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ARTICLE

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Abstract

Despite decades of international political emphasis, little is known about the in-country determinants of technology transfer for climate change mitigation. We draw upon the conclusions of a series of standardised, official governmental statements of technology priorities, coupled with questionnaire-based data collection, to shed light on the nature of those determinants. We find that there is a disconnect between what developing country governments perceive as the key enablers of, and barriers to, technology transfer, and what bilateral and multilateral technology transfer programmes can offer, given budgetary constraints and the logic of development aid spending. We show that the well-established notion of making climate change mitigation actions an integral part of sound development plans is especially relevant for technology transfer. We offer pointers as to how this might be done in practice, in the context of the 'technology action plans' developed as part of the United Nations-sponsored Technology Needs Assessment process.

Introduction

In the context of multilateral climate change negotiations, scaling up the adoption of lower-carbon energy technologies in developing countries is referred to as ‘technology transfer’ (Metz & Turkson 2000). While, over the years, the concept of technology transfer has become central to these negotiations, both the debate about, and the approach to, technology transfer has been “characterised by a highly narrow and instrumentalist (and sometimes even naïve) understanding of technology, and the conditions under which technology transfer occurs” (Haselip *et al.* 2015).

Reflecting the shortcomings noted above, the extent to which the plethora of past and ongoing technology transfer initiatives have been effective and efficient at scaling up the adoption of cleaner energy technologies in developing countries is unknown (Chatterji 2016). Identifying the in-country determinants of technology transfer, and mapping them against the outcomes of these initiatives, is a prerequisite to evaluate the efficiency and effectiveness of the initiatives. We explore this question, focusing on a selection of energy-related technologies, and a small group of developing countries, to offer some indicative results as a means to stimulate debate and identify areas for more in-depth research. With the aim of drawing broadly applicable findings that are relevant to multi-lateral climate change negotiations, we do so from an aggregated point of view, by structuring our research around four technology clusters – household consumer goods, industry retrofits, new industry investments, and large infrastructure projects. We find that there is a disconnect between what developing country governments perceive as the key enablers of, and barriers to, technology transfer, and what bilateral and multilateral technology transfer programmes can offer, given budgetary constraints and the logic of development aid spending. Given that our analysis is informed by the conclusions of non-OECD

country-driven processes (principally the TNAs, as discussed in section 2) our analysis is focused on non-OECD country perspectives, albeit from our own developed-world perspective.

The disconnect referred to above reflects governance deficiencies that are common in many developing countries, and have the unintended consequence of undermining sectoral policy goals, by unduly contra-positioning development priorities to those sectoral goals (Bulkeley & Newell 2015). In the area of climate change mitigation, a large part of the solution to this deficiency entails striking a balance between the additional cost of lower-carbon energy technologies (compared to the cost of traditional alternatives), and the imperative to adopt inexpensive technologies, with a view to stretching limited budgets as far as possible. The so-called technology action plans, a set of detailed, national-level blueprints for the adoption of lower-carbon energy technologies, prepared under a United Nations-sponsored initiative to promote technology transfer in developing countries, offer an opportunity to strike this balance. With regard to the role of technology transfer, the credibility of the international climate change regime may suffer if this opportunity is missed (UDP 2015b).

1. Background

'Technology transfer' is a key tenet of the 1992 United Nations Framework Convention on Climate Change (UNFCCC). Article 4 in the UNFCCC requires its signatory parties to "promote and cooperate in the development, application and diffusion, including transfer, of technologies, practices and processes that control, reduce or prevent anthropogenic emissions of greenhouse gases not controlled by the Montreal Protocol in all relevant sectors".

An emphasis on the role and importance of technology within the UNFCCC stems partly from the success of the 1989 Montreal Protocol, which relied on a narrow 'hardware' focus to achieve a relatively rapid and widespread technology switching, following the ban on chlorofluorocarbons.[1] However, unlike chlorofluorocarbons, greenhouse gases are emitted by virtually all sectors in the economy, directly or indirectly, through a wide range of technologies. For this reason, technology switching is far more complex in the area of climate change, as it involves more than just a limited number of manufacturing processes within a relatively small industry that has few large producers.

Acknowledging that a narrow focus on manufacturing processes would be unsuitable for the ubiquitous nature of climate change, the Intergovernmental Panel on Climate Change (IPCC) defined 'technology transfer' rather broadly (Metz & Turkson 2000):

> *"The broad set of processes covering the exchange of knowledge, money and goods amongst different stakeholders that lead to the spreading of technology for adapting to or mitigating climate change. [The] word 'transfer' [is used] to encompass both diffusion of technologies and cooperation across and within countries."*

Indeed, much of the academic debate reveals a paucity of detailed, operational definitions of technology transfer (Karakosta *et al*. 2010, Popp 2011). In this article we use the IPCC definition, which emphasises the importance of cooperation. This is an aspect that the academic literature is

[1] Chlorofluorocarbons were used in refrigerants, propellants and solvents. They were responsible for the destruction of the ozone layer, a portion of the Earth's stratosphere that absorbs most of the Sun's medium-frequency ultraviolet radiation, which is damaging to life. For a discussion on the relative role and importance of commercial patents as a driving force behind multilateral agreements to tackle ozone and greenhouse gas emissions see, for example, Seidel and Ye (2015).

increasingly focused on, using the term 'cooperation' in order interrogate the political and economic dynamics behind such exchange.

In response to Article 4 in the UNFCCC, various multilateral and bilateral funding mechanisms have been set up to accelerate technology transfer for climate change mitigation (and adaptation) (de Coninck & Puig 2015).[2] For example, in the year between July 2014 and June 2015, the Global Environment Facility, a multilateral fund, approved USD 221.4 million worth of investments in lower-carbon energy technologies in developing countries. The Green Climate Fund (GCF) and the Climate Technology Centre and Network (CTCN), are expected to play key roles in providing or (in the case of the CTCN) enabling finance for technology transfer.

The extent to which these multilateral institutions have promoted ‘technology transfer’ is unclear. Research on the determinants of technology transfer has focused on two main aspects: evidence on the mechanisms that help promote technology transfer across a wide spectrum of technologies (Ockwell & Mallet 2012), and evidence on the conditions that facilitate the adoption of a specific technology, often in a particular socio-economic context (Audretsch *et al.* 2016). These two streams of work have supported, respectively, international climate change negotiations, and the development of financial plans for lower-carbon energy technologies.

Notwithstanding its usefulness, this work overlooks an intermediate level that can be characterised by clusters of technologies sharing key market attributes, notably with regard to the affordability of these technologies by the relevant stakeholders. As such, we use the term 'clusters' to capture the basic market categories common to all national-level economics, where the 'intermediate' level focuses on policies that correspond to this national level. Research at this intermediate level is much needed, because this is the level at which national planning for climate change takes place (Boldt *et al*. 2012).[3] In this sense our analysis is focused through a political economy lens, where we assume that private sector actors (investors, technology suppliers and consumers) are the principle drivers in the uptake and diffusion of lower-carbon energy technologies, in a given economy (Ockwell and Byrne, 2015). Thus, the question is how governments and state agencies can create, steer and scale up markets for these technologies, by incentivising economic actors to increase investment in the supply and demand.

By extension, it is appropriate for us to anchor this article in the broader literature on technology innovation systems and sustainability transitions, where there is growing academic discussion about the drivers, mechanisms and implication of the uptake and diffusion of lower-carbon technologies in non-OECD countries, outside the context of the UNFCCC. The contours of this debate are well articulated in a special issue on sustainability transitions in developing countries edited by Hansen et. al. (2017) and in Ockwell and Byrne's (2016) edited book. A key theme within this debate is the limitation of some of the analytical approaches (e.g. Technology Innovation Systems) to understanding the topic in non-OECD contexts, and how studies often focus on one technology and / or the macro-economic level, hence fail to take into account the socio-economic contexts surround processes of technology transfer. By focusing our analysis on technology clusters in the context of the

[2] Multilateral and bilateral funds are channelled through grants, or a range of financial products. Grants are often aimed at increasing technical and institutional capacities in developing countries. Financial products, typically in the form of equity, concessional debt, or guarantee instruments and risk sharing, often seek to leverage larger volumes of private sector financing for capital and infrastructure investment.

[3] The Paris Agreement, the international blueprint for climate change management, requires parties to the UNFCCC to formally report their actions to manage climate change. These reports are known as Nationally Determined Contributions (or NDCs for short). The approach used in this paper, focused on the ‘intermediate level’ of planning outlined above, is directly relevant to the type of analysis around which the NDCs are structured.

UNFCCC (as opposed to individual technologies and / or countries as a whole), we aim to contribute to these wider debates.

Our research question is "for a range of 'technology clusters' that are relevant to most developing country plans for climate change, what are the determinants of technology transfer?" Drawing upon conclusions of official statements of national climate change technology priorities, we provide tentative answers to this question. In doing so, we sketch some of the requirements for promoting the actual transfer of lower-carbon energy technologies.

This article is structured around four additional sections. Section 2 introduces the 'technology needs assessment process', from which our data is drawn. Section 3 outlines our methodology. Section 4 presents our findings. In a final section we raise points for discussion, indicating areas of possible future research.

2. The TNA project

Among the various multilateral efforts aimed at promoting technology transfer, the 'technology needs assessment (TNA) process' is a long-standing one. The TNA process was conceived as a means to "track evolving needs for new equipment, techniques, practical knowledge and skills to mitigate greenhouse gases and adapt to the adverse impacts of climate change". Since 2001, and with support from international organisations, more than 85 developing countries have completed an assessment of their technology needs for climate change. The latest generation of TNAs were mandated by the UNFCCC's Poznan Strategic Programme on Technology Transfer, in 2008. According to this programme, the TNAs enable developing countries to "demonstrate commitment" to technology transfer, as a step toward accessing public finance for it.

The TNA process is organised around three main steps: (i)identify and prioritise mitigation (and adaptation) technologies for key sector and/or sub-sectors at the national level; (ii) identify, analyse and break down barriers to technology diffusion, and detail an "enabling framework" for that diffusion; and (iii) articulate 'technology action plans' (TAPs).[4] The first step results in the so-called TNA reports, from which most of our data is drawn. The TAPs resulting from the third step, which are framed around concrete opportunities for technology switching, are a second source of data for our work.

The TNA process reflects national priorities and concerns.[5] By relying on TNA data, our findings are consistent with these – as opposed to conclusions derived from an externally developed economic optimisation model, or a particular governance model. As such, our data reflects a diversity of technology priorities and rationalities regarding the barriers to technology transfer, and the means to overcome them. What these priorities and rationalities have in common, however, is that they are all nationally determined analyses, and statements of official, sovereign intent.

For the technology-prioritisation process, the TNA process used multi-criteria decision analysis Multi-criteria analysis is a decision-support tool that enables participants to identify, select and evaluate options on the basis of agreed-upon criteria. Unlike cost-benefit analysis, multi-criteria

[4] All reports are available online at: http://www.tech-action.org/

[5] For some countries, the results of the TNA project are clearly reflected in the NDC. The extent to which this is so depends, among other issues, on (i) how recent the TNA ranking is, and (ii) whether or not the NDC is detailed enough to highlight specific technology-related priorities.

decision analysis does not depend upon a monetisation of values, thus enabling participants to capture and value a wider range of issues (one of which may the monetary value of a technology's costs and benefits) and discuss their relative importance. This multi-criteria analysis was conducted as a participatory process, involving various stakeholders, as selected by the national governments responsible for implementing the TNA.

3. Methodology

Based on the conclusions of the TNA reports, we identify key determinants of successful technology transfer. These determinants are a combination of the barriers that would have to be removed, and the enabling factors that would have to be introduced, which, taken together, increase the likelihood of technology transfer taking place. We cluster these determinants by type of market – household consumer goods, industry retrofits, new industry investments, and large infrastructure projects – and identify the key determinants in each cluster. When defining the clusters, our main consideration was how the technology upgrading would be financed, combined with a simple division of consumer categories. This reflects the main issue as expressed in the TNA reports. For the ‘households’ cluster, the main determinant is having sufficient disposable income (and a willingness to pay); for the ‘industry retrofits’ cluster it's mostly about returns on capital investment. For the ‘new industry investments’ the main issue is access to investment in new production facilities and longer-term returns, and the ‘large infrastructure projects’ cluster is mostly concerned with access to sovereign loans (i.e. government history of debt repayments or defaults).

Countries participating in the TNA process were provided with specific guidance developed for the project, including a standardised assessment methodology prepared by the UNEP DTU Partnership (Haselip et al., 2015). Nonetheless, individual TNA reports are not always directly comparable, as countries were given a significant degree of flexibility with regard to conducting the technology prioritisation process and barrier analysis, as befit their technical capabilities and preferences.

For the analysis presented in this paper, we have complemented the data from the TNA reports with a survey on enablers of, and barriers to, technology transfer (Supplementary Information 1). The survey was sent to the TNA project coordinators in the countries participating in the first phase (2011-2014), who were typically government officials and the national climate change focal points within relevant Ministries, thus assumed to have an informed overview of the key determinants of technology transfer in their countries. This survey allowed us to (i) increase the comparability of the TNA report data across countries, and (ii) collect data that was missing in the TNA reports. The resulting dataset (Supplementary Information 1), while limited to a reduced number of countries, allows us to draw some tentative conclusions that reflect the realities in the countries surveyed, and possibly beyond (Section 5).

4. Findings

We characterise the determinants of technology transfer through three survey questions – drivers, enablers, and barriers (Supplementary Information 1). Responses for each of these questions are elicited by country and technology. Here, we present aggregated findings by technology cluster.

Table 1 summarises key survey results by technology cluster. In the following paragraphs, we compare these results with the typical design of bilateral and multilateral technology transfer programmes.

[INSERT TABLE 1]

With regard to the drivers of technology transfer, we find that 'cost savings' dominates in three out of four technology clusters. In the fourth cluster ('new industry investments'), meeting government targets appears to be the main driving force. This suggests that technology transfer is more likely to occur where energy prices are not unduly low, and government has introduced certain performance targets for large energy consumers. Whilst this is perfectly consistent with current wisdom, it has not deterred funders of technology transfer programmes from deploying these programmes in countries where these two pre-conditions are not met, as evidenced by the geographic scope of most such programmes.[6]

In three out of four technology clusters, subsidisation is cited as the main enabler of technology transfer. While bilateral and multilateral technology transfer programmes often rely on an element of subsidisation, this is seldom the dominant aspect in these programmes. This is because subsidy-based programmes contradict the predominant market-based (or neoliberal) logic that drives decision-making among multilateral lenders. From this perspective, subsidy-based programmes are generally viewed as expensive, and not seen as a sustainable option upon programme completion. Instead, other options, such as technology-specific credit facilities (possibly combined with a small subsidy to cover the costs of the technology), represent what is widely viewed as a more sustainable alternative (CPI 2012). This highlights a fundamental disconnect between what countries perceive to be the main enabler for technology transfer, and what bilateral and multilateral programmes can offer, given the political economy around, and known limitations of, subsidy-based programmes (UNEP 2005).

In the fourth cluster ('large infrastructure projects'), foreign direct investment is perceived as the most likely enabler of technology transfer.[7] Two issues are worth noting here. Firstly, 'bilateral and multilateral loans' was only cited in the context or large hydropower dams – not for carbon capture and storage, or for geothermal energy. Secondly, the fact that technology transfer for certain large infrastructure projects may depend on foreign direct investment underscores the need to widen the traditional technology transfer debate, which continues to be heavily focused around development aid-funded implementation modalities. However, without wishing to drift into the realm of speculation, it seems fair to say that multilateral initiatives could do more to secure investment for specific technologies, supporting national funding agencies that are less willing to take on the financial and non-financial risks associated with certain large-scale infrastructure projects such as hydropower or wind farms located in remote areas with contested land tenure and access rights. The Lake Turkana project in Kenya is a case in point where various sources of finance (public, private, Kenya, foreign) came together to build what was the largest single wind farm in Africa (310 MW), at the time of construction (2017).

In two out of four technology clusters, issues related to affordability are cited as the main barriers to technology transfer. Specifically, the barriers cited are high up-front costs ('household consumer

[6] The Global Environment Facility reports on funding for technology transfer. The latest report dates to 2014, and includes a full list of beneficiary countries (UNFCCC 2014).

[7] To the extent that some NDC targets are conditional on external support, it may be expected that some countries single out large infrastructure projects as key targets for such external support.

goods' cluster), and high capital costs, also combined with high import taxes ('industry retrofits' cluster). In the case of the 'household consumer goods' cluster, breaking down these barriers requires macroeconomic policies that encourage savings, thereby increasing disposable income. However, increasing disposable incomes does not necessarily lead to the purchase of more energy efficient consumer goods. Rather, changes in consumption also depend on shifts in consumer willingness to pay, which is partly a function of changing cultural practices, education and concern about the non-financial (environmental and social) costs of consumption. Related to this is the rapidly evolving landscape of technologies and business models for service provisions, such as mobile and pay-as-you-go technologies, which are being applied to off-grid solar PV system, for example.

In the case of the 'industry retrofits' cluster, increased profitability can help break down the cost barrier. Profitability is a function of several parameters, some linked to the investment structures within the industry concerned, and some linked to the fiscal and industrial policies in the host country. Few bilateral and multilateral technology transfer programmes attempt to bring about these types of changes, as evidenced by the scope of most such programmes (UNFCCC 2014).

In the remaining two clusters, the main barriers cited relate to the regulatory framework: lack of financial incentives ('new industry investments' cluster), and regulatory inefficiencies ('large infrastructure projects' cluster). This is an area that bilateral and multilateral technology transfer programmes have prioritised, in some countries and sectors more than in others (UDP, 2015). Increased emphasis on these issues might thus be warranted.

5. Discussion

In its broad definition of technology transfer, the IPCC captures the multiple dimensions of the concept (Metz & Turkson 2000). Conversely, international climate change negotiations under the UNFCCC arguably fail to recognise these complexities, as evidenced by the narrow focus of the Poznan Strategic Programme on Technology Transfer, which lacks a holistic framework that embeds technology transfer within a country's broader socio-economic context (UNFCCC 2008). Indeed, the UNFCCC's Technology Mechanism, with its Climate Technology Centre and Network, predominantly takes a narrow project focus.[8]

Expectations about the Technology Mechanism by some developing country governments are similarly narrow, in the sense that (limited) developed country funding levels are typically brandished as the main obstacle to technology transfer in the TNAs. This is a simplification of the issue, in that it overlooks the fundamental role that the regulatory and institutional frameworks play with regard to successful technology transfer. More generally, the funding argument may mask key developmental deficiencies, notably those related to the suitability of a country's fiscal and investment frameworks, including transparency and rule-of-law, which translate into differing risk profiles.

The 'technology action plans' (TAPs) prepared as the final outputs of the technology needs assessment process represent a valuable opportunity to correct the shortcomings referred to above. These plans outline targeted actions that, by helping remove barriers to the adoption of climate change (adaptation and) mitigation technologies, can facilitate the uptake of those technologies. Here, it is important to reiterate that the TAPs are nationally determined plans that reflect the will and preference of the governments (informed by their appointed stakeholders), not externally calculated optimisation

[8] Limited funding to-date for the Climate Technology Centre and Network is one of the reasons for this.

models based on a host of assumptions. To stimulate technology transfer beyond current levels, it is necessary to articulate and present opportunities, beyond a discussion of hardware and funding, to include revisions in related policy and the broader enabling framework (UNFCCC, 2014 and 2016). This brings us back to the primacy of the political economy of technology transfer processes, in which private investors, technology suppliers and consumers are the key actors that governments and state agencies must engage with to create, steer and scale up markets for low-carbon energy technologies.

If technology is to play a truly meaningful role in the mitigation of greenhouse-gas emissions, the UNFCCC rhetoric about ‘technology transfer’ and ‘sustainable development’ has to be made operational, and scaled-up significantly in the coming decades. This would mean framing technology transfer as an intrinsic and core element of broader development plans – an aspiration that is at least as old as the notion of ‘technology transfer’ itself, but toward which relatively little progress has been achieved thus far.

Therefore, thinking beyond the life of the TNA/TAP process, multilateral mechanisms that aim to scale up access and investment in low-carbon energy technologies should also think about the developmental benefits of the technological transition they aim to support. Here, it is important to acknowledge how the basic political economy of low-carbon technology 'transfer' has shifted in recent years, to operate increasingly on market lines. On the supply side, especially for the large-scale infrastructure cluster, it is private investors who are driving the transition in low-income countries (Nygaard et al., 2017). As such, donors now play a predominantly supporting role in many low-income countries, to kick-start and de-risk projects that otherwise operate on commercial grounds (Rodríguez-Manotas et al., 2018). This movement - from projects to markets - creates new challenges and opportunities for governments, and their development partners, to optimise the enabling framework for low-carbon energy technologies. This includes the enactment of laws, policies and regulations to accelerate the large-scale diffusion of low-carbon energy technologies through market-creation incentives; create local employment by capturing larger shares of value in the global value chains in the supply of technologies; and ensure that wider development objectives are met through private sector engagement, as enshrined in SDG7, SDG8 and SDG9.

In order to avoid 'missing the boat' in capturing these developmental benefits of the technology transition, non-OECD governments should appeal to their development partners (multilateral or bilateral) for support in working with relevant ministries and their policy makers, regulators, public utilities, local research institutions and private sector actors. Here, the basic aim should be to identify elements of a reformed enabling framework for specific technologies, with an emphasis on securing a greater share of the market value chain in the local economy.

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