

Making intellectual property rights work for climate technology transfer and innovation in developing countries

Su Jung Jee^{1,2} , Kerstin Hötte³ , Caoimhe Ring^{4,5} , Robert Burrell^{4,6,*} 

¹Leeds University Business School, University of Leeds, Maurice Keyworth Building, Moorland Road, Leeds LS6 1AN, United Kingdom

²Institute for New Economic Thinking, University of Oxford, Manor Road, Oxford OX1 3UQ, United Kingdom

³Kedge Business School, 40 Av. des Terroirs de France, 75012, Paris, France

⁴Faculty of Law, University of Oxford, St Cross Building, St Cross Road, Oxford OX1 3UL, United Kingdom

⁵University of Bristol Law School, Wills Memorial Building, Queens Road, Clifton, Avon, Bristol BS8 1RJ, United Kingdom

⁶Melbourne Law School, 185 Pelham Street, Carlton VIC 3053, Australia

*Corresponding author. Professor of Intellectual Property and Information Technology Law, The Faculty of Law, University of Oxford, St Cross Building, St Cross Road, Oxford OX1 3UL, United Kingdom. E-mail: robert.burrell@law.ox.ac.uk, robert.burrell@spc.ox.ac.uk

The role of intellectual property rights (IPRs) in climate technology transfer and innovation in developing countries remains controversial, often cast as a barrier to development. Using a systematic literature review and case study methodology, we assess the impact of IPRs on three sources of climate technology: (1) international technology transfer, (2) adaptive innovation, and (3) indigenous innovation. We examine four cases across regions with different development levels: Bangladesh, India, Kenya, and South Africa. Our contributions are threefold. First, existing debates overstate IPRs' importance, whereas national capabilities and development levels are more decisive. Second, lower-tier IPRs may nevertheless incentivize climate innovation in developing countries. Third, we develop a framework for IPRs to support climate change mitigation and adaptation, considering the broader context of trade and climate policy. IPRs and market mechanisms may encourage the transfer of mitigation technologies under certain conditions, while adaptation requires more institutional support to meet local needs.

Keywords intellectual property rights, TRIPS, climate policy, trade policy, developing country, climate change mitigation, climate change adaptation

'[R]emoving obstacles to knowledge sharing and technological transfer – including intellectual property constraints – is crucial for a rapid and fair renewable energy transition.'

UN Secretary-General Antonio Guterres (UNFCCC 2022).

1. Introduction

Climate change adaptation and mitigation technologies can help developing countries address climate risks and achieve sustainable development (IPCC 2022). Although developing countries bear the brunt of climate change, they often lack access to climate technologies¹ predominantly held by developed countries.² In this context, the role of intellectual property rights

(IPRs) in climate technology transfer and local innovation remains controversial, and is often portrayed as a barrier to access to essential technologies or as an impediment to development (Ockwell et al. 2010; Drahos 2011; Sarnoff 2011; Rai et al. 2014; Tur-Sinai 2018; Athreye et al. 2023).

IPRs increase the costs of accessing foreign technologies needed for development and technological catch-up (Maskus 2010; Urias and Ramani 2020; Dreyfuss and Benoliel 2021) and may reduce opportunities for technological learning through imitation (Auriol et al. 2019). However, IPRs enable inventors to appropriate gains; incentivize research and development (R&D); and facilitate international technology transfer (ITT) by fostering trust and incentives for sharing technology across borders (Lopez 2009; Abdel-Latif 2015; Cockburn et al. 2016; Spielman and Ma 2016; Zhang and Yang 2016).

Recent debates have focused on the Trade-Related Aspects of Intellectual Property Rights (TRIPS) Agreement, an international treaty that establishes minimum standards of intellectual property (IP) among World Trade Organization (WTO) members (Raiser et al. 2017; Zhou 2019; Dussaux et al. 2022). IPRs represent a trade-off between the costs of market power and the benefits

¹ See Section 2.1.2 for the definition of *climate technology* we adopt in this study.

² Article 3.1 of the United Nations Framework Convention on Climate Change (UNFCCC) recognizes these imbalances through the principle of 'common but differentiated responsibilities' (CBDR), outlining mechanisms under Articles 4(1)(c), 4(3), 4(5), 4(9) and 11(1) for developed nations to facilitate the climate technology transfer to developing countries (adopted 9 May 1992; entered into force 21 March 1994; 1771 UNTS 107).

of incentivizing innovation (Hall 2007), but this trade-off benefits countries of different development levels unevenly (Chang 2002; Grossman and Lai 2004). To date, there is limited empirical knowledge on how domestic IPR systems impact the diffusion of climate technologies in developing countries (Maskus 2009; Ring 2021; IPCC 2022).

This study contributes evidence to these debates by addressing the following questions:

Are existing technology transfer mechanisms and the TRIPS framework suitable for promoting the diffusion and innovation of climate technologies in developing countries? How and when do they work? What reforms can make national and international policies work better for this purpose?

Given the complex relationship between IPRs and development, heterogeneities among climate technologies, and poor empirical data on developing countries, we conducted a systematic literature review and 20 in-depth interviews with IP experts from four selected countries (Bangladesh, Kenya, India, and South Africa) to understand current practices and future directions. Guided by the literature review, we focus on three main areas where IPRs interact with climate technology: (1) ITT (trade, foreign direct investment (FDI), and technological cooperation), (2) indigenous innovation (original development of solutions), and (3) adaptive innovation (modifying or repurposing existing technology).

Combining the literature review and thematic analysis of our interview data, this study makes three major contributions: First, we found that the significance of IPRs for climate technology innovation in developing countries is more limited and more nuanced than either side of the debate suggests (see Section 2 for the review). Rather, the importance of IPRs must be evaluated within a broader context, where more pressing socio-economic barriers persist.

Second, we found that IPRs such as patents play a limited role in low-cost, adaptive innovation and indigenous innovation in developing countries, while trademarks appear useful as a means of fostering indigenous and adaptive climate innovations by local entrepreneurs for marketing and quality assurance. Interviewees also supported the use of utility models (second-tier patents for minor inventions) to promote simple, high-impact climate innovation, although the efficacy of these mechanisms is unclear. This finding extends previous studies (e.g. Baroncelli et al. 2005; Suthersanen 2006; Kim et al. 2012; Dreyfuss and Benoliel 2021), calling for more empirical evidence on lower-tier IPRs for climate technologies in developing countries.

Third, we develop a framework for incorporating IPRs in national and international climate and trade policies, outlining support mechanisms for mitigation and adaptation, which distinguishes between market- and institution-oriented policies. Institutional support, such as finance and co-development assistance, should be prioritized for adaptation where the market is immature, but solutions are urgently needed. In contrast, for mitigation, markets are mature, but demand is low. Market support mechanisms (e.g. tariff reductions) and demand-pull policies (e.g. environmental regulation and reducing local deployment costs) appear more relevant than relaxing IPRs for mitigation. Our analysis extends to policy discussions concerning IPRs and industrial policy and the developmental/entrepreneurial state relevant to policymakers at regional, national, and international

levels. This novel contribution informs future policies that integrate fragmented discussions on climate technologies and IPRs at different levels into a single framework.

This article is structured as follows: Section 2 reviews the literature on IPRs, ITT, and innovation in the climate context. Sections 3 and 4 are dedicated to the fieldwork. Sections 5 and 6 discuss the findings and policy implications. Section 7 concludes by highlighting the limitations of this study and identifies future research agendas.

2. IPRs, climate technology transfer, and innovation

We analyse the debate through three themes: the relevance of IPRs to climate technologies (Section 2.1), the impact of IPRs on ITT (Section 2.2), and their influence on innovation and development (Section 2.3).

2.1 IPRs and climate technology

2.1.1 IPRs: rationale and complex reality. Economic theory views IPRs as addressing knowledge's public good nature, granting temporary monopolies over embodied knowledge *via* patents, design rights, or copyright, incentivizing R&D by enabling inventors to charge higher prices, thereby ensuring a return on investment (Arrow 1962; Lopez 2009; Hall et al. 2014). Micro-level interactions, however, are complex. First, innovators use trade secrets alongside patents, with importance varying by sector (Hall et al. 2014; Jee and Sohn 2021). Second, R&D motivations extend beyond profit (Taussig 1915; Seelos and Mair 2009; Phillips et al. 2015; Bollinger and Neukam 2021) and public research drives many climate breakthroughs, making IPRs less relevant (Mazzucato 2013; Thursby and Thursby 2007; Hötte and Jee 2022). Third, seeking IPRs is not only about protecting an invention but rather about attracting finance, using patents as collateral, signalling devices (Long 2002; Hsu and Ziedonis 2008; Chava et al. 2017; Mann 2018), or for defensive purposes (Macdonald 2004), with variation across sectors. Overall, there is mixed evidence that IPRs promote innovation, though there is relatively robust positive evidence in the pharmaceutical and chemical sectors (Granstrand 2009).

2.1.2 Climate technology and IPRs in developing countries. Climate technologies 'help us reduce greenhouse gases and adapt to the adverse effects of climate change' (UNEP and UNFCCC 2022), whereby technology is defined as 'a piece of equipment, technique, practical knowledge or skills for performing a particular activity' (IPCC 2000). This includes tangible (e.g. equipment) and intangible items (e.g. know-how), transferred within and between countries. Climate technologies are diverse, and their effectiveness in adaptation and mitigation depends on the local context, including technological and financial capabilities, social acceptance, incumbent technologies, and geographic factors (Olawuyi 2018). Since the impact of IPRs is technology-specific (Granstrand 2009), a differentiated view is needed (Maskus 2010; Ockwell et al. 2010).

Four key factors are notable. First, many climate technologies, particularly those used in renewable energy, are mature, and various competing solutions exist (IEA 2020). Hence, concerns that IPRs limit access to these technologies may be misplaced,

as relevant IPRs often have expired. Second, many climate risks in developing countries require low-tech or nature-based solutions (NbS), which rarely rely on patented technologies (Rai 2008; Seddon et al., 2020; Dreyfuss and Benoliel 2021). Third, cutting-edge patented solutions from advanced economies may be unfit for developing countries, and low-tech and NbS may offer more suitable alternatives with co-benefits for other sustainable development goals (SDGs) (Seddon et al. 2020). Fourth, effective diffusion requires more than access to technology. Absorptive capacities, including capabilities to understand, maintain, use, and eventually adapt imported technology, are needed to ensure effective and sustainable use of these technologies (Olawuyi 2018; Lema et al. 2020).

The relationship between IPRs, innovation, and diffusion is complex. For example, certain climate technologies are not yet mature, and IPRs may impede ITT of emerging technologies in the areas of clean manufacturing, aviation, agriculture, biotechnology, and synthetic fuels. More generally, stringent IPRs can promote R&D investments and technology diffusion but may lead to monopolies, excessive pricing, and hinder adaptive innovation (Maskus 2010; Dreyfuss and Benoliel 2021).

There is a further specific issue about mitigation technologies. Such technologies contribute to the global public good of mitigating climate change, showing a second public good feature, next to the positive knowledge externality applicable to all innovations. This is called the 'double externality' of climate technologies, justifying public support for innovation and diffusion (Jaffe et al. 2005).

2.2 IPRs and climate technology transfer

ITT is embodied in various market-based activities like trade, licensing, and FDI. The impact of IPRs on ITT varies across these activities. Previous studies offer different conclusions, depending on their field of study or empirical focus. ITT also occurs through institutional routes such as development assistance, where IPRs play a minor role. However, institutional support mechanisms can enhance absorptive capacities, facilitating market-based ITT (Schmidt and Huenteler 2016; Olawuyi 2018).

Economic studies often show a positive link between strong IPR protection and market-based ITT. For instance, Cockburn et al. (2016) report a positive impact of stringent IPRs on the global diffusion of new drugs. Montobbio et al. (2015) find that IPRs enhance R&D collaborations. In agriculture, IPRs have been found to help close the yield gap between developing and developed countries (Spielman and Ma 2016). Such studies suggest that firms more often transfer technologies to countries with robust IPR protection, especially in technology-intensive sectors (Maskus 1998).

Studies on development and international relations emphasize the importance of strong IPRs for trade and FDI. Developing countries are encouraged to enhance protection for IPRs to facilitate the importation of innovations, although the suggested level of IPR protection varies across countries and sectors. For example, weak IPR protection in Africa has been said to hinder technology transfer, contributing to low absorptive capacity (Olawuyi 2018). Adopting stronger IPR standards may boost inward FDI in developing countries (Zhang and Yang 2016) and promote exports of new products, especially in sectors like pharmaceuticals and medical equipment (Abdel-Latif 2015; Bhatnagar et al. 2023). However, IPRs can have limited effects on FDI in countries with large informal sectors and weak IPR enforcement (Lee et al. 2018). FDI in

developing countries is principally shaped by economic opportunities, such as market size, purchasing power, and growth potential (Elfakhani and Mackie 2015), which are often more important than IPRs.

The legal literature tends to question the efficacy of IPRs for ITT in climate technologies, focusing particularly on pre-market R&D incentives (Drahoš 2011; Sarnoff 2011; Tur-Sinai 2018; Ring 2021). Scholars argue that patents may not incentivize climate technology innovation due to weak demand for these solutions (Olawuyi 2018; Tur-Sinai 2018). There are also longstanding debates about whether existing international IP and climate agreements establish sufficient ITT obligations for developed countries (Rimmer 2011; Zhuang 2017). Part of this discussion has focused on amendments to IP law, including restrictions on the patenting of essential climate technologies. Other proposals include compulsory licensing and government use provisions to address obstacles posed by high licensing costs and patent holders' refusals to license (Vindigni and La Terra 2016; Zhou 2019).

2.3 IPRs and climate technology innovation

Developing countries face specific challenges relating to climate technologies. Many solutions, including renewable energy, clean transport and production, are already available, although cost-effective implementation and scaling remain challenging (Sovacool 2008; IEA 2020; IPCC 2022). Developing countries can access these solutions through ITT channels like FDI, trade, or licensing. This may be crucial in sophisticated high-tech areas such as biotechnology, clean combustion, and batteries.

In many cases, however, countries need to adapt foreign technologies. Follow-on *adaptive innovation* can address specific regional demands or enhance efficiency. For example, implementing clean technologies can require follow-on innovation and development to optimize them for local infrastructure or climatic conditions (Raiser et al. 2017). Adaptive innovation involves incremental improvements, building on existing technologies. Effective adaptive innovation requires absorptive capacity (Cohen and Levinthal 1990; Hobday et al. 2000; Sasidharan and Kathuria 2011). Countries lacking these capabilities struggle to absorb or adapt foreign climate technologies (Li 2011; Olawuyi 2018). Local adaptive innovation, therefore, depends on a country's development stage and local circumstances (Aghion and Howitt 2005).

Beyond adapting foreign technologies, there is a need for locally specific technologies, as climate risks and solutions are often localized (Dodman et al. 2012). Developing countries, especially those with higher temperatures, face climate threats to food security, economic growth, and public health. Technologies tailored to local needs are therefore essential, especially in agriculture (IEA 2022).

Most climate solutions are developed and held by commercial actors in advanced economies (Jee and Srivastav 2024), and their R&D prioritizes the needs of developed rather than developing countries (Papaioannou 2014). Incentives to develop technologies tailored to the needs of developing countries are often absent, given low purchasing power and the presence of diffusion barriers. Consequently, there is underinvestment in relevant technologies. *Indigenous innovation* by local entrepreneurs can help

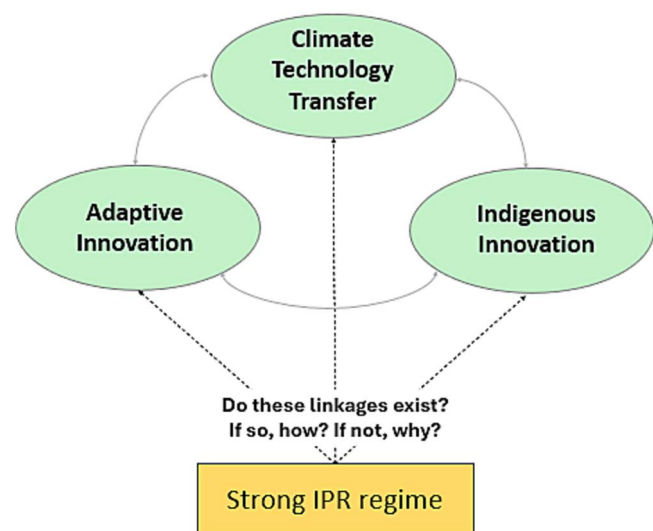


Figure 1 Research questions and conceptual building blocks from the review.

close this technology gap. Due to limited technological capacities, indigenous innovations are often low-tech solutions, utilizing unskilled labour and ensuring easy maintenance in conditions characterized by unstable electricity supply and weak supply chains (Fu et al. 2011; Ockwell and Byrne 2016). Moreover, in catch-up economies, finance and local capabilities, rather than IPRs, are key constraints on incremental and imitative innovation (Abdin et al. 2024).

IPRs tend to be geared towards high-tech, expensive innovations and may not impact local development of NbS or simple, low-tech solutions (Kapczynski and Syed 2012). Patents are unlikely to significantly enable or inhibit innovation in low-tech solutions and related ITT between developing countries. South-South ITT is important as developing countries sometimes face similar climate risks and socio-economic conditions, making solution sharing viable (Urban 2018). Recent trends show increased indigenous innovation and ITT between developing and emerging economies (Corvaglia 2014; Herman 2021), yet evidence is lacking on whether IPRs can play a role in this emerging channel of ITT.

However, there is a legitimate concern that IPRs could deter developing countries from adopting and adapting climate technologies. For adoption, IPRs may increase the costs of accessing technologies. Adaptive innovation that builds on existing technologies risks infringing IPRs. However, evidence about infringement risks being a barrier to climate technology diffusion in developing countries is lacking.

Figure 1 depicts our main research questions positioned within the key concepts derived from the literature. There is an analytical difference between innovation primarily driven by local knowledge, expertise, and challenges (indigenous innovation) and follow-on innovation involving improvements to imported technologies *via* ITT (adaptive innovation). In practice, however, there is no clear-cut distinction since indigenous innovation may build on imported knowledge. Further, there may be a positive feedback loop between ITT, indigenous, and adaptive innovation: success in one channel may promote success in the other channels (Fu et al. 2011).

3. Methodology

Our methodology is exploratory (Stebbins 2001) and develops new insights in an area with little empirical evidence (Maskus 2009; Ring 2021; IPCC 2022). We use in-depth case studies and interviews studying Bangladesh, India, Kenya, and South Africa. Each country serves as a unique instrumental case study, allowing for deeper insights (Stake 1995). We conducted 20 semi-structured interviews with key stakeholders, guided by the literature review and project objectives.³ While our overall sample places limitations on the generalizability of this study (Payne and Williams 2005), our research aims to produce an intensive examination of cases to inform wider research (Stake 1995). The findings complement our literature review to outline areas for future research in Section 6.

Our case study sampling was completed in two steps: (1) we selected countries relevant to our research questions based on the literature review, and (2) we chose expert interviewees from each country whose professional roles related to our questions, following Merriam and Tisdell (2015).

3.1 Case selection: country profiles

We used a diverse-case selection method to identify countries, which incorporates variation among the cases (Seawright and Gerring 2008), since the literature highlighted that the effectiveness of IPRs differs significantly across countries (Grossman and Lai 2004; Li 2011; Olawuyi 2018). We therefore used a comparative country analysis to understand how IPRs work in practice without generalizing across cases. We chose climate-vulnerable developing economies from different regions that share comparable income classifications but differ in their institutional and legal contexts. The four nations selected are situated in two major developing regions: South Asia, comprising Bangladesh and India, and Sub-Saharan Africa, comprising South Africa and Kenya. These countries were chosen for their relevance to central debates of the legal and economic literature, as outlined below.

First, all countries represent lower- and middle-income economies (World Bank 2025), which facilitates meaningful comparisons between the cases. Bangladesh and India are classified as lower-middle-income countries with comparable gross domestic product (GDP) *per capita*: USD 2,457 (Bangladesh) and USD 2,256 (India). Beyond current income levels, economic growth in each country is increasingly driven by services and industry in a departure from agriculture (World Trade Organization and World Bank 2023).

By selecting pairs from the same region, we capture intra-regional contrasts. For instance, although weak IPR protection in Sub-Saharan Africa has been linked to limited technology transfer and absorptive capacity (Olawuyi 2018), Kenya and South Africa differ markedly in their income levels. South Africa is an upper-middle-income country with a GDP *per capita* of USD 6,994, while Kenya has a GDP *per capita* of USD 2,006 (2021). This variation enables us to examine whether low purchasing power or weak market demand constrains climate technology innovation (Tur-Sinai 2018) or whether stronger IPRs can still attract FDI under such conditions (Zhang and Yang 2016).

³ The interview guide is provided in Appendix B.

Moreover, while Bangladesh is a lower-middle-income nation, it is also classified as a Least Developed Country (LDC) (UN 2024), which gives access to support for global trade and more flexible obligations under the TRIPS Agreement. Given its expected graduation from LDC status in November 2026, a study of IPR practices in Bangladesh is timely, as the transition requires adopting more stringent IPRs (UN 2021). Furthermore, although the GDP *per capita* of South Africa and India differ significantly, both countries leverage their status as BRICS emerging economies on the international stage.

Second, all countries are highly exposed to climate change impacts and represent priority areas for adaptation (Dodman et al. 2012; IPCC 2012, 2022). Bangladesh is the seventh most extreme disaster risk-prone country globally and vulnerable to extreme weather events such as floods, heatwaves, and cyclones (Szabo et al. 2018). India is also dependent on seasonal monsoons and faces challenges such as drought, flooding, heatwaves, and declining groundwater reserves (Krishnan et al. 2020). Kenya is sensitive to drought-flood cycles, with negative impacts on vital sectors such as agriculture and hydropower (World Bank 2021b; Kenya Meteorological Department 2024). Similarly, South Africa is prone to drought and extreme rainfall events, threatening agriculture, biodiversity, and urban infrastructure (Ziervogel et al. 2014).

Third, each country faces distinct distinct mitigation and adaptation challenges and has differing technological capabilities (UNFCCC 2012). All countries have national climate strategies in place (Government of India *n.d.*; Government of Kenya 2016, 2023a; Government of Bangladesh 2022; Government of South Africa 2022, 2022b). Yet, distinct challenges confront each country. India, for example, has a significant impact on global mitigation efforts given its projected population and economic growth. India's priority areas for mitigation include the expansion of renewable energy provision, while adaptation needs focus principally on building resilience in agriculture, water, and regional communities (Government of India *n.d.*). Similarly, current strategies in South Africa prioritize mitigation, such as expanded use of renewables (Government of South Africa 2022a), given the country's heavy reliance on coal, with only 10.5% of energy consumption based on renewables in 2019. By contrast, although priority areas for mitigation exist, Bangladesh and Kenya currently place more emphasis on adaptation due to their vulnerability to extreme weather events (UNFCCC 2012; Government of Bangladesh 2021; Government of Kenya 2025). For both, extreme weather poses risks to agriculture, which employs approximately 37.7% of the population in Bangladesh (World Bank 2021a) and 80% of the population in Kenya (World Bank 2021b).

Finally, all countries share similar legal systems based on common law backgrounds in the British Commonwealth tradition to facilitate meaningful comparisons. All are Member States of the TRIPS Agreement 1994 but face different conditions for compliance. For instance, while South Africa was a founding member of the TRIPS Agreement (Adebola 2023), Bangladesh still benefits from a transition period to implement these obligations (Islam and Apurbo 2023).

3.2 Case selection: expert interviewees

As a research topic where empirical data is scarce, we interviewed experts to aid theory development (Bogner and Menz 2009). We

those participants with specialized, context-specific knowledge, and decided to interview five experts from each country, including civil servants, government officials, not-for-profit representatives, entrepreneurs, academics, and participants with diplomatic appointments or roles at multinational intergovernmental organizations (see [Appendix A](#)).

This approach is supported by earlier survey studies of IPRs and climate technology innovation (UNEP, EPO, and ICTSD 2010). Alternative strategies, such as solely selecting firms or public sector officials, were considered inappropriate due to the institutional focus of this study. By incorporating a range of participants, we explore how IPR frameworks can be operationalized in government, industry, and academia (Suominen et al. 2023).

3.3 Data collection and analysis

We contacted interviewees *via* email or telephone, provided background information, obtained appropriate consent, conducted 45–60-minute video interviews, transcribed them, and used pseudonyms for interviewees. Thematic analysis was completed using NVivo software (Clarke and Braun 2021). Data was initially coded line by line, then grouped under recurring themes using grounded theory methods (Strauss 1987; Bryman 2016). Thematic analysis was guided by emerging themes in the data, findings from the literature review, and relevant policy documents (see Fig. 2 in Section 5).

4. Findings

4.1 Bangladesh

Participants offered a complex image of the relationship between IPRs, climate innovation, and development in Bangladesh. For one, interviewees highlighted existing climate-friendly policies, including the Bangladesh Delta Plan 2100, the National Adaptation Plan (NAP) 2023–50, and the Bangladesh Climate Change Strategy and Action Plan (BCCSAP). However, as an academic participant highlighted, climate technology *‘policies were already there, and innovation already happened . . . [though] implementation is a challenge.’* A key area included adaptation solutions such as early warning and water sanitation technologies for disaster-affected areas.

Interviewees characterized Bangladesh's current IPR system as at a formative stage, being paper-based, underutilized, and difficult to access. One foreign climate technology entrepreneur in Bangladesh explained that *'filing a patent from Bangladesh is very difficult'*. A civil servant stated that at *'university level or secondary level, most of our students and even teachers are not aware of intellectual property; how to use [it], how to manage, and how to develop a product within the framework of IP'*. Interviewees discussed the existence of IP training and education programs, but explained that the public was relatively *'indifferent'* to IPRs due to a lack of awareness and enforcement.

Participants highlighted recent reforms to modernize the IPR system, including the digitization of the patent registration process. When the interviews were conducted, the Bangladesh Patent Act 2022 had recently been enacted. The 2022 Act repealed the patent provisions of the colonial Patents and Designs Act 1911. Among other changes, the 2022 Act introduced the substantive

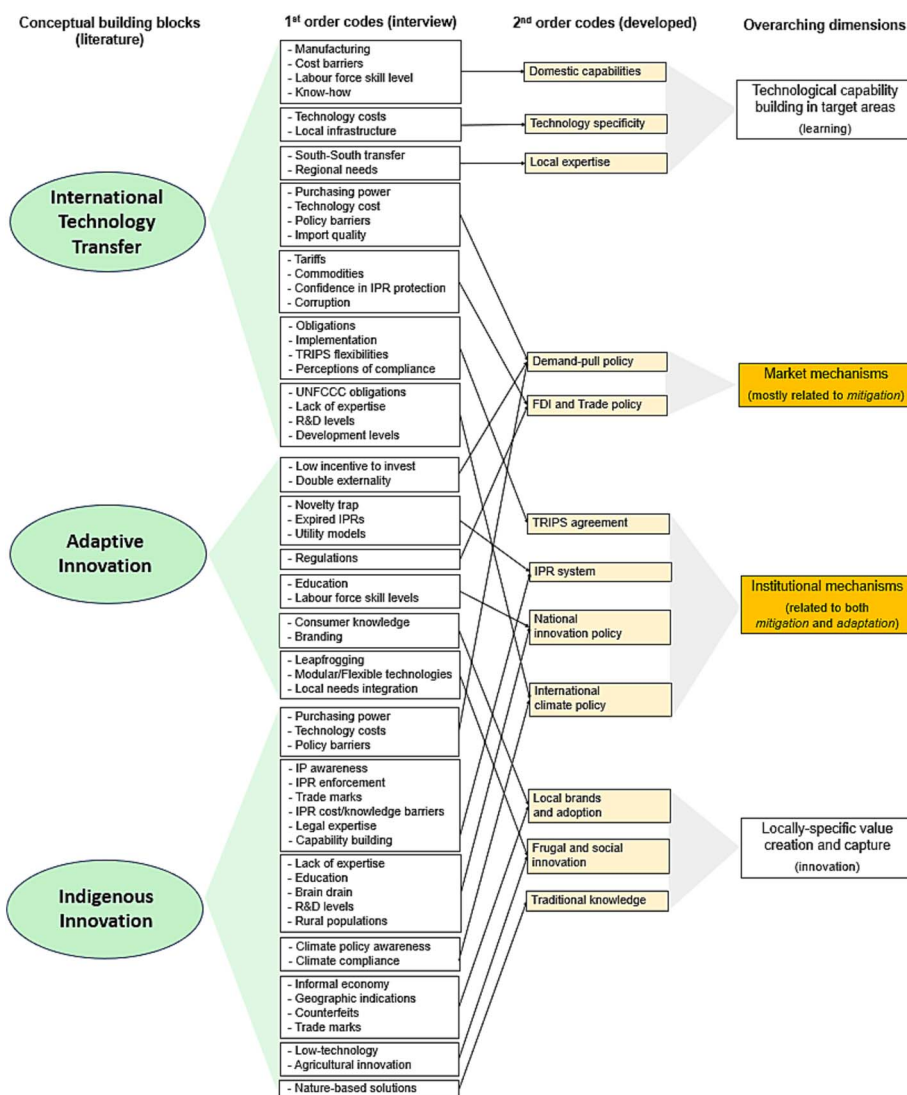


Figure 2 Process of coding and thematic analysis.

examination of patent applications and extended protection from 16 to 20 years.

A recent reform to incentivize indigenous, 'low-tech' innovation was the introduction of a utility model ('petty patent') under section 32 of the 2022 Act. Utility models have a term of protection for eight years⁴ and protect minor improvements.⁵ Interviewees mentioned that utility models may stimulate innovation in local climate change adaptation technologies in various sectors, including agriculture, and adaptive innovation based on imported mitigation technologies in transport and energy. However, in Bangladesh, their impact will depend on whether robust examination standards are introduced to prevent granting protection to low-value modifications (Islam and Apurbo 2023). Respondents indicated that trademarks are more widely used than patents by many small- to medium-sized enterprises to establish a brand, making them conducive to indigenous innovation. However, one interviewee highlighted that counterfeiting poses 'a pressing and tricky problem' and that

small businesses face challenges in using their trademarks to build an overall brand.

Moreover, interviewees agreed that IPRs can give foreign investors a sense of investment security, consistent with the literature (see Section 2.2). Indeed, most patent applications in Bangladesh are filed by foreign inventors, with 67 resident applications in 2023 as opposed to 252 by foreign applicants (WIPO 2025). However, it was also said that investment decisions would be driven by market conditions, irrespective of the strength of IPR protection. A foreign entrepreneur highlighted that 'weak IPR enforcement in Bangladesh is unlikely to discourage technology transfer if there is a strong enough business case to enter the market, and it seems that foreign companies are aware of and willing to accept the risks associated with entering the market in a low-income country'.

Interviewees also described adaptive innovation occurring without recourse to IPRs. A foreign entrepreneur based in Bangladesh described it as a 'Greenfield environment' for certain innovations. For instance, 'solar systems have been widely adopted across the country', in part, due to the successful uptake of off-grid modular solar energy generators as an example of 'leapfrogging'

⁴ Bangladesh Patents Act 2022, s 32. We thank Ataul Karim for providing a translation and analysis of this provision.

⁵ Bangladesh Patent Act 2022 (Act No. 5 of 2022), s 32.

to be expanded upon. Another interviewee explained that Bangladesh was encountering ‘recent shocks’ due to power outages and increased prices that threaten a stable electricity supply. Overall, broader socio-economic conditions were thought to be more pressing concerns for climate technology innovation, while the Bangladeshi IPR system matures.

4.2 India

The findings on India underscored tensions between economic and sustainable development. Interviewees highlighted the challenge India faced as a rapidly developing economy with an expanding population and the need to find affordable, sustainable solutions. To accelerate mitigation and to facilitate climate-related ITT, India’s Nationally Determined Contributions explicitly assert that developed countries should actively engage in R&D collaboration, whereas India and other developing countries should be exempt from IPR costs (Government of India 2022a).

Aligned with its emphasis on economic growth, India increasingly supports strong IPRs to foster industrialization. For instance, India initially restricted the grant of IPRs for genetically modified organisms (GMOs) (Lalitha 2004), but has recently adopted a more permissive stance, approving an increasing number of patents for GMO inventions.

Interviewees asserted that ‘India is the most successful at having intellectual property policies that suit their national development objectives’, referring to its previous backing of provisions for compulsory licensing under the TRIPS Agreement in the lead-up to the Doha Declaration on public health in 2001.⁶ However, despite being relatively well-established, on-the-ground experiences from interviewees suggest that India’s IPR system remains challenging to use due to cumbersome bureaucracy, weak enforcement, and low public awareness. Similar to Bangladesh, interviewees in India viewed trademarks as more user-friendly than patents, which were considered overly technical and obscure. For instance, a local entrepreneur explained that trademarks overcome ‘loop-holes in the IPR system’ by making their brand widely recognizable, attempting to compensate for weak patent enforcement.

One area of growth highlighted by participants was the significance of adaptive innovation. Despite India’s reliance on fossil fuels, interviewees were optimistic about India’s ability to transition to renewable energy through locally adapted hybrid and electric vehicles (EVs), including e-rickshaws, which account for about 60% of EV sales in the country and are more affordable than technologies from developed countries.

Participants emphasized that IPRs are poorly suited to address frugal innovation in informal economies or rural contexts. Frugal innovations include high-quality technologies that are affordable and scalable (Prahalad 2008). In the informal sector, local inventors may lack awareness or be unable to access IPR protection due to costs or because their inventions fail to satisfy the requirements for such protection (Sharma and Kumar 2018). However, this view was not without exception. One entrepreneur, who developed a rainwater management system for rural farmers, used a trademark to establish a brand to encourage adoption in poor and low-literacy communities.

At times, IPRs were thought to conflict with sustainable development. One interviewee stated that they did not want to prevent copying if allowing infringement would foster climate technology uptake, describing Gandhian innovation driven by impact rather than profit: ‘serving the last person in the queue in the best possible way. My objective of this innovation, rather than making money or rather than earning money through patent rights, I was more eager to make the impact maximum.’

Interviewees believed that the current IPR system may not always encourage indigenous or adaptive climate innovation, as adaptive innovations may struggle to meet the requirements for patent protection. How IPRs incentivize expensive solutions was seen as conflicting with local needs, particularly regarding solutions relevant to agriculture or poorer communities in rural areas.

Indeed, an academic interviewee reported that ‘the IP system can provide some protection for innovators at the expense of things which may be easier, cheaper ... more adapted to the Global South.’ Moreover, some interviewees expressed the attitude that discussions about IPRs may only be relevant after the demand for mitigation technologies has increased.

As for ITT, participants explained that foreign investors at least look at IPR protection as a ‘tick in the box’ when making their decisions. However, it was noted that other legal barriers impede foreign technology adoption. For instance, one interviewee (a foreign entrepreneur with a business presence in India) described the difficulty of navigating the complex legal rules to set up a company as an outsider. Another entrepreneur explained that backlogs in the courts made patent enforcement challenging, explaining that ‘unless you’ve got some world-beating technology, you might judge whether it’s worth your while to do it in India simply because if someone does steal it, if you take them to court, it will take forever.’ In sum, participants described avenues where IPRs could foster climate technology innovation but highlighted key hurdles, including enforcement and areas where frugal innovation occurs without the need for IPR protection.

4.3 Kenya

Participants described the challenges Kenya faced in balancing economic development with sustainability. While Kenya’s priority is adaptation, interviewees highlighted the need to shift to solar and wind energy in a departure from biomass and fossil fuels. Progress in renewable energy was considered encouraging; however, interviewees reported that hydropower is coming under pressure due to droughts, leading to water shortages affecting agriculture. As a result, Kenya is turning to solar energy and biogas, given the abundance of sunlight and biogas on farms (Government of Kenya 2023b). Leapfrogging was discussed in the areas of off-grid energy and clean transport. EVs for urban areas were expected to become competitive with fossil fuel vehicles, as EVs can be manufactured domestically at lower costs, whereas most traditional vehicles face importation costs.

Participants noted that the IPR system in Kenya is still young and public awareness is low. A civil servant explained that IP ‘awareness is not where we would like it to be.’ IP was described as ‘legalistic,’ ‘inaccessible,’ ‘bureaucratic’ and ‘paper-based.’ Businesses seeking patent protection find the system lengthy, complex, and not user-friendly. One entrepreneur commented that ‘the process is like a mirage, it’s really not clear.’ The environment

⁶ Agreement on Trade-Related Aspects of Intellectual Property Rights, 15 April 1994, Marrakesh Agreements Establishing the World Trade Organization, Annex 1C, 1869 U.N.T.S. 299 (‘TRIPS Agreement’).

for enforcement was described as a ‘wild west,’ with widespread infringement, particularly of trademarks, which are widely used in the country.

Interviewees offered diverging perspectives on the relationship between IPRs and development. For some, strengthening IPR enforcement would aid development in the long term, though it was a lower-level priority in the short term. One foreign entrepreneur based in Kenya suggested that ‘Kenya has other problems to deal with before it deals with IPRs’. A local entrepreneur suggested that development should be prioritized over the expansion of the IPR system: ‘we need to put the environment first; we need to put human beings first, then other things should follow, including ownership of those patents.’ Two interviewees, a civil servant and government employee, by contrast, suggested that IPRs could aid sustainable development but explained that broader socio-economic factors shape the efficacy of IPRs. That is, IP is ‘not derailing economic development, neither is it derailing innovation.’

Levels of domestic innovation in climate technologies were considered low. Funding to commercialize local innovations was cited as a key barrier. Interviewees explained that much mitigation technology is imported from Europe and China, making it expensive. A local entrepreneur contended that Kenya is a ‘consumer of already available technology out there and 80 per cent of the time we import products.’ The same participant explained that counterfeit imports of climate technology pose risks, including poor-quality lithium-ion batteries. In this context, Kenya’s introduction of a mandatory ‘recordal’ system is considered a positive step towards tackling counterfeiting (Government of Kenya 2021a, 2021b). The new rules require that goods incorporating intellectual property be declared to the Kenyan Anti-Counterfeiting Agency as a condition of importation, with associated systems for detecting and intercepting counterfeits (Schneider and Nam 2022).

One area where IPRs could address development levels concerns utility models, which may encourage high-impact, low-cost, and locally specific innovation. A civil servant explained that the Kenyan utility model system may ‘help small-scale startups and entrepreneurs to prevent others from infringing their ideas for at least a period of 10 years.’⁷

The informal sector was cited as an area where IPRs could be used to ensure that inventions are ‘standardized’ to support diffusion. Finally, interviewees noted greater domestic use of trademarks, though predominantly by ‘the big players, not the small players’.

Participants expressed scepticism about the efficacy of IPRs for FDI and ITT. An interviewee argued that ‘international IP is very unfair; it favors some of these big countries’, not developing nations. ITT initiatives were viewed with scepticism, and the costs of IPR-protected technology were cited as a barrier to access. Consequently, a foreign firm in Kenya argued that ‘one has to rethink what patent law means on a global scale’ to meet local needs. IPRs were not at the forefront of the drivers of FDI or the decision to enter the Kenyan market due to weak enforcement. Participants stated that foreign firms face low infringement risks when bringing climate technologies to Kenya due to a low capacity for reverse engineering, particularly in complex renewable energy

technologies. Conversely, Kenya’s lack of technical expertise poses a challenge to adopting climate technologies that rely on local skills. Overall, interviewees stressed the importance of developing local capabilities and funding opportunities for indigenous and adaptive innovation to address local climate needs and overcome the costs of imported technologies.

4.4 South Africa

Participants described South Africa as a rapidly growing economy, predominantly reliant on fossil fuels, marked by stark income inequality and rural development gaps. South Africa is the largest producer and consumer of coal in Africa, comprising 69% of its energy supply in 2023 (IEA 2023). Other focus areas included adaptation to address drought and food security.

South Africa focuses predominantly on mitigation technologies, including renewables such as solar power. Interview discussions were dominated by prevailing blackouts and the energy crisis, affecting the economy, particularly in the manufacturing and agricultural sectors. Discussions on climate adaptation focused predominantly on droughts and floods, including the need for warning systems, climate-smart agriculture, and new crop varieties less vulnerable to changing climate conditions.

Participants described the IPR system as relatively mature but poorly integrated into the day-to-day practices of local businesses. Interviewees highlighted weak local knowledge of climate technology solutions, creating a relationship of dependency with importers from the Global North. IPR awareness among the public is considered low, and IPRs are perceived as ‘legalistic’ rights for the elite. Participants suggested that training programs may alleviate this problem, such as those run by the South African Intellectual Property Office to promote awareness and IP understanding.

Different perspectives were offered on the practice of not substantively examining patent applications and granting them if procedural requirements are met.⁸ It can encourage patenting by minimizing bureaucratic hurdles. However, without formal examination, applicants may have little confidence in patent validity. Participants generally agreed that IPR protection in South Africa would promote the adoption of IPR systems on the African continent, referring to the country’s position in the negotiation of the IP chapter of the African Continental Free Trade Agreement (African Union 2018).

Respondents felt that domestic innovation was not strongly influenced by IPRs, in part, because domestic climate innovation activities remain low. As a participant explained, ‘we rely on expertise from outside the country’. Additionally, local innovation was not thought to be driven by IPRs. One interviewee noted that ‘IPR had little impact on local innovation before South Africa signed the TRIPS Agreement or afterwards’. Rather, the costs of adoption and technology scale-up are the main issues, while relevant key patents have already expired.

One area highlighted for further action is counterfeiting. Counterfeiting was thought to negatively impact trade and the environment because seized counterfeit goods are discarded. As a civil

⁷ Utility models are governed under section 82 of the Industrial Property Act 2001 (Kenya) (Act No 3 of 2001).

⁸ ‘Substantive examination’ in this context refers to a system in which patent examiners working within the patent office assess whether the claimed invention clears the legal thresholds for patentability, in particular, through assessment of whether the invention is novel, involves an inventive step (is non-obvious), is capable of industrial application, and is sufficiently disclosed.

servant explained, counterfeits are ‘*manufactured in the country of origin and there’s an impact on the environment and there’s another impact when it’s destroyed*’.

Interviewees reported significant interest in FDI, though scepticism was expressed about FDI's contribution to ITT. This includes an unprecedented interest in renewable energy projects in Africa, such as investments as part of China's Belt and Road Initiative. A local entrepreneur described '*a lot of investment coming in from a lot of different angles, it's definitely something I think every single person at my company can agree is something we've never seen before*'.

Interviewees agreed that IPRs are important for foreign investor confidence, yet weak enforcement harms confidence. However, participants expressed resistance to the idea that FDI is IPR-driven. An interviewee explained that multinational corporations might have a presence in South Africa, but that this did not establish local capabilities; *'it's not local production, it's the company coming, whether from the States or from the United Kingdom, coming and establishing itself and it's not really a transfer of technology.'* Another interviewee noted that sectors in which foreign investors are currently most interested, such as mining, often use off-patent, mature technologies. In sum, South Africa faces substantial challenges in developing local innovative capabilities and transitioning away from fossil fuel sources, impeded by development-related challenges. Despite the pressing need for climate technology innovation, low institutional capacity in terms of IPR awareness, counterfeiting, and weak enforcement impedes progress on these goals (Yoon et al. 2024).

5. Discussion

Our results suggest that existing debates likely overstate IPRs' importance, whereas wider socio-economic barriers are more pressing. However, the findings identify opportunities to use IPRs to advance climate-related goals and SDGs. In the following section, we contextualize insights from the literature and interviews, and derive policy implications related to IPRs and beyond, structured along the three domains: ITT ([Section 5.1](#)), indigenous innovation ([Section 5.2](#)), and adaptive innovation ([Section 5.3](#)). [Figure 2](#) summarizes the process of thematic analysis, starting from the literature review to semi-structured interviews and subsequent analysis.

5.1 International technology transfer

ITT involves market and institutional channels. Below, we discuss the role of these channels, focusing on IPR-related aspects in a national and international context.

5.1.1 Market mechanisms.

5.1.1.1 FDI policy Interviewees stated that strong domestic IPR protection is moderately important for FDI, though it was a mere ‘*tick in the box*’ procedural consideration rather than a driver of FDI. IPR protection was deemed important but less significant than wider market opportunities. Indeed, while stronger IPRs can increase ITT in climate mitigation technologies (Dussaux et al. 2022), our study indicates that without finance and local capabilities, ITT delivers little local innovation. Moreover, participants noted that many existing FDI projects do not offer adequate

knowledge exchange but focus on market exploration: *'it's not local production, it's the company replicating its processes in another country'* without building domestic industrial capabilities. Even where knowledge-intensive FDI activities are present, many developing nations lack absorptive capacities to assimilate these capabilities (Li 2011; Olawuyi 2018; Matthew et al. 2023). Making FDI effective for ITT requires co-production and co-development activities to build technological capabilities (Lee and Yoon 2015).

Our results align with previous studies (see [Section 2.2](#)). For example, China and India have attracted significant FDI despite weak IPR enforcement ([Tikku 1998](#); [Rai 2008](#); [Awokuse and Yin 2010](#)). There may, however, be a positive relationship between robust IPR protection and FDI in technology-intensive sectors, where FDI goes beyond low-cost manufacturing or resource extraction and includes elements of joint ventures and R&D collaboration ([Leahy and Naghavi 2010](#); [Abdel-Latif 2015](#)).

The findings highlight the importance of ensuring that low-carbon projects do not continue the trend of resource-focused FDI without domestic capacity building. Policies to stimulate knowledge flows in FDI may alleviate this problem, for example, through training, local content requirements, and joint ventures (Maskus 2010; Corvaglia 2014; Rai et al. 2014; Pandey et al. 2022). Yet, the success of such measures depends on the setting of realistic targets and a broader industrial policy (Cheung and Ping 2004; Fu et al. 2011; Scheifele et al. 2022).

5.1.1.2 Trade and demand-pull policy Interviewees noted ‘*at the end of the day, the key constraint for developing countries is cost*’, not IPR protection *per se*. Labour and production costs were cited as key barriers for both IP-protected and off-patent climate technologies. Climate technologies from China and India are becoming preferred alternatives to European imports due to their affordability (Lema and Lema 2012; Quitzow 2015).

Although IPRs theoretically increase the cost of climate technologies, many mitigation technologies are traded in competitive markets and substitutes without patent protection are often available. Nevertheless, local demand for climate technologies remains lower than desired, due to cost barriers. To overcome cost-related obstacles, tariff reductions in Preferential Trade Agreements (PTAs) for relevant technologies could incentivize adoption (Maskus 1998; Brewer 2008; Corvaglia 2014; Brandi et al. 2020; De Melo and Solleder 2020). However, the definition of eligible climate-related goods in PTAs needs careful consideration to avoid the exclusion of products from developing countries (De Melo and Solleder 2020).

Additionally, promoting trade among developing countries, focusing on technologies suited to local contexts, could aid access to lower-cost technologies. Examples include e-rickshaws and off-grid renewables. Certain agricultural technologies have benefits in neighbouring countries with similar climates or agricultural production systems. As one interviewee said, *‘what works in Bangladesh can also work in Sri Lanka’*. Trade among developing countries has historically been informal, though it remains empirically underexplored (Bouet et al. 2018).

We find that patent protection is often unavailable for low-tech products developed in developing countries (Dreyfuss and Benoliel 2021). This lack of protection reinforces concerns that developing countries are becoming ‘dumping sites’ for low-cost, low-quality imported climate solutions. Against this background, trademarks are seen as quality assurance markers that are

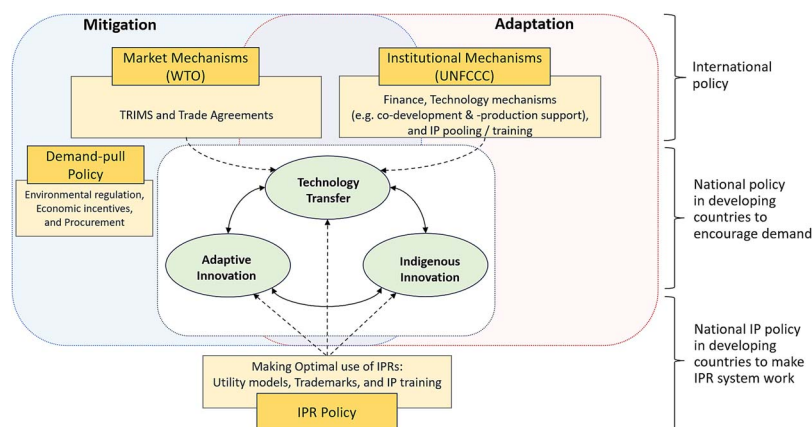


Figure 3 Results in a nutshell.

studies (Baroncelli et al. 2005; Suthersanen 2006). Trademarks are relatively easy to register, which may promote low-cost climate innovation and local entrepreneurship. They can help build consumer loyalty and trust, encouraging the creation of reliable and functional solutions. The relative use of trademarks compared to other IPRs correlates with development levels (Kang et al. 2020). In sum, the impact of IPRs on indigenous innovation was positioned as a question of the needs of local development and climate vulnerability.

5.3 Adaptive innovation

5.3.1 Locally specific value creation and capture.

Adaptive innovation can be beneficial locally and may accelerate the diffusion of existing technology. For example, the rise of e-scooters, e-rickshaws, and off-grid solar PV solutions in developing countries shows the market potential for adaptive innovation (Lema and Lema 2012; Urmee and Anisuzzaman 2016; Akamanzi et al. 2016). Adaptive innovation also offers opportunities for sustainable growth and leapfrogging by skipping emission-intensive stages of industrialization.

5.3.2 National innovation policy and IPR system. Adaptive innovation exposes the negative and positive impacts of IPRs on climate technology diffusion. On the one hand, follow-on innovation that involves significantly adapting or repurposing cutting-edge imported technologies is more likely to be patentable (Dreyfuss and Benoliel 2021). This increases the potential for patents to incentivize local innovators, which may guarantee returns in export markets when adaptive innovations are adopted. On the other hand, adaptive innovations may be hindered if they risk infringing the IPRs of imported technologies. The dual potential impacts of IPRs present a trade-off between incentivizing follow-on adaptive innovation through protection and hindering adaptive innovation due to infringement risks and access costs (Hall 2007).

Our results suggest that adaptive innovation is not yet sufficiently widespread in the countries studied to adequately understand the role of IPRs on adaptive innovation. National strategies should develop local capabilities to spur adaptive innovation and leapfrogging, after which IPRs may have greater impacts. As one interviewee stated, '[w]e have many high-tech solutions in rich countries but what's needed are low-tech solutions, but if there is a barrier to protect these inventions and if [IPR] isn't a barrier to

local development, then it might be a barrier to upscaling green technology diffusion'. At present, the full impacts of IPRs on adaptive innovation are unclear, though there may be opportunities for IPRs to aid the diffusion of adaptive technologies that exhibit sufficient novelty and originality.

An alternative, mentioned by interviewees and consistent with existing studies, is that *utility models* may offer an incentive for the development of low-cost and low-complexity climate technologies (Suthersanen 2006; Dreyfuss and Benoliel 2021; Kim et al. 2012). However, the efficacy of second-tier systems for protecting innovation is controversial. For example, the Australian *innovation patent* started being phased out in August 2021, having thought to have little overall benefit.¹¹ Whether this experience holds lessons for developing countries is still to be determined.

6. Policy implications

Our findings indicate that IPRs play a relatively minor role in promoting climate technology in developing countries at present. Current debates on weakening IPRs often adopt an insufficiently nuanced analysis, and risk undermining ITT and investor confidence. This does not mean that TRIPS flexibilities or access-oriented mechanisms are without merit; rather, such measures are best targeted at contexts where IPRs pose specific barriers, rather than being treated as the principal response to climate technology ITT. These findings suggest a need to reorient debates away from IPR reform alone towards examining the broader enabling environment for climate technology innovation.

Our interviewees suggested that domestic demand-pull policies should be prioritized to strengthen demand for mitigation technologies. This conclusion is in line with emerging discussions on the importance of demand- rather than supply-focused policies to support the sustainability transition (Rai et al. 2014; Boon and Edler 2018). Cost and access to finance were consistently cited barriers to climate technology innovation. Demand-focused policies include environmental regulation and financial incentives, with the latter including subsidies, public procurement programs and carbon pricing, while recognizing that scarce public budgets remain a barrier to fiscal support in developing countries. Local demand is a precondition to attract FDI (Elfakhani and Mackie 2015), and while robust IPRs may

¹¹ See Intellectual Property Laws Amendment (Productivity Commission Response Part 2 and Other Measures) Act 2020 (Cth).

provide confidence to foreign investors and facilitate knowledge transfer and capacity building, overall market opportunities are more influential. Interviewees emphasized that local market demand for climate technology remains low due to the 'double externality' problem and IPRs are consequently a weak driver of innovation (Jaffe et al. 2005; Olawuyi 2018; Tur-Sinai 2018). FDI therefore must be accompanied by specific plans for skill and capability transfer. The local IPR system may play a limited but positive role alongside, for example, joint ventures, local sourcing, and collaboration requirements.

For indigenous and adaptive innovation, local capability formation should be prioritized through building technical expertise and ensuring the availability of finance. Interviewees affirmed the importance of locally tailored adaptive inventions (Dodman et al. 2012; IEA 2022). Meaningful measures include funding to implement simple but impactful solutions and formalized systems for targeted knowledge transfer. Once local businesses can produce indigenous and adaptive innovations, the creation and expansion of domestic and international markets for these technologies using IPRs can become important to aid diffusion.

Interviewees from all countries agreed that trademarks already play an important role domestically in creating brand loyalty and may perform the same role in cross-border trade if the trend towards South-South technology transfer continues. Several interviewees spoke in positive terms about the potential for utility models to incentivize local innovators. Given the somewhat chequered history of second-tier patent systems, this is an area where more research is needed (Suthersanen 2006; Dreyfuss and Benoliel 2021). Taken together, these findings suggest that IPRs other than patents, such as trademarks, may still support technology diffusion through different mechanisms.

None of the above suggests that IPRs may not hinder the diffusion of climate technologies, and it may be necessary to consider additional mechanisms to weaken IPR protection or aid access to technology through other means. However, such mechanisms must be tailored to development levels and local capabilities to be effective. This suggests that licensing and government use proposals must be closely attuned to differing institutional contexts (Vindigni and La Terra 2016; Zhou 2019).

In sum, our study is built around three key channels of climate technology diffusion: (1) ITT, (2) indigenous innovation, and (3) follow-on adaptive innovation. The findings suggest that the three routes are mutually reinforcing and that their relative power depends on the level of technology-specific capabilities. Once essential capabilities have been acquired through ITT, indigenous and adaptive innovation can be fostered through implementing appropriate mechanisms, including a positive role for trademarks and, potentially, utility models. Enhanced domestic capabilities, grounded in indigenous and adaptive innovation, can in turn facilitate the ITT of more advanced solutions. Figure 3 illustrates our understanding of the current landscape, and the interdependencies between different levels of policy, the three sources of climate technology (ITT, indigenous innovation, and adaptive innovation), and their relative relevance for mitigation and adaptation in developing countries.

7. Conclusions

The need for climate technologies in developing countries has sparked debates about whether IPRs hinder or foster access to

and use of these technologies. This study contributes by combining a systematic literature review with 20 in-depth expert interviews in Bangladesh, India, Kenya, and South Africa, examining the impact of IPRs on ITT, adaptive innovation, and indigenous innovation. Overall, we find that IPRs play a limited and context-dependent role, shaped by national capabilities and development levels, underscoring the need to integrate trade and climate policies for adaptation and mitigation.

Our contributions are threefold. First, prevailing debates overstate the importance of IPRs, whereas national capabilities and development levels pose more pressing barriers. IPRs are necessary for ITT and FDI in developing nations (Maskus 1998; Spielman and Ma 2016), though they must be accompanied by finance and wider institutional support. This suggests that critics of ITT obligations under the TRIPS Agreement may overlook these structural constraints (Rimmer 2011; Zhuang 2017). In line with the literature, IPRs promote innovation once demand exists (Jaffe et al. 2005; Tur-Sinai 2018), but demand for climate technologies remains low due to cost barriers. Despite claims that IPRs hinder adaptive innovation (Maskus 2010; Dreyfuss and Benoliel 2021), we find that adaptive innovation is still emerging and often relies on off-patent technologies or design-around solutions. Climate technology innovation is therefore constrained less by IPRs than by financial constraints, low demand, and gaps in local capabilities.

Our second contribution is that patents play a limited role in low-cost, adaptive innovation and indigenous innovation in developing countries, whereas trademarks appear more accessible and aligned with local entrepreneurial activity, supporting diffusion through branding and quality signalling. Patent protection was deemed costly and ill-suited to low-cost, frugal innovation (Radjou et al. 2012; Sharma and Kumar 2018). Interviewees noted interest in utility models for simple, high-impact climate technologies, although their efficacy remains uncertain and suggests that further empirical research is needed (e.g. Baroncelli et al. 2005; Suthersanen 2006; Kim et al. 2012).

Third, we propose a framework for integrating IPRs in climate and trade policies. The localized needs of climate change adaptation technologies mean that low-tech, high-impact technologies fall outside the scope of patent protection and are therefore unlikely to attract ITT and FDI. Institutional support (e.g. finance, co-development, and co-production) can help developing countries address local climate risks through indigenous innovation. While trademarks do not encourage invention, they support diffusion by promoting brand awareness. For climate change mitigation, IPRs have little impact on technology diffusion because high cost and low demand remain key barriers. Market mechanisms for ITT, including trade and FDI, may reduce costs but must be accompanied by local capacity-building initiatives. Support mechanisms such as tariff reductions and demand-pull environmental regulation can lower the cost of mature climate technologies in developing nations.

7.1 Limitations and future research

Despite our findings, several limitations persist. First, while differentiating between mitigation and adaptation, there is substantial heterogeneity within each category. Policymakers and future studies should consider the specifics of each technology, including maturity level, distribution of complementary resources, technological complexity, and the extent to which IPRs are likely

to promote innovation in each field. Second, while this study examined diffusion, future studies could examine pre-market innovation, such as indigenous basic research or local absorptive capacities, including manufacturing capabilities. Third, while significant, our sample size is small. The findings have limited generalizability and exclude some perspectives, including those of developing nations with differing institutional capabilities and legal traditions. Future research may broaden the sample of countries or adopt in-depth national case studies. Fourth, our findings highlight interest in utility models among lower-income nations, however, it remains to be seen whether these schemes will succeed or replicate their shortcomings observed in some advanced economies. Overall, our study highlights the importance of interdisciplinary, empirical studies that consider climate technology in broader socio-economic contexts.

Acknowledgements

The authors want to thank the attendees of the research seminar of the Institute for New Economic Thinking in Oxford for their comments. This article is based on the study 'Intellectual Property Rights, Climate Technology Transfer and Innovation in Developing Countries', commissioned by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ). The contents of this article do not represent the official position of either BMZ or GIZ. The authors gratefully acknowledge valuable comments on the research received by GIZ and BMZ members.

Author contributions

Su Jung Jee (Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Validation, Visualization, Writing—original draft, Writing—review & editing), Kerstin Hötte (Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Validation, Visualization, Writing—original draft, Writing—review & editing), Caoimhe Ring (Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Validation, Visualization, Writing—original draft, Writing—review & editing), and Robert Burrell (Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Validation, Writing—review & editing)

Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding

This work was supported by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH on behalf of the German Federal Ministry for Economic Cooperation and Development (BMZ).

Data availability

The interview data and details on the interviewees are confidential. There is no additional data associated with this article.

Ethics approval

The authors declare that the research conducted in this study has received ethical approval from the University of Oxford's Central University Research Ethics Committee (CUREC) R76424/RE001.

Appendix A. Interview participants

Setting	Number of participants	Role
Bangladesh	2	Inventor/entrepreneur
	1	Government representative or civil servant
	1	Academic
India	2	Inventor/entrepreneur
	1	Government representative or civil servant
	1	Academic
Kenya	2	Inventor/entrepreneur
	1	Government representative or civil servant
	1	Academic
South Africa	2	Inventor/entrepreneur
	1	Government representative or civil servant
	1	Academic
International	2	Multinational organisation
	2	Academic/researcher

Appendix B. Interview guide

1. Please outline your expertise and how you have come across intellectual property law and climate technology innovation in your work, if at all?
2. What is your definition of sustainable development?
3. What are the main challenges for sustainable development in your country?
4. What was the impact of the Paris Agreement on sustainable development in your country?
5. How does climate technology innovation feature in those challenges? What kinds of technologies are important for [X country]?
6. Would you say that IPRs are important for domestic climate technology innovation? Why or why not?
 - What sort of IPRs matter?
 - Are IPRs important for any other reasons?
 - *In what ways do IPRs impact your business/export decisions? Could you please give an example?
7. Do you think IPRs are important for international trade in this context? Why or why not?
 - *How do IPRs affect foreign direct investment? Would you say it has a positive or negative impact? Why or why not?

8. Do IPRs facilitate climate technology transfer?

- From developed economies to the developing world? Between developing nations?
- Is technology transfer being realized to its full potential? Why or why not?
- Can you think of any improvements that would increase technology transfer?

9. *What was the impact (if any) on [X country] of joining the international intellectual property law system under the TRIPS Agreement?

- Can you describe any advantages or disadvantages? Can you give any examples?

10. Do any aspects of IPRs need to be reformed? Why or why not? What needs to change?

11. I am sure you are aware of the debates surrounding IPRs in relation to COVID-19 vaccine technologies. What have we learned from these debates?

12. Based on your view of climate technology innovation in [X country], would you say that IPRs promote climate technology innovation, or hinder it?

13. Is there anything else I didn't discuss that you would like to cover?

Note. * Denotes possible follow-up questions depending on the interviewee's role.

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