Introduction to the Special Section on Business and Climate Change

Rajesh Chandy,[a] Glen Dowell,[b] Colin Mayer,[c] Erica Plambeck,[d] George Serafeim,[e] Michael Toffel,[e] L. Beril Toktay,[f] and Elke Weber[g]

[a] London Business School, London NW1 4SA United Kingdom; [b] Cornell University, Ithaca, New York 14853; [c] University of Oxford, Oxford OX1 1HP United Kingdom; [d] Stanford University, Stanford, California 94305; [e] Harvard University, Soldiers Field, Boston, Massachusetts 02163; [f] Georgia Institute of Technology, Atlanta, Georgia 30308; [g] Princeton University, Princeton, New Jersey 08544

Contact: rchandy@london.edu, https://orcid.org/0000-0001-6633-2073 (RC); gwd39@cornell.edu, https://orcid.org/0000-0003-3829-7404 (GD); colin.mayer@sbs.ox.ac.uk, https://orcid.org/0000-0002-6292-2065 (CM); elp@stanford.edu, https://orcid.org/0000-0001-9378-5190 (EP); gserafeim@hbs.edu, https://orcid.org/0000-0002-1528-6473 (GS); mtoffel@hbs.edu, https://orcid.org/0000-0002-1224-9159 (MT); beril.toktay@scheller.gatech.edu, https://orcid.org/0000-0001-7446-8253 (BT); eweber@princeton.edu, https://orcid.org/0000-0002-1678-3631 (EW)

1. Introduction

We are pleased to present this special section of *Management Science* on "Business and Climate Change." We launched the Call for Papers in 2019 to draw more scholarly attention to the major risks and opportunities climate change poses for a wide array of companies and industries, and for society at large. In the four years since then, we have seen a growing number of examples of the physical manifestations of climate change that scientists had been forecasting for decades, including intensive heat waves, wildfires, hurricanes, and flooding. At the same time, a growing number of policymakers and companies are taking seriously the need to understand and respond to climate change by enacting appropriate adaptation and mitigation measures. There is therefore a critical need, and an enormous opportunity, for scholars to provide insights to help organizations plan, measure, site, forecast, innovate, develop products and services, and manage supply chains to address these mitigation and adaptation pressures.

We are delighted to share the 22 papers of this special section. They were drawn from 239 submissions across a wide range of management science disciplines including accounting, finance, management, marketing, operations, and strategy, and span an array of climate change domains. We have categorized the papers into the following six areas: the performance implications of climate change's physical manifestations; understanding and managing climate risk; optimizing operational systems; the influence of investors; effectiveness of subsidies and other incentives; and non-market strategy. We briefly describe each of the papers below.

2. The Performance Implications of Climate Change's Physical Manifestations

(1) In "Climate Change, Firm Performance, and Investor Surprises," Pankratz, Bauer, and Derwall relate the performance of 17,000 firms in 93 countries between 1995 and 2019 around their earnings announcements to their heat exposure. They record evidence that extreme temperatures reduce firm revenues and income. Furthermore, increased heat exposure has a negative impact on financial performance relative to analyst predictions and earnings

announcement returns, suggesting that stock markets do not fully predict the financial effects of heat as physical climate risk."

(2) "Adjusting to Rain Before It Falls" by Downey, Lind, and Shrader estimates the damages to the construction industry caused by increased precipitation volatility. Volatility forecasts with different lead time exist and can help. The authors find that employment in this sector in the US falls in response to forecasted rainfall and more so as the forecast horizon increases. Increased future rainfall volatility due to climate change will lead to even more costly adjustments, unless volatility forecasts improve or the construction industry will find ways to adapt better

(3) In "Sellin' in the Rain: Weather, Climate, and Retail Sales," Roth Tran studies the impact of weather on retail sales in light of the extreme weather patterns associated with climate change. Data from a US-based apparel and sporting goods brand suggests that weather can have large effects on sales in the short run. In the longer run, shoppers become less sensitive to weather as they develop experience dealing with precipitation, snow, and cold weather events – but not extreme heat events, the negative effects of which do not diminish with experience. These results suggest that consumer adaptation to extreme weather may moderate some but not all of the adverse effects of climate change on sales.

(4) In "Panic Selling When Disaster Strikes: Evidence in the Bond and Stock Markets," Huynh and Xia use disaggregated establishment-level data to examine firms' exposure to physical climate risk and investors' reactions to natural disasters in the U.S. corporate bond and stock markets. They find that, when a firm is exposed to disasters, investors overreact by depressing bond and stock prices, raising future returns. Firms with strong environmental profiles experience lower selling pressure on their bonds and stocks, suggesting that investments in environmental profiles benefit firms when climate change risk materializes.

(5) In "Rising Temperatures, Falling Ratings: The Effect of Climate Change on Sovereign Creditworthiness," Klusak, Agarwala, Burke, Kraemer, and Mohaddes simulate the effect of climate change on sovereign credit ratings for 109 countries. They find evidence of climate-induced sovereign downgrades from 2030, increasing in intensity across countries over the century. Climate policy honoring the Paris Climate Agreement could nearly eliminate the effect of climate change on ratings, but climate-induced sovereign downgrades could substantially increase the cost of corporate and sovereign debt.

3. Understanding and Managing Climate Risk

(6) In "Climate Risk and Capital Structure," Ginglinger and Moreau use firm-level data on forward-looking climate risk to examine its impact on corporate capital structure. They find that greater climate risk leads to lower leverage post-2015 period after the Paris Agreement and standardization of climate risk disclosure. The reduction in leverage derives from both a demand effect (decreases in firm's optimal leverage) and a supply effect (bankers and bondholders widen spreads when lending to firms with the greatest risk). The results are consistent with climate risk affecting leverage through greater distress and operating costs.

(7) In "Climate Policy Risk and Corporate Financial Decisions: Evidence from the NOx Budget Trading Program," Dang, Gao, and Yu find that manufacturing firms adopt more conservative capital structures in response to the Nitrogen Oxides (NOx) Budget Trading Program (NBP), a regional cap-and-trade program aimed at mitigating the NOx emissions of power plants in 11 midwestern and southeastern states in the United States. Firms respond to the cap and trade program by decreasing their financial leverage. This response is more pronounced

for firms that face greater electricity intensity and therefore greater costs, financial distress probability, or competitive pressure and a weaker market position. Their study shows how climate policy risk affects firms' capital structure and financial policies and how those responses are contingent on firms' operating and competitive environment.

(8) In "Pricing Climate Change Exposure," Sautner, van Lent, Vilkov, and Zhang estimate risk premia for firm-level climate change exposure of S&P 500 stocks between 2005 to 2020. Forward-looking expected returns suggest an unconditionally positive risk premium of 0.5% to 1% p.a. between 2011 and 2014, and lower premia since 2015. The risk premium primarily originates from uncertainty about climate-related upside opportunities. Risk premia are negatively associated with green innovation, the top three asset management firms' holdings, and ESG fund flows, and positively associated with climate change adaptation programs. The creation of markets to trade emission allowances is considered a key tool for climate change mitigation, therefore making the issue of how companies respond to such markets salient.

(9) "Climate Change and Uncertainty: An Asset Pricing Perspective" by Barnett examines the effect of climate model uncertainty on macroeconomic and asset pricing outcomes. With the help of a stochastic and dynamic general equilibrium model that quantifies the effects of different mixes of cheap, dirty inputs and expensive, clean inputs as well as different degrees of aversion to climate model misspecification, the author finds that climate change can be expected to result in increased use of clean inputs and reduce emissions. There is evidence that climate risk reduces asset prices, an effect that increases as climate change increases, as the result of aversion to climate model uncertainty. These model implications are consistent with empirical observations and emphasize the important role of climate model uncertainty in affecting macroeconomic and asset pricing outcomes.

(10) "The Social Cost of Carbon When We Wish for Full-Path Robustness" by Zhao, Basu, Lontzek, and Schmedders provides a way of computing the social cost of carbon (SCC) in a way that provides answers that are robust to existing deep uncertainty. The authors show that it is possible to use this method to derive optimal values of SCC that result in time-consistent optimal deterministic Markov policies. For the year 2020, the optimal SCC to keep temperature increases on a 1.5°C path is determined to be a high value of US$162 per ton of carbon dioxide (tCO2) with an annual growth rate of 2.5%. The authors define a SCC robustness premium as the additional SCC price tag for robustness and estimate it to be between US$1.41 and US$25.89 per tCO2 and growing significantly over time. These model forecasts are provided as a way to aid managerial decisions while transitioning from a carbon-intensive economy to a regenerative economy.

(11) In "Climate Change Concerns and the Performance of Green versus Brown Stocks," Ardia, Bluteau, Boudt, and Inghelbrecht use climate change news published by major U.S. newspapers and newswires to construct a daily Media Climate Change Concerns index, and find that on days with an unexpected increase in climate change concerns, there is a differential stock price reaction based on a firm's total (Scope 1, 2 and 3) greenhouse gas emission intensity. For firms with low intensity ("green") stock prices tend to increase, whereas for firms with high intensity ("brown") prices decrease. Decomposing returns to a cash flow and discount rate effect, the authors find their results to be driven by discount rate changes. Using topic modeling, they find that this effect holds for concerns about both transition and physical climate change risk. This study sheds light on how increasing widely disseminated news on climate change might affect price formation in capital markets.

4. Optimizing Operational Systems

(12) In “When should the Off-grid Sun Shine at Night? Optimum Renewable Generation and Energy Storage Investments,” Kaps, Marinesi, and Netessine model how energy storage technologies combined with solar power can help off-grid locations such as islands or remote villages. The goal is to reduce emissions, lower electricity costs, and increase electricity access by partially replacing fossil fuel generation. The authors formulate and solve an analytical model in which random amounts of generated solar energy satisfy electricity demand that varies over time while charging/discharging storage whenever needed. Using real-world data, they make predictions with respect to storage technology adoption and its effect on emissions.

(13) Desalination plants are increasingly used, in part due to changes to precipitation patterns induced by climate change, and so increasingly more residual concentrates from seawater require disposal. Selective salt recovery can meet this challenge in a manner that reduces the need for concentrate disposal and generates additional revenue. In “Rethinking Salt Supply Chains: Cost and Emissions Analysis for Co-production of Salt and Freshwater from U.S. Seawater,” Sošić builds an optimization model to determine the optimal number and location of plants for co-production of salt and freshwater in the U.S. and their potential markets for the sale of co-produced salt. The results indicate that there exists the potential for building several co-production plants in the U.S. that would be both financially competitive with existing desalination plants and lead to a reduction in carbon emissions.

5. The Influence of Investors

(14) In “Climate Impact Investing,” De Angelis, Tankov and Zerbib present evidence on the association between investor climate beliefs and company emissions. The analytical model they build indicates that companies’ emissions decrease as the proportion of assets managed by climate sensitive investors increases. Companies face greater incentives to reduce emissions when these investors forecast a higher probability of climate-related technological innovations and that climate externalities will be internalized by climate-related regulations. In contrast, increased uncertainty regarding climate risks alleviates these investors’ pressure companies’ cost of capital and leads them to increase emissions.

(15) In “Tailor-to-Target: Configuring Collaborative Shareholder Engagements on Climate Change,” Slager, Chuah, Gond, Furnari, and Homanen investigate the process by which coalitions of investors come together to influence firms’ climate practices. Using a dataset of shareholder engagements through the Principles for Responsible Investment effort, the authors employ multiple methods, including fuzzy-set qualitative comparative analysis, regression, and qualitative interviews to identify configurations of practices that are associated with both successes and failures. Their paper develops a richer contextualization of the idea that a better ‘fit’ between activist investors’ attributes and strategies and the firms they target will lead to successful engagements.

(16) In “Leviathan Inc. and Corporate Environmental Engagement,” Hsu, Liang and Matos examine the implications for the environment of a resurgence of state-owned, publicly listed enterprises. Using a dataset of state ownership of publicly listed firms in 44 countries over the period of 2004–2017, they show that state-owned enterprises are more responsive to environmental issues and concerns regarding climate change. Larger effects are found in

economies with weak energy security and strong environmental regulation, and among firms with more local operations and domestic government ownership. The results suggest that the impact of state ownership is particularly significant in dealing with environmental externalities.

4. Effectiveness of Subsidies and Other Incentives

(17) In "Consumer Tax Credits for EVs: Some Quasi-Experimental Evidence on Consumer Demand, Product Substitution, and Carbon Emissions," He, Ozturk, Gu, and Chintagunta examine tax credit incentives' impact on vehicle sales and carbon emissions using incentive changes in South Carolina and Oregon via various quasi-experimental approaches. The authors find that unit sales of incentivized plug-in-hybrid electric vehicles increase by an average of 3.7% following a $2,000 incentive. Sales remain unchanged after the incentive's termination, implying a positive net sales effect. The authors also estimate the average cost of reducing carbon emissions through tax credits for EVs and show that it is less expensive than tax rebates for conventional hybrids and subsidies for residential solar panels.

(18) In "Field Experimental Evidence on the Effect of Pricing on Residential Electricity Conservation," Burkhardt, Gillingham, and Kopalle examine how residential consumers can be encouraged to conserve electricity during summer peak periods and shift electricity consumption from the day to off-peak, nighttime hours. They show through a pricing experiment with unique electricity consumption data from individual appliances in a sample of households in Texas that much of the reduction in electricity consumption (and thus carbon emission) that occurs from changes in peak period pricing is due to changes in air conditioning usage by consumers during the peak hours of the hottest days. In contrast, much of the change in these outcomes during off-peak times is due to changes by consumers, prompted by changes in pricing, in the programming of the timing of electric vehicle charging.

(19) In "Demanding Innovation: The Impact of Consumer Subsidies on Solar Panel Production Costs," Gerarden estimates a dynamic structural model of competition among solar panel manufacturers and their investments in innovation to reduce future production costs. He finds that government subsidies for consumers increase panel adoption directly and by inducing investments by manufacturers that improve panel energy-conversion efficiency and lower prices, both in the country with the subsidies and elsewhere.

(20) To reduce deforestation, many countries have adopted Payment for Ecosystem Services (PES) programs that pay forest owners to conserve forests. In "Simple and Approximately Optimal Contracts for Payment for Ecosystem Services," Dai Li, Ashlagi, and Lo compare the performance of conditional and linear PES contracts. They find that at intermediate environmental value regimes, conditional contracts may exclude a large population of landowners who find full conservation too costly even with the PES payments, leading to low levels of take-up. They identify a simple and robust linear contract with a distribution-free per-unit price that guarantees at least half of the optimal contract payoff, improving conservation outcomes.

7. Non-market Strategy

(21) In "Corporate Political Connections and Favorable Environmental Enforcement," Heitz, Wang and Wang use a close election setting to examine whether the Environmental Protection Agency (EPA) enforces the Clean Air Act to the same degree in politically connected and

unconnected firms. While they find no difference between the two groups in regulated pollutant emissions or EPA investigations, connected firms experience less regulatory enforcement and lower penalties. The results, which extend our understanding of the regulation of global warming, are most pronounced in firms that are important to their supported politicians and for firms connected to politicians who can influence regulatory bureaucrats.

(22) In "There Is No Planet B: Aligning Stakeholder Interests to Preserve the Amazon Rainforest," McGahan and Pongeluppe explore the impact of the actions of Natura, a Brazilian cosmetics company, on forest conservation and fire incidents in the Amazon rainforest. To analyze the impacts of the firm's interventions, they use a differences-in-differences analysis that compares municipalities Natura entered to those it did not, using satellite imaging as a determinant of Natura's entry into a municipality. Their results suggest that Natura's entry into a municipality helps to preserve forested areas. Using information on crop yields and carbon density, the authors find that the company sharing value with local stakeholders around decisions to cultivate forest-generated crops rather than to clear forested land for future agricultural or pasture use are important mechanisms for incentive alignment. Given the importance of forests for carbon sequestration and avoiding the release of carbon into the atmosphere due to deforestation, the results are directly relevant to future climate outcomes.

8. Conclusion

The co-editors would like to thank the many people who made this special section possible, including *Management Science* editor-in-chief David Simchi-Levi for his enthusiastic support and guidance, and Toni Riley for her editorial assistance. We are especially grateful to the following 67 individuals who served as associate editors, and the 340 reviewers who dedicated their time to providing developmental feedback. Finally, we thank the hundreds of authors of the 239 papers who submitted their work. The very strong response is a promising sign of the growing interest in this critical domain, and we hope to see many more articles addressing climate change published in *Management Science* and other top journals in the coming years.

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