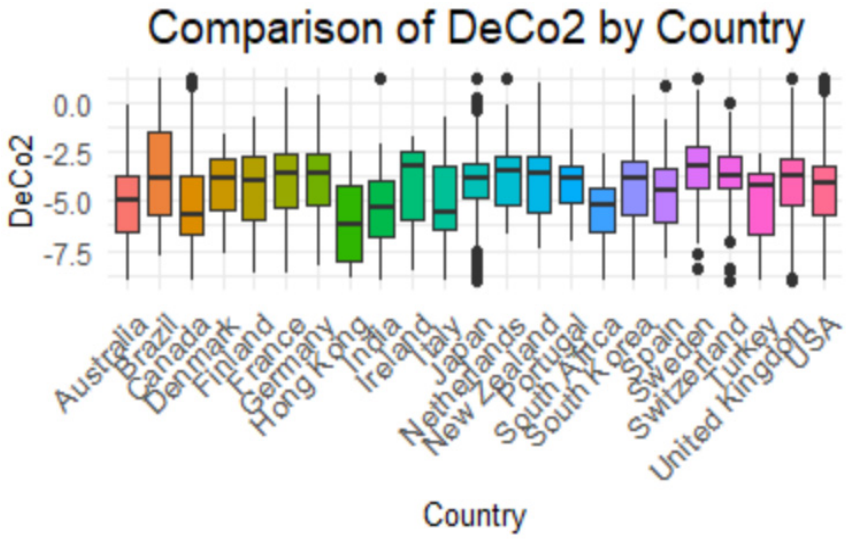

Figure 2. Boxplot of DeCo2.

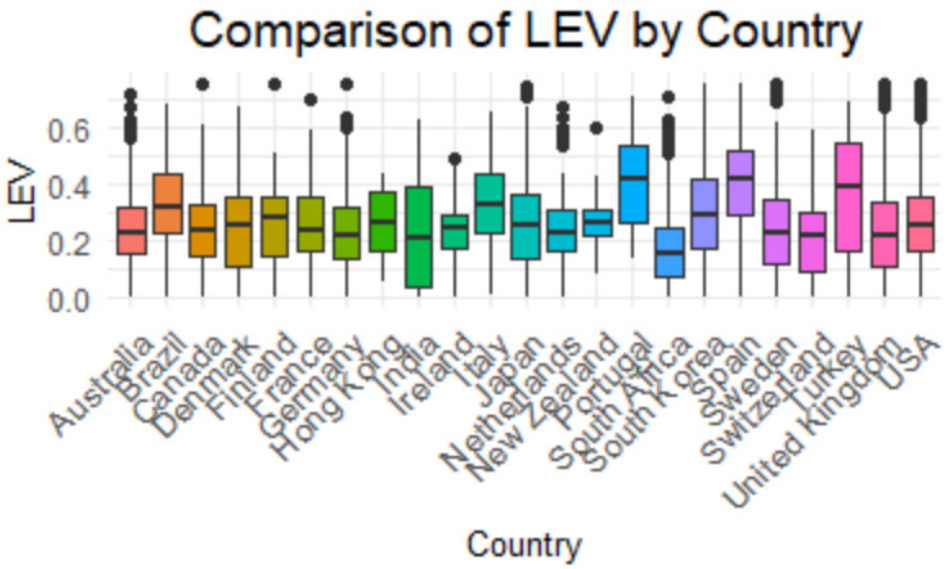

Figure 3. Boxplot of LEV.

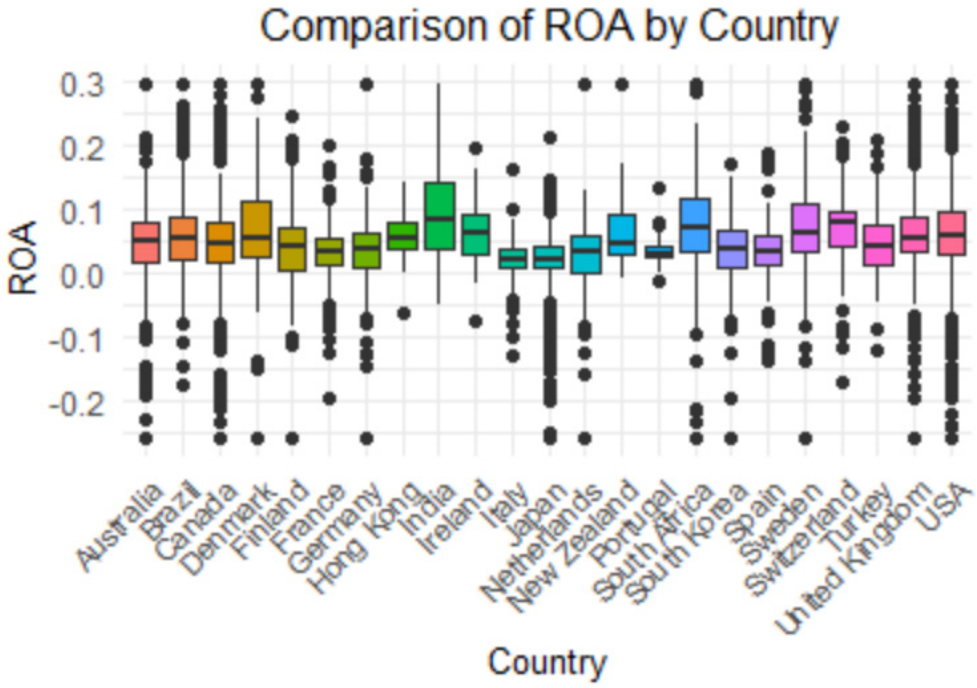

Figure 4. Boxplotof ROA.

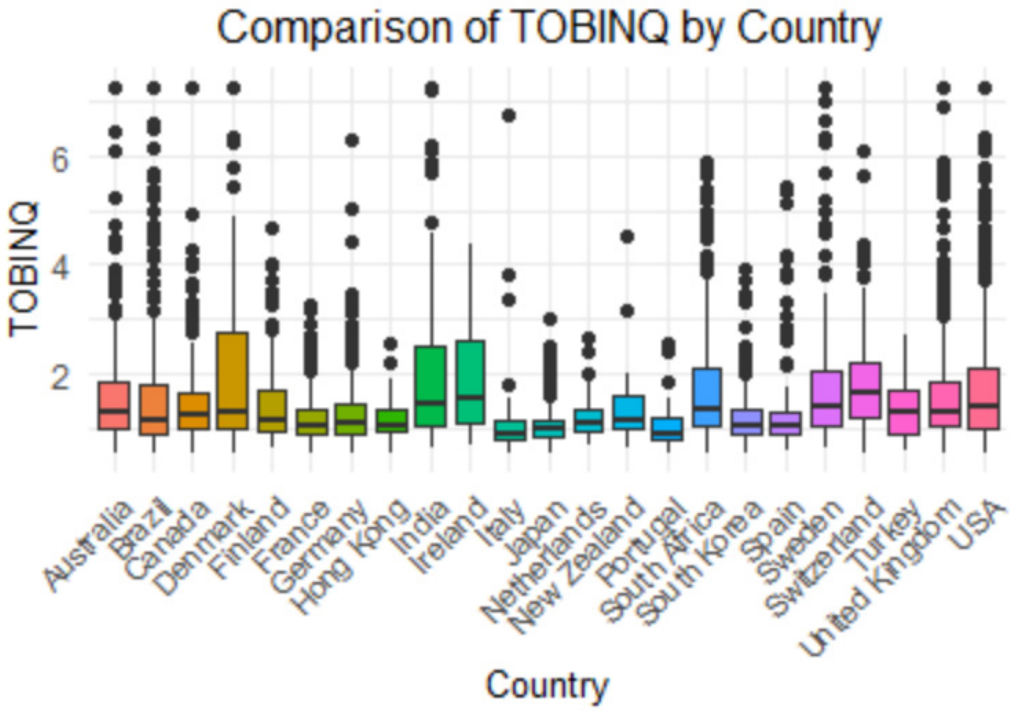

Figure 5. Boxplot of TOBINQ.

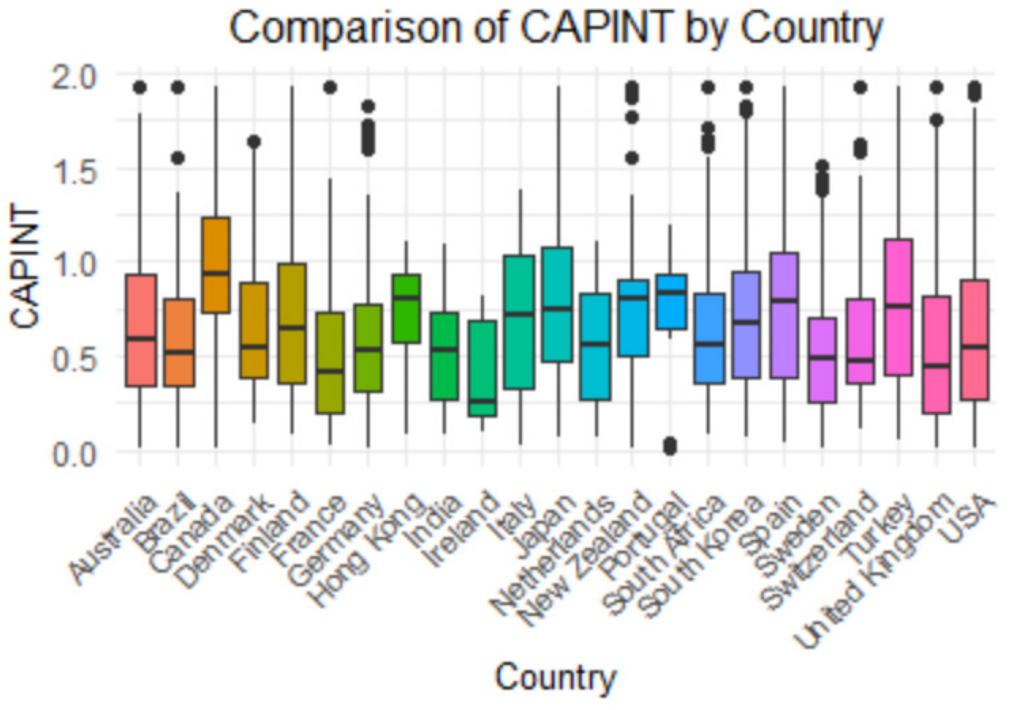

Figure 6. Boxplot of CAPINT.

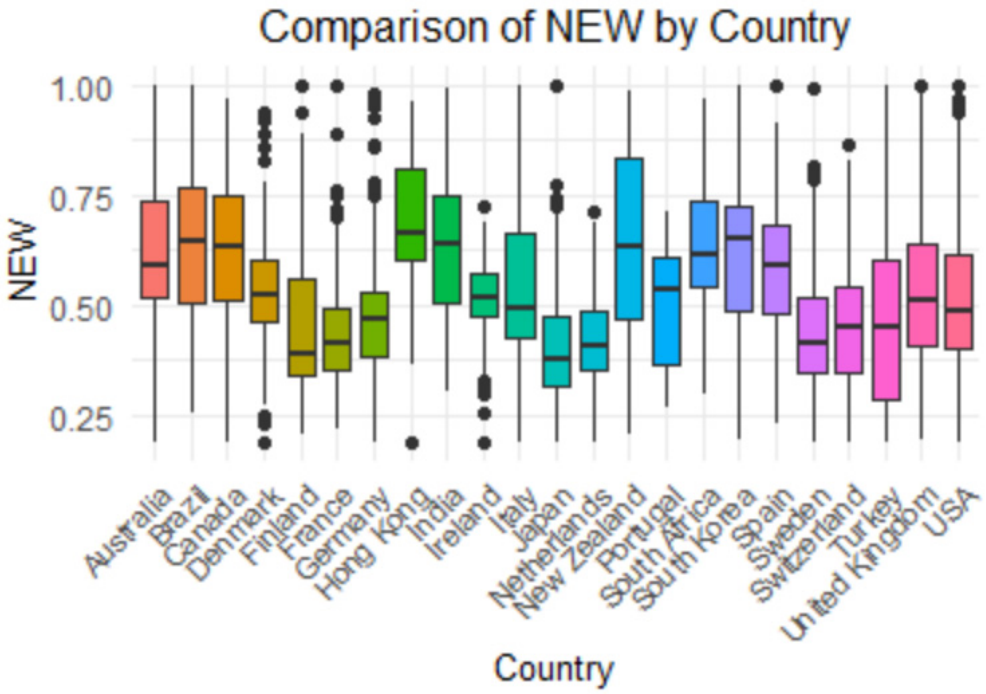

Figure 7. Boxplot of NEW.

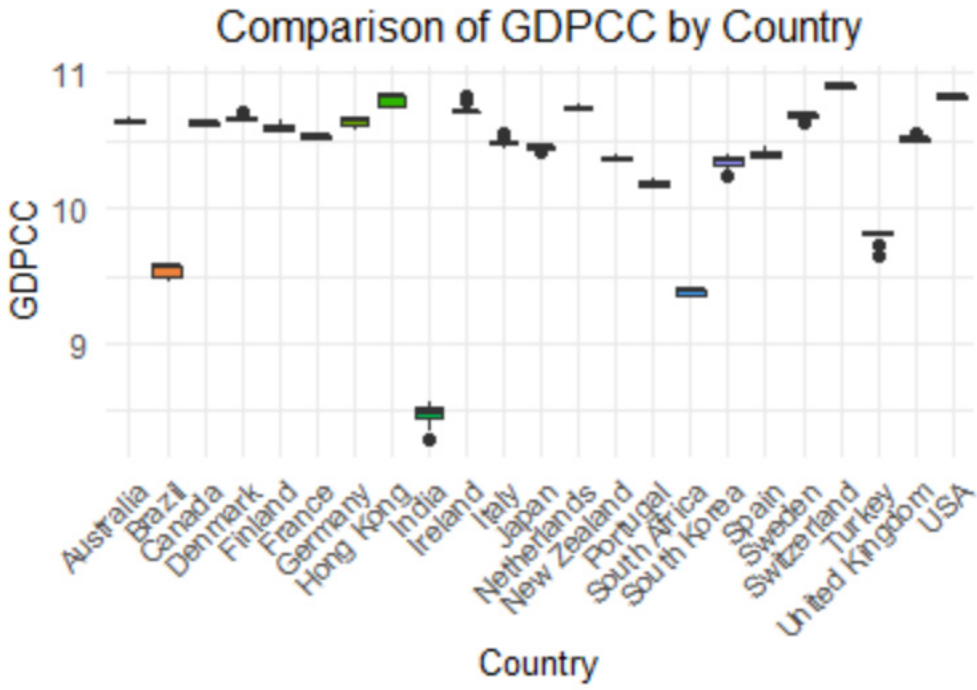

Figure 8. Boxplot of GDPCC.

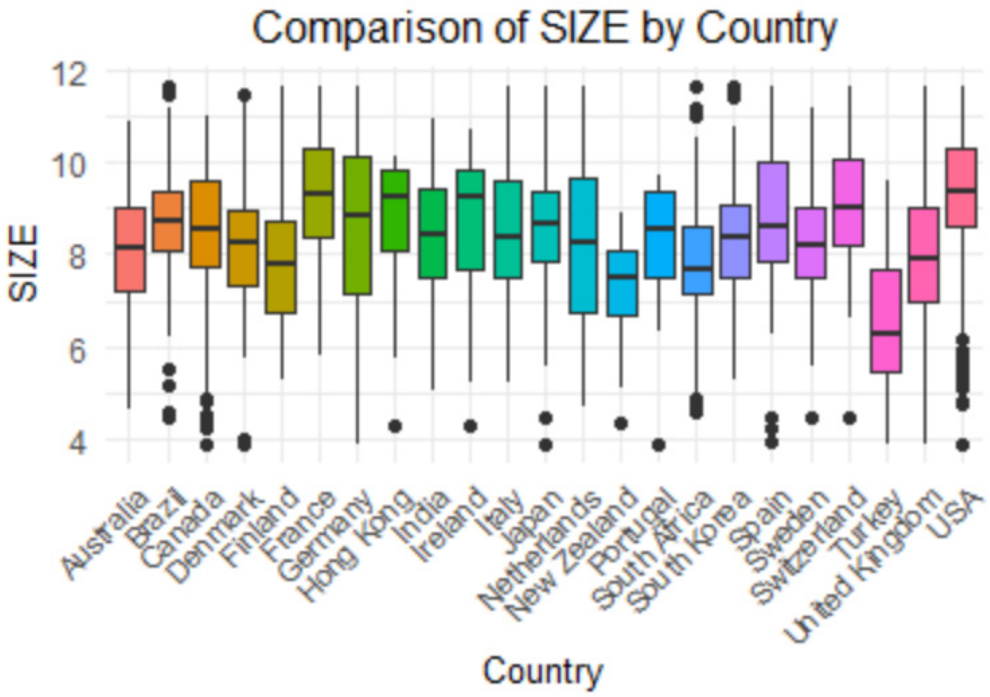

Figure 9. Boxplot of SIZE.

5.2. Time-Varying Effect of the Culture on Decarbonization

To capture the time-varying effect of cultural factors on carbon emissions, we propose a time-varying model of coefficients (Fan and Yao 2008). For details of models and algorithms, readers can refer to Appendix A.

Figure 10 shows the estimated values for $\beta_l(t)$ $(l = 0, \ldots, k)$, with the UASV as a dimension of the national culture variable. The curves depicted in the figure indicate that all coefficients change significantly over time. Specifically, the bottom of the range of fluctuation of the coefficient of UASV is positive, which supports our first hypothesis that UASV enhances decarbonization performance. Furthermore, the figure also reveals that the magnitude of the coefficient initially increases and then decreases over time. This observation is consistent with the understanding that the influence of culture on carbon performance is contingent upon changes in various social, economic, and institutional factors that are associated with carbon-related issues. These factors undergo constant restructuring, reformation, and reconfiguration, leading to changes in the sensitivity of carbon performance to the culture dimension.

The estimated values of $\beta_l(t)$ $(l = 1, \ldots, 10)$ with FOSV as the national culture dimension are shown in Figure 11. In the figure, it can be seen that the coefficient for FOSV decreases significantly over time. In addition, we can observe a positive relationship between FOSV and DeCo2. This result supports our hypothesis (H2) that companies in a FOSV society are more likely to have better decarbonization performance. However, the magnitudes of the coefficients of FOSV in our model steadily and significantly decrease over the period of the investigation. This means that the impact of FOSV on carbon falls over time.

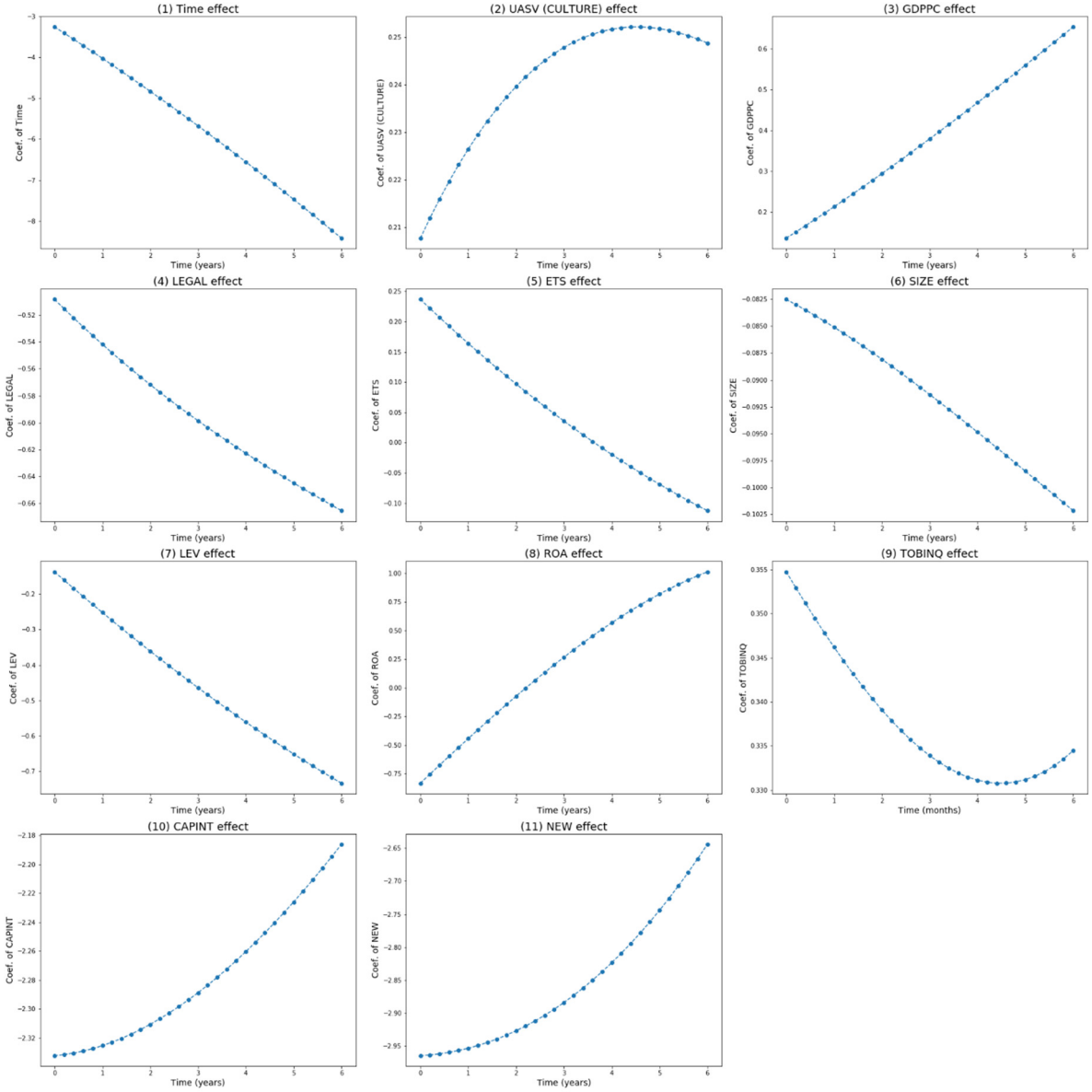

Figure 10. Coefficient estimates for model (1) with UASV as the national culture dimension.

Figure 12 displays the estimated values for $\beta_l(t)$ $(l = 1, \ldots, 10)$ while utilizing POSV as the national culture dimension. This figure showcases the degree to which coefficients exhibit temporal variation. Specifically, the coefficient for POSV indicates a negative correlation, which aligns with H3, suggesting that POSV has an adverse influence on decarbonization levels. A pronounced decline in the POSV coefficient over time is observable. This indicates that the detrimental effects of POSV are progressively more pronounced over the examined period. The underlying cause for this trend can be attributed to the fact that if an organization overvalues financial performance while neglecting carbon controls, the resulting negative impact on its decarbonization outcome is compounded. The relationship between financial and environmental performance is more conspicuous in later years, as climate change as an issue becomes increasingly salient.

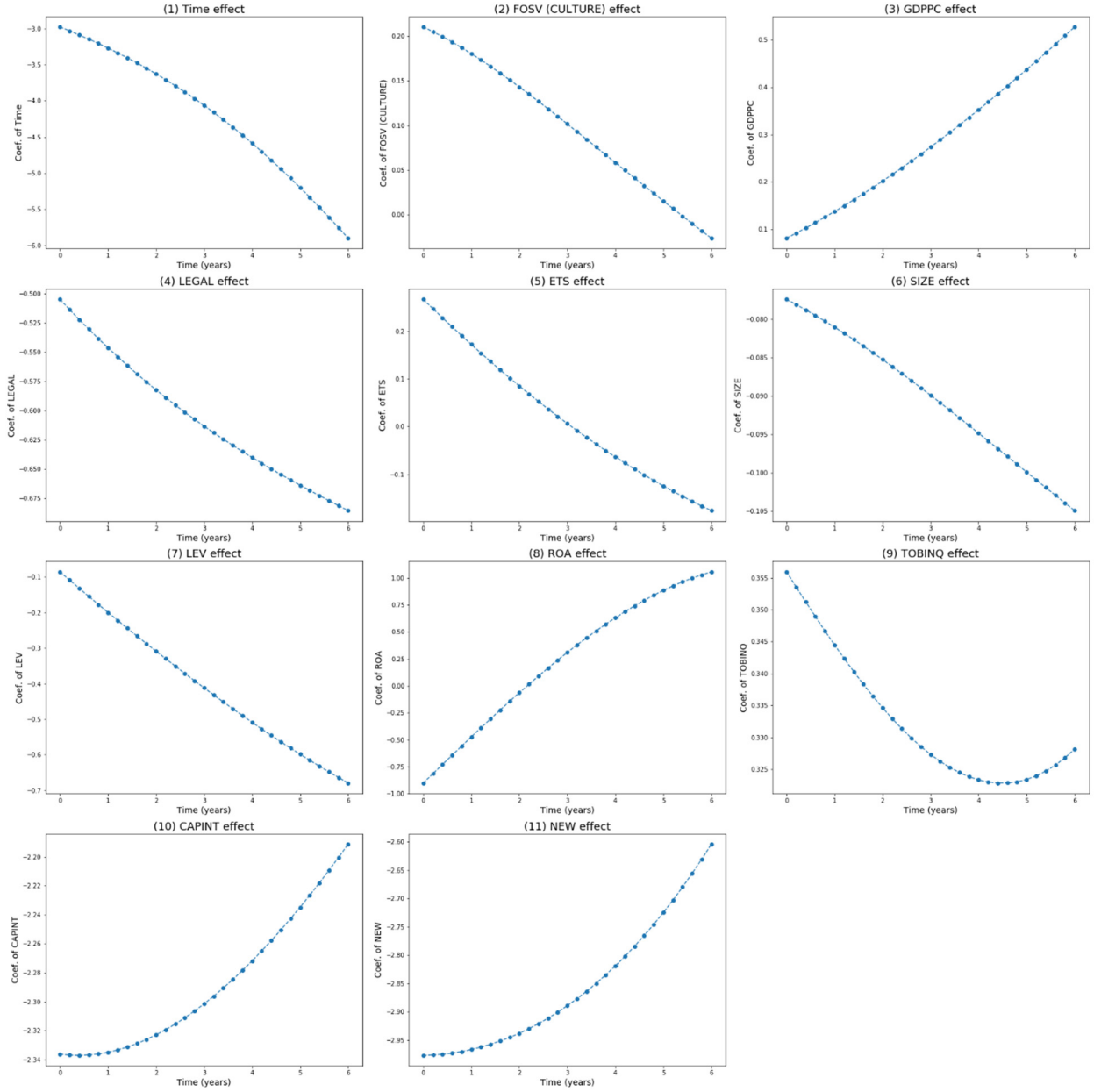

Figure 11. Coefficient estimates for model (1) with FOSV as the national culture dimension.

The results presented in Figures 10–12 collectively demonstrate a consistent pattern in the coefficient function across different cultural dimensions. However, there are variations in the coefficients for specific variables. Notably, the coefficients of GDPCC and TOBINQ show a positive relationship, indicating that higher economic development and firm market value are associated with better carbon performance. On the other hand, the coefficients for LEGAL, SIZE, LEV, NEW, and CAPINT demonstrate a negative correlation, suggesting that factors such as a strong legal system, smaller firm size, lower leverage, established companies, and lower capital intensity are associated with improved carbon performance.

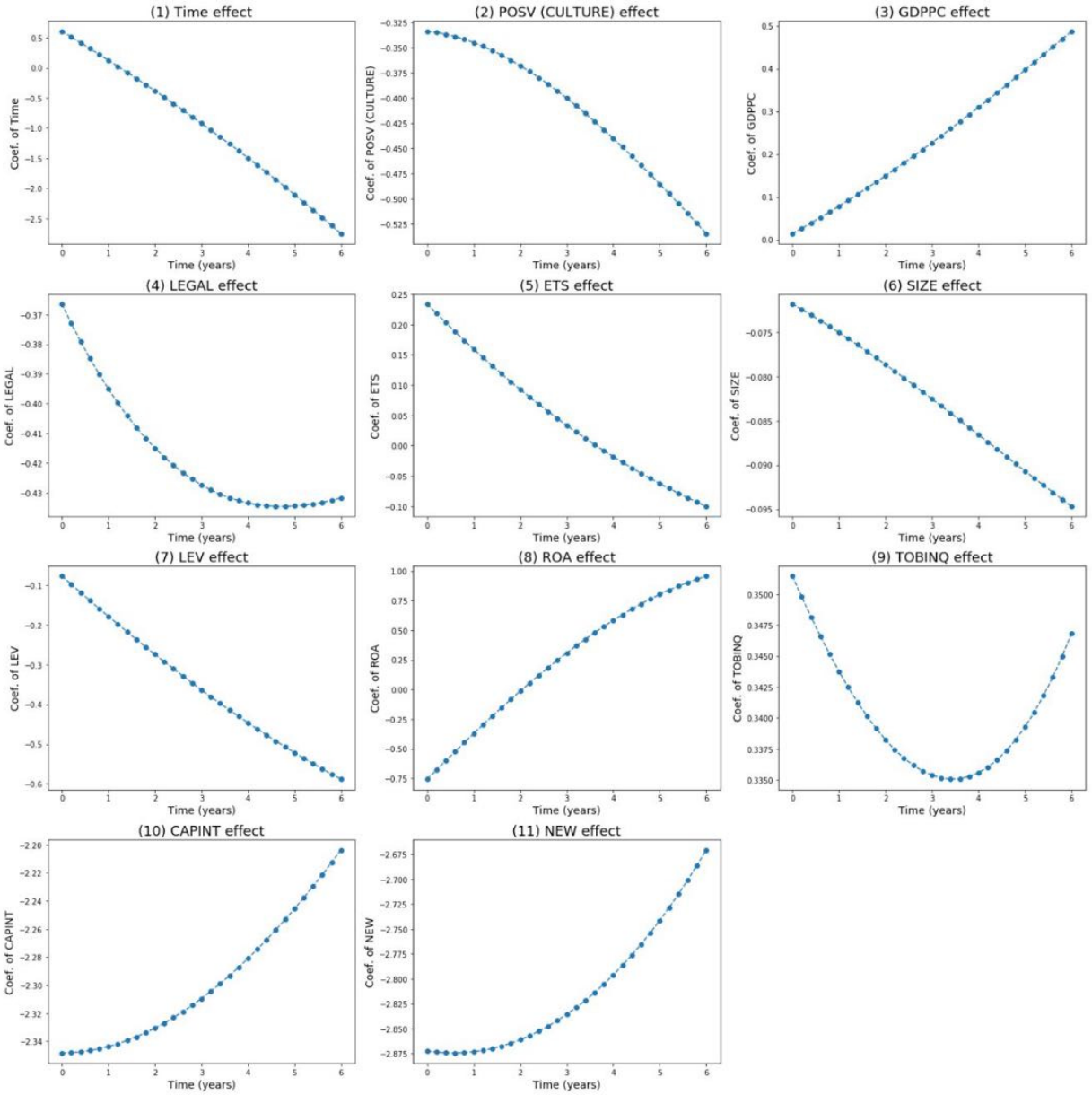

Figure 12. Coefficient estimates for model (1) with POSV as the national culture dimension.

The observed decline in the impact of cultural factors can be attributed to the increasing presence of carbon-related legislation and regulations. As these legal requirements have become more comprehensive and stringent, they have reduced the level of uncertainty surrounding carbon issues. Consequently, managers are now more inclined to prioritize adherence to legal obligations rather than being guided by cultural values when making decisions regarding climate change. In other words, the influence of cultural dimensions on carbon performance has been superseded by the regulatory framework. This shift indicates that the legal environment has become a more dominant force shaping managerial behavior in relation to carbon emissions.

Furthermore, Figures 10–12 indicate that all coefficients exhibit temporal variation, indicating that the relationship between the variables and carbon performance is dynamic. This temporal variation suggests that employing a time-varying model is appropriate for capturing the dynamic characteristics of the data and understanding the changing dynamics of cultural factors and their impact on carbon performance over time.

6. Discussion

The literature makes use of topology in business studies. For example, Corvellec et al. (2018) use a topological paradigm to examine the effects of accounting inscriptions on sustainability. Following this line from the literature, in this section, we explain and conceptualize the impacts of culture on decarbonization with a topological approach. Culture contributes to change in how management relates to emissions by making modifications in their operating systems through setting carbon reduction targets, assessing carbon risks, improving carbon governance, adopting green initiatives, and disclosing carbon emissions and activities. By establishing new spaces, cultural values develop the devices to deal with the new spaces and move emissions from the traditional backstage (Laporte 2002) to the front stage of public life. They create an intimacy between private emissions data and public awareness. As in a fold, cultural values bring people and climate matters together, and a new emotional closeness appears between individuals and the emissions they made, which encourages managers to change climate change behaviors.

6.1. Defining the Distance between Climate Protection and the Economy

Cultural values indicate the distance between climate protection and the economy in a number of ways. For instance, the values of UASV and FOSV are directly related to the uncertain nature of climate change damage and the long-term returns possible from green investment. This multifaceted relationship establishes a fold that literally makes a stronger link between climate stabilization and the economy by decreasing the cognitive distance between them. Further, apparently, the influence of cultural value preferences creates a nonproblematic shortcut between climate goals and financial constraints. Cultural values can be used to build a readable passage from economic goals to corporate efforts for climate stabilization. This actually makes a calculative immediacy that can elude the conflict-ridden relationship between the climate and the economy. Cultural preferences, such as UASV and FOSV, pair the financial consideration of directors of a firm with the material rationality of the carbon policy of the government.

In addition, cultural values bridge the gap between economic preferences and climate-relatedaspects of decarbonization. Cultural influence can raise managers' awarenessof the urgency of decarbonization, leading to the prioritizationof environmental benefits and the integration of financial and climate motives in an inseparable way. These examples show that cultural values eliminate the significance of conventional dichotomies between financial and climate stabilization rationality. One can start with either perspective and reach the other. The objective of reducing emissions, which is a common environmental goal in decarbonization strategies, also results in cost savings, which is typically a primary financial objective. In turn, cost reductions create an incentive to minimizeemissions waste.

Cultural values, thus, create a Möbiusstrip[1], wherein decarbonization may move from the economic concern todecarbonization without crossing a boundary. Management passes from wealth creation to climate considerations without an obvious change in perspective at any point. Cultural value preferences dissolve the meaning of the basic question: Which is more important: the financial value or the climate? Joining the two goals together, cultural values make the distinction beside the point and establish a distance that is contradictory between these values which seem opposite. Decarbonization incurs costs, yet it also protects the environment and, thus, benefits our society. Thus, cultural preferences can merge economic and environmental rationalities, obliterating the gap between these two often conflicting goals.

Cultural values even influence the distances via detours. A detour through cultural preference is at work here. FOSV and UASV make emissions and their negative impact more visible. However, cultural influence takes a detour through considerations of responsibility and morality, bringing financial priority and the climate target closer together. Since direct financial benefits and economic savings that decarbonization engenders are often negligible, people often appeal to moral arguments and business ethics. FOSV can be related to a Jonasian concept of responsibility of the current generation for the well-being

of future people (Jonas 1984). This means an equivalence between decarbonization, on the one hand, and ethical values in business, on the other hand. This cultural preference will lead management to feel a stronger sense of social responsibility to our planet. Decarbonization reflects the conviction that people contribute, fundamentally, to a stable climate. A decarbonization program can create a sense of being an ecologically conscious manager, which enhances the significance of decarbonization and boosts managerial self-esteem. Overall, culture does play a role in bridging the gap and shaping the distance between value creation and climate protection via decarbonization.

The cultural preferences of UASV and FOSV make managers aware of their responsibility to make choices regarding the handling of emissions. The centering of the individualization of ecologic responsibility can transform managers into subjects of governmental climate policies. Culture can create nuanced patterns of moral visibility (Lowe 1997), and acknowledging this can further enrich our understanding of the gap between what the status quo is and what ought to be done.

6.2. Linking Firms with Government via Cultural Preferences

By means of successive translations, culture does not just shift from one scope to another, but also enables governmental officers in charge of monitoring decarbonization programs to catch opportunities to build direct bridges and patterns of proximity between firms and public policies for climate change.

Cultural preferences, such as UASV, allow governments to help firms understand the urgency of climate protection behaviors. Cultural values can be a direct path of communication between those who initiate environmental policies and those who implement and benefit from them. By embodying in cultural preferences the political aims of public bodies, they exhibit the government in the role of a sustainable organization (Tregidga et al. 2014). This shortens the distance between corporate decarbonization actions and governmental environmental policy. On the other hand, in the absence of any influence of culture in this way, such action may increase the social distance between business actors and governmental bodies. The power of the connection (Allen 2011) that culture creates among the people that it influences is also a power of disconnection for those that are not under its influence. Therefore, cultural values act asbridges that span legal, practical, and administrative rationales and connect managers, employees, corporate boards, householders, those concerned with carbon emissions, and politicians in government. These bridges, then, redefine administrative and political distances.

Where government officials and corporate managers share the same cultural values, culture can form new trajectories that allow policymakers to exercise administrative powers across hierarchical structures to achieve governance (Woolgar and Neyland 2013) of corporate decarbonization. Eventually, the efficiency of the governmental climate policy depends on the relationships of trust or interest between firms and the governmental strategy. Cultural efficiency ultimately enhances the credibility of governmental management on climate change. Trust can be a detour that ultimately leads to proximity. Another must-take detour is the sense of CSR of management (Hopwood 2009). Governmental environmental policy is set for the provision of services to the public. The cultural and ideological readiness of firms to make sense of social responsibility is a condition of policy efficacy. The development of a spirit of CSR characterized by a continuous commitment to environmental performance and eco-accountability is another detour that the culture must take to affect decarbonization in firms. Through the adoption of a concept of environmental rationalism (Gray 2010) and by enjoining management to optimize their choices, cultural values can turn firms into voluntary participants in public climate programs, and the firm becomes a customer of public service. Thus, culture redefines and transforms the distance to government from a traditional administrator–administrated one to a service delivery–service consumption distance.

7. Conclusions and Policy Implications

Although a considerable body of literature has addressed corporate incentives for carbon activity, only a limited number of studies have examined the impact of cultural factors on the business response to climate change. Our research investigates the influence of national culture on decarbonization, as cultural values shape philosophies of environmental protection and, as such, play a pivotal role in corporate carbon decisions regarding climate change risk. Our findings reveal that the cultural tendencies of UASV and FOSV can facilitate decarbonization, indicating that societies that prioritize social norms, rules, and long-term planning are more likely to prioritize carbon reduction. On the other hand, POSV, which emphasizes achievement and material success, appears to hinder the achievement of carbon reduction targets. These cultural effects are observed across different legal systems and emissions trading schemes, independent of the level of economic development and industry memberships. By providing nuanced insights beyond traditional explanations based on legitimacy, institutions, and regulations, our research offers valuable guidance for the implementation of global climate agreements (Paris Agreement 2015) in societies with distinct cultural preferences. Furthermore, our study highlights the dynamic nature of the relationship between culture and carbon performance. We find that the sensitivity of corporation carbon performance to cultural factors fluctuates over time, reflecting changes in the carbon context. This temporal variation underscores the need for ongoing monitoring and adaptation of climate programs and corporate social responsibility practices to promote or accelerate decarbonization. Finally, we provide innovative insight into the role of culture, demonstrating that culture, which creates distance, can either shorten or lengthen the link between governmental climate programs and corporate CSR behavior to promote or delay decarbonization.

Our sample is limited to large firms, which we selected because their environmental policies are likely to reflect more cultural influence. However, caution is required when extending our evidence to small or medium-sized firms. Moreover, we only consider three dimensions out of all of those identified by House et al. (2004). Future studies may incorporate other dimensions of culture, such as individualism, power distance, masculinity, and human orientation. Our study focuses on carbon emissions. However, it is important to recognize that other contextual factors, such as industry-specific dynamics, regulatory frameworks, and socio-political factors, can also shape corporate decarbonization efforts. Therefore, the field is open to future researchers to examine the influence of these factors on carbon control procedures. Finally, the Paris Agreement on climate change (Paris Agreement 2015) emphasizes the importance of adaptation to climate change. Investment in adaptation may not directly decrease emissions but will still enhance the needed capabilities and resilience for sustainable development on a warmer planet. This may also become a focus for further study in carbon research.

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Appendix A

Models and algorithm: Let Y_{ij} denote the jth year of DeCo2 for the ith company for $j = 1, \ldots, n_i$, where $1 \leq n_i \leq 7$ for i = 1, …, 1626. There are 10 independent variables, $X_{ij} = \left(X_{ij0},\ X_{ij1}, \ldots, X_{ijk}\right)^T$ (k = 10), associated with Y_{ij}, in which the explanatory variable is one of the three dimensions of GLOBE national culture, that is, FOSV, UASV, and POSV. The remaining nine independent variables are control variables thatare aforementioned: economic development (GDPCC), legal system (LEGAL), primary climate change policy (ETS),firm size (SIZE), leverage (LEV), return on asset (ROA), Tobin's Q (TOBINQ), capital intensity (CAPINT), and newness (NEW).

To capture the time-varying effect of cultural factors on carbon emissions, we propose the following time-varying model of coefficients for the data $\{(Y_{ij}, X_{ij}, t_{ij}), i = 1, \ldots, n$ and $j = 1, \ldots, n_i\}$:

$$Y_{ij} = X_{ij}^T \beta(t_{ij}) + \epsilon(t_{ij}),\ i = 1, \ldots, n,\ j = 1, \ldots, n_i \tag{A1}$$

where $\beta(t) = (\beta_0(t), \ldots, \beta_k(t))^T$ are unknown smooth functions of time, t, and $\varepsilon_i(t_{ij})$ is a zero-mean stochastic process. We assume that X_{ij} and ε_i are independent.

Estimation and Bandwidth Selection

To estimate the coefficient vector, $\beta(t)$, in model (1), we employ the well-known local linear smoother (Fan and Yao 2008). For each l given, we assume that the first derivative of $\beta_l(t)$ exists, and $\beta_l(t_{ij})$ is estimated by minimizing local least squares for the fraction of the data within the neighborhood of t_{ij} for $l = 0, \ldots, k$.

Specifically, for $t_{ij} \approx t$, using the Taylor expansion, we have

$$\beta_l(t_{ij}) \approx \beta_l(t) + \beta_l'(t)(t_{ij} - t) \equiv b_{0l} + b_{1l}(t_{ij} - t)$$

Running the local linear smoother, we minimize

$$\sum_{i=1}^{n} \sum_{j=1}^{n_i} \left[Y_{ij} - \sum_{l=0}^{k} X_{ijl} \{ b_{0l} + b_{1l}(t_{ij} - t) \} \right]^2 K_h(t_{ij} - t)$$

over $b_l = (b_{0l},\ b_{1l})^T$, where $K_h(\cdot) = h^{-1}K(\cdot/h)$, with $K(\cdot)$ being a kernel functionsuch as the Gaussian kernel, and h being b and width, controlling the amount of data in the smoothing. Let the minimizer be $\hat{b}_{0l}$ and $\hat{b}_{1l}$. Then, $\hat{b}_{0l}$ estimates $\beta_l(t)$, and $\hat{b}_{1l}$ estimates $\beta_l'(t)$. To stress the dependence of the estimator on time, t, we use $\hat{\beta}_l(t)$ to denote $\hat{b}_{0l}$.

We employ K-fold cross validation (Friedman et al. 2001; Stone 1974) to select the optimal bandwidth. The procedure is as follows.

Step 1. Choose a positive integer K, for example, K = 10.

Step 2. Split the n observations into K roughly equal index groups. Each group represents a fold of observations $\{(Y_{ij}, X_{ij}, t_{ij}), i = 1, \ldots, n$ and $j = 1, \ldots, n_i\}$ with index i. Then, train on $K - 1$ folds of observations and use the held-out fold of observations as validation data for testing the model. Repeat this process K times such that each fold of observations is used for validation exactly once.

Step 3. Calculate the average meansquare prediction error:

$$AMS(h) = K^{-1} \sum_{k=1}^{K} AMS_k(h)$$

where $AMS_k(h) = m_k^{-1} \sum_{i \in foldk} n_i^{-1} \sum_{j=1}^{n_i} [Y_{ij} - X_{ij}^T \hat{\beta}^{(-k)}(t_{ij})]^2$, with m_k being the number of indexes in fold k, and $\hat{\beta}^{(-k)}(t)$ being the local linear estimator of $\beta(t)$, leaving out the kth fold observations. The bandwidth is calculated as the minimizer of $AMS(h)$.

The estimators of model (1) are computed using the standard Gaussian kernel, with bandwidth $h_{CV} = 4.0$ selected by the 10-fold cross validation. In model (2), the estimators are computed using the standard Gaussian kernel with the cross-validation band width

$h_{CV} = 3.5$ and the estimators of model (3) are computed using the standard Gaussian kernel with the cross-validation bandwidth $h_{CV} = 4.0$.

Appendix B. Summary of Variables

Variable	Definition	Source
DeCo2	Negative sign of the natural logarithm of the ratio of total Scope 1 and Scope 2 greenhouse gas emissions	CDP
UASV	to total sales	House et al. (2004)
FOSV	Uncertainty avoidance society value	The World Bank
POSV	Future orientation society value	La Porta et al. (1998)
GDPCC	Performance orientation society value	Website
LEGAL	The natural logarithm of the gross domestic product per capita	DataStream
ETS	An indicator variable that equals 1 if the firm is located in a common law country and 0 otherwise	DataStream
SIZE	An indicator variable that equals 1 if the firm is located in a country that has an operating national emissions trading scheme and 0 otherwise	DataStream
LEV	The nature logarithm of total assets	DataStream
ROA	Total debt (measured as short-term debt, current portion of long-term debt, and long-term debt) divided by total assets	
TOBINQ	Net income before extraordinary items/preferred dividends divided by total assets	
CAPINTNEW	Total market value based on year-end price and the number of shares outstanding, plus preferred shares, the book value of long-term debt, and current liabilities, divided by the book value of total assets.	
	The ratio of gross property, plant, and equipment to total assets	
	The ratio of net property, plant, and equipment to gross property, plant, and equipment	

Note

[1] The Möbius strip is a non-orientable surface, meaning that, within it, one cannot consistently distinguish clockwise from counter clockwise turns. Every non-orientable surface contains a Möbius strip.

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