



A global review of ecological fiscal transfers

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Ecological fiscal transfers (EFT) transfer public revenue between governments within a country based on ecological indicators. EFT can compensate subnational governments for the costs of conserving ecosystems and in principle can incentivize greater ecological conservation. We review established EFT in Brazil, Portugal, France, China and India, and emerging or proposed EFT in ten more countries. We analyse common themes related to EFT emergence, design and effects. EFT have grown rapidly from US\$0.35 billion yr⁻¹ in 2007 to US\$23 billion yr⁻¹ in 2020. We discuss the scope of opportunity to expand EFT to other countries by 'greening' intergovernmental fiscal transfers.

The environmental benefits of conserving ecosystems accrue at all scales from local to global, while many economic costs of conserving ecosystems are borne locally. As a result, local public resources to address large-scale environmental challenges such as climate change and biodiversity loss are often underfinanced¹. One mechanism for overcoming the scale mismatch between the environmental benefits and the economic costs of ecosystem conservation is ecological fiscal transfers (EFT).

EFT transfer public revenue between governments within a country based on ecological indicators (Fig. 1). Here, 'ecological' refers to ecological public functions of governments², which encompass both nature conservation and abatement of environmental pollution. EFT may transfer revenue 'vertically' from higher-level to lower-level governments or 'horizontally' between governments at the same level. EFT may be 'general-purpose' transfers to subnational government budgets that can be spent on any priority of recipient jurisdictions, whether ecological or non-ecological. Or they may be 'specific-purpose' transfers earmarked for a particular ecological use, for example, reforestation or water treatment.

EFT can compensate subnational governments for the management costs of conserving ecosystems and the opportunity costs of forgone tax receipts from revenue-generating activities. In principle, EFT can also incentivize subnational governments to provide greater ecological conservation, thereby contributing to global efforts to increase conservation and restoration, fight climate

change^{3,4}, stem biodiversity loss⁵, enhance nature's cultural services and achieve sustainable development goals. EFT have been recognized as an innovative approach to financing conservation^{6–8}.

EFT can be established by modifying existing intergovernmental fiscal relations, that is, institutional channels of regular financial flows between different levels of government. This can make EFT institutionally easier to implement than programmes that require approving new, additional, annual budget outlays. Relative to such programmes, EFT can also have lower start-up costs, lower transaction costs across heterogeneous regions and greater long-term stability. EFT have been established in five countries and eighteen Brazilian states (Table 1), and are emerging or have been proposed in at least ten more countries (Fig. 2).

EFT are a subset of intergovernmental fiscal transfers (IGFT). More than US\$4.9 trillion yr⁻¹ is transferred from national governments to lower-level governments through grants and subsidies⁹. Most countries have some form of IGFT. IGFT make up about two-thirds of subnational government financing in developing countries and about one-fifth in OECD countries¹⁰. The US\$23 billion per year transferred through EFT globally in 2020 (Fig. 3) represents less than 0.5% of overall transfers through IGFT.

EFT are an instrument for financing ecological conservation, alongside complementary mechanisms such as payments for ecosystem services^{11,12}, reducing emissions from deforestation and forest degradation (REDD+)¹³, and finance for protected areas¹⁴.

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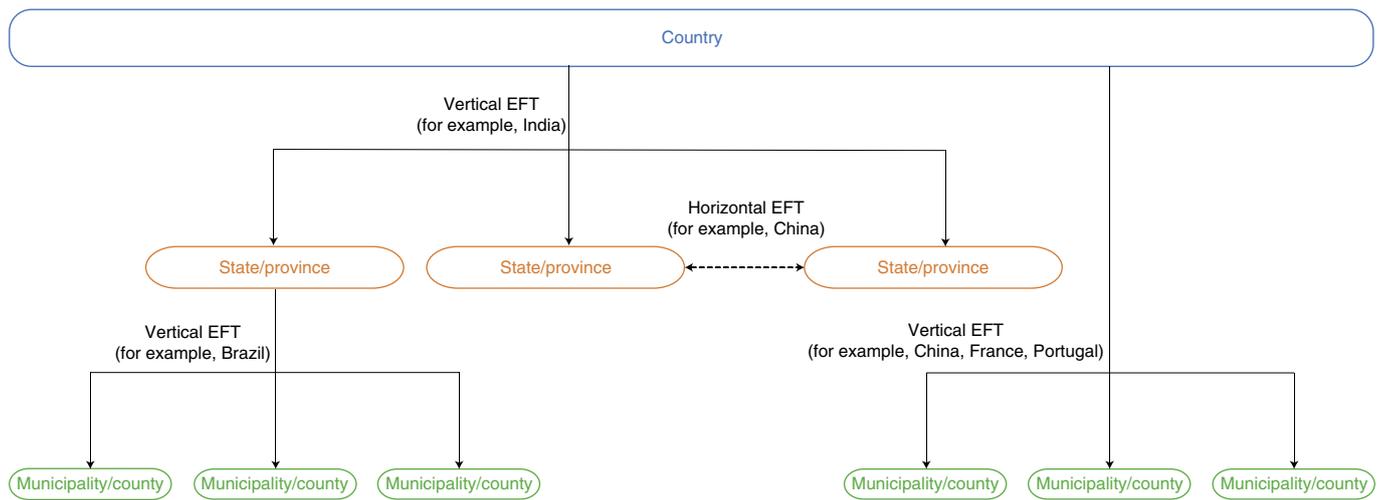


Fig. 1 | Alternative scales of EFT in intergovernmental fiscal relations. Arrows indicate directions of fiscal transfers. Vertical transfers are possible between levels of government; horizontal transfers are possible within levels of government.

While payments for ecosystem services generally transfer funds to private or communal landholders, and REDD+ transfers funds internationally, EFT are distinguished in that they transfer funds within a country to subnational governments.

The academic literature on the practice and theory of EFT is still relatively small relative to these other instruments. Previous reviews of EFT have focused on Brazilian states' EFT¹⁵ and existing and proposed EFT in Europe¹⁶. There is a need for a comprehensive, global, synthetic review of EFT experiences and literature, which we provide here.

In this global review, we have sought to include every established, emerging and proposed EFT worldwide. We provide the first documentation in an English-language peer-reviewed publication for emerging EFT in Indonesia, Mongolia, and Uganda as well as proposed EFT in Ukraine.

We discuss common themes of EFT and the literature that has studied them, related to emergence, design and effects. We have sought to include every paper on EFT published in an English-language academic journal, as well as selected other publications. We compiled studies on the basis of the collective knowledge of 23 researchers from 15 countries who participated in an expert workshop in September 2020, supplemented by a Google Scholar keyword search for 'ecological fiscal transfer'.

We also discuss the scope of opportunity for expanding EFT to other countries by greening a fraction of the US\$4.9 trillion yr⁻¹ in IGFT. This is especially timely in light of the updated climate pledges national governments are making to the United Nations Framework Convention on Climate Change (UNFCCC), the Convention on Biological Diversity (CBD) post-2020 framework and the United Nations Decade on Ecosystem Restoration.

Established EFT

Brazil. Brazil's federal constitution has authorized Brazilian states to levy a value-added tax since 1922, with its current formulation as a Tax on Commerce and Services (*Imposto sobre Circulação de Mercadorias e Serviços*, ICMS) dating to the 1988 constitution. Constitutionally, 75% of revenue raised by the ICMS is retained by the state government, while the remaining 25% must be devolved to municipal governments. Each state may determine the formula by which 25% of this latter municipal quarter of revenue (6.25% of the total ICMS revenue) is distributed^{15,17,18}.

Following the creation of national water and biodiversity protection areas in the state of Paraná in the 1980s, municipal leaders

felt disadvantaged, and organized themselves to obtain technical and political support from the state legislature and government agencies¹⁹. These agencies supported the right of municipalities to be compensated for the revenue lost due to protected areas that they would otherwise have received from taxes on economic activity. In 1991, as a mechanism for compensating municipalities, Paraná added protected areas for biodiversity conservation and watershed protection to its ICMS formula, each accounting for 2.5% of municipal revenue, alongside indicators related to agricultural production, population, rural properties and municipal area^{20,21}. This marked the first time an ecological indicator had been included in a state's ICMS allocation formula, making it an ICMS *Ecológico* (ICMS-E).

Over the next three decades, the ICMS-E concept spread throughout Brazil. As of 2020, ecological indicators had been included in the ICMS of 18 of Brazil's 27 states^{22,23}. In some states the ICMS-E is termed the ICMS *Verde* or ICMS *Socioambiental*, or has no specific name²². Land area under protection is an indicator in 15 states, indigenous land is included in 11 states²⁴ and basic sanitation (including waste management, wastewater and water treatment) is an indicator in at least 7 states²². Other ecological indicators include forest area in Minas Gerais²⁵, deforestation reduction in Pará²⁶, fire control in Tocantins and areas flooded by dams in Rio Grande do Sul²². The share of municipal ICMS revenue based on these ecological indicators varies from 1% in São Paulo state to 20% in Acre. Wilson Loureiro, an agronomist at the Paraná State Environmental Agency, was instrumental in drafting the original ICMS-E legislation and helping it expand to other states, while non-governmental organizations The Nature Conservancy and SOS Mata Atlântica maintained an influential website until 2019 showing how much money municipalities received from the ICMS-E. Over time, the rationale for the fiscal transfer evolved to include incentivizing greater provision of protected areas and waste treatment by municipal governments^{19,20,27}.

Brazil's federal system allows different state legislatures to experiment with different revenue allocations across municipalities. For example, the states of Minas Gerais, Paraná, Piauí and Rio de Janeiro introduced qualitative indicators of protected area management. A further level of variation occurs at the level of municipal governments, which allocate ICMS revenues in accordance with their budget priorities. States also varied in the degree to which their EFT experienced delays between enactment by a legislature and implementation by a state agency²⁸.

Table 1 | Characteristics of EFT

Country (state)	Year enacted	Levels	Indicator(s)	Percentage of IGFT that is ecological	Source of funds
Portugal	2007	1→3	PA	2.5–2.7	National general budget
France	2007	1→3	Strictly protected terrestrial area; marine park	0.02	National general budget
China	2010	1→3	Multi-element formula to local governments with NKEFA	0.95	National general budget
China	2012	2→2	Water quality	100	Provincial budgets; national general budget
India	2015	1→2	Area of high or moderately dense forest	2015–2020: 7.5 2020–2021: 10	National tax revenue
Brazil (Paraná)	1991	2→3	PA; IT; water protection	5	State VAT
Brazil (São Paulo)	1993	2→3	PA; water protection	1	State VAT
Brazil (Mato Grosso do Sul)	1994	2→3	PA; IT; waste treatment	5	State VAT
Brazil (Minas Gerais)	1995	2→3	PA; IT; waste treatment; forest area; water resources	1.35	State VAT
Brazil (Rondônia)	1996	2→3	PA; IT	5	State VAT
Brazil (Rio Grande do Sul)	1997	2→3	PA; IT; environmental quality index; waste treatment	7	State VAT
Brazil (Amapá)	1998	2→3	PA; IT	1.4	State VAT
Brazil (Mato Grosso)	2000	2→3	PA; IT; sanitation	7	State VAT
Brazil (Pernambuco)	2000	2→3	PA; waste treatment	3	State VAT
Brazil (Tocantins)	2002	2→3	PA; IT; water conservation; forest fire control; soil conservation; environmental policy	13	State VAT
Brazil (Acre)	2004	2→3	PA	20	State VAT
Brazil (Rio de Janeiro)	2007	2→3	PA; water quality; waste treatment	2.5	State VAT
Brazil (Goiás)	2007	2→3	PA; watershed protection	5	State VAT
Brazil (Ceará)	2007	2→3	Waste treatment	2	State VAT
Brazil (Piauí)	2008	2→3	Environmental seal (an award based on nine indicators)	5	State VAT
Brazil (Paraíba)	2011	2→3	PA	5	State VAT
Brazil (Pará)	2012	2→3	PA; IT; deforestation reduction; cadastral registration	8	State VAT
Brazil (Alagoas)	2020	2→3	Biodiversity conservation; related criteria	3	State VAT

Data from refs. ^{15,18,22–24,32,35,41,58}. Level 1 is the national, level 2 the state/provincial level and level 3 the county/municipal level. PA, protected area; IT, indigenous territories; VAT, value-added tax. Year enacted in Brazil refers to year of initial legislation.

Between 1992 and 2017, the ICMS-E devolved more than 21 billion reais (around US\$8.8 billion) to municipal governments (authors' estimates based on Institute for Applied Economic Research data). There is evidence from panel regressions across Brazilian states that EFT led to a tripling in municipal protected areas¹⁸ and a shorter average time to protected area designation²⁹. However, there are questions about whether some of these new protected areas are unmanaged 'paper parks'³⁰—an extreme example is an entire municipality in Minas Gerais that was made into an environmental protection area to benefit from the ICMS-E¹⁹. Proposals for a Brazil-wide national-to-state EFT have been introduced to the Brazilian Parliament since 1999, but none have yet passed into law³¹.

Portugal. Portugal's Local Finances Law (*Lei das Finanças Locais*, LFL) defines the conditions and rules for the transfer of funds from the general national budget to the budgets of more than 300 local municipalities on the basis of indicators including population and area^{32,33}. In 2007, inspired by the Brazilian case, Portugal

implemented a national-to-local EFT by adding an indicator related to the area and percentage of land under nature protection, including the European Union's Natura 2000 network. The main purpose was to compensate municipalities for lost revenue resulting from protected areas. The introduction of EFT was part of a larger reform of fiscal transfers in 2007, which also included deep changes in the Local Finances Law and many simultaneous changes to the fiscal transfer criteria.

The 2007 introduction of EFT was an initiative of Portugal's central government, approved by Parliament. Municipalities were not generally involved in its discussion or design. This became a problem as EFT were not perceived by many mayors. Only later, in 2014, was the Association of Portuguese Municipalities (ANMP) formally consulted as part of the work of the Commission for the Reform of Green Taxation, supporting Commission proposals to reinforce the mechanism, isolate and make visible the EFT values received by each municipality in the annual fiscal transfers, and explore the potential for a partial earmarking of received transfers.

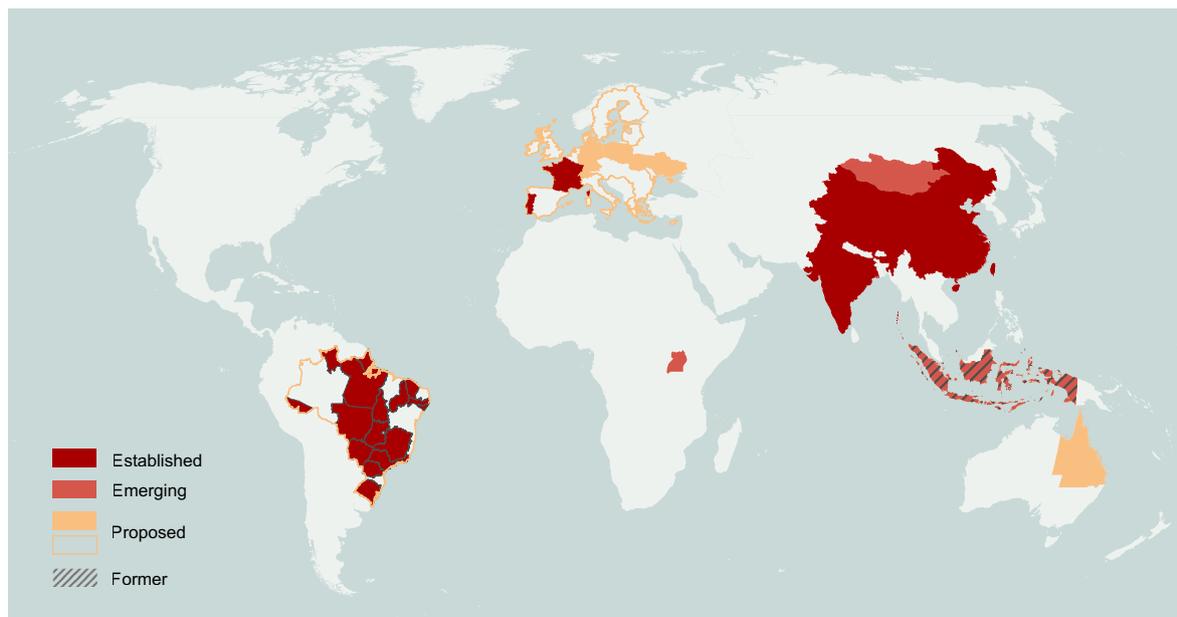


Fig. 2 | World map of EFT. An EFT at the global level has also been proposed by Droste et al.⁸⁷. Proposed European Union-wide and Brazil-wide EFT are outlined to show a distinction from EFT in European countries and Brazilian states.

The Portuguese EFT transferred between €789–852 million (around US\$988–1,067 million) to municipalities between its first year of payment in 2008 and 2020. It represented 2.5–2.7% of total fiscal transfers (authors' calculations based on data from *Direção-Geral das Autarquias Locais* and Annexes of *Lei do Orçamento do Estado*), although this funded more than 30% of some municipal budgets in some years³². Most protected areas in Portugal were created at the national level and EFT were not relevant to incentivizing additional efforts at this level. Nevertheless, a synthetic control econometric analysis found that EFT may have been responsible for an increase in the number of regional and local-level protected areas³⁴.

France. The French *dotation globale de fonctionnement* (DGF) is an instrument that has been in place since 1979 for redistributing funds from the unitary central government to local public authorities including departments and municipalities. The DGF is divided, with 85% allocated as a lump sum on the basis of population, area and other criteria, while the remaining 15% is an 'equalization allocation' that compensates for differences between rural and urban areas and compensates municipalities whose fiscal capacity is lower than the average national fiscal capacity³⁵.

In 2007, two ecological criteria were added to the lump-sum portion of the DGF: municipalities with an area within the core of a national park, or with some area within a marine park³⁶. The purpose was to compensate municipalities with a portion of their territories under strict protection and therefore subject to restrictions regarding land use. However, on the basis of these limited criteria, only 150 municipalities out of nearly 35,000 were eligible to receive funding. The 'ecological allocation' amounted to around €3 million (around US\$4 million), or just 0.02% of the €13.6 billion (around US\$18.9 billion) that was distributed to French municipalities via the DGF in 2011³⁵. Although the funding is allocated on the basis of ecological indicators, it is not earmarked and need not be used for conservation actions.

The 2019 Finance Law (article 256) changed EFT to include a third type of protected areas—Natura 2000 sites. Natura 2000 sites are much more widespread in France than national parks and marine parks, covering around 13% of French territory³⁷. With

this change, the number of eligible municipalities increased from 150 to 1,120. The EFT are apportioned such that 40% is distributed to municipalities with territory in core national park areas, 5% to municipalities with marine natural parks and 55% to municipalities with 75% of their territories within a Natura 2000 area. In all cases, municipalities must have fewer than 10,000 inhabitants to receive this ecological allocation.

China. China combines administrative centralization, in which upper-level government pushes mandatory administrative orders to lower-level governments, with fiscal decentralization, in which lower-level governments have autonomy in raising revenues and providing public goods and services^{38,39}. The Chinese system of intergovernmental fiscal transfers includes three types of EFT^{40,41}.

The most important EFT are the general-purpose fiscal transfer payments for National Key Ecological Function Areas (NKEFA), established nationwide in 2010 to compensate county-level governments for their expenditures and to stimulate them to promote nature conservation in areas with vulnerable biodiversity⁴². China's Major Function Oriented Zoning scheme of 2010 categorizes land into four land-use types: prioritized development; optimized development; restricted development; and prohibited development⁴³. The EFT distributes around 0.95% of the general transfer from the central government to local governments to those counties that have NKEFA on the basis of an allocation formula that includes multiple elements related to ecosystem quality (for example, biological richness, vegetation coverage, water network density, land stress, pollution load and environmental restrictions). The transfer scheme also includes bonus payments for local governments that perform well, and fines for local governments that perform poorly, based in part on an ecological index^{44,45}. The central government transferred approximately 79 billion yuan (around US\$11.4 billion) via the NKEFA scheme in 2020^{46,47}.

Second, the central government allocates more than 80 billion yuan annually in specific-purpose transfer payments to subnational governments for seven programmes with nature conservation targets. These programmes include the Natural Forest Protection Project, Conversion of Cropland to Forest and Grassland Program (CCFGP), Returning Pastureland to Grassland Project, Beijing–Tianjin

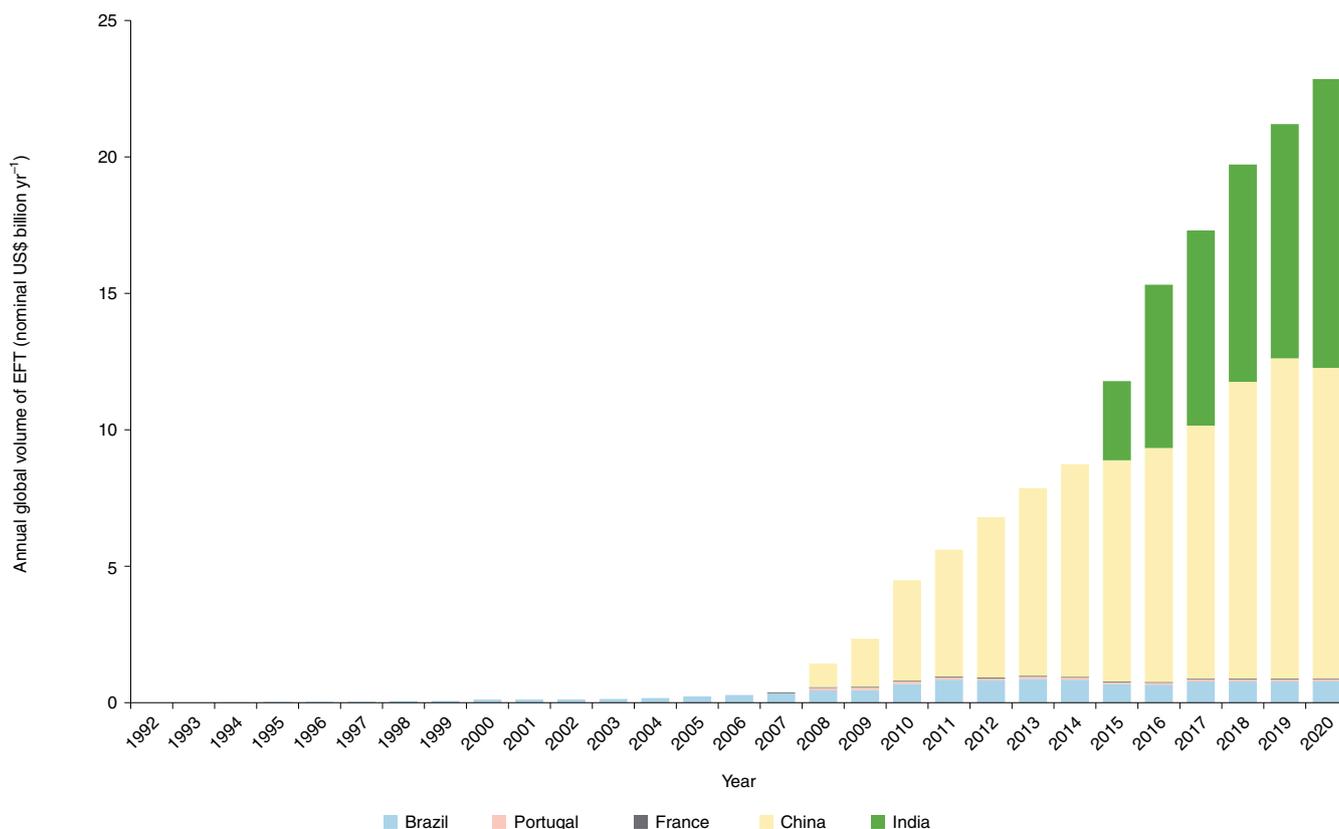


Fig. 3 | Annual global volume of EFT. Authors' calculations. Data for Brazil for 2018–2020 are extrapolated from 2017, the most recent year for which data are available for all states. Data for France data are extrapolated from 2011. Nominal values are not adjusted for inflation.

Sandstorm Source Control Program, Forest Ecological Benefit Compensation Fund, Subsidy and Rewards for Ecological Protection of Grasslands (National Grassland Eco-Compensation Program) and the Marine Ecological Protection and Restoration Funds.

The third EFT is a horizontal, bidirectional agreement between neighbouring provinces for governing the environmental externality of water quality. Pioneered by the provinces of Anhui and Zhejiang, the downstream Zhejiang pays upstream Anhui for improvements in the water quality of the Xin'an River above a benchmark. If water quality deteriorates below the benchmark, Anhui must pay Zhejiang⁴⁰. The central government monitors, enforces and contributes 300 million yuan (around US\$43 million) per year to the 700 million yuan (around US\$100 million) horizontal EFT. Without the involvement of the central government, lower-level governments face prohibitive transaction costs to setting up their own horizontal transfers. This type of horizontal EFT has expanded to other provinces in the past decade⁴⁸. Horizontal EFT have also been proposed for farmland preservation⁴⁹.

Several studies have found China's NKEFA payments to have had a positive effect on some aspects of environmental quality. Quasi-experimental studies using propensity score matching found that transfer payments reduced pollution-intensive activity in the Yangtze River Basin⁵⁰ and improved environmental quality in Guangdong Province⁵¹. Panel regressions across Chinese provinces found that transfer payments reduced pollution but did not increase natural ecological land cover⁵², and that payments improved water quality, with this improvement mediated by local government spending on environmental protection⁵³.

India. India's Finance Commission—an independent, apolitical body whose recommendations are generally accepted without revision—decides every five years how much tax revenue is distributed

from the Union to state governments ('vertical devolution'), and the formula for how this revenue is distributed between states ('horizontal devolution'). The horizontal devolution formula included population since its inception in 1952, later joined by income and land area, and in some years infrastructure and fiscal discipline.

India's EFT began in 2015 when the 14th Finance Commission included the areas of high- or moderate-density forest as 7.5% of the distribution formula⁵⁴, as proposed by ref.⁵⁵. The rationale was to compensate states for 'fiscal disability' of forgone tax revenue due to forest cover, and also to recognize forests' 'huge' ecological benefits⁵⁶.

Previously, the 12th and 13th Finance Commissions had provided states with specific-purpose grants for forestry of 10 billion rupees (around US\$40 million) and 50 billion rupees (around US\$200 million) respectively⁵⁷, comprising less than 0.05% of national-to-state transfers. When the 14th Finance Commission replaced these grants with lump-sum general-purpose EFT in the allocation formula for sharing the divisible pool of tax revenue, the funding increased by several orders of magnitude. In the first five years of the EFT, more than 34 trillion rupees (approximately US\$37 billion) were transferred to states on the basis of forest cover. The introduction of EFT was concurrent with a substantial increase in transfers to states as vertical devolution was increased from 32% to 42% of tax revenue.

India's Nationally Determined Contribution on climate references the EFT as supporting achieving India's forest cover goal of 33% (ref.⁴). Evidence from simple correlations does not yet show an association between larger contributions of EFT to state revenue and increased forest cover⁵⁴ or state forestry budgets⁵⁸, perhaps because state policymakers were uncertain whether the EFT would continue, because of time lags before new trees become visible to satellite monitors⁵⁸ or because the transfers were not granted directly

to the forestry sector⁵⁹. The 15th Finance Commission strengthened the EFT in its 2020 interim recommendations, by increasing the share of revenue states receive from forests from 7.5% to 10%, changing the name of the criterion from ‘forest cover’ to ‘forest and ecology’ and updating the measurement year for forest cover, giving confidence to state governments that increases in forest cover would be rewarded with increases in funding.

Emerging EFT

EFT are emerging—that is, have recently been enabled through government legislation, decrees or planning documents, but do not yet have a record of financial transfers—in several countries.

Indonesia. A former specific-purpose EFT, Indonesia’s Reforestation Fund, distributed national funds to provinces and districts on the basis of ecological indicators from 1976–2004 before being amended^{60–62}.

More recently, numerous proposals for EFT in Indonesia have been put forward. EFT from the central government to subnational governments in the form of general-purpose transfers through the General Allocation Fund (*Dana Alokasi Umum*, DAU) have been proposed both by scholars^{63,64} and provincial⁶⁵ and district⁶⁶ governments. Revenue-sharing arrangements for REDD+^{67,68}, non-state budget grants funnelled through transfers^{69,70} and EFT to villages^{70,71} have also been proposed.

The first general-purpose EFT to be implemented in Indonesia was the Ecological Provincial Budget Transfer (*Transfer Anggaran Provinsi berbasis Ekologi*, TAPE)⁷², which involves budget transfers from provincial to district governments on the basis of ecological indicators to be decided by each province. Motivations for the EFT include increasing provincial influence over environmental management in a country where since 2001 considerable authority has been devolved to districts, reducing inequality among districts and providing positive incentives from the general provincial budget directly to districts and villages to improve environmental performance.

The first province to implement this EFT was North Kalimantan. In 2019, the governor issued a regulation⁷³, followed by implementation in 2020 with a size of around 5 billion rupiah (US\$340,000), and monitoring and evaluation related to impact assessment⁷⁴. The five ecological indicators set by North Kalimantan are reduction in forest fires, water quality, air quality, waste management and an open space index.

Mongolia. Mongolia decentralized nature conservation functions to subnational governments in 2012. These local conservation functions are financed in part by locally collected natural resource use fees, a minimum portion of which is earmarked for this purpose^{75,76}. The residual deficit between the above fees and estimates of local governments’ recurring conservation expenditures remainder is financed by support transfers from the central government. These estimates on which transfers are based now include ecological factors such as the presence of protected areas, natural formations of the territory and land restoration needs⁷⁷.

Uganda. Uganda plans to pilot an EFT focused on forest cover⁷⁸ as a reward system for the sustainable management of natural resources. The rationale is to raise funds for biodiversity in a country where protected area-based tourism is an important economic driver. Natural resource fees collected by local governments would be transferred to the national government, then returned to local governments based on an index of ecological indicators that could include areas of protection, the reintroduction of species or the removal of invasive species.

Proposed EFT

In Germany, many specific-purpose state-to-local environmental fiscal transfers already exist^{2,79}. EFT considering nature conservation

through the addition of protected area-related indicators to the financial equalization systems at the national-to-state level^{16,80} and state-to-local level^{79,81} have been proposed.

In Switzerland, Köllner et al.⁸² proposed including indicators for biodiversity conservation based on cantonal benchmarking in Switzerland’s fiscal transfer system. Although Switzerland’s amended fiscal transfer system as of 2005 did not consider biodiversity-related indicators, it introduced a specific-purpose result-oriented programming approach for the environment⁸³, which since 2008 has included multi-annual national-to-cantonal programme agreements in areas such as landscape and nature conservation, wildlife protected areas, noise and sound protection, protective buildings and hazards, forests and revitalizations.

In Poland, the Association of Rural Municipalities proposed a Polish EFT scheme in 2012, following the implementation of the EU’s Natura 2000 network¹⁶. The so-called Ecological Subsidies Act would have allocated about €200 million annually in lump-sum transfers to municipalities hosting Natura 2000 sites.

In Ukraine, Kotenko and Ilyashenko⁸⁴ proposed implementing ecological conditional transfers by including indicators related to environmental services, anthropogenic pressure, environmental deterioration and implementation of environmental programmes within the system of vertical alignment.

In Australia, Hajkowicz⁸⁵ proposed that an index of 29 environmental, cultural and economic indicators be added to the formula determining how a AUD\$146.6 million fund for combating water salinity, which has since expired, should be transferred from the government of Queensland to 14 regional governments.

Europe-wide, Droste et al.⁸⁶ proposed compensating national governments for conservation efforts through a European Union scheme in which the Programme for Environment and Climate Action (LIFE) or European Fund for Regional Development (ERDF) would be broadened to include area and management quality of Natura 2000 network sites.

Globally, Droste et al.⁸⁷ proposed an intergovernmental transfer scheme to support the achievement of Aichi Biodiversity Target 11 on protected areas, in which protected area coverage, human development and population density would be considered.

Common themes

Emergence. Multiple rationales have been put forward for the introduction of EFT⁸⁸. EFT may be introduced to compensate local governments for their costs in providing ecological public goods and services, or for the lost tax revenue they might otherwise have received from land uses that produce greater revenue streams and thus a larger tax base⁸⁸. Compensation to local governments for top-down impositions on land use is part of the rationale in all five countries with existing EFT. In addition, EFT can be justified as paying for the benefits of ecological public goods and services that spill over beyond the boundaries of decentralized jurisdictions⁸⁸; such goods will otherwise be underprovided. Incentivizing greater provision of environmental public goods is part of the rationale for EFT in Brazil, China and India. Furthermore, EFT sit within larger IGFT systems, which in some countries have the rationale of redistribution, or equalization, of public revenue to raise the public budgets of poorer states or municipalities⁸⁸. In all five countries with EFT, equalization is a rationale and criterion of the overall IGFT, although not the EFT.

Several factors seem to make the emergence of EFT more likely. Certainly, one factor is an established mechanism for redistributing public funds between different levels of government; that is, an IGFT. Land area as an element of IGFT has commonly been a precursor to EFT. The emergence of EFT has often been preceded by land-use restrictions followed by political processes recognizing a need to compensate affected municipalities. Evidence from Brazilian states finds that EFT emergence is more likely in

non-election years²⁹. EFT that have an incentivizing rationale are probably more likely to emerge in countries where recipient governments have greater decentralized authority to make land-use decisions, as in Brazil, China and India⁸⁹. Emergence may be more likely in a more decentralized or federal system such as Brazil's, where states such as Paraná can be policy innovators, and where states may be less likely than the national government to value environmental public goods over private development benefits in the absence of incentives⁹⁰. Meanwhile, the expansion of EFT may be easier in a more centralized or unitary system.

Design. Indicators for an EFT may relate to either nature conservation or abatement of environmental pollution. They may be based on natural endowment (for example, forest cover in India), changes in the status of the endowment (for example, avoided deforestation in Pará) or actions or instruments to conserve that endowment (for example, firefighting in Tocantins; and protected areas in Portugal, France and many Brazilian states). Indicators may be either quantitative or qualitative¹⁶ (for example, protected area quality in some Brazilian states).

Indicators should be easy to monitor. They should be based on reliable, authoritative, standardized data that is collected consistently across all recipient jurisdictions, rather than data that is reported independently by each recipient or is subjective. An indicator should also have a reasonably predictable value so that recipient revenues do not fluctuate erratically. There is a trade-off between a simple indicator, which may have lower transaction costs, be easier to explain to the public and which policymakers tend to prefer, or a weighted index of indicators which might better capture more complex systems. For example, India's EFT might have considered altitude, biodiversity, pristineness, or connectivity of forests³⁷; instead they chose an indicator based on area of dense forest only. A simple indicator might also reduce manipulation of fiscal transfers for partisan politics⁹¹.

If EFT are intended to have an incentive effect, the outcome measured by the indicator should be within the authority of the recipient jurisdiction to control^{34,89}. The indicator should be performance-based and closely tied to the desired outcome⁸⁶ to avoid recipient jurisdictions increasing the indicator without improving the outcome.

The ideal size of an EFT, in terms of the amount of funding or percentage of IGFT, depends on its rationale. If the primary rationale is allocating sufficient financial resources for the provision of ecological public goods and services, then estimates of required resources for the relevant ecological public functions (considering current underfinancing) are a starting point. If the primary goal is incentivizing conservation, then the size of the transfer would need to be comparable to or greater than opportunity costs. For example, EFT in India were sized proportionally to estimates of forgone state tax revenues. Alternatively, the EFT could be based on ecosystem services valuation. If the rationale is related to ecological benefits that spill over beyond jurisdictional boundaries, then the EFT might cover only the spillover benefits, with internal benefits covered by the jurisdiction through matching funds². Or, more commonly and pragmatically, the size of an EFT could start with a politically reasonable number, with the amount evolving over time with experience⁹².

Specific-purpose EFT have the putative benefit of increasing specific budgets for environmental goals. However, general-purpose EFT give recipient governments more spending autonomy^{2,87}, and will typically be larger, as in India, potentially resulting in more systemic transformation. Specific-purpose transfers may be legally restricted in some countries, as in Brazil. General-purpose and specific-purpose transfers can be combined, as in China's eco-compensation programme, which includes general-purpose transfers for NKEFA and specific-purpose transfers for six other

programmes. At least in China, the general-purpose transfers are supported by a dedicated institutional funding channel (the general transfer from central government to local budgets), so they have greater long-term stability than the specific-purpose transfers, which depend on projects having appropriations from the central government budget.

Effects. The effect of EFT on the revenues of jurisdictional recipients will vary by the origin or type of funds to be allocated¹⁶, as well as on the allocation formula. There is a trade-off between the amount of IGFT revenue that can be allocated on the basis of ecological indicators and the amount allocated on the basis of other indicators such as population or land area. Some recipient jurisdictions gain revenue from the introduction of EFT, while others lose revenue (as in Portugal³², for example).

There is evidence cited above that EFT have already incentivized subnational governments to increase protected area coverage in Brazil and Portugal and improve environmental quality in China. As noted earlier, EFT intended to incentivize the greater provision of ecological public goods should be within the authority of the recipient jurisdiction to control, performance-based and closely tied to the desired outcome. Understanding the design features and contexts that make subnational governments more responsive to the financial incentives remains an important topic for future research, with relevance not only to EFT but to other payment-for-performance instruments such as REDD+ as well⁹³.

There may be synergies between EFT and other goals of IGFT, particularly equalization. Regions that 'win' by receiving greater EFT due to their greater share of land protection or forest cover may also be more remote, with greater fiscal need and lower fiscal capacity (for example, as in Germany⁸⁰). Meanwhile, regions that 'lose' by receiving less EFT may be more urban and well off, with IGFT comprising a much smaller share of their budget, and higher government revenues from other sources, such as business and land taxes. Thus there can be a double dividend of revenue equalization and the promotion of ecological outcomes. However, redistributing public revenue on the basis of ecological indicators could run counter to the goal of equalization if more protected or more forested regions are very thinly populated or receive high income from other sources.

The visibility and transparency of EFT funds to recipients also varies. In Paraná, the ecological portion of the ICMS is transferred separately into municipal accounts³⁰, and even appears on constituents' electric bills in some municipalities¹⁹, creating high visibility and debate on fund allocation. Conversely, in Portugal, where the EFT lacks a named designation and the size of transfers is not communicated, recipients may be less inclined to be supportive.

EFT can have other effects beyond environmental and revenue outcomes. Such effects can be intended or unintended. Within recipient jurisdictions, EFT can influence power dynamics and local governance⁹⁴ as well as social equity and perceptions of conservation⁹⁵. What outcomes are achieved are determined in part by the capacity of recipient governments³⁰ and the engagement of local environmental organizations¹⁹. EFT may also introduce competition for the ecological funds among municipalities¹⁷. The onward allocation of EFT funding within municipalities can have its own effects, for example, to support forest restoration goals⁹⁶. EFT can have a decentralizing effect on environmental decision-making³⁴. For example, when Portugal devolved responsibility for protected area designation, municipalities may have designated protected areas that conserved locally important ecosystems, rather than nationally important areas.

Last, but not least, EFT are just one instrument in the wider conservation policy mix⁸⁸. They cannot be expected to accomplish all policy goals. Motivating decision makers other than subnational governments is best addressed directly by other instruments.

Opportunities for expansion

EFT have compensated subnational governments in five countries for the costs of top-down land-use restrictions. They have incentivized the formation of new protected areas in Brazil and Portugal, improved environmental quality in China and supported international climate commitments in India.

EFT are emerging in Indonesia, Mongolia and Uganda, and there is scope for other countries to enact EFT as well. Governments may find EFT an attractive way to distribute finance for environmental outcomes, since in many countries this would not require legislatures to appropriate new, additional annual funding from constrained public budgets. Instead, existing and regular financial flows to states or municipalities could be redistributed among the same public recipients in a way that incentivizes greater provision of environmental services. Incentivizing greater environmental service provision without appropriating new funding may be especially attractive to governments in post-Covid recovery⁷.

Only a minuscule share of IGFT—about US\$23 billion yr⁻¹—is based on ecological indicators at present; that is, are EFT. More than 99.5% of the US\$4.9 trillion yr⁻¹ in IGFT funding is based on other indicators. For the vast bulk of IGFT, this is appropriate. IGFT mainly have other goals that supersede environmental objectives, for example, to provide stable and predictable funding to subnational governments to provide public goods and services for their inhabitants, and to equitably rebalance budgets across jurisdictions of varying income levels. In addition, some IGFT are dedicated to supporting goals in other sectors, such as education, health or infrastructure.

However, greening even a small fraction of IGFT could go a long way towards addressing environmental challenges related to climate change, deforestation, biodiversity loss, water quality, nature's cultural services and so forth. Even if only 2% of IGFT was 'greened,' the volume of funding mobilized would be equal in magnitude to developed countries' Copenhagen pledge of US\$100 billion yr⁻¹ for climate mitigation and adaptation. National governments are formulating pledges of heightened environmental ambition to the UNFCCC, CBD and the UN Decade of Restoration. Given their potential, EFT could comprise an important element of these pledges.

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J.B. and I.R. designed the review and led the writing of the paper. All authors provided source material and contributed to writing and editing the paper.

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The authors declare no competing interests.

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