PROMOTING GREEN TECHNOLOGIES FOR LOW-INCOME COUNTRIES: AN ECOLOGICAL IMPACT FUND

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Human activities are driving our world toward a climate catastrophe with worsening harms from extreme weather events, expanded reach of tropical diseases, increasing scarcity of food and water, and extinction of biological species. Our emissions also cause other harms, such as millions of annual deaths from air pollution (Vohra et al. 2021). These problems will not be solved by drastically curtailing the conveniences of modern life or by reducing the human population. If we will solve them at all, then through swift development and deployment of green innovations ("greenovations") coupled with deep changes in individual and societal behaviour to make consumption and production sustainable. But such a profound, rapid transition faces serious collective action problems.

Before new technologies can be sold and used, they must first be invented and developed. This requires risky research and development (R&D) investments whose cost must be borne by someone. Currently, this problem is addressed through state funding, used to support research at public and private universities, institutes and companies, as well as through the additional incentive of state-enforced patent awards, which have been globalized to a uniform standard in 1995. Annex 1C of the founding treaty of the World Trade Organization requires WTO members to issue patents of at least 20-year duration on eligible innovations (World Trade Organization 2005: esp. Articles 27, 28 and 33). This regime enables successful innovators to reap substantial markups, royalties, or licensing fees from early users in nearly all countries.

While this regime incentivises development of new technologies, it also raises their sales price to a supra-competitive level, thereby disadvantaging them relative to older technologies that, offered by multiple suppliers, are available at competitive prices.[1] The reduction in sales caused by this disadvantage is doubly regrettable: it reduces the new technology's impact, and it diminishes originator rewards along with the incentive to invest in innovative R&D.

This headwind against uptake is aggravated by the present innovation regime's insensitivity to third-party benefits. This is especially significant for greenovations because nearly all their benefits go beyond buyers and users to present and future living beings all around the planet. These large potential benefits often remain unrealized because neither potential buyers (through a price surcharge) nor potential suppliers (through a price discount) are willing and able to finance them privately. The resulting lower sales volume is predictable, and many highly beneficial greenovations are therefore not even developed.

To illustrate, consider a factory that could be operated with or without a certain filter reducing harmful emissions. Deploying this device is expensive, partly because it requires paying a licensing fee to the patentee. In deciding whether to bear this cost, plant owners may weigh the health benefits to themselves and their employees. But they are rarely willing and able to take full account of the vastly larger difference their decision makes to the whole planet, future generations included.

Let's assume that, over time, each filter deployment has a small effect on the composition of the atmosphere, increasing the life expectancy of 20 billion present and future human beings by 63 seconds on average. That's 40,000 human life years per device installed. Nonetheless, many factory owners will not pay even EUR 20,000 more for these third-party benefits. Nor will typical patent holders make such a financial sacrifice. As rational market actors, they set the profit-maximizing price. They prefer selling 100 licenses at EUR 20,000 each over selling 150 licenses at EUR 13,000 each – even if the latter decision would avert the loss of over 2 million human life years at a total cost of only EUR 50,000.[2] In this realistic example, forty years of human life are lost for each additional dollar earned by the patentee.

This second collective action problem causes technologies with high positive externalities to be greatly underutilized. This in turn discourages innovators – expecting

lower uptake – from attempting to develop such technologies in the first place, reducing R&D investment in the greenovation sector below the socially optimal level.

This is a classic market failure. It can be solved through governments instituting environmental regulations, levies on emissions, or green subsidies, all of which incentivize the choice of green technologies by prohibiting, limiting, or discouraging the use of their dirtier alternatives. Among these three options, emission levies – denominated as a certain monetary charge per metric ton of CO_2e emitted (EUR/tCO_2e)[3] – seem especially suitable because they favour the development and deployment of the most cost-effective greenovations while avoiding unfair burdens on non-polluting taxpayers (who would contribute to the cost of green subsidies). By penalizing actors for present and future harm caused by their emissions, such levies shift their incentives toward deploying greenovations, which in turn stimulates green R&D investment.

Environmental regulations might be said to share the advantage of favouring development and deployment of those greenovations that can achieve the most cost-effective compliance. But they ensure only "local" cost-effectiveness, in each area of regulation. They do not ensure that all the many regulations (of air traffic, cement production, oil well maintenance, animal feed, etc.) are holistically designed to instantiate the same marginal cost-benefit threshold. Even the best of experts, continuously monitoring and adjusting all the diverse regulations in view of changing technologies and circumstances, would fall well short of maintaining an optimally cost-effective design. Being subject to various political pressures, real-world politicians fall short to an even greater extent. It is better, then, to impose a simple levy on emissions, or an overall emissions ceiling with market trading, to incentivize emission reductions according to their cost-effectiveness.

Leaving the imposition of such emission levies to national decisions replicates the second collective action problem: each country imposing such a levy bears its full economic cost while gaining only a small fraction of its ecological benefit. States being disadvantaged when they charge a higher emission levy than other states, there is a competitive pull toward lower levy rates, which makes it difficult for any state to lead by example and makes achieved agreements vulnerable to unravelling into a race to the bottom. This collective action problem helps explain why the total amount charged as emission levies – USD 84 billion in 2021 (Twidale 2022) – is still much too low relative to the great present and future harms caused by current emissions. Less than a quarter of all emissions worldwide are subject to any kind of levy, and levy rates are often much too low to have a meaningful impact on investment decisions (Jessop/Twidale 2022). More widespread levies on our actual 40-plus billion tCO_2e of anthropogenic emissions, at more appropriate rates of USD 50–100/tCO_2e, would have raised somewhere around USD 3 trillion in 2021, some 36 times more than the actual amount.

This international collective action problem has a straightforward solution: an agreement among states to impose national emission levies at the same rate, ensuring that no state gains a competitive advantage and that every state shares in the cost of reducing emissions. International uniformity also ensures global cost-effectiveness: the cheaper any specific emissions are to avert, the stronger the incentive to avert them. Ideally, such a globally uniform levy should be high enough so that the negative externalities of any remaining emissions are fully internalized: those who benefit from activities associated with harmful emissions pay, embedded in the cost of their activity, a proportional penalty at a globally uniform rate (EUR/tCO_2e).

Such globally uniform national emission levies are politically difficult to institute in a world of over 200 sovereign states against heavy political resistance from fossil fuel owners, producers, and consumers, who work hard in many countries to prevent or to reduce national emission levies.

And there are two further kinds of resistance specifically from the Global South. One is the moral argument that the developing world should not have to impede its own economic development by putting a price on emissions, given that the presently high-income countries became wealthy by emitting with abandon when they passed through similar phases in their development. Here the South is, as it were, saying to the North: "you say that you did nothing wrong when your economic development imposed heavy losses and damages on the rest of the world (cf. Milman 2022) and that you owe us no part of your accumulated riches as compensation. How then can you demand that we refrain from pursuing a similar development path, unhampered by ecological restraints?" This argument has rhetorical appeal. But then the people most vulnerable to air pollution and climate change are in the Global South. Constituting an ever-increasing share of

the global total, emissions originating in the Global South are harming and killing mostly people in the Global South.[4]

The other source of Southern political resistance to globally uniform national emission levies is the distribution of ownership of green patents, which mostly belong to originators in affluent states. Putting a price on emissions creates incentives to deploy greenovations, of which some 15,000 are newly patented each year in the U.S. alone.[5] This makes emission levies profitable for patentees who can increase sales, even at higher prices, because deployment of their green technology now produces large savings in emission levy costs. Such increased monopoly rents have the welcome effect of attracting additional R&D investments to the green-technology sector, thereby accelerating the pace of green innovation.

But there is a snag. Patent holders are heavily concentrated in wealthier countries, including China, whose innovative corporations, often with government support, have the capital and human resources to advance the innovation frontier. Firms in lower-income countries are less able to compete effectively. This asymmetry in innovation capacities creates an asymmetry in the flow of patent income: far more of it flows South-to-North than North-to-South. Uniform emission levies would exacerbate this imbalance; and lower-income countries are understandably reluctant to support such redistributive capital outflows. This reluctance is reinforced by the preceding realization that the North became wealthy on a "dirty" path of economic development. Why should lower-income countries impose on themselves an emission levy that would cause them to bleed wealth to the vastly richer Global North for permission to help avert a global disaster that the North has unleashed through its disproportional production and consumption? This compelling question indicates not merely a political but also a moral obstacle to globally uniform national emission levies. It would be unjust to arm-twist poorer countries into accepting such an agreement and unjust also for their governments to impose it on their populations.

Such arm-twisting is central to the Climate Club idea that – pioneered by William Nordhaus (2021) – is being promoted by some affluent states. It envisions creating a club of states that meet two requirements:

- Each member imposes an emission levy within its jurisdiction, starting at a certain level and then gradually increasing on a pre-agreed schedule (Nordhaus uses a base level of USD 50/tCO2 in 2025, set to increase 3 % annually in real terms).
- Each member state imposes a flat tariff (Nordhaus envisions 5–10 %) on all imports from exactly those states that refuse to be members.

This Climate Club proposal appears fair because it treats all countries equally. But in fact, it is profoundly unfair by ignoring great differences among them. Three are especially important.

- Some countries are more than 100 times more affluent than others and therefore can much more easily afford to slow their economic development.
- Those richer countries became rich in emission-intensive ways, causing great harm especially to poorer populations; emissions of just the U.S. during the 1990–2014 period have caused damages abroad estimated at nearly USD 2 trillion (Milman 2022).
- By greatly multiplying the use of green innovations, worldwide emission levies would greatly increase income from green patents, mostly owned by Northern corporations. Poorer countries would suffer substantial new capital outflows.

Forcing lower-income countries to join such a club on pains of cancelling their free-trade privileges would aggravate the injustice of the global economic order.

One obvious way of avoiding such injustice is to exempt lower-income countries from the punitive tariffs, allowing them to stay outside the Climate Club without penalty. But this solution damages the urgent struggle to reduce emissions. Although U.S. emissions are eight times higher per capita, we must not ignore India's emissions, which are quite large already and may grow massively as India's economy expands further.

Currently, incentives to deploy green technologies are far too weak in the Global South, leading to their massive underutilization. An example regarding coal-fired power plants may illustrate. Mitsui Babcock charged manufacturers of steam boilers about USD 1.5 million per 600 MW boiler for using its patented "ultra-supercritical" technology (Tan/Seligsohn 2010: 7). Consequently, many plants in India and other lower-income countries deployed less efficient subcritical or supercritical technologies (Barnes 2016: 4) that will generate up to 30 % higher emissions for decades.[6]

Scant deployment of green technologies in the Global South is a big problem. In the remainder of this 21st

century, many of these countries may experience massive economic growth, intensified by large population increases. The technologies they will use, the practices and habits they will form, the roles they will be prepared to play in the fight for a liveable planet will matter far more than any choices affluent nations will make within their borders. Rapid emission reduction requires that highly effective and locally appropriate green technologies be widely and quickly deployed throughout the Global South.

These reflections define our task. We need a structure that

- provides cost-effective incentives toward developing and deploying greenovations worldwide,
- treats countries of the Global South fairly, and,
- mainly for viability, preserves the patent regime in its present globalized form.

One obvious way to conceive such a structure would supplement the global Climate Club with side payments compensating low-income countries for the outflow of royalties and licensing fees. For each such fee that users of a greenovation in a country of the Global South pay to Northern patentees, Northern states would make a compensating payment to the Southern country concerned. This idea should be further explored. But let us here explore another solution that, distributively similar, is more efficient and politically realistic.

AN ECOLOGICAL IMPACT FUND (EIF)

Emission levies have the great merit of substantially increasing deployments of green technologies, thereby also accelerating the pace of green technology progress by stimulating green R&D. But they do not alter the fact that green-technology patents impede the diffusion of patented products by adding a supra-competitive markup to their price. Despite the substantial deadweight losses they entail, such inflated prices seem appropriate in many cases where willing buyers pay a monopoly markup on a novel product they prefer – on a novel watch or toy or cosmetic, perhaps – and thereby ensure that judicious investments in desirable innovations are incentivized. In such cases, buyers and originators benefit without directly imposing costs upon third parties. But inflated prices are highly undesirable in the green technology sector, where we urgently need wide and fast deployment.

The Ecological Impact Fund promotes this goal by inviting originators to EIF-register any new green technology, with two legal effects in all countries below a specified per-capita income:

- the originator permanently forgoes, throughout the EIF-Zone, any monopoly rents it could earn from its registered technology; and
- the EIF rewards this technology for the emissions averted with it in the EIF-Zone through deployments completed within a six-year period.

The EIF would doubly support diffusion of green technologies in the EIF-Zone: by avoiding the headwind of monopoly markups and by adding the tailwind of impact rewards. This substitution of impact rewards for monopoly rents transforms originator motivations. While monopoly rewards incite considerable efforts to find, stop, prevent, and deter patent infringements, impact rewards encourage originators actively to promote the rapid, frequent, and effective deployment of their greenovation for increased impact earnings. Even without profiting from its sales price, such originators would promote its effective use by providing technical support, maintenance, and sometimes even subsidies – insofar as they expect the increase in impact rewards earned through such promotional investments to exceed their cost.

EIF rewards might be paid through preannounced annual disbursements that could be scaled up over time. Any patentable new green technologies could be registered for participation in six consecutive such disbursements, each divided among registered innovations according to emissions averted with them in the EIF-Zone in the preceding year. This principle of division ensures fairness among participating originators, who are rewarded in proportion to emissions averted, all at the same reward-to-benefit rate (EUR/tCO_2e).

Because participation is optional, this EIF's reward rate emerges endogenously and equilibrates to a level that makes participating originators content with their EIF-Zone-limited swap: permanent waiver of monopoly rents in exchange for six years of impact rewards. When originators find the going rate unattractive, registrations dry up and the reward rate rises as older innovations exit at the end of their reward period. When the reward rate is seen as generous, registrations multiply, and the reward rate declines. Such equilibration reassures participating originators and contributors that the reward rate will be fair between them, and stable over time.

The easiest way for registrants to relinquish their potential monopoly rents in the EIF-Zone is not to apply for patents there. This would save the registrant money while allowing multiple manufacturers to sell the technology in the EIF Zone at competitive prices. Alternatively, a registrant might patent the registered greenovation in some or all EIF-Zone countries and then, during the patent period, offer cost-free licenses to those who want to produce or sell it there. Either way, the registrant would be free to manufacture and sell the registered technology too, but would have to do so, in the EIF-Zone, at a competitive price. Deriving its earnings from impact rewards, the registrant would be motivated to ensure that its registered technology is widely and cheaply available throughout the EIF-Zone and used for optimal impact. To this end, the registrant would collaborate with manufacturers and sellers of its technology and keep its own sales price low, often even below cost.

The EIF should be designed so that its reward rate equilibrates to a low level, making it as efficient (tCO_2e/EUR) as possible at averting emissions. For this reason, the EIF should not demand too much from registrants. This thought motivates limiting the EIF to the lower-income countries. Because demand for greenovations at monopoly prices is much weaker there, limiting the EIF to those countries greatly reduces the opportunity costs of EIF registration, and therefore the EIF's endogenous reward rate (EUR/tCO_2e), while correspondingly increasing its ecological impact relative to the amounts it disburses (tCO_2e/EUR). The exact qualification for membership in the EIF-Zone could then be based on the same desideratum: the EIF-Zone should include the countries in which uptake of patented green technologies has been poor. This would likely include at least the ca. 120 countries whose annual per capita gross national incomes fall below USD 10,000.

Other design question can be approached with the same guideline. Thus, consider whether, during the reward period, the registrant should have the option to offer its registered technology at a non-profit price throughout the EIF-Zone without having to permit others to manufacture and sell it as well. If it turned out that many potential registrants strongly value this option, then this would be a reason to give it to them in order to lower their reservation price and thereby achieve a lower EIF reward rate.

FEATURES AND VIRTUES OF THE EIF

The EIF would organize a wide competition across the whole greenovation sector, including electricity generation, traffic, residential and office heating and cooling, construction, meat production, agriculture, forestry, industrial manufacture of steel, cement and other commodities. Across all these areas, the EIF would attract the greenovations that achieve the greatest emission reductions relative to cost as they would be the most profitable ones to register. By increasing the profitability of highly cost-effective innovations, the EIF would also stimulate additional R&D investment into developing such innovations, thereby accelerating technological advance. Here the EIF would not "bet on" specific technologies or subsectors but would rely on the greater expertise of innovators, who estimate which R&D investments and which additional deployments will yield the greatest ecological benefits.

High-impact greenovations from all areas would be competing on one EIF-created market toward the single goal of averting emissions. In this competition, all participants can be winners, that is, earn more in rewards than they have invested. And a registrant with low EIF earnings can still be highly successful, if its income is especially high relative to its investment.

Participation in this market would train originators to holistically organize their research, development, marketing, and delivery operations toward realizing the most cost-effective impact. Covering R&D costs and originator profits as public goods, the EIF would make access to registered greenovations widely affordable at competitive prices – with registrants highly motivated to promote impactful deployments.

The EIF would boost diffusion of high-impact green technologies in the EIF-Zone, with massive emission reductions in the Global South. The constrained sales price, supplemented with impact rewards, would further benefit lower-income populations by enabling originators to make good profits from selling to people who cannot pay high markups. This would encourage R&D that targets their specific needs in their specific circumstances: locally appropriate greenovations sensitive to sociocultural context and congruent with equitable access so that they mitigate existing socio-economic inequalities. The EIF would open whole new areas of green R&D and accelerate the overall pace of green innovation.

Moreover, in the competition to develop greenovations geared to the Global South, innovators in the EIF-Zone would not face the usual crushing head start by Northern originator firms. The EIF would therefore also help build, in lower-income countries, capacities in R&D, manufacturing, distribution, installment, operation and maintenance of green technologies.

The evolving EIF reward rate would be indicative of the EIF's efficiency – but would also understate it substantially because the EIF's full ecological impact greatly exceeds the sum of the assessed and rewarded impacts of all EIF-registered innovations. This is so not only because the EIF confines the rewardable impact of a registered greenovation to deployments during the first six years. A more important reason is that, by accelerating the pace of innovation, the EIF raises the standard against which newly registered innovations will be assessed. Over time, this effect will become quite large. A greenovation registered in 2040 will be rewarded for the emission reductions it achieves relative to the alternatives being deployed in that year. But this 2040 state-of-the-art will be far superior to what it would have been if the EIF had not existed for the preceding decade or more. This acceleration of green innovation is an achievement the EIF need not pay for. It is likely to be especially significant in classes of green technologies that, under the current regime, suffer neglect because they are suitable for use only in the Global South, are more expensive to manufacture and deploy than their dirtier alternatives, or bring widely diffused benefits that buyers care little about.

An experimental pilot could test and refine the EIF idea and thereby make adoption of the EIF more likely. This pilot might involve a single reward pool of, say, EUR 100 million, to be split among preselected green originators in proportion to the emission reductions they achieve with their respective innovations, competitively priced, in a self-selected region of the EIF-Zone over a 2-year period. The pilot would show concretely how green originators respond to competitive impact rewards and how ecological impact can be assessed in a reliable and timely manner. It would help refine impact assessment and provide an indication of the cost-effectiveness of the new impact rewards. The EIF pilot would also yield its own ecological benefits and policy insights through the pilot projects it monitors and rewards.

The UNFCCC's Green Climate Fund – mandated to "promote the paradigm shift towards low-emission and climate-resilient development pathways by providing support to developing countries to limit or reduce their greenhouse gas emissions" (Green Climate Fund 2011: 2) – is well suited to administering the EIF and its pilot. Both should be supported by high-income countries, which can most easily afford the cost, have contributed most to the global climate emergency, and continue to benefit from the great wealth they have accumulated through their decades of high pollution. Supporting the EIF would help the high-income countries discharge their responsibilities under Sustainable Development Goals 13 and 17 and to fulfil their 2009 promise to devote USD 100 billion annually to climate change mitigation and adaptation in the developing world (Timperley 2021). The EIF would benefit high-income countries by reducing emissions and by augmenting the income innovative firms in the Global North derive from their greenovations.

The EIF has no optimal size. As its annual reward pools increase, it will attract more registrations, avert more emissions, and do more to accelerate technological progress. States and other contributors could monitor these effects and gradually grow the EIF in light of data so collected. They might start with modest annual disbursements of, say, EUR 1 billion, raising this level gradually, perhaps with new contributors joining the partnership. With real data about its effects, the EIF will also be able to raise additional funds in the international offset markets. As the EIF grows, its reward rate will tend to rise as less efficient technologies get registered. But a larger EIF will also enjoy enhanced operational efficiencies (impact assessment and administration) and greater impact on the pace of green innovation which increases that part of its ecological impact that the EIF need not pay for. In any case, the various financing commitments sustaining the EIF must be designed so that it can meet the legitimate expectations of registrants who have developed and registered a greenovation in anticipation of participating in six annual disbursements.

The EIF is politically realistic because it requires no painful concessions. It can be implemented unilaterally by a coalition of willing states, perhaps supported by other funders looking for new cost-effective ways of reducing emissions. Conferring clear benefits, the EIF would be welcomed by the countries of the EIF-Zone whose governments and populations would benefit from better and cheaper options for greening their activities, from domestic capacity building, from substantial declines in air pollution, and from a slowing of climate change. The

EIF proposal will find support also among firms with significant green technology patent portfolios, as it would substantially increase their opportunities to earn money from developing and selling greenovations into the EIF-Zone while leaving them the choice whether to pursue these opportunities. Green movements around the world would applaud the EIF, as would organizations concerned for living conditions in the Global South. Defenders of intellectual property rights would find the EIF palatable because it applies only to EIF-Zone countries and, with each greenovation, lets its originator choose between the two rewards. Some wealthy states might be initially reluctant to contribute to the EIF's cost – but others could and should readily proceed without them. The EIF would, as intended, reduce the use of dirty technologies throughout the EIF-Zone but would also give the firms selling them ample new opportunities to supply state-of-the-art green substitutes. With even modest political support, the EIF could be instituted without significant political resistance.[7]

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1 The magnitude of supra-competitive markups in the green-tech space varies across products and is difficult to quantify. Typical estimates cluster around 10 % (de Rassenfosse/Zhou 2020) – certainly large enough to frequently tip the scales in favor of a more-polluting technology.

2 The relative loss amounts to 2 million years of human life because each of the 50 (=150–100) devices not licensed would have averted the loss of 40,000 life years. The patentee's EUR 50,000 in extra earnings are the difference between licensing fees of 100 x EUR 20,000 versus 150 x EUR 13,000.

3 'CO2e' stands for CO2equivalent, a measure that converts other greenhouse gases according to their global warming impact over a specific time horizon (such as 20 or 100 years). Specifying the time horizon is important, because different greenhouse gases fade from the atmosphere at different rates. Methane (CH4), for example, has over 80 times the warming potential of CO2 over a 20-year horizon, but only about 30 times its warming potential over 100 years. While a 100-year time horizon is commonly used, I favor a 20-year horizon, which assigns higher importance to short-lived gases like methane. This can be justified by the crucial importance of the level at which we can get global warming to peak. The higher this peak, the more deeply the Earth's patterns will be disturbed, with increasing risks of potentially massive positive feedback effects on its future climate.

It is worth mentioning that, while CO2 and CH4 contain carbon, other important greenhouse gases – such as N2O, SF6, and NF3 – do not. I therefore avoid expressions like "carbon emissions" and "carbon neutrality."

4 For details, see Vohra et al. (2021) and also the series of essays in the New England Journal of Medicine on the topic: Fossil-Fuel Pollution and Climate Change, https://www.nejm.org/doi/full/10.1056/NEJMe2206300 (15.11.2023). Also disproportionally affecting people in the Global South are the other negative effects of human emissions such as extreme weather events, the expanded reach of tropical diseases, and the increasing scarcity of food and water.

5 https://stats.oecd.org/index.aspx?queryid=29068 (03.06.2023).

6 If only 35 rather than 45 % of the coal's energy content is converted into energy, then one must burn 30 % more coal to generate the same amount of electricity (Pearce/Prater 2020).

7 This essay is adapted from Pogge, Thomas (2023): An Ecological Impact Fund. Green and Low-Carbon Economy, 1(1), 15–21. https://doi.org/10.47852/bonviewGLCE3202583 (15.11.2023). For valuable discussions of the impact fund approach and its promising alternatives, the author thanks Aidan Hollis, Sebastian Kistler, Max Matthey, Zeke Ngcobo, Tobias Orthen, Benjamin Roth, and Halit Ünver.