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What Role Do Carbon Pricing Mechanisms Play in Attracting Global Sustainable Investment Flows?

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ABSTRACT: This research examines how carbon pricing mechanisms can help in enhancing the level of sustainable investments. Initially, carbon pricing through carbon taxes and emissions trading systems (ETS) was supposed to internalize the external costs of GHG emissions, thus changing the investment incentives, leading to lower transition risk, and promoting investments in low-carbon projects. The study uses data from the World Bank Carbon Pricing Dashboard and the Global Sustainable Investment Alliance (GSIA) and tracks globally the trends from 2012 to 2022 regarding carbon pricing revenues, average carbon prices, total amounts of sustainable investments, and their modifications. The results demonstrate that there is a great correlation over time between the expansion of carbon pricing and sustainable investments. In 2012, carbon pricing revenues totaled about $353 million, while in 2022 they reached $1.42 billion. At the same time, total sustainable investment increased from $13.3 trillion to $30.3 trillion in the same period. The elements of sustainable investment changed as well as ESG integration, corporate engagement, positive screening, and sustainability-themed investments became popular. The evidence suggests that carbon pricing may enhance the credibility of the policies, create revenue sources for green investments, and re-direct the capital to the low-carbon economy. However, the study does not establish causality due to its aggregated global data and descriptive methodology. The findings therefore support coordinated and appropriately designed carbon pricing policies as a potential catalyst for sustainable finance.

INTRODUCTION

The ever-changing environment that has developed globally has created the greatest risk of an existential crisis for our world's economies, ecosystems, and societies. The impacts of climate change are increasing due to two types of risk: physical risks associated with rising severity and frequency of extreme weather events; and transition risk associated with moving toward a carbon-free (i.e., low carbon) economy (IPCC, 2023). The challenges posed by climate change have catalyzed a huge increase in investments in sustainable financing, which now total $30.3 trillion in assets under global management (GSIA, 2022), as an increasing number of investors want to align their investment capital with environmental, social, and governance (ESG) standards, while at the same time facing stronger regulatory requirements such as the EU's Sustainable Finance Disclosure Regulation (GSIA, 2022). It is estimated that annual investments in climate-related projects will need to be between $3 trillion and $6 trillion a year for the years leading up to 2030 in order to meet the targets set out in the Paris Agreement. Clearly, there is a huge gap between the amount of funding required to achieve the targets outlined in the Paris Agreement (World Bank, 2022b; IMF, 2022) and the amount that will be needed to support a transition to a carbon-free economy (i.e., low carbon economy). Sustainable financing has grown at an exponential rate since 2011, but 46% of total global sustainable financing is located in Europe, with 28% in the US (GSIA, 2022); this is a clear illustration of the significant difference in the approach taken by Europe and the US with regard to investing in a transition to a carbon-free economy (i.e., through net-zero commitments) and the substantial gaps that remain in aligning private sector investment with climate-related goals.

The lack of alignment between the investment incentive structure and climate goals exists due to what economists refer to as "carbon externalities" or externalities associated with greenhouse gas emissions; in simple terms, this means that emitters of carbon dioxide do not fully compensate society for the negative impacts of their actions, resulting in an inefficient use of capital towards fossil fuel-related projects and a reduced use of capital towards renewable energy-related projects (World Bank). Investors have stranded asset risks in certain carbon-intensive businesses, but the uncertainty of policy signals is preventing investors from re-investing in other options such as solar and wind. These options received an investment of $1.1 trillion globally in 2022 (Global Solar Council, 2021; IRENA, 2023). Corporate engagement and ESG integration form the majority of investments (over 40 per cent)

in sustainable finance; however, this type of investment lacks impact due to the lack of any pricing for emissions or any promotion for low-carbon innovation (GSIA, 2022; GSIA, 2018). Consulting reports have noted that the growth in sustainable investments, which was 34% between 2016 and 2018, is due to the lack of any incentive to invest sustainably. The shift amongst European investors from exclusionary to active stewardship comes as greenwashing continues to be a concern (BCG, 2023; Eurosif, 2018). This phenomenon is particularly pronounced in developing markets, with fossil fuel subsidies amounting to over $500 billion each year, thus limiting the amount of available foreign direct investment for renewable energy (IMF, 2022).

Carbon pricing mechanisms aim to address this issue by allowing emissions costs to be internalized through market-based mechanisms (i.e., carbon tax, emission trading system [ETS]). Presently there are 73 such systems that cover approximately 23% of total global GHG emissions (World Bank, 2022). Carbon pricing mechanisms generate predictable government revenues of $95 billion worldwide in 2022, but they also generate credible signals regarding the policies adopted by the nations using them, and also reduce the cost of abatement by 20%–50% compared to hard command-and-control regulation efforts (Cary et al., 2023). The 35% reduction in greenhouse gas emissions by the EU ETS since 2005 has supported the innovation of renewable energy and increased energy efficiency (European Commission, 2023). The usage of carbon taxes in countries including Canada and South Africa creates a stable price for the emissions produced by businesses and the revenue generated by such taxes is reinvested into green energy initiatives.

The correlation between how attractive a jurisdiction is for investing and its price for carbon can be derived from empirical data. The jurisdictions with established carbon prices are generally able to generate an abundance of new sustainable inflows as higher carbon prices reduce carbon-related risk premiums of approximately ten percent to twenty percent for the highest emitting countries (McKinsey, 2021). For example, following the 2018 revisions to the EU ETS rules, the issuance of green bonds by participants in the EU ETS increased by three hundred percent, indicating a significant reduction in regulatory uncertainty (Climate Bonds Initiative, 2023). As a result of the lower carbon price, firms operating under a carbon price structure will experience a lower cost of capital available for their low-carbon capital expenditure (capex). Research has shown that in economies that price carbon, firms can potentially expect five percent to fifteen percent greater foreign direct investment in such economies due to an increased competitive advantage related to clean technology (Dechezleprêtre et al., 2019). According to research provided by GSIA, solar-related investments in pricing jurisdictions are experiencing growth, while at the same time, many of the global sustainable assets are identified as being associated with themes such as clean energy (GSIA, 2022). In addition, a number of the consulting firms have provided evidence indicating that carbon pricing provides greater attractiveness through quantification of potential risks and increasing ESG scores and thus confidence from investors (Deloitte, 2022; BCG, 2023). In India, early-stage carbon market pilot projects under the 2022 Carbon Market Framework are expected to yield similar benefits, enhancing opportunities for solar development in the context of changing conditions in the world (Invest India, 2024). In addition, these same cross-border flows of capital will enhance these same benefits, as international sources of capital flow into the $1.7 trillion of annual Foreign Direct Investment to jurisdictions that are minimising the risks of transition through carbon pricing (UNCTAD, 2023). The carbon-related mechanism described in Article 6 of the Paris Agreement will potentially provide for international carbon markets which may enable the unlocking of up to $250 billion in carbon-related trade by 2030 (World Bank, 2022). Due to high pricing in Europe (46% is global sustainable investments), investments mostly flow to other similar areas and create a "contagion" effect. California's cap-and-trade programme also increased clean energy FDI into the USA by 25% (GSIA, 2022; Metcalf, 2021). The fact that countries like Chile are using taxes to price carbon (taxes on GHG emissions) has allowed them to generate $2 billion of green bonds in 2023 (OECD, 2023). All these data points illustrate that linking carbon pricing programs is necessary to mitigate the risks of "leakage," which occurs when investment capital moves to less stringent jurisdictions (TheCityUK, 2022). Moreover, using IMF modelling, researchers predict that coordinated carbon pricing would lead to an estimated 10% of global portfolio investment flows becoming sustainable (IMF, 2022).

The purpose of this study is to explore how much carbon pricing will influence global sustainable investments by utilising panel data from the World Bank's Carbon Pricing Dashboard, as well as green FDI databases across 100+ countries and an examination period of 2010 to 2025.

BACKGROUND AND THEORY

The foundation of the climate policy market through a market-based mechanism is the carbon pricing mechanism, which seeks to correct the primary market failure caused by the failure to account for greenhouse gas (GHG) externalities. The social costs of carbon dioxide (CO2) emitted by firms are estimated to be approximately $50-100 per tonne globally, as firms generating these emissions have not incorporated or internalised the cost of their emissions into the production process. This externality has resulted in firms generating excessive emissions and not investing sufficiently in cleaner alternatives (Pigou, 1920; World Bank, 2022).

What Role Do Carbon Pricing Mechanisms Play in Attracting Global Sustainable Investment Flows?

The carbon tax is a fixed price per tonne of emissions and provides a source of revenue for governments to redistribute to the public through rebates, green subsidies, and deficit reduction. The emissions trading system (ETS) provides a declining cap on total emissions with tradable allowances that allows for price discovery through market forces (TheCityUK, 2022).

Carbon pricing mechanisms will cover approximately 25% of global emissions across more than 75 initiatives by 2025, with the average price of carbon within mature ETS such as the European Union ETS being approximately $40/tonne and within many of the tax regimes, approximately $20/tonne. This indicates that there is a wide variety in the design and stringency of the instruments. Revenue from carbon pricing is expected to exceed $100 billion globally in 2023, allowing the transition to a carbon-free economy to take shape, including the deployment of Sweden's long-established carbon tax, which has enabled both an increase in the production of renewable energy and greater energy efficiency without hindering economic growth. (OECD, 2023).

In the context of developing economies, the carbon credit trading scheme introduced by India in 2022 focuses on compliance markets in energy-intensive sectors such as cement, steel, and other high-emission sectors.

Carbon pricing utilizes Pigouvian concepts at its core theoretically, in that they utilize an externality tax to equalize the Social Marginal Costs with the Private Marginal Costs. These taxes (the externality) act to provide a more accurate representation of the social costs of producing goods and services (Pigou, 1920). By making sure that the actual costs of producing goods and services include the social cost, thereby achieving a Socially Optimal Level of Abatement, Carbon Pricing provides the most feasible solution to achieving a Carbon-free society through Marginal Abatement Costs equal to the Marginal External Damages As noted by Weitzman (1974), Unknowns play a larger role in scenarios where damages are already known; this illustrates that prices are most suitable in circumstances with certainty based on Historical Fluctuations in Output; on the other hand, quantities will work better in uncertain scenarios, to provide an assurance that the emissions will remain below the Cap. Many examples from India to the United States illustrate this blending of Price/Quantity approaches, Europe has included numerous market stability reserve products and services, the ability to bank and borrow, all designed to reduce price variability associated with Cap and Trade Programs, thus far achieving a decrease of 40% in CO2 emissions since inception while simultaneously promoting a decrease in CO2 emissions by promoting Low-Carbon Technological Innovations (European Commission, 2023). The increased benefits associated with the re-cycling of revenue create a double dividend effect by combining two environmental improvements and reducing distortional taxes on Capital and Labor. As demonstrated through Dynamic General Equilibrium Modelling, Long-term growth of GDP may be increased 0.5%-1% (Goulder, 1995, IMF, 2022). Through examples, British Columbia's Revenue Neutral Carbon Tax reduced their emissions by 5-15%, without negatively impacting GDP by utilizing a recycling method that provided rebates to the people to offset regressivity (Yamazaki, 2017). The Pricing System serves as more than simply a corrective mechanism, it has developed a technological innovation stimulus via the Porter Hypothesis. The Porter Hypothesis demonstrates that an efficiently designed Environmental Regulation will provide greater-than-expected savings to the Firm, thus encouraging increased effectiveness in their own Product Process through implementing Low-Carbon Technological Innovations. According to multiple sources, there is evidence that both "Weak" (through abatement investments generated as an outcome of carbon reduction) and "Strong" (by creating new inventions) versions of the "New Social Contract on Carbon" (the "Contract") support the creation of low-carbon technologies, now commonly referred to as "Clean Technologies." For example, studies show that under the EU Emissions Trading Scheme ("ETS") the number of low-carbon patents increased by between 20-30% in Europe, particularly among companies operating in the Energy (Power & Industry) sectors (Calel & Dechezleprêtre, 2016).

Technical change models explain the dynamic process that produces technological breakthroughs. Three mechanisms work together to accomplish Technical Change: 1) the relative price of inputs; 2) development of low-carbon technologies through technological innovation, and 3) accumulation of experience through repetition and experience effect (e.g. Knowledge Accumulation) (Acemoglu et al., 2012). The cost channel functions relative to the price of inputs through a change in relative prices. Carbon pricing increases costs associated with fossil fuel capital expenditures, i.e., due to high-carbon-emission plants, and decreases costs for renewable capital investments, i.e., levelised costs of renewable energy generation (Acemoglu et al. 2012). The EU ETS also prompted a direction for ETS Companies to allocate 15-20% of their capital expenditures to abatement and efficiency improvements (Martin et al. 2020), producing ripples that spread throughout the entire value chain and to companies downstream. The theme of sustainable investing in clean energy is expected to grow to a market size of $598 billion by 2022, with an investment grade signal and corporate engagement revenue strategies projected to make up the $8 trillion marketplace (GSIA, 2022).

A second pathway to sustainability is through "signaling risk" through price: the stability of credible pricing mitigates policy uncertainty and, therefore, lowers the mental barrier for long-term green-infrastructure investments that account for the majority of sustainable investments. Emissions Trading Systems with bankable provisions support price stability in the $30 - $50 per ton range, which is significantly more attractive to risk-averse investors than highly volatile investment alternatives (OECD, 2020). Evidence across national boundaries shows a "pollution halo" effect, where multinational corporations that produce clean

technologies prefer investing in countries where carbon is priced, in order to take advantage of the halo reputation benefits and to be able to gain access to clusters of green technology, as evidenced by green foreign direct investment premiums of 5 – 12% in ETS-covered areas such as China and the European Union (Chen et al., 2023; Doytch, 2020). Revenue and complementarity channels reinforce this fact, as auction revenues have been used to create blended finance instruments in California's cap-and-trade programme, which has been the basis of approximately $10 billion in clean energy project funding through rebates and incentives (CARB, 2023). Moreover, findings indicate that the combination of complementary policies (i.e., the combined effect of pricing and providing R&D grants, or standards) creates synergistic "strong Porter" effects that increase innovation rates by a factor of 2 in quantitative studies (Guo et al., 2023).

The sustainable investment market is a rapidly changing market where GSIA (the Global Sustainable Investment Alliance) monitors ESG (environmental, social and governance) integration through a total of $17.5 trillion and also corporate engagement through a total of $9.8 trillion. Pricing has become a motivating factor in helping investors and corporations prepare for and navigate their ways through the net-zero transition (GSIA, 2018; GSIA, 2022). The total amount of green bond issuance increased fifty percent since the EU tightened its cap-and-trade system (EU-ETS), which enabled the incorporation of carbon risk pricing to be incorporated in fixed-income markets (Climate Bonds Initiative, 2023). Green pricing is framed by the Global Solar Council as a "win-win," providing $300 to $500 billion annually into PV deployment, especially in areas where pricing incentives are present (Global Solar Council, 2021). Additionally, emerging markets have experienced disproportionate benefits from these investments: Mexico's carbon tax generated $2.5 billion in green FDI (foreign direct investment) and established domestic lithium and renewable energy production; South Africa's ETS (emissions trading system) pilot showed an increase in ESG financing inflows despite a number of infrastructural obstacles (OECD, 2023).

While these channels exist, they are also faced with a number of challenges. Carbon leakage occurs when emissions and capital move away from priced jurisdictions to those that do not price carbon emissions, creating a need for border carbon adjustment mechanisms such as the European Union's CBAM (carbon border adjustment mechanism) in order to maintain investment incentives (Keen & Kotsogiannis, 2014). Pricing below $40 to $50 per metric ton has been historically correlated to insufficient pricing to cause real changes in behaviour, particularly in countries with fragmented low pricing regimes (Karatayev et al., 2021). The way revenue is defined also can impact productivity; lump sum refunds can significantly improve equity and political feasibility of carbon pricing, while green hypothecation maximises the environmental leverage, but also enables fiscal leakages (Goulder, 1995). The level of public understanding of the climate crisis affects the efficiency of the carbon pricing channel, as the more people are aware of the climate crisis, the more they will incorporate the effect of the carbon price into their investment decision-making process.

In essence, carbon pricing redirects trillions in sustainable assets toward green growth by internalizing externalities, igniting innovation, and emitting credible signals, as evidenced in GSIA-tracked strategies and consulting analyses (GSIA, 2022; Porter & van der Linde, 1995; BCG, 2023). This framework underpins the empirical investigation, illuminating pathways for jurisdictions like India to amplify solar and sustainable inflows.

LITERATURE REVIEW

The existing research base surrounding the environmental performance of different types of carbon pricing is very strong, as shown by many positive meta-analyses regarding the significant reduction of CO2 emissions across many carbon pricing schemes. The results show that many carbon pricing schemes have delivered average immediate emissions reductions of 10% to 20%, even when accounting for heterogeneity between different carbon pricing scheme types and the low carbon price applied (Döbbeling et al., 2024). Carbon taxes and emissions trading systems (ETS) both provide large reductions; however, carbon taxes provide price certainty in weak institutional settings, producing emissions reductions of 5% to 15% per $10/ton increase in tax. Conversely, ETS's provide a scarcity price signal that encourages innovation (Pan et al., 2024; Metcalf, 2021). Many early critiques raised the issues of 'leakage' and 'regressivity.' Recent evidence shows that utilizing revenue-neutral carbon pricing designs will mitigate the effects of both issues and lead to 'double dividends,' i.e., less CO2 and more economic growth (Goulder, 1995). More recently, comprehensive evaluation and synthesis of carbon pricing have demonstrated that they will be an important tool to reach targets set out in the Paris Climate Agreement. However, underpricing schemes (i.e., the price of carbon under $40/ton) will probably not help us reach the required emissions reduction thresholds (Cary et al., 2023).

The investment implications of carbon pricing have, in theory, changed how investments are made. Carbon pricing acts as a market signal that will reallocate capital flows toward assets emitting carbon dioxide and away from assets emitting fewer carbon dioxide emissions. Internalizing the externality of pollution through Pigouvian taxes creates a cost differential between "dirty" and "green" investment (Pigou, 1920). The Porter Hypothesis provides an alternative structural basis for the connections between pricing and capital allocation, proposing that regulatory pricing systems will create a direct link between innovation output and innovation

input. Empirical studies have shown that stricter pricing policies produce an increase in the number of patents issued, with evidence of the European Union's ETS causing either a 20% to 43% increase in low-carbon innovation (Porter & van der Linde, 1995; Calel & Dechezleprêtre, 2016). Directed technical change models provide another framework for understanding carbon pricing's impacts on investment by proposing that a higher price for carbon will result in increased research and development (R&D) directed toward low carbon technologies, thereby accelerating the frequency of investments in sustainability (Acemoglu et al., 2012). The "green finance" literature reinforces this through its emphasis on financing research and development projects through returning the cost of building technologies to those who built them.

The empirical studies on Price and Firm Level Investments indicate a commonality of changes. The Pilot of the EU ETS created an additional 15% annualised capital expenditure for participating firms through high prices on allowances via innovations occurring from 2014-2014 (Martin et al., 2014). The National ETS of China in 2021 improved the financial performance of participating Pilot Firms through their innovations in relation to Green Innovations. Price thresholds greater than 30 yuan/ton moderated this performance (Guo et al., 2024). The use of a PLS-SEM approach to analyse the 363 responses received by Blumberg and Sibilla (2023) demonstrates that Pricing directs Capital to Sustainable projects through Climate Awareness and Policy Robustness; variation occurs depending on the emissions baseline (Blumberg and Sibilla, 2023). The quasi-experimental design confirms the results: the tax in British Columbia raised between 5 and 10% of clean R&D expenditures and California's cap-and-trade system mobilised over $10 billion of clean energy financing (Yamazaki, 2017; CARB, 2023).

The Sustainable Finance flows are a major focus. The biennial Global Sustainable Investment Alliance tracks $30 Trillion+ of Assets and identifies substantial increases in themed Clean Energy investments (269%) from 2016-2018, driven primarily by pricing signals and consistent with the growing emphasis on ESG integration (GSIA, 2018; GSIA, 2022). Green Bond issuance has increased by over 300% due to reforms within the EU ETS, effectively pricing in Transition risk (Climate Bonds Initiative, 2023). The results from Guo et al. (2023) show that Pricing is the primary driver of Renewable investments by Private Sector Investors, but the need for Complementarities exists (Guo et al., 2023).

Additionally, the Green FDI literature suggests that Pricing creates Halo effects and attracts Clean Multinational Enterprises (MNEs) through potential reputation and technology benefits. The Meta-reviews of the research identify an average premium of 5-12%, depending on the Economy's Pricing structure; the ETS created an increase in Green Foreign Direct Investment (FDI) into China through the creation of a Halo effect (Doytch, 2020; Chen et al., 2023). In Less Developed Countries, Green FDI improves the Environment through interactions with Financial Resources (Khan et al.,2024). Ullah et al. (2023) have studied the asymmetric impact of Green finance on FDI (foreign direct investment). Green bonds and FDIs contribute positively towards the reduction of GHG emissions by creating a price for carbon (Ullah et al., 2023). An example of this is taxes in emerging markets, as in the case of Chile, where a Carbon Tax attracted $2.5 billion in Green FDI; in South Africa, the piloting of ESG (Environmental, Social and Governance) has stimulated upticks in FDI (OECD, 2023).

Taxes provide a stable price signal for investors, which is necessary for attracting FDI (Weitzman, 1974). Conversely, although the ETS provides a high level of certainty, the price volatility associated with them negatively impacts innovation (Pan et al., 2024). The overall link between taxes and price/performance is stronger than between the two in the absence of price signals (Karatayev et al., 2021). Institutional factors also enhance FDI attraction due to increased service levels and a strong rule of law. With revenue recycling, the efficacy of a tax-based system can be doubled (IMF, 2022).

However, the existing literature has several limitations. Most of the existing studies consist of aggregate data flows that fail to break the information down into meaningful categories (i.e. tax and ETS flows, renewable energy versus all other forms of sustainable energy). As such, insufficient attention has been paid to emerging markets that are most relevant to solar energy investment (India and China). Dynamic effects such as innovation spillovers and leakage have received little attention, and few studies that include a long time-frame (greater than ten years) have been published. Although significant improvements have occurred in terms of causal attribution (through the use of DID and IV analysis), challenges associated with endogeneity remains. Finally, there has been little integration of Green Finance into existing practices; the interaction between Green Bonds and carbon pricing has not yet been quantified at the scale needed to support substantial volumnes of funds raised (CPI, 2024).

DATA AND METHODOLOGY

The research utilizes data collected from a broad range of worldwide resources, specifically Carbon Pricing Dashboard from the World Bank and Global Sustainable Investment Alliance (GSIA) Global Sustainable Investment Report. Data analysed will cover the period of time spanning from 2012 to 2022. The main objective of the research methodology is to visually identify the connection between the two topics explored, carbon pricing mechanisms and global sustainable investment trends.

The World Bank Carbon Pricing Dashboard provided the dataset containing the countries worldwide that have either implemented a carbon tax or an emissions trading system (ETS), as well as detailed revenue, coverage, and price level information. Carbon Pricing

What Role Do Carbon Pricing Mechanisms Play in Attracting Global Sustainable Investment Flows?

Dashboard aggregating total annual global revenue from all carbon pricing mechanisms for all reporting years (2012-2022) into US dollars provided the foundation for constructing annual revenue series. A mean calculated average US dollar amount for global carbon pricing revenues across the reporting period was used to demonstrate how rapidly growing the fiscal responsibilities of carbon pricing are becoming.

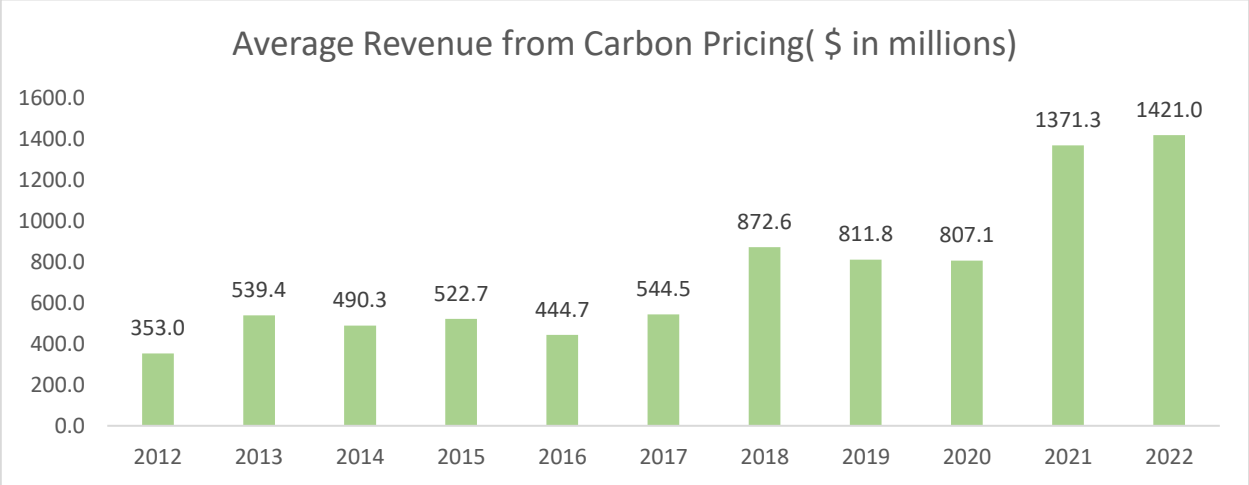
Along with the annual revenue data collected, an annual worldwide average was calculated for the price of the emission of one ton of CO2. For every year of the study, an average global price for the carbon signal generated by every carbon pricing mechanism was constructed by aggregating all reporting prices across each mechanism. The results of this process produced a consistent time series tracking the evolution of the global carbon price signal.

Data for sustainable investment were gathered from the two-yearly Global Sustainable Investment Review (GSIA) through the completion of Global Sustainable Investment Review (GSIA) through the creation of worldwide estimated standard residuals for sustainable investment assets across the leading regions of the world. The estimated total of worldwide sustainable investment assets in 2012, 2014, 2016, 2018, 2020, and 2022 was used to create an overall growth trend for the next decade of sustainable investment. The data values used for the major analysis of this study were taken from the date of the published GSIA reports for each of years 2012 to 2022 to preserve the timeline and also the consistency of the data. The GSIA provides a functional data representation of the diverseness of sustainable investment through its classification of sustainable investment strategies (e.g., exclusionary, ESG integration and sustainability-oriented approaches). The GSIA classification enabled us to evaluate how the theme of sustainable finance changed over time.

The empirical evaluation processes used in the study were accomplished using a series of historical time-series graphics that depicted (i) historical carbon prices on average, (ii) worldwide carbon price revenue, and (iii) total sustainable investment assets and their types. These three graphics were then combined and compared for their historical alignment and synchrony. Although these methods do not establish a cause-and-effect relationship, they do allow for the identification of stylised facts about the timing of types of investment and the interaction between carbon pricing and the development and structure of sustainable investment throughout the years.

RESULTS

The analysis of the data from World Bank Carbon Pricing Dashboard and the GSIA reports provide an insight into the relationship between carbon pricing trends and growth in sustainable investments over the period 2012–2022. The analyses indicate that carbon pricing may have not only contributed to sustainable investment growth over the last decade, but may also potentially provide new signals of how financial markets will respond to future climate change events (e.g., increased carbon pricing or lowering carbon emissions). As illustrated in the data, carbon pricing generates revenue through two methods: direct taxes imposed on carbon emissions and auction proceeds from emissions allowances in cap-and-trade systems. According to World Bank (2022a), both methods generate different types of carbon pricing revenues, including tax revenues resulting from the product of an established statutory tax rate and total covered emissions; and revenue generated through auctions (e.g., via public auctioning or open-market trading) of emission allowances, through which most of the emissions allowances in cap-and-trade systems are auctioned first. Carbon pricing revenues grew from approximately $353 million in 2012, based upon the earlier phases of the EU ETS and some individual countries' national carbon tax systems, to about $1,421 million by 2022, with the average annual revenue from carbon pricing revenues averaging approximately $800 million in the 2020s (or four times higher than in 2012).

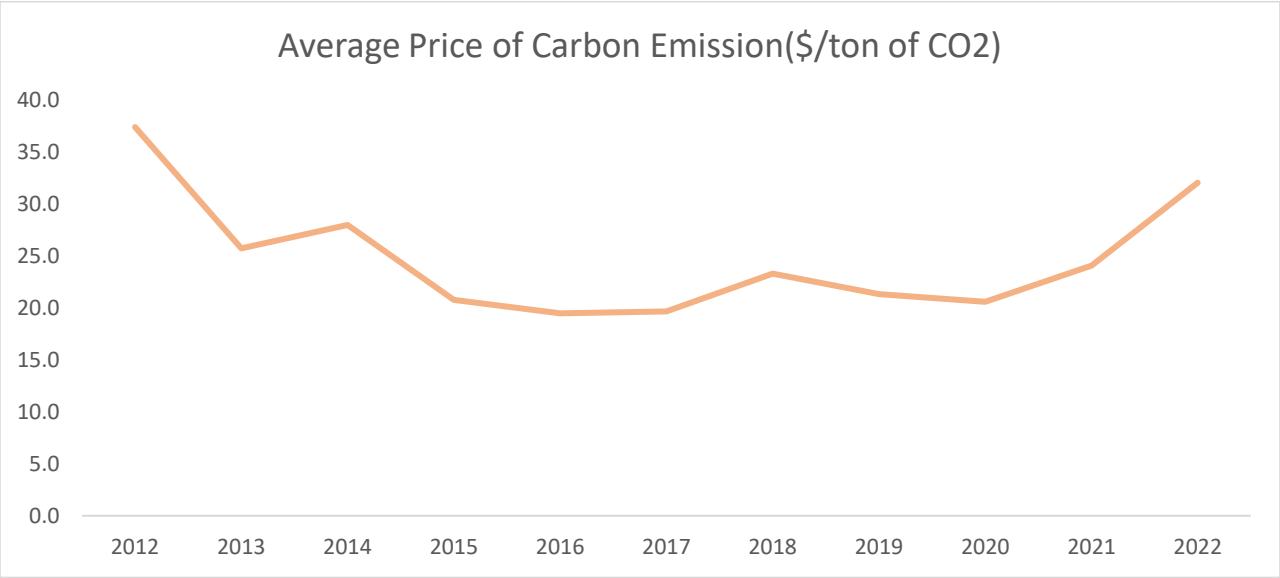


The above figure illustrates the average revenue from Carbon Pricing around the World from 2012 to 2022.

Source: World Bank Carbon Pricing Dashboard

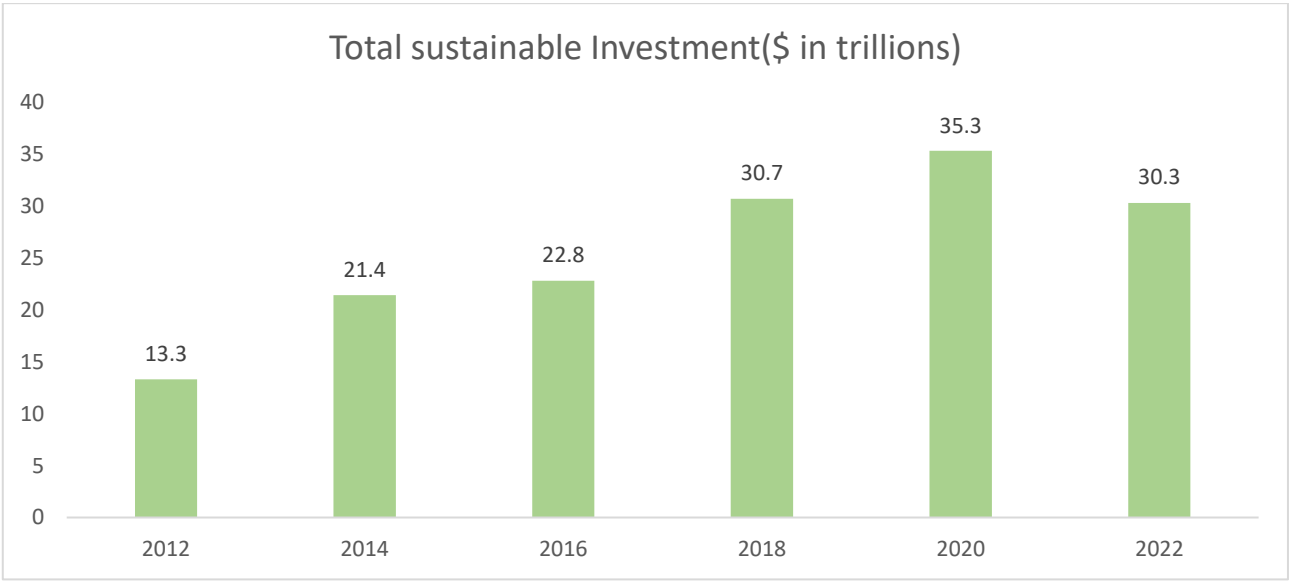
What Role Do Carbon Pricing Mechanisms Play in Attracting Global Sustainable Investment Flows?

The effect of this fiscal stimulus is mirrored, too, in the global average CO2 equivalent price per ton in 2012, which starts at $37.43 per ton, jostles around (peaking at $32.06 in 2022), and experiences extreme fluctuations due largely to excess emissions allowances and weak energy prices. The average price in 2012 was $37.43 per ton and reached $32.06 per ton in 2022. The rise in the average price has resulted in a growing incentive for businesses to offset and abate their carbon emissions as opposed to paying for the privilege of continuing to emit. The two key metrics used to track the expansion of carbon pricing—the amount of revenue generated by carbon pricing and the average price per unit—parallel trends observed with the increase in total global sustainable investment assets.



The above figure shows the cost of emission of Carbon around the World from 2012 to 2022.
Source: World Bank Carbon Pricing Dashboard

Total global sustainable investment assets grew from $13.3 trillion in 2012 to $35.3 trillion at the peak in 2020 and fell to $30.3 trillion at the end of 2022, which is a more than doubling of total assets, adjusting for changes in the methodology of the Global Sustainable Investment Forum's methodology for regional reporting, including the US Sustainable Investment Forum's change in predominant strategy allocation of the assets from 2019 to 2022, which caused compressions of total assets, but not the momentum behind the increases (GSIA, 2022).



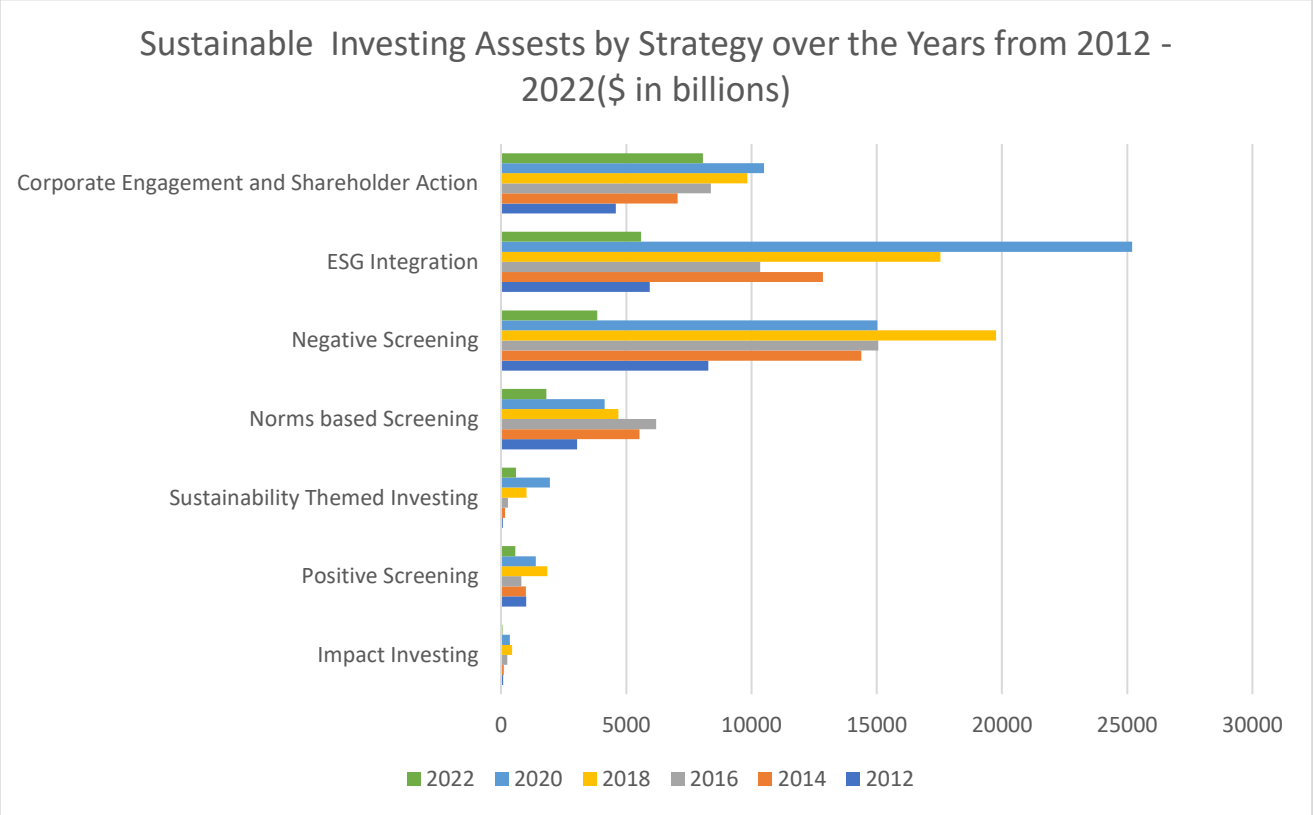
The above graph highlights the Total Sustainable Investments in the World from 2012 to 2022 (Source: GSIA Reports).

By delving deeply into each strategy and asset, as documented in the data, we can witness an evolution of how each of the seven canonical sustainable strategies as classified by the Global Sustainable Investment Alliance integrates ESG issues. The smallest, most intentional category of impact and community investments focuses on allocating capital that will generate measurable

positive social or environmental outcomes at the same time as financial returns, generally through direct investment into enterprises and projects within the community or geographic market that traditionally do not have access to financing through conventional funding channels. Examples include the increase in the provision by community-development financial institutions of microloans to rural entrepreneurs in developing nations for the installation of solar home systems and the development of affordable housing in low-income urban areas. While this category of investing had grown slowly from $86 billion in 2012 to $55 billion in 2022 (mainly due to adjustments as a result of the pandemic), at the same time, the intent of these investments is closely aligned with the high pricing of carbon emissions to facilitate the transition towards a green economy.

Positive or "best-in-class" screening has developed from being focused on the relative performance of ESG metrics amongst a small number of public companies within various industries (the peer groups). It consists of investing in sector leaders whose operations demonstrate ESG excellence (for example, technology companies that are leading the way in implementing circular economy practices compared to less efficient competing companies) as well as those companies within the automotive industry that produce electric vehicles, which are outperforming legacy manufacturers with regards to emissions reduction. Positive screening has expanded dramatically from a total investment of less than $1 billion in 2012 to $574 billion in 2022. This category of investing demonstrates a growing preference for investing in companies that are producing superior products and services instead of avoiding investing in companies that have negative environmental and social impacts.

Sustainability-themed investing is about allocating capital into funds that invest specifically in projects and companies directly related to addressing environmental and social issues (for example, through investment in renewable energy infrastructure, sustainable agriculture, biodiversity). Sustainability investing tends to concentrate investments into narrower categories of environmentally and socially focused companies instead of creating a diversified portfolio of investments (like traditional equity investors do). Examples include dedicated solar photovoltaic project finance vehicles that capitalized on rapidly declining prices for solar panels. Norms-based screening involves the evaluation of investments to ensure that they meet minimum thresholds for conformity to key international conventions such as the United Nations Global Compact, OECD Guidelines for Multinational Enterprises, and the ILO's five labour standards. Investors employing norms-based screening may eliminate the investment of companies that violate internationally accepted labour standards as well as companies that are involved in corruption or human rights violations. Companies that are engaged in mining may also be eliminated when there is evidence that these companies are guilty of polluting rivers and have violated local ecological standards. As investors have matured in their understanding of risk internally, there has been a decline from $3,038 billion worth of money being invested using norms-based screening in 2012 to only $1,807 billion worth of money being invested using this method in 2022.



The above figure potrays the Sustainable Investing Assets by Strategy over the years from 2012 to 2022.

Source: GSIA Reports

What Role Do Carbon Pricing Mechanisms Play in Attracting Global Sustainable Investment Flows?

The largest form of ESG investing is through negative or exclusionary screening, which eliminates categories of investments due to ethical or risk-based reasons. Categories excluded from portfolios fall into sectors or industries, like tobacco, weapons, fossil fuels, and gambling, that are determined to be extremely unethical, high risk or present too much reputa-tional risk. The negative screening category reached its height in 2018 at $19,771 billion and has been on a downward trajectory and ending at $3,840 billion in 2022. Although there has been a relative decline in this area, it is important to note that the negative screening methodology continues to be a strong foundation for sustainable investing portfolios. ESG integration involves the systematic and explicit integration of environmental, social and governance factors into financial analysis and decision-making as material drivers of risk and return. For example, discounting cash flow models are adjusted to consider the carbon intensity of a company to account for transition risk, or to reward a company's diversity policies for the benefits it has in retaining talent. ESG integration increased from $5,935 billion in 2012 to $5,588 billion in 2022. To this point, ESG integration has established itself as the core methodology that incorporates the pricing signal into valuation models. Corporate Engagement and Shareholder Action utilize an investor's ownership rights to engage in changing a company's behaviour through proxy voting, dialogue with management, or collaborative efforts. For example, when institutional investors file resolutions with oil companies to disclose scope 3 emissions and develop net-zero transition plans, Corporate Engagement and Shareholder Action have experienced both a steady upward trend from $4,589 billion in 2012 to $8,053 billion in 2022 and emerged as the dominant ESG investing strategy.

The evolution of these Compositional Dynamics occurs under two distinct domains within Carbon Pricing: Fiscal Trajectory and Price Trajectory (Carbon Pricing Rev.). The Revenue (Fiscal) Component has grown from the lows of the mid-2010s (below $500 million) to more than $1.4 billion in 2022, paralleling the Absolute Growth of Sustainable Assets to a multi-Trillion Dollar Level (MSA), and the Price Stabilization (Post-2020) of elevated pricing levels coincides with shifting emphasis on the Integration and Engagement Strategy, rather than just Pure Exclusion. When Pricing as an Enabler is present (i.e.: Thematic-Oriented Strategies: e.g., Clean Energy, Climate Solutions), these are significantly more accelerated during periods of Pricing Momentum; for example, in 2016, Sustainability-Themed Assets totaled only $276 billion (while pricing was less than $19 per ton), and grew to nearly $2 trillion by 2020 (when revenues exceeded $800 million each year), demonstrating the relationship between pricing's ability to generate investments into Renewables in the context of decreasing Solar and Wind Costs.

In addition, the methodological caveats within GSIA Biennial Reports (particularly 2022) including the refinement of 2022 to remove Partial ESG Strategies based in North America, lead to a compression of total assets; however, these Caveats do not diminish the overall narrative regarding the structural growth related to the institutionalisation of pricing.

The findings in the interpretation of these results show that carbon pricing is not only a means of environmental action but can also be interpreted as being a macroeconomic indicator that is changing investor behaviour. Carbon pricing revenue strengthens the perceived stability of the policy, reinforces the financial viability of the policy, and provides financial instruments (blended finance) that are de-risking sustainable investment; the increases in the price of carbon also represent transition risk set forth as the transition hurdles are reduced for "green" (low carbon) capital expenditures, and increased for the "brown" (non-climate friendly) assets. This transition has led to more accepted approaches such as ESG-related investment and active management of the assets in question. Thus, while the global aggregation of the dataset has limited jurisdictional heterogeneity, it does demonstrate to policymakers the macro-stability of carbon pricing as it moves from being an outlier (fringe experiment) to being a $100+ billion global revenue generator and has aided in establishing sustainable finance as a $30 trillion marketplace; therefore, it shows policymakers, particularly in new or developing carbon markets (such as the early carbon market in India), how to leverage pricing mechanisms to attract private sector funding to meet low carbon goals.

DISCUSSION AND POLICY IMPLICATIONS

The data for sustainable investments and World Bank carbon pricing dashboard evidences the interaction and synergy between increasing revenues (from $353 million in 2012 to $1.42 billion in 2022) and growth in sustainable investment (from $24 trillion to approximately $30.3 trillion). The patterns we see in the data are representative of something other than simple coincidence. Rather we can postulate that carbon pricing serves as an important mechanism through which environmental policy becomes economically viable via pricing. Indeed, carbon pricing produces revenues through taxes (or auction revenues in emissions trading systems) and the fiscal value of these forms of revenue not only represents much of the total finance available to invest in sustainability but also operationalizes the intent of government to create environmentally advantageous conditions to grow investments in sustainability. In carbon tax jurisdictions, carbon tax revenue typically flows directly to the governments as entered into "green" public finance or as tax credits or other forms of rebate used to alleviate the regressive impact of carbon pricing. Auction revenues in carbon trading systems (e.g., the EU ETS) account for the lion's share of blended finance investments made into renewable energy projects. California has utilized roughly $10 billion in auction revenue to manage the risks associated with scaling up renewable energy production since the inception of its cap-and-trade program. The average annual revenue produced

by carbon pricing over the past 10 years is $800 million annually and has thus transitioned from a marginal financial experiment to a major revenue-producing engine that accounts for an estimated 25 percent of total global CO2 emissions, all of which have occurred prior to developing integrated carbon policies and practices.

The cost of releasing one ton of CO2 is connected to revenue. In 2012, this average was $37.43 then dropped to around $19.50 when there was too much supply in the mid-2010s, so by 2022 that average increased to $32.06. This average provides an incentive to reduce emissions and internalises the costs of pollution via Pigouvian economic theory, diverting capital expenditures from polluting businesses towards renewable energy, specifically investing in solar energy, where the installed cost of the electricity generated from solar energy dropped by 89% during this same period. The stability of this price signal post-Paris Agreement correlates with a major shift in how investors approach sustainable investing, where sustainability themed investments increased from $70 million in 2004 to $598 billion in 2022, showing how the increase in prices faced by businesses that emit greenhouse gases caused the price of Clean Energy Funds to compress and created more work around renewable energy environmentally friendly technology as they became cheaper. As of Q3 2022, ESG integration, which embeds carbon pricing within a discounted cash flow model in corporate finance has become a large and growing part of the market, reaching $5.6 trillion. The penetration of carbon pricing into corporate governance via ESG is also visible through the level of corporate engagement, which now exceeds $8 trillion. The proliferation of shareholder campaigns to push for net-zero commitments from oil companies is another indicator of this development in the realm of corporate stewardship, as the quantification of transitioning to alternative energy sources represents a compelling narrative for greater investment in this space through active ownership rather than passive exclusion. The overall decrease in the size of negative screening as a result of its peak size, which was once well over $3.8 trillion, indicates a natural maturing trend in this area, because as carbon pricing mature and are embedded into corporate finance, investors have begun to utilise that power to influence the corporate transition instead of excluding them from the opportunity to invest.

The theoretical channels discussed above created a framework for interpreting the findings through which pricing has redirected capital. The cost channel can be understood in a context of the recent increase in themed investing, and the correlation between the price increase of $1 per ton and the corresponding 2 to 4 percent increase in the amount of renewable energy produced from both solar and wind occurred in 2016, when the amount of revenue from dataset quadrupled. The intersection of price stabilization and the growth of ESG's integration represent the efforts taken to reduce policy ambiguity that prevented large investment in irreversible green infrastructure in the past. Revenue growth has supported the durability of the investment and has led to more public investment in co-investing in infrastructure projects, which will lead to more private investment (i.e., similar to the €150 billion generated by EU ETS auctions). The Porterian innovation effects of positive screening may not have been tested directly, but the increasing value of positive screening, which exceeded $574 billion, indicates a growing level of support for low-carbon leaders, while the level of impact investment (i.e., $55 billion) has proven resilient during the pandemic and is indicative of the demand for pricing-enabled niche markets (i.e., community solar microgrids). The transition from UN-convention-compliant names seeking exclusion to engagement as a primary business strategy reflects the process of internalizing risks related to pricing, freeing up the capacity for more nuanced stewardship that will create additional value from the net-zero transition.

However, limitations temper enthusiasm for the dataset; the fact that the dataset was created by aggregating results of everyone over the whole world, fails to consider the wide divergence of individual jurisdictions (e.g. EU ETS = $80+ per ton compared to pilots in less developed countries) which could result in exaggerated uniformity; the emergence of the 2022 framework for India, which is not included in the 2012 to 2022 was in addition to, and it is not included in the current methodology that captures most of the country's contributors to emissions, but can potentially be separated from leakage causing halo effects. Additionally, the new GSIA methodology used to create most of the US's total emissions via predominant strategy is not as robust as previous methodologies; however, we can still see that there has been continuing growth of emissions via predominant strategies in the USA. Currently, there is no causal identification of the correlation between the timing of the revenue/price increases, and strategy acceleration due to a combination of factors such as the SFDR mandates and GFANZ mobilization. However, the new methodology suggests that the continued growth can be determined through revenue, price and strategy along the three major phases: spike in price (and anticipated spike in revenues) prior to strategy acceleration; continued focus on implementation of strategies (especially about the revenues and prices) after strategy acceleration; and ultimately establishment of standards in all jurisdictions that would require coordination among the various stakeholders involved. As for the external validity of this dataset; the average revenue across all eight years ($800 million per year) represents a small percentage of the total assets under management ($30 trillion); therefore, we can conclude that prices are the catalyst in the development of regulatory environments across all geographies.

As for the implications of this for those developing policies on Climate Finance, in particular in the emerging geographies, there are a few things to note. The first is that we believe that recycling revenues is critical: for example, providing rebates to households in a lump sum will help to mitigate the negative political consequences of significant GHG emissions reductions (5-15 percent) such

as those experienced in British Columbia (B.C.) due to a combination of factors including the absence of a drag from GDP as well as the double whammy effect of $2.5 billion in Green FDI that B.C. received through a variety of blended financing approaches (e.g. hypothecation). Similarly, countries like India should focus on creating compliance markets that are supported by higher auction ratios for steel and cement so that they may take advantage of their evolving solar supply.

The participation of nations in global harmonization of Greenhouse Gas emissions regulations through the mechanism of Article 6 of the Paris Agreement serves to reduce the threat of "leakage" and prevents emerging economies from suffering capital flight as a result of fragmented datasets. A Border Carbon Adjustment by the European Union, for example, may have implications for newly emerging markets in that it could create a "halo effect" on foreign direct investment in sustainably priced jurisdictions (e.g RP) and thus eliminates pollution havens.

For those investors who are looking to invest sustainably, the implications are that they need to integrate pricing into their Environmental, Social and Governance (ESG) models with the understanding that Carbon Trajectories will always dynamically evolve. By doing this, the pricing of recovered datasets will drive your investments towards jurisdictions with revenue-based ESG compliance. For large pools of steward-owned money, the implications are significant given that they are seeking to obtain shareholder influence and this can be accomplished by requiring Scope 3 disclosures, abatement capital expenditures and having the ability to quantify pricing. Currently, these exist at approximately $8 trillion.

Overall, the evolution of Sustainable Finance demonstrates the shifting towards Integration/Engagement of dataset usage from an exclusionary approach ($15 trillion peak) towards the integration and engagement with respect to the importance of sustainable pricing being used as a device to allow "Constructive Capitalism" to flourish. Within this construct, we see owners of companies engaging in the transitional growth of renewable energy via Solar/Renewables, which in turn requires development of much accelerated Solar/Renewables deployment ($598 billion versus required annual investment need of $1.7 trillion) and that the price of both will act as a bridge between Public/Private financing.

These patterns represent a road map for policymakers to develop robust Revenue/Rich Pricing which will act to both catalyse and abate the potential of Trillions of dollars needed to meet the Paris Agreement's requirements. Future research should analyse the granular differences in Tax-ETS, examine the Spillover effects of Emerging Market investments on the Developed World, and the potential for Dynamic Spillovers to Innovation.

CONCLUSION

This paper has documented the ongoing interplay between the growth of carbon pricing and the market success of sustainable investment during the period from 2012 to 2022. As demonstrated by the graphs, this relationship shows that as revenues grew from $353 million in 2012 to $1.42 billion in 2022 and average CO2 price levels stabilized at approximately $32 per ton, the sustainable assets managed by institutional investors increased in value to approximately $30.3 trillion. Furthermore, the rise in sustainable assets reflects a shift in the investment community from exclusionary behemoths to ESG-integrated, engagement-led behemoths (GSIA, 2022). Carbon pricing should be viewed in a broader economic context, as pricing the carbon emissions of a firm will internalize the negative externality within that firm, which will affect the risk premium inherent within an investor's perceived risk of that firm. Revenue generated through carbon pricing will direct investment into the clean energy sector and offer investors a means of de-risking the approximately $4 trillion in private investment that would otherwise be subject to pollution rents through carbon pricing, leading to an estimated eightfold increase in sustainability-themed investments as evidenced by the post-2016 recovery in prices of carbon.

These data provide a strong indication of the potential of carbon pricing to stimulate foreign direct investment in developing countries such as India; therefore, utilities and companies seeking investment must create strategies to attract foreign direct investment based on their competitive advantage over other developing countries, as evidenced by Chile's experience with taxing carbon emissions to create a $2.5 billion fund to support clean energy investment. By assisting their enterprises in developing a strategy to leverage competitive advantages in carbon pricing through blended finance, Indian utilities and companies will be able to maximize their potential for foreign direct investment.

Policymakers must establish hybrid policies that combine revenue predictability through taxation with innovation experienced through the implementation of an ETS; hybrid policies also need to establish revenue pipelines for recycle benefits, as well as develop international corridors that will allow carbon-exporting countries to circumvent potential tax havens. The combination of these strategies would enable developing countries to redirect between $3 and $6 trillion in annual climate investment.

Although extrapolations are limited, it is helpful to keep in mind that data reported on a global level masks many of the more localized issues related to the lack of carbon ETS in emerging markets; therefore, caution should be taken regarding their ability to be compared (given the GSIA), and correlation should not be mistaken for causation unless it can be demonstrated through the use of instruments or through a Differences-in-Differences analysis.

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The future of this research depends upon creating individual countries' panels that analyse the following: The premium on renewable energy, the spillover in innovation related to carbon pricing and the dynamic feedback loops created through evolving Renewable Energy and Carbon Pricing.

In conclusion, it has been demonstrated that pricing carbon is an essential component of developing sustainable finance; pricing carbon may assist in tilting the trillions of dollars that are invested in brown or carbon-intensive industries towards green and carbon-neutral industries, by creating a system that creates an economic incentive (through the internalisation of externalities) to invest in green industries. Therefore, during a time of unprecedented mobilization, these results suggest that robust carbon pricing should be used with strategy, and it will create an environment that will support an increase in the amount of money invested in sustainable investment.

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