HARNESSING AI BUTTERFLY EFFECT FOR SUSTAINABILITY:

DIGITAL BOOST OR RECIPE FOR DISASTER?

Authors

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The hype around the twin transitions paints a seductive picture of the power of AI to provide solutions for countless sustainability challenges. AI's boost in computing power helps firms identify opportunities and address the risks of sustainable innovations. The AI revolution has immense power to generate new solutions and transform business models, making them less wasteful, more energy-efficient, and more socially responsible. The potential to use AI to reimagine business and develop sustainable models for long-term value creation seems boundless. Recent research shows, for example, that firms using AI for decarbonization purposes gain more financial benefits by reducing operational costs through improved energy efficiency and waste-reduction initiatives.[1]

However, there is considerable concern about AI spinning out of control when used in an irresponsible and disorderly fashion. The global AI race could involve tech firms cutting corners while downplaying the risks. Firms using AI to improve their sustainability performance must be aware of the social responsibility hazards that come with it.

AI's fast-increasing carbon impact from soaring energy consumption is a serious concern.[2] Big Tech is receiving heavy criticism about the exponential growth in AI-driven data center energy consumption.[3] AI risks following in the footsteps of blockchain and cryptocurrency, both of which suffered significant reputational damage due to excessive energy consumption.[4]

Given that AI leads to data-driven decision-making, there is worry about the potential consequences for people's privacy, data security, and exposure to bias and discrimination. Scandals stemming from algorithms leading to ethnic profiling and discrimination abound.[5]

How can firms strike a balance between relying on AI for sustainable solutions and not creating social and environmental problems?

We propose a framework to help managers harness the seemingly uncontrollable elements. Using the analogy of the butterfly effect, our framework shows how managers can use AI for sustainability while putting simple guardrails in place to harness opportunities responsibly and prudently curtail risks (see Figure 1).

> **AI'S FAST-INCREASING CARBON IMPACT FROM SOARING ENERGY CONSUMPTION IS A SERIOUS CONCERN**

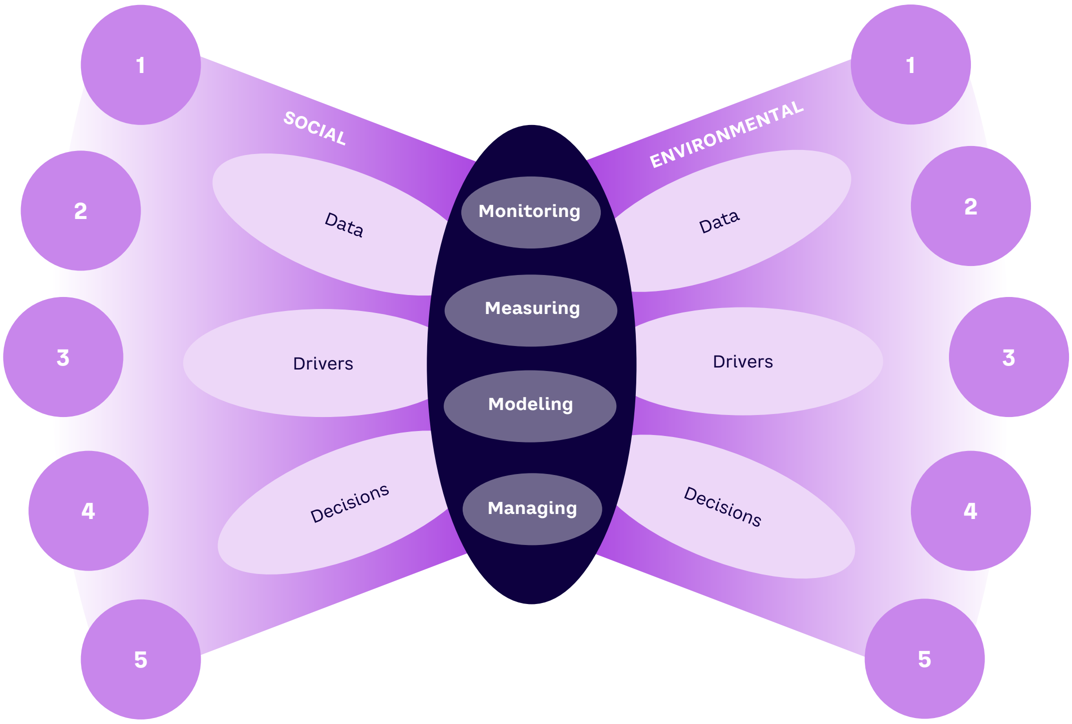

Figure 1. AI Butterfly Effect framework

The framework demonstrates how managers can leverage AI's unique attributes to perform the tasks of monitoring, measuring, modeling, and managing to improve sustainable business practices while keeping undesirable consequences stemming from reliance on data-driven decision-making based on algorithms at bay. By highlighting AI's positive and negative impacts across social and environmental dimensions, we explain how using AI for sustainability can create complex decision-making scenarios that need careful thought before taking action.

USING AI FOR SUSTAINABILITY

AI has the potential to become a general-purpose technology, as its applications are numerous and far-reaching.[6] Typical features include processing vast amounts of data, using neural networks to train and learn from previous tasks to adapt and improve, and speeding up decision-making processes. Intuitively, these features should help firms accelerate their transition to net zero, operate in a circular way/close resource loops, and become resilient to external shocks.

AI is useful in the context of sustainability because social and environmental issues confront managers with ambiguous data that cannot easily be translated into business-relevant information. For example, what is the value of protecting biodiversity or ending modern slavery? How will sustainability initiatives help a firm improve its financial bottom line or regulatory compliance? AI should prove pivotal in unlocking the value of sustainability-related data because it can process vast amounts of complex data at high speed that can be integrated into strategic decision-making processes.

Take Octopus Energy, which was founded in 2015 and is already the fifth-largest energy supplier in the UK. Much of its success comes from harnessing AI and data analytics. Its digital skills allow Octopus to get the most value out of renewables like wind and solar power.

Recognizing that customers are increasingly buying electric vehicles (EVs), heat pumps, and solar panels, Octopus offers a range of smart tariffs that best fit each technology's energy needs. In return for handing over some control over their appliances, Octopus customers can use them when electricity tariffs are at their lowest point. Using AI, Octopus improved its value proposition and began offering novel product-service combinations. The firm no longer sells energy alone; it gives customers the opportunity to buy heat pumps, home batteries, and solar panels.

Managing intermittent renewable energy flows is just one example of AI underpinning a business model that creates long-term value while advancing sustainability. However, being a sustainable business goes beyond offering renewable energy. Sustainability comprises many social, environmental, and economic issues, each posing unique challenges:

- **How can firms deliver on their promise that products like garments or chocolate have been produced without any form of modern slavery?** AI can assist firms in monitoring the firms involved in their supply chains and what practices they are using.
- **How do firms know whether their deforestation policies are having the intended impact of protecting primary forests across the globe?** AI can use remote sensing based on satellite data to help firms monitor remote areas they are trying to protect from further deforestation.
- **How do chemical firms know whether new chemicals contain toxic substances?** Based on information about materials, AI can help firms estimate whether these chemicals could be hazardous without having to test each one individually.

AI can broaden the scope of sustainability issues that firms can manage by facilitating more insight and control over what is happening in their global supply chains. With advanced estimation techniques that can handle vast amounts of data, firms can roll out sustainability initiatives more quickly.

At the same time, it is not always obvious how AI can help drive a firm's sustainability strategy. Which advanced tasks will AI perform, and how will improving these tasks drive social and environmental performance? Once the use case of AI for sustainability is clear, how can managers ensure their digital solutions are, on balance, improving sustainability performance rather than creating social responsibility hazards?

HARNESSING AI BUTTERFLY EFFECT

Using AI for sustainability can induce a butterfly effect, whereby seemingly harmless AI applications generate adverse social and environmental impacts that quickly spin out of control. Even if AI is used with the best of intentions, butterfly effects can occur because it is difficult to foresee how digital solutions will change sustainable business practices over time or in remote places.

AI relies on algorithms, so the way it shapes sustainable business practices can easily change when the algorithms are reprogrammed to fulfill a different purpose. Our framework is built on two elements that together give rise to potential unintended social and environmental impacts.

> **BUTTERFLY EFFECTS CAN OCCUR BECAUSE IT IS DIFFICULT TO FORESEE HOW DIGITAL SOLUTIONS WILL CHANGE SUSTAINABLE BUSINESS PRACTICES**

As mentioned, the first element consists of four tasks (monitoring, measuring, modeling, and managing) through which AI can improve sustainability performance. These tasks are on a continuum from identifying problems to formulating solutions.[7]

The second element consists of three parts of a data-driven decision-making process (data, drivers, and decisions) with algorithms as the foundation. The way AI for sustainability can lead to unintended impacts depends on: (1) the data involved in training and applying AI tools, (2) the drivers emerging from how algorithms optimize the data analysis, and (3) the decisions made using data or drivers containing errors or biases.

Whether social responsibility hazards occur depends on the specific task for which AI is used and the potential flaws in decision-making due to errors or biases in data, drivers, or decisions. As these hazards can be manifold, our framework does not specify them. Rather, the framework is a mapping tool for business leaders to list potential social and environmental hazards (up to five each). In the end, a firm's specific context determines which potential unintended impacts emerge and how they can best be managed.

MONITORING

A key part of managing sustainability is understanding a firm's impact on society and the environment. The potential social and environmental issues that might be material for a firm can be endless. Business leaders want to make sure they don't neglect an issue that could make them a target of social activists, shareholders, or the media. AI can vastly expand how much data is collected and analyzed, so it helps firms keep abreast of a large number of issues.

For example, managing biodiversity in the agri-food sector seems like an insurmountable task. But today, agri-food firms can use sensors to measure precipitation, temperature, soil quality, and more to keep an eye on the health of the natural systems on which they rely. AI also helps these firms uncover potential social and environmental issues. For example, remote sensing using satellite data helps them detect deforestation and modern slavery practices. Satellite imagery can detect sites like mines or quarries that are prone to using modern slavery and show how widespread such sites are.[8]

However, collecting vast amounts of data for AI adds to the need for more energy-consuming data centers. Managers must start weighing the benefits of that data against the burden of soaring energy consumption. Currently, data is considered a low-priced commodity, which does not fit with the potential hidden environmental costs.

There are social costs, too. Monitoring people working in remote places involves ethical considerations. The better the satellite-imagery resolution, the more remote sensing can lead to privacy violations, and exposing modern slavery practices can harm the vulnerable people who are victim to this.[9] Having more data broadens the scope for firms to better monitor their social and environmental impacts; managers must anticipate how the data could be used by someone without good intentions.

MEASURING

Measuring sustainability is akin to trying to measure the immeasurable.[10] Although there have been many attempts to measure social and environmental impact (e.g., social return on investment), each methodology comes with limitations. AI is not a panacea for this problem, but it lets firms capture and analyze many more data sources to reach a more reliable estimate of their sustainability impact.

Recently, machine learning has been used to estimate to what extent utilities around the world are investing in renewables and fossil fuels. Renewables are gaining ground, but the analysis showed that the vast majority continue to invest in fossil fuels.[11]

One key application for AI is in measuring a firm's carbon footprint. A firm can estimate direct emissions (Scope 1) from its fuel mix, but measuring indirect (Scope 3) emissions relies on assumptions about how goods are produced and consumed along its supply chains. AI can vastly improve estimation of indirect emissions because of its learning potential. For example, it can detect anomalies in the greenhouse gas emissions reports from a firm's suppliers.

Measurement's main social responsibility hazards occur due to AI's connection to the role of data and drivers in the decision-making process. Measurement relies on data availability, and AI can create better estimates for sustainability issues for which there's abundant data. A lack of data quality can seriously harm the reliability of decisions because AI starts filling in missing data without necessarily disclosing how.

As what is measured tends to be managed, the way AI algorithms measure social or environmental impact affects what managers will consider relevant for their decision-making. An algorithm's objective function determines how sustainability data is analyzed, and optimal solutions are found. Changing the objective function will affect how various social and environmental factors are traded against one another in the process of measuring a firm's sustainability impact.

A lack of transparency in how algorithms work and optimize data can lead to bias in drivers of a firm's sustainability performance. Managers should take care not to become totally dependent on algorithms in their decision-making without knowing the criteria used to measure social and environmental factors and their relation to overall sustainability.

MODELING

Better measurements help firms detect which social and environmental problems are material to their business. However, only when AI-improved measures become part of modeling exercises does their relevance become clear. Modeling reveals how urgent the problems are and which solutions best address these problems.

AI excels in identifying patterns and trends, leading to improved forecasting and modeling. Modeling is central to managing sustainability because firms need to know which trajectory they are on and whether their emissions are decreasing fast enough to stay within a safe operating space (preventing catastrophic climate change and ecological degradation).

Modeling is also essential to estimating which solutions are most appropriate to improve social and environmental performance. Firms need to know the potential impact of investing in specific solutions, such as green hydrogen for long-term carbon emissions, in part to convince potential investors.

As with measuring, the main hazard related to social responsibility is in how modeling affects which drivers managers consider important in their decision-making. Modeling exercises can provide insight into potential futures, but they are not necessarily based on real-world practices. Models use AI to uncover the most cost-efficient or fastest way to reduce emissions by plugging in green technologies that help achieve such objectives.

However, using algorithms to predict which green technologies can lead to the least expensive or fastest emission reductions can lead to an optimism bias that sustainability challenges can be solved quickly. For example, a green technology's success within a model might start driving investment decisions without data on whether the market is keen to adopt it.

Using historical data to train models to predict future trends can be risky because technology adoption curves are nonlinear, with growth often slowing. For example, sustainable solutions like hydrogen and electric cars tend to get caught up in a hype cycle. Exponential growth in one period might mean their success goes from boom to bust rather than growing further along the same trajectory.

Solving sustainability issues using models is no guarantee that there won't be any unforeseen problems in practice. Using AI for modeling can lead to managers forgetting about the difference between the model and the real world. They must be careful to avoid straying too far from what is technically possible and commercially viable in the near term and be cautious with letting modeling-based outcomes be the drivers of their decision-making.[12]

MANAGING

Although improved monitoring, measuring, and modeling can give a firm insight into how it is doing regarding sustainability, these are mainly diagnostic tools. They do not necessarily motivate managers to address issues by taking decisive action. Using AI to manage sustainability issues is solution-driven and potentially more impactful.

As argued, managing sustainability is all about managing and optimizing complex data. For example, integrating renewables that involve intermittency (solar and wind) will be nearly impossible without AI-based optimization processes. Similarly, any attempt to create a circular economy relies on managing complex material flows across organizational boundaries and optimizing who should do what to be practical and cost-efficient.

There is so much complexity involved in knowing what each intermediate product contains and whether a firm should reduce, reuse, or recycle it to optimize its sustainability performance that such decisions can only be made at scale using AI. Getting consumers on board also depends on AI because green technologies such as EVs, solar panels, and heat pumps rely on optimizing their integration into a home's energy system. People must be able to use green products without sacrificing too much of their current lifestyle; otherwise, they will not embrace them.[13]

The main social responsibility hazard related to managing sustainability with AI relates to which decisions AI will be used for. Although AI's potential to optimize processes and smooth new technology integration seems endless, firms might not be motivated to use AI for sustainability as their main priority.

It remains to be seen whether firms will use AI to optimize decision-making predominantly for sustainability or for other purposes (like operations) that could augment AI's negative consequences. Recently, Microsoft was accused of hypocrisy for selling both AI solutions to develop climate solutions and those designed to help oil and gas companies find more fossil fuel reserves.[14]

AI can help firms obtain financial benefits when managing sustainability, but the financial returns of applying it to other parts of the business (or highlighting other parts of their value offering, such as improving people's comfort) can be tempting. Even if AI is used to manage sustainability, the decision to use it at a larger scale for many other applications could offset any gains in sustainability performance.

CONCLUSION

AI holds the promise of creating a sea change in sustainable business practices, but the environmental costs of collecting, storing, and processing data and the social costs of relying on algorithms for decision-making are becoming visible. We hope that, over time, the benefits will prevail.

Our framework encourages business leaders to pause before using AI for sustainability. They can use it to assess which tasks they intend to use AI for, how their reliance on AI will change how they manage data, what drives their social and environmental performance, and which decisions are most impactful. In this way, they are much less likely to lose sight of sustainability when applying AI in their business.

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