Final Research Paper

MPA 2476: Global Environmental Policymaking

Systemic Substitution Asymmetry and Infrastructural Lock-In: An Operational Analysis of the Ozone and Climate Regimes

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Introduction

Researchers in global environmental governance keep circling back to the same stubborn question. Why do certain international agreements manage to reverse serious environmental harm relatively quickly, while others stall for years with little to show for the effort? The standard answer in the field has been to zoom in on institutional details, such as how treaties are written, how decisions get made, and whether countries actually comply. That line of work has produced real insights, but it still misses something fundamental. It pays too little attention to the material and economic realities that decide whether an agreement can actually be put into practice. These treaties are not just pieces of paper. They are massive industrial shifts that depend on whether companies can invent, finance, and roll out new technologies at the scale the world needs. If the market cannot supply those changes at a workable price, even the smartest treaty cannot touch the chemistry of the atmosphere.

This paper compares two atmospheric problems that share many features but yield very different results. One is the Montreal Protocol on Substances that Deplete the Ozone Layer. The other is the climate regime anchored in the United Nations Framework Convention on Climate Change and the Paris Agreement. Both tackle pollutants that cross borders and affect the whole planet. Yet one has delivered near-total success while the other continues to struggle. The Montreal Protocol has driven the removal of almost every targeted ozone-depleting chemical. The Paris Agreement has brought nearly every country on Earth into the fold, but global emissions are still not falling fast enough to avoid serious climate disruption.

Work by Sprinz and Vaahtoranta (1994), Allan (2019), and Hadden (2025) highlights a key variable that helps explain the gap. Regimes tend to succeed when clean substitutes for the harmful substance are affordable, widely available, and straightforward to scale. This paper gives that pattern a name: Systemic Substitution Asymmetry. The basic idea is simple enough. Success depends on how tightly a pollutant is woven into existing factories, supply chains, and industrial systems. When a good replacement can be adopted without high extra cost or upheaval, the cost of cleanup drops sharply. Large industries that might have fought the rules often end up backing them instead. That change in incentives makes it far easier for governments to settle on strong, enforceable commitments. When substitutes are missing or far too expensive, the opposite happens: momentum stalls.

Case Selection and Methodological Framework

The analysis relies on a comparative case design drawn from John Stuart Mill's Method of Difference. It examines two cases that look alike in structure and geopolitics but produced sharply different historical records. Ozone depletion and climate change both fit the classic tragedy-of-the-commons pattern. The pollutants drift across borders, remain invisible, and cause effects that surface years later. Fixing either problem demands near-universal cooperation, fair cost-sharing, and credible enforcement. The main players are the same in both stories: national governments that run the negotiations, multinational firms that advance their interests, scientists who provide the evidence, and United Nations bodies that keep the process moving. What gives the comparison real analytical bite is the contrast in outcomes despite all those similarities. That contrast lets us zero in on how differences in technological substitution capacity have limited or expanded what diplomacy could actually deliver.

Case Description 1: The Ozone Depletion Regime (Product-Level Transition)

The global push to protect the ozone layer offers one of the cleanest examples of how international rules and industrial adaptation can work in tandem. In the 1970s, chemists discovered that chlorofluorocarbons (CFCs) drift into the stratosphere and break down ozone. Back then, CFCs were used in refrigerators, air conditioners, aerosol cans, and cleaning solvents. A thinner ozone layer lets more ultraviolet-B radiation reach the ground, raising skin cancer rates, damaging ocean plankton, and reducing crop yields.

Early diplomatic steps stayed modest. The 1985 Vienna Convention created a channel for sharing scientific data but placed no real limits on production or use. Chemical companies lobbied hard against tighter rules, worried about the cost of retooling plants and the risk of losing money on existing equipment. The turning point came when measurements confirmed a large "ozone hole" over Antarctica. That evidence gave governments enough urgency to adopt the 1987 Montreal Protocol.

The Protocol worked because it built flexibility and market signals into the rules. It set gradual reduction targets that gave industry time to develop replacements. Later amendments in London in 1990 and Copenhagen in 1992 tightened deadlines once hydrochlorofluorocarbons and then hydrofluorocarbons became available. The Multilateral Fund helped developing countries cover the extra cost of switching technologies, removing a major equity barrier. Trade rules under Article 4 blocked commerce in controlled chemicals with countries that stayed outside the agreement, giving companies a strong reason to comply (Barrett, 2005). The 2016 Kigali Amendment carried the same approach forward for hydrofluorocarbons, which are powerful greenhouse gases. Coordinated action has now cut more than 98 percent of ozone-depleting substances, and the ozone layer itself is recovering.

Case Description 2: The Climate Change Regime (Systemic Infrastructural Bottlenecks)

Climate efforts show a persistent disconnect between diplomatic milestones and actual emission reductions. The 1992 United Nations Framework Convention on Climate Change laid out the broad goal of stabilizing greenhouse gas concentrations, yet it set no binding targets or deadlines. The 1997 Kyoto Protocol represented the first serious attempt to impose mandatory cuts, requiring wealthy countries listed in Annex I to reduce emissions roughly 5 percent below 1990 levels. The exclusion of major emitters, plus the high projected costs of transitioning away from fossil fuels, triggered fierce political pushback in industrialized nations. In the United States, the Senate passed the Byrd-Hagel Resolution 95-0, vowing to reject any treaty that either left developing countries out or harmed the American economy. The United States never ratified the agreement, which undercut its credibility. The 2009 Copenhagen summit ended without a binding follow-up, revealing how hard it is to force sovereign states to accept painful economic shifts when those shifts clash with their perceived national interests.

The 2015 Paris Agreement grew out of that more modest outlook. It replaced top-down quotas with voluntary Nationally Determined Contributions and a five-year cycle for reviewing and raising ambition. The agreement achieved near-universal participation, a diplomatic victory. Its environmental results, however, have been disappointing. Allan (2019) describes the design as "dangerous incrementalism." To bring the biggest emitters on board, negotiators dropped strong enforcement tools, trade penalties, and legal obligations. Global carbon dioxide emissions from fossil fuels have continued to climb since the Paris meetings. Current pledges point toward roughly 2.4 to 2.8 degrees Celsius of warming by 2100, well above the 1.5-degree limit scientists consider essential. Hadden (2025) points to several ongoing obstacles, including shifting U.S. political priorities, a high national debt that constrains green investment, and geopolitical frictions over energy security. International cooperation has frayed, and numerous countries have missed deadlines for updating their plans. These shortcomings highlight the structural weakness of a governance system built primarily on voluntary pledges rather than aligned economic incentives.

Hypothesis: Systemic Substitution Asymmetry and Infrastructural Lock-In

Placing the ozone and climate cases side by side brings a single explanatory factor into sharp focus. The effectiveness of international environmental regimes depends critically on the technological and economic conditions surrounding substitution. This paper terms that factor Systemic Substitution Asymmetry. The concept captures the uneven ease with which harmful substances can be replaced within existing industrial systems. Treaties do not themselves reduce emissions. Engineers must develop viable alternatives, companies must invest in new capital equipment, and consumers must adopt different products. When substitutes are affordable, scalable, and compatible with prevailing supply chains, the marginal cost of abatement falls sharply. That economic shift alters domestic political incentives. Industries that once opposed regulation often become advocates because binding rules create protected markets for their new technologies. For governments to reach agreement on stringent and enforceable commitments, domestic business interests and environmental objectives must therefore converge. When substitutes are unavailable, immature, or would require wholesale replacement of core infrastructure, abatement costs remain prohibitively high. In such circumstances, negotiators are driven toward non-binding pledges and soft-law approaches because powerful incumbent industries mobilize to protect their existing assets and business models.

Defending the Hypothesis: Applying the Interest-Based Matrix

The interest-based model developed by Sprinz and Vaahtoranta (1994) gives a clear way to test this hypothesis. The model argues that a country's stance on international environmental policy comes from the interaction of two domestic factors. Ecological Vulnerability reflects the extent of environmental damage a country is expected to suffer. Abatement Costs measure the cost of reducing the pollutant in question. Plotting these two variables on a simple matrix produces four behavioral types. Countries facing high vulnerability and low abatement costs become "Pushers" and demand ambitious rules. Countries with low vulnerability and high costs act as "Draggers" and resist binding deals. Countries with low vulnerability and low costs tend to stay on the sidelines as "Bystanders." Countries with high vulnerability but high abatement costs fall into an "Intermediate" category because they see the threat but lack the resources or political will to move quickly.

The ozone case shows the mechanism in action. Rapid commercialization of hydrochlorofluorocarbons and later hydrofluorocarbons lowered abatement costs for the United States and its chemical industry, shifting both from the Intermediate to the Pusher category. Early on, companies like DuPont opposed CFC controls because they feared large retooling expenses. Once the U.S. Environmental Protection Agency signaled it might regulate domestically, DuPont stepped up research into alternatives. The company realized it could produce substitutes using its existing supply chains and capture global market share under the cover of an international treaty. DuPont, therefore, moved to support the Montreal Protocol as a form of green mercantilism. Binding standards would force foreign competitors to adopt the same technologies, giving the American chemical sector a protected market for its patented products that delivered high margins (Barrett, 2005). The U.S. government backed strict targets because the technological alternative made long-term compliance economically attractive. The Multilateral Fund further reduced abatement costs for developing countries and brought them into the coalition.

Applying the same matrix to climate change explains why progress has been slow. Fossil fuels form the backbone of the entire global economy. Shifting away from them requires rebuilding power grids, transportation systems, and heavy industry at a cost measured in trillions of dollars. For the first twenty years of talks, no alternative matched the energy density, reliability, and low price of coal, oil, and gas on a global scale. Within the Sprinz and Vaahtoranta framework, the lack of substitutes kept major emitters in the Intermediate or Dragger categories. Unlike DuPont, fossil fuel companies cannot patent the wind or the sun. Their core business model faced existential risk, so they spent heavily to weaken or block agreements such as the Kyoto Protocol. International negotiators responded by creating the voluntary structure of the Paris Agreement because no other design could reconcile the conflicting economic interests. The result, as Zelli and van Asselt (2013) and Allan (2019) note, is a fragmented and weakly institutionalized system.

Conclusion and Evidence for Future Testing

A comparison of the Montreal Protocol and the UNFCCC yields a clear conclusion. Diplomatic frameworks alone do not generate environmental outcomes. Effectiveness is ultimately determined by the physical infrastructure, industrial logistics, and domestic political economies of participating states. The ozone regime succeeded because chemical manufacturers developed CFC substitutes that were both profitable and relatively straightforward to integrate into existing production systems. Once those alternatives existed, governments could impose strict rules while simultaneously shielding domestic industries from competitive harm. The climate regime has encountered persistent difficulties because the modern economy remains deeply locked into fossil-fuel infrastructure. For the first 20 years of negotiations, no substitute matched the performance and price of coal, oil, and natural gas globally. The resulting high abatement costs gave incumbent industries powerful incentives to resist structural change. To evaluate the Systemic Substitution Asymmetry hypothesis more broadly, researchers should apply the same material lens to other ongoing global environmental negotiations. The current United Nations process toward a binding plastics treaty offers a particularly promising test case. Strict targets are likely to materialize only once bioplastics or advanced chemical recycling technologies reach cost parity with conventional petrochemicals. At that point, major producing countries would face lower compliance costs, and petrochemical firms would have diminished reason to obstruct progress. Process-tracing methods could usefully be applied to the maritime shipping sector as well. As green methanol and ammonia become commercially available in global supply chains, analysts can examine whether these technologies emerge before the adoption of mandatory emissions limits.

History offers repeated illustrations that international environmental objectives falter when they exceed what is technologically and economically feasible at a given moment. The Paris Agreement exemplifies the consequences of pursuing ambitious goals in the absence of viable substitutes. Diplomatic ambition proved insufficient. The landscape is nevertheless beginning to change. Costs for solar photovoltaics, wind turbines, and battery storage have declined rapidly and now approach parity with fossil-fuel generation in many markets. Should this trajectory persist, the same substitution dynamic that propelled the Montreal Protocol toward success could eventually transform climate governance. Corporate profitability and climate objectives would begin to converge. That convergence would provide the political capital necessary for the Paris

Agreement to evolve from a system of voluntary pledges into one capable of delivering binding, effective commitments.

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