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Advancing climate change adaptation technologies: Exploring patenting motives and barriers of low- and middle-income inventors

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Advancing climate change adaptation technologies: Exploring patenting motives and barriers of low- and middle-income inventors

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Abstract

Climate change adaptation technologies (CCAT) are critically needed in low- and middle-income countries (LMIC), which tend to be most affected by climate change. Inventors from LMIC (i.e. LMIC inventors) tend to possess valuable local knowledge for developing CCAT inventions. While previous research shows that IP rights regimes, such as patent systems, tend to be weak in LMIC, little is known about the motives for LMIC inventors that still apply for patents and the barriers they face. In this study, we focus particularly on LMIC inventors that develop CCAT inventions, investigating their patenting motives, benefits, and barriers.

We identified CCAT inventions that originated from LMIC using the Y02A CPC patent classification. From an astonishingly small sample of 71 patents, we interviewed thirteen inventors using a semi-structured interview approach. From an inductive coding approach, six propositions emerged that we discussed subsequently with policy experts, such as from the United Nations Climate Technology Centre and Network (CTCN) and WIPO Green.

Despite the fact that patent regimes in LMIC tend to be weak, our findings indicate the important role of patents for LMIC inventors to attract investments and facilitate technology diffusion. However, weak national patent systems and corruption in LMIC tend to limit the protection of inventions, which appears to be a barrier for inventors. The results also indicate that national and international organisations should consider better supporting LMIC inventors by providing more IP education and more effective technology matchmaking models. Findings also imply that the need for CCAT inventions represents an innovation opportunity for LMIC, with potential substantial economic benefits.

Keywords: Intellectual property, patenting motives and barriers, climate change adaptation technology, low- and middle-income countries

1. Introduction

Climate change is a global challenge, but low- and middle-income countries (LMIC) are experiencing the greatest risk (Dechezlepretre, et al., 2020). While climate change mitigation technologies (CCMT) are needed to reduce CO2 concentrations in the atmosphere, climate change adaptation technologies (CCAT) are needed particularly in LMIC that are likely to be most affected by climate change.

While global north actors appear to dominate the development of CCAT, those living in LMIC develop CCAT inventions. One might even argue that they possess particularly valuable local knowledge to potentially develop highly effective and resource efficient CCAT inventions that are of value not only in their own region and country, but possibly even to other LMIC (Lee & Mwebaza, 2020).

So far, IP related research has paid little attention to studying LMIC inventors developing CCAT inventions. With our research, and this initial study particularly, we aim to better understand what role intellectual property (IP) rights might play to help LMIC inventors in their endeavours to develop CCAT inventions and the barriers they encounter, particularly related to patenting. This research focuses on patenting motives and patenting barriers of LMIC inventors that developed CCAT inventions. We identified LMIC inventors that developed CCAT inventions using the Y02A subclass within the Cooperative Patent Classification (CPC) from the United States Patent and Trademark Office (USPTO) patent database. Different factors affect the patenting decision, and it is the scope of this paper to identify them, complementing the current literature which covers the topic mostly for inventors in high-income countries (HIC).

The following section reviews the extant literature summarising what is known about patenting motives and barriers of LMIC inventors. Afterwards, we explain our methodology and explain the sampling strategy and interview approach. In the results section, we present six propositions which emerged from this study, followed by a discussion of the implications for LMIC inventors and international organisations. Finally, the paper closes with a summary of the findings and a reflection on the limitations and recommendations for future work.

2. Existing literature

From an analysis of two systematic literature reviews of the IP literature, we found little coverage for the role of IP in LMIC (Holgersson & van Santen, 2018; Holgersson, 2013). Therefore, the research was divided into three thematic areas of interest: IP and innovation, with focus on patenting motives and barriers; LMIC; CCAT. With this study, we test the findings from the literature, largely based on studies in HIC, to the field of CCAT patents developed by inventors in LMIC, as these countries experience a substantial risk from the negative impacts of climate change (Dechezlepretre, et al., 2020).

From the review of the existing literature, several topics emerged that are relevant for this study. One of the first considerations is that few patents can be found in developing countries, where the utilisation of the IP systems is considerably limited (Ghazinoory, et al., 2012). This is affected by several factors, recognised in the literature as patenting determinants. Some papers argue that there is no relevant difference in patenting determinants between developed countries and developing countries if we focus on the type of innovation (Amdaoud & Le Bas, 2021). Moreover, the factors affecting patent propensity are similar to the ones which distinguish weak institutional environments from strong ones, and the institutional environment is often one of the main differences between developed and developing countries (Barros, 2015).

On the other hand, some papers explore differences in patenting determinants based on the development of the country. According to Amdaoud et al. (2022), in LMIC an invention is more likely to be patented if it represents a novelty in the market, rather than just within the company. Another determinant in LMIC is the limited resources for R&D (Ghazinoory, et al., 2012). The poor R&D resources combined with the high standards required for the patent application, often prevent inventors from protecting their invention with IP, as this does not appear aligned with the dynamism of growing industries in LMIC and with the needs of innovators (Maskus, 2014).

Finally, other patenting determinants which appear relevant in LMIC are the limited resources of local firms, high patenting costs, weak infrastructure for information and transportation, and weak policies (Adenle, et al., 2015).

All these considerations appear to be fragmented in the literature, and needs to be contextualised in the innovation environment which characterises each country. Morever, what is relevant for this project is understanding how these patenting determinants affect local players like companies and inventors. Therefore, the next step is focusing on the patenting motives and barriers.

2.1 Patenting motives and propensity

From the literature, five groups of patenting motives emerged from the aggregation of several studies: protection, bargaining, improving corporate image, attracting external financing, and internal motives (Holgersson & Granstrand, 2017). These patenting motives can be ranked in order of importance, with protection at the first place, followed by improving the corporate image, internal motives, bargaining, and attracting external financing.

However, these five patenting motives do not have the same relevance in all contexts. For instance, attracting external financing appears to be more relevant in SMEs than in large firms (Holgersson & Granstrand, 2017). In specific industries, patents represent even a requirement for SMEs to attract investors such as venture capitalists, as these investors recognise the longstanding benefits of patenting the invention (Holgersson, 2013). Despite these considerations, large firms appear more active than SMEs in patenting their inventions because of the higher resources and better understanding of IP, while SMEs often lack of IP competence as it is not perceived as a tool which enables growth (Holgersson, 2013).

The difference in the patent propensity between large firms and SMEs is not the only one identified in the literature. From a study involving 19 industries, it emerged that different industries present considerably different patent propensity rates, with the examples of the textiles industry, where 8.1% of the invention are patented, and pharmaceuticals, where a patent is developed in 79.2% of the cases (Arundel & Kabla, 1998). Moreover, product and process innovations show different patent propensity, with 35.9% of the product innovations patented against 24.8% of the process innovations (Arundel & Kabla, 1998).

In conclusion, different factors affect the patenting decision, but from this overview of the literature, no consideration emerged for LMIC, which could present a different patenting environment compared to the one assessed in developed countries.

2.2 Patenting barriers

Patents are supposed to guarantee exclusivity to the invention in exchange for its disclosure, facilitating collaborations for the development and diffusion of the protected invention. However, Levin et al. find that theoretical exclusivity often translates poorly, thereby introducing barriers in terms of appropriability, infringement, and poor protection, which prevent inventors from applying for patents in the first place (Levin, et al., 1987).

From a review of the literature, three main patenting barriers emerged. The first one is that competitors can “invent around” the technology, undermining its function of protection (Harabi, 1995). This affects the exclusivity of the technology and hinders the effective protection of inventions. The second barrier is the disclosure of the technology during the patent application process, which represents a risk (Duguet & Kabla, 2000). A concept known as disclosure effect explains how patents can support negotiations by increasing the amount of information available to the buyer. However, when tested on real negotiations, the disclosure effect was not verified, concluding that the public availability of information introduces risks without improving the outcome of the negotiations (de Rassenfosse, et al., 2016). The third barrier is that the patent application, maintenance, monitoring, and enforcement are activities associated with costs (Cohen, et al., 2000). Therefore, small entities with limited resources could be disincentivised from applying for a patent.

These are not the only patenting barriers which appear in the literature. Another one is the lack of IP competence or the poor integration of IP with other parts of the company. According to Holgersson & van Santen (2018), the IP function appears frequently isolated from the business strategy.

To conclude, as for the patenting motives, also these findings emerged from studies conducted in developed countries. According to Barros (2015), in weak institutional environments, which are common in LMIC, firms opt for alternatives to patents when the patent system appears characterised by a high degree of formality and an inadequate protection against infringement. Therefore, even an ineffective patent system could represent a patenting barrier in LMIC which present weak institutional environments, suggesting that more barriers might emerge compared to developed countries.

2.3 Gaps in the Literature

From the review of the extant literature, two main gaps emerged. First, we find that the patenting motives, benefits, and barriers arose from studies focusing on developed countries, which are usually characterised by an effective patent system. Very little information is known about patenting in developing countries. The second gap is related to the patenting determinants: the role of investments, of the private sector, policies, and national and international institutions in supporting local innovation is recognised by the literature, but these concepts are not directly linked with IP. Therefore, it is not clear to which extent IP can affect the different patenting determinants and support local innovation.

From these two gaps, three main questions were developed. The first research question aims at assessing the patenting motives and benefits in LMIC and identifying possible differences with the current knowledge in developed countries. Similarly, the second question is focused on the patenting barriers. Finally, the role of IP in national and international institutions to promote local innovation represents the third research question of this study.

3. Methodology

The study follows a three-step approach. First, we identify relevant LMIC inventors who patented CCAT. Second, a total of 15 interviews were conducted, split in 13 semi-structured interviews with LMIC inventors and two structured interviews with WIPO Green and the CTCN. Third, the Gioia approach was utilised to analyse the results of the interviews and develop six propositions which represent the main results of this paper (Gioia, et al., 2012).

3.1 Sample creation

We identified potential interviewees by deploying a top-down approach based on all CCAT patents from the United States Patent and Trademark Office (USPTO) with priority date between 2000 and 2020. Focusing on US patents allowed us to only include high-value inventions, as local patent offices – especially in LMICs – are known to differ regarding their processes, data availability, and quality of the patent document. Most importantly, by including only USPTO patents we have also mitigated potential language barriers, as that ensures patents with the same format and language. Obviously, identifying LMIC inventors using patent data limits this study to patented CCAT inventions, which probably only represents a fraction of all CCAT.

CCAT patents were identified using the cross-sectional Y02A-classification, a patent classification class within the CPC, which covers technologies for adaptation to climate change[1]. The Y02A class distinguishes six adaptation technology categories (see Tab 1). Since this class was only introduced in 2018, few studies have so far used the scheme to identify CCAT patents, with few exceptions (Hötte & Jee, 2022; Dechezlepretre, et al., 2020).

CPC group-codes for CCAT patents	Group description
Y02A 10	Coastal zones
Y02A 20	Water management
Y02A 30	Protecting infrastructures
Y02A 40	Agriculture and livestock
Y02A 50	Human health
Y02A 90	Indirect contribution

Table 1: Technology classification codes for CCAT patents

2,500 CCAT patents were tagged as Y02A patents in the USPTO. Each patent has at least one assigned inventor. While applicants are often organisations that hold the legal patent rights, inventors are individuals. We matched the country location of the inventors to the 2020 World

[1] https://www.uspto.gov/web/patents/classification/cpc/html/cpc-Y02A.html#Y02A

Bank Country Classification[2], which classifies countries in four groups: high-income, upper middle-income, lower middle income, and low-income countries. As we are interested in LMIC inventors, we excluded patents from inventors based in high-income countries. The sample included no patent from any low-income country, while 47 patents were filed by inventors from lower middle-income countries, including a restricted sample of 5 patents from India. The decision of taking only a sample from Indian patents was made to keep the diversity of the sample, as 587 patents emerged from India, which is categorised as a lower middle-income country. This sample was complemented by 24 patents with applicants from upper middle-income countries, selecting only countries with a GDP per capita lower than $5,000. The result was a sample of 71 patents. A representation of the process is described in Figure 1.

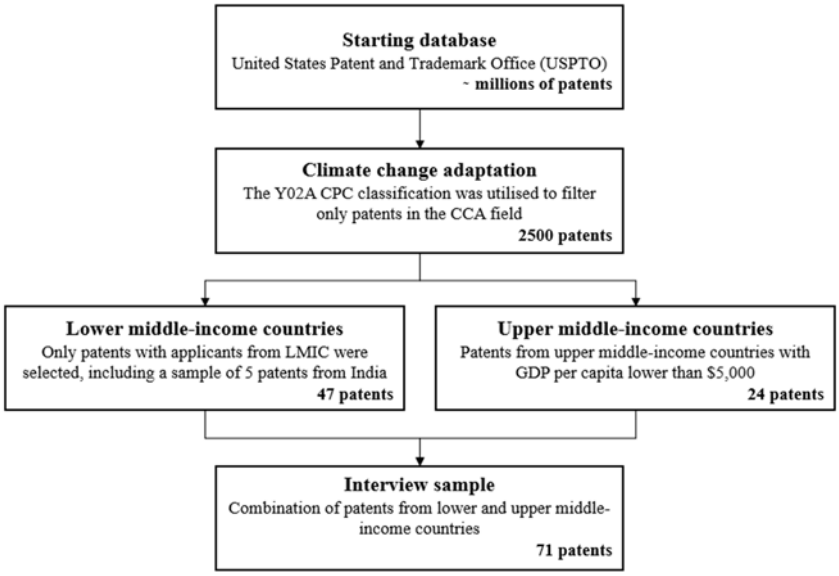

Figure 1:Identification of suitable CCAT inventors as interviewees based on CCAT patents

Starting from these 71 patents, all the 128 LMIC inventors were contacted through their work or personal email, and social platforms such as LinkedIn. This approach resulted in 29 replies and 13 interviews, 8 with inventors from lower middle-income countries and 5 from upper middle-income countries. This indicates a response rate of 23% and a request-to-interview rate of 10%. A summary of the countries included in the interviews and database samples is presented in Figure 2, dividing the contribution of lower and upper middle-income countries. Many inventors responded that they only worked on the technical part of the patent, with limited knowledge on IP and the underlying motives and barriers that eventually lead to the

[2] https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

decision to file a patent. For this reason, two of the 13 interviewees provided limited contribution.

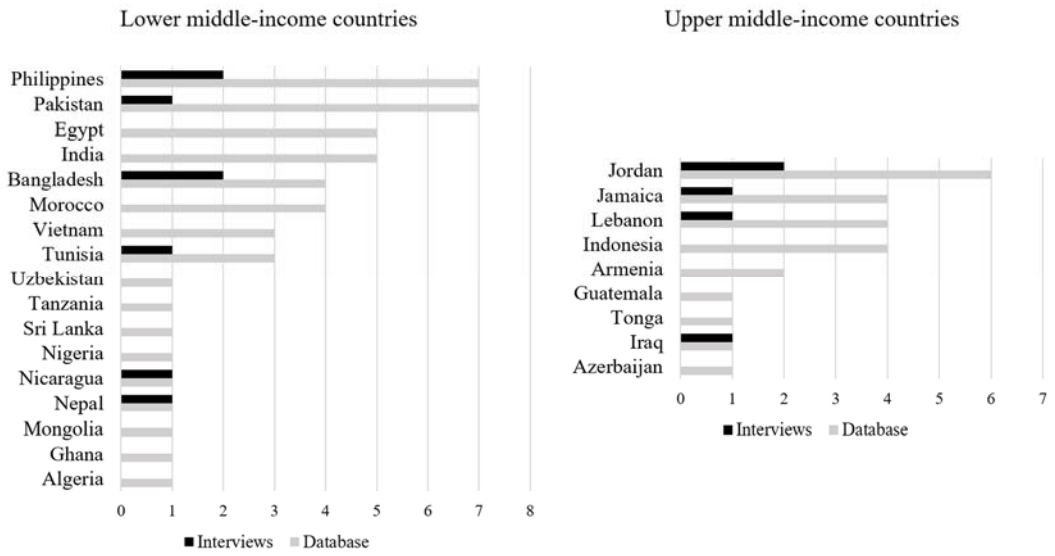

Figure 2: Countries of applicants for interviews and database samples

The following table shows the 13 interviewees from LMIC with their unique identifier (ID), their country location, applicant type, technology code and priority year of the patent. In addition to this table, two interviews were conducted to discuss the results with the Climate Technology Centre and Network and with WIPO Green. The CTCN was chosen because of their technology transfer activities in the field of CCA towards LMIC, while WIPO green was selected to discuss the role of IP for CCAT.

ID	Applicant type	Technology code	Priority year
INT1	Research Institute	Y02A40	2013
INT2	Research Institute	Y02A40	2013
INT3	Research Institute	Y02A50	2001
INT4	Research Institute	Y02A50	2011
INT5	Research Institute	Y02A50	2018
INT6	Company	Y02A40	2016
INT7	Company	Y02A50	2006
INT8	Company	Y02A50	2012
INT9	Inventor	Y02A30	2007
INT10	Inventor	Y02A30	2015
INT11	Inventor	Y02A40	2016
INT12	Inventor	Y02A50	2011
INT13	Inventor	Y02A90	2009

Table 2: List of interviewees from LMIC

Our set of interviewees comprises inventors from ten different countries and patents with priority application years from 2001 to 2018. As a robustness check, we checked the distribution of our sample against the originally available CCAT patents sample regarding the representation in terms of applicant types and technologies using CPC codes. The results are illustrated in **Error! Reference source not found.**.

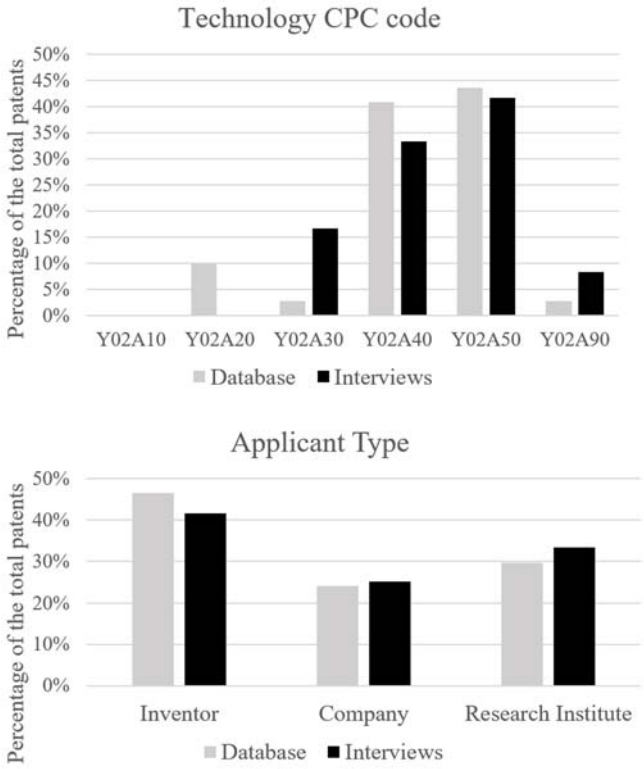

Figure 3: Technology and applicant type comparison between interviewees and patent database

Error! Reference source not found. Regarding the represented technologies, our sample has a slight overrepresentation of Y02A30 and Y02A90 inventions. Moreover, we were not able to interview any inventor for patents in the Y02A20 class. For the applicant types, we found that the distributions are similar.

Therefore, despite the small sample of interviews, it can be concluded that the distribution of the interview sample is reasonably representative of the overall distribution in the patent database selection in terms of technology and applicant types. These are the two main parameters which could affect the results of this study.

3.2Data collection

The unit of analysis for this study are LMIC inventors, as they experienced the patent application process. In order to investigate the factors which affect the patenting decision of CCAT inventions, we developed a semi-structured interview approach, as interviews allow for

the collection of qualitative data to better understand the patenting motives, benefits, and barriers in LMIC.

The semi-structured interview methodology was carried out developing a questionnaire focused on six main themes: patented technology and link with CCA; patenting motives; patenting benefits; patenting barriers; role of national and international institutions; south-south technology transfer. In the interviews, the inventors were first introduced to the theme and invited to express their opinion or experience, without asking for specific questions. Afterwards, more specific questions were adopted to incentivise the elaboration of the concepts emerged from the previous discussion. This type of interview allowed the identification of common results among inventors with different experiences, as the discussion was led towards the same themes while allowing the inventors to elaborate on their experiences.

All interviews were conducted remotely using Microsoft Teams or Google Meet and were carried out between May and June 2022. They lasted between 30 to 70 minutes, based on the availability of the inventor and on the insights shared during the discussion. The interviews were recorded and transcribed to facilitate the analysis.

3.3 Data analysis

The transcripts obtained from the interviews were subject to a content analysis performed using the NVivo software. It was used to identify patterns in the inventors' responses and facilitate the identification of relevant results.

Moreover, the inductive Gioia approach was adopted to group the concepts and develop six main propositions which represent the results of this study (Gioia, et al., 2012). Starting from the first order concepts which emerged from the interviews, second order themes were developed as an aggregation of similar first order concepts. Subsequently, second order themes were combined to generate aggregate dimensions, which gather themes related to a same perspective on IP. These aggregate dimensions provided the background for the 6 propositions, which identify the main results in each aggregate dimension. The results of the Gioia approach are presented in the next section in Figure 4.

While the development of first order concepts is objective, the creation of second order themes and aggregate dimensions requires the personal contribution of the researcher, resulting in possible subjective interpretations. This limitation is recognised by Gioia et al. (2012), that states that the researchers should be knowledgeable about the topic and capable of identifying patterns in the data and relationships between concepts. To mitigate the impact of this limitation and obtain a more objective interpretation of the results, the Gioia approach was validated through a discussion with another researcher within the team, who is knowledgeable in the field but was not directly involved in the interview process.

Moreover, to understand the quality of the findings, two additional structured interviews were conducted with the directors of the international organisation CTCN and WIPO GREEN. In these interviews, the propositions which appeared to be more relevant for these organisations were discussed, to obtain their perspective on the topic and start a discussion about available solutions or future projects to tackle the challenges which emerged.

4. Results

4.1 Proposition framework

Eleven second order themes and three aggregate dimensions emerged from using the Gioia approach. The aggregate dimensions represent the main categories which emerged from the second order themes: (i) Complementary skills and resources for IP, (ii) State of the national patent system, (iii) International organisations and global perspective. The "Complementary skills and resources for IP" dimension includes general findings regarding LMIC inventors, such as the lack of IP experience and education in LMIC, and difficulties in assessing the market and the patentability of inventions. The "State of the national patent system" dimension includes themes such as the lack of support for patent applications, the lack of IP expertise in LMIC, and the difficulties when enforcing patents. Finally, the "International organisations and global perspective" dimension comprises the role of international organisations in supporting inventors, the role of the private sector to attract investments into patented technologies, and the south-south technology transfer mechanism to disseminate LMIC inventions into other global south regions.

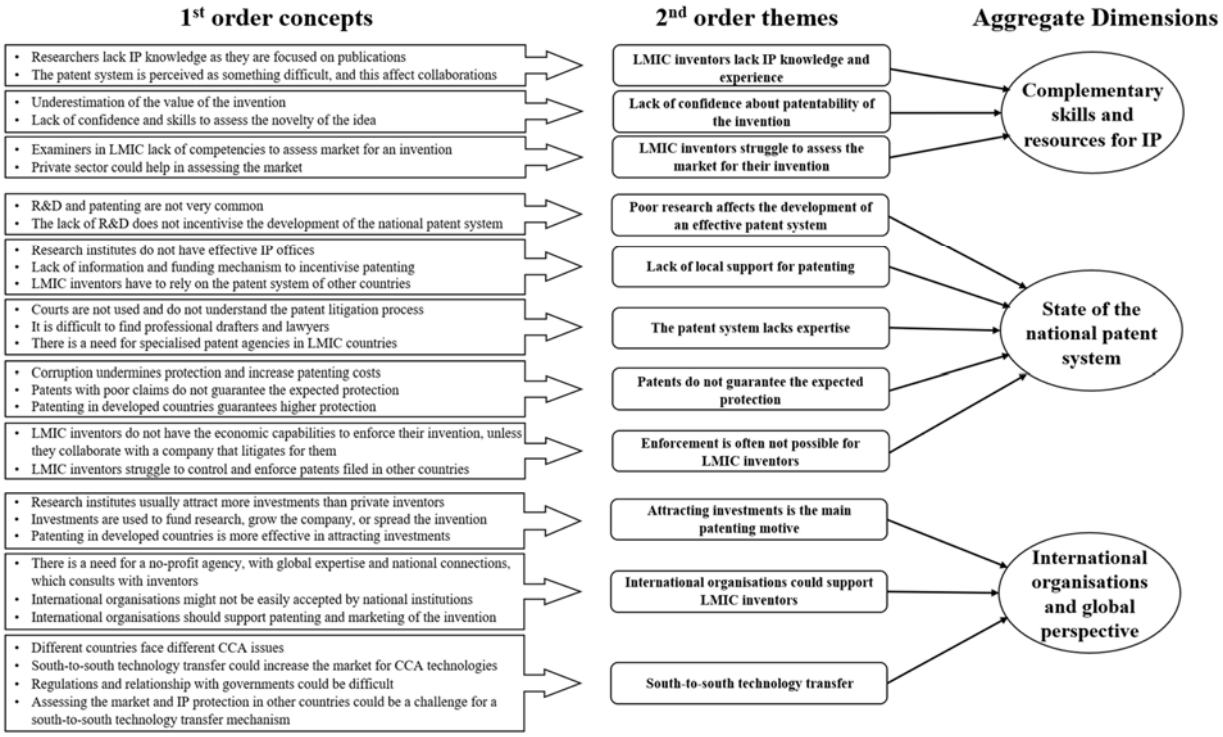

Figure 4: Themes and aggregate dimensions based on the Gioia approach

These aggregate dimensions were combined with the patenting motives, benefits, and barriers to develop a framework, as illustrated in Figure 5. This framework creates a structure for the six main propositions, resulting from this exploratory study as a combination of second order themes in the same aggregate dimension. Moreover, each proposition is assigned to one of the categories of patenting motives, benefits, or barriers, according to the part of the interviews in which it was discussed.

	Patenting motives	Patenting benefits	Patenting barriers
Complementary skills and resources for IP		**Proposition 1:** LMIC inventors highlighted uncertainty regarding the role of patents in facilitating or hindering the diffusion of their technology	**Proposition 2:** LMIC inventors lack: 1. Experience with IP 2. Confidence and skills to assess the novelty of ideas 3. Skills to assess the market of the invention
State of the national patent system	**Proposition 3:** According to LMIC inventors, protection of the invention is a strong patenting motive, but it is not perceived as a benefit obtained through the patent		**Proposition 4:** LMIC inventors face patenting barriers resulting from the state of the national patent systems: 1. Lack of support during the patent application process 2. Legal system not equipped for enforcement
International organisations and global perspective	**Proposition 5:** Attracting investments to develop their invention is a relevant patenting motive for LMIC inventors	**Proposition 6:** local solutions are required to tackle a local CCA problem. However, IP and the support of international organisations can enable south-south technology transfer, which can spread the benefits of local innovations in countries facing similar issues.	

Figure 5: Proposition framework

4.2 Propositions

The propositions are grouped following the aggregate dimensions and are supported by quotes from the interviewees.

4.2.1 Proposition 1: Role of IP in technology diffusion

"LMIC inventors highlighted uncertainty regarding the role of patents in facilitating or hindering the diffusion of their technology"

Successfully getting their CCAT inventions adopted and diffused emerged as a relevant patenting motive for LMIC inventors. However, the role of patenting for the diffusion of CCAT was not clearly identified from the interviews, with some inventors providing arguments about how patents can support diffusion, and others focusing on the barriers.

The first consideration which supports the positive role of patenting is related to the involvement of private sector: a patent enables licensing and cross-licensing agreements which attract companies and possible collaborations. Moreover, the patent system provides global exposure, possibly attracting the interest of foreign investors. This clearly emerged from a researcher at a research institute:

"Some donors care about patenting because with private sector the delivery of the technology is faster" INT2.

On the other hand, some LMIC inventors chose not to patent as they fear this would not facilitate, but rather negatively impact the diffusion of their CCAT invention. A quote from the director of a research institute provides an example:

"Sometimes it was decided on purpose not to patent because the invention was so important for the field that they did not want to make a protection. […] You put the invention on the market so that everyone can use it" INT3.

Moreover, sometimes companies and inventors in LMIC appear to be concerned about the possible legal implications of collaborating with other companies owning a patent, as they are not knowledgeable about what can breach the IP rights. This seems to prevent new collaborations, which could promote the technology diffusion.

4.2.2 Proposition 2: LMIC inventors lack IP understanding

"LMIC inventors lack:

1. *Experience with IP*
2. *Confidence and skills to assess the novelty of ideas*
3. *Skills to assess the market of the invention"*

A basic knowledge about IP seems to be important for inventors to consider patenting their inventions. According to seven interviewees, in LMIC few inventors have a clear understanding of the patenting process and of the opportunities associated with patenting. Even researchers at research institutes are rarely supported by an internal IP department. A clear statement was provided by the director of a research institute while describing the situation he found when he joined that institute more than 30 years ago:

"No IP program was present when I arrived. […] Total absence of patenting understanding: even basic aspects like what you can patent are not mastered by the scientists" INT3.

In this case, the situation was improved by developing a collaboration with another research institute from a HIC country, which provided support by sharing their IP expertise.

According to our data, another patenting barrier seems to be the low confidence that LMIC inventors have in their inventions. Some inventors decided not to patent because they had assumed their invention was already patented or it did not fulfil the patenting requirements (i.e. novel to the world, inventive, industrial applicable). This is supported by a quote from an inventor:

"Many inventors think that other people have already developed the same idea. […] There is no search engine, or they do not know how to see if the idea is innovative" INT9.

In line with this, our data also shows that inventors do not have the skills to conduct a preliminary assessment of the novelty of their invention, which seems to prevent LMIC inventions from being patented. The lack of confidence seems to also result from an underestimation of the commercial value of the invention in the market. This concept could be linked to the difficulty in assessing the market, that combined with the limited resources for patenting reduces the number of patent applications from LMIC inventors.

4.2.3 Proposition 3: Value of IP protection in LMIC

"According to LMIC inventors, protection of the invention is a strong patenting motive, but it is not perceived as a benefit obtained through the patent"

From an analysis of the patenting motives and benefits, a significant misalignment was noticed in the protection category. Specifically, most of the inventors mentioned protection as one of the reasons that motivated their patenting decision, but very few interviewees mentioned it as a patenting benefit. Investigating why protection is not perceived as a patenting benefit by LMIC inventors, several explanatory factors emerged, mainly concerning the state of the national patent systems.

The first relates to corruption and lack of honesty during the patent application process, which may result in the loss of the IP rights. This concept is supported by four interviewees, and the following quote best represent the concept:

> *"Corruption and dishonesty of patent offices in LMIC are higher. […] Patent offices can break confidentiality with other inventors. Therefore, inventors could lose their patent rights on the invention" INT13.*

A second factor relates to infringement. Inventors argued that infringement is common in LMIC, and most of the time it remains "unpunished" because courts are not used to the litigation process. This disincentives inventors from applying for patents. Rather, inventors prefer to patent the technology in countries where the patent system is more reliable.

The lack of protection appears to be linked to weak regulations in LMIC, which do not disincentivise competitors from using patented inventions. Weak IP regulations prevents companies from investing in local technologies, as explained by a researcher:

> *"I tried talking to some pharma companies, but they said they were not interested [in investing] because it would have meant spending a lot of money and not being able to protect the invention because of the loose rules that we have in our country" INT4.*

4.2.4 Proposition 4: National patent system barriers

"LMIC inventors face patenting barriers resulting from the state of the national patent systems:

1. *Lack of support during the patent application process*
2. *Legal system not equipped for enforcement*

The barriers related to the national patent system can be divided into two different categories: lack of support during the patent application process, and lack of expertise to enforce the invention.

Regarding the application process, the patent systems in LMIC often do not provide experienced patent attorneys to support inventors preparing patent applications. This results in patents with poor claims, which do not guarantee the expected protection to the invention. Another challenge related to the patent application process is the lack of expertise by patent examiners when assessing the novelty of inventions at a global scale. Inventors are therefore forced to rely on support from other countries, increasing the application costs. These

observations are supported by six interviewees, best represented by the following quote from an inventor:

"The examiners in LMIC lack competencies on the process of patent application and in assessing the novelty. […] The examiners in LMIC have to ask for help, and the costs become higher" INT13.

Even if LMIC inventors succeed in obtaining a patent, some challenges are likely to emerge in enforcing their invention in case of infringement. According to four interviewees, courts in LMIC are not sufficiently trained and experienced to handle litigation processes. This argumentation is supported by this quote:

"The [patenting] process is not clear, and courts do not understand very much the idea of patenting. […] The legal system and judges are not equipped to do litigation. Therefore, problems emerge when the private or public sector violate your invention" INT7.

These two patenting barriers appear to be related to what has sometimes been called a "weak patent system" or "weak patent regime". As mentioned by an inventor, a possible reason for its insufficient development might be the lack of fundings for research in LMIC. This is supported by the following quote:

"In my country there are no funds for research. Demand creates supply: there is a patent office, but nobody is applying for patents, so it hardly ever works" INT4.

Therefore, few new inventions emerge, and therefore the development of the national patent system is not incentivised.

4.2.5 Proposition 5: Relevance of investments for LMIC inventors

"Attracting investments to develop their invention is a relevant patenting motive for LMIC inventors"

In LMIC, inventors struggle to bring their inventions to the market because of the limited access to investments: these are essential to fund more research and assess the applicability of the invention in the market.

Even though eight of the interviewees mentioned costs and difficulties to access investments as patenting barriers, the extent to which this is a barrier seems to vary between applicant types (i.e. research institutes, companies, independent inventors). For instance, LMIC inventors from research institutes appear to be more successful in accessing fundings and investments because of their networks with private sector companies.

According to the director of a research institute, patents provide greater credibility towards investors also in LMIC:

> *"If you can say to a company that you have a patent, it will immediately create the impression that you can actually do that kind of work. So, it attracts more visibility from investors" INT1.*

However, assessing the potential market for the invention remains essential to attract investments. As a results, a research institute developed collaborations with the private sector to assess the market before patenting inventions, choosing only the inventions which can attract further investments and reach the market. The following quote supports this statement:

"We patent what a company is interested in, because if there is no interest from companies, this means that the patent does not have a real market space." INT1

Patents also guarantee global visibility, which can facilitate finding partners or investors. This visibility could be improved through national and international conferences, which four interviewees mentioned as effective mechanisms to promoting new collaborations, as long as the protection of the invention is guaranteed.

4.2.6 Proposition 6: Local innovation and south-south technology transfer

"Local solutions are required to tackle a local CCA problem. However, IP and the support of international organisations can enable south-south technology transfer, which can spread the benefits of local innovations in countries facing similar issues"

According to the inventors, local innovations for CCA are easier to integrate in the society, as they adapt to cultural and religious aspects that are often not considered while transferring technologies from developed countries. However, south-south technology transfer could be an alternative approach to local innovation, importing technologies from nearby countries which face similar risks. Only three interviewees were sceptical of this approach, while the others suggested the potential of this mechanism to increase the market for the inventions, incentivising inventors to patent.

However, all the interviewees highlighted several challenges that this south-south mechanism might face. These could be divided in three categories: (i) different regulations between countries involved in the technology transfer; (ii) difficult estimation of the market for the invention; (iii) guarantee protection to invention in different LMIC.

Regarding regulations, the main players are governments, patent offices, and the legal system. The role of governments appears to be particularly important in LMIC, as explained by a researcher:

> *"South-south technology transfer needs permissions from the national governments. I know about a no-profit organisation that developed a method to do a rapid test. […] Several countries were approaching them to export the method, but the government did not give the permissions" INT4.*

Moreover, different countries are likely to have different regulations and legal systems, resulting in inventors needing support from organisations with international knowledge.

Related to this concept is the challenging task of assessing the market in other countries, identifying competitors and local regulations. The interviewees stated that the private sector is in the best position to solve this challenge. Companies which operate in different LMIC are likely to have developed this knowledge when commercialising their products. Thus, they could possibly support local researchers and inventors in this south-south technology transfer.

Finally, the last challenge raised by LMIC inventors relates to the protection of their inventions in other countries. They appeared concerned about not being able to litigate their invention abroad in case of infringement. Therefore, transferring their invention to other global south countries appears to them as a process which is difficult to control. This finding was supported by three interviewees, and the best quote comes from a company:

> *"You need to discuss how well your idea would be protected: you don't want to give your idea to a technology transfer company and then have it lost or have difficulties to enforce it with companies in other countries" INT6.*

5. Discussion

Our study provides an investigation of the patenting motives and barriers for LMIC inventors developing CCA technologies. From the results of the interviews, it is possible to conclude that the five groups of patenting motives identified by Holgersson and Granstrand also apply to inventors in LMIC (Holgersson & Granstrand, 2017). However, the inventors usually highlighted a different hierarchy in the relevance of these motives compared to the one identified by previous studies in HIC, suggesting possible differences in the IP environment in LMIC. Moreover, we identified new patenting barriers which were not discussed in prior literature. Most of these barriers appeared to be well known by international organisations operating in LMIC, which validated the results. Overcoming these barriers could benefit LMIC inventors who could take advantage of the CCAT opportunity using their local knowledge.

The following paragraphs discuss the main differences and new concepts that emerged from this study, providing insights for LMIC inventors and international institutions.

5.1 Contributions to the extant literature

5.1.1 Role of investments and patenting costs

From our data, attracting investments emerged as the most frequent patenting motive for LMIC inventors. Investments represent an essential support for the establishment of a company or to fund more research for further development of the invention.

According to Holgersson & Granstrand (2021), patents could increase the market for innovation appropriation by opening the doors for investments from the financial market. This was confirmed by the interviewees, who claimed that some donors and investors require a patent to start the negotiation.

Therefore, from a theoretical perspective, the role of patenting in attracting investments appear to be clear, as it provides global visibility and exclusivity, representing a competitive advantage for the patent owner. However, being able to protect an invention exclusivity seems to be essential to attract investments, as a company would be more inclined to invest knowing that its competitive advantage can be assured. Moreover, after patenting, inventors could rely on international conferences, technology transfer offices, and matchmaking databases to match their inventions with the needs of local companies, improving their global visibility.

Despite this, attracting investments is ranked in the literature as the last patenting motive (Holgersson & Granstrand, 2017). An exception was identified in SMEs, where investments appeared to be more relevant than in large firms (Holgersson, 2013). Moreover, the patenting barriers identified by the literature for SMEs present some similarities with the ones faced by LMIC inventors, suggesting that these considerations could be generalised for entities with limited resources, which need to use patents as a tool to attract investments and grow their business.

Therefore, promoting CCA inventions at local conferences, developing specific funds to patent CCAT, and strengthening the exclusivity ensured by the patent systems in LMIC could prove fundamental to increase the role of patents in attracting investments for CCAT.

5.1.2 National patent system and protection of the invention

To guarantee protection to the inventions, the national patent systems should: (i) develop transparency and efficiency during the patent application process, (ii) ensure protection of the IP rights in case of infringement, and (iii) support the drafting of strong patents.

Starting from the patent application process, the disclosure of the invention represents one of the main patenting barriers (Duguet & Kabla, 2000). This step implies a risk, especially in weak institutional environments where corruption could cause a leakage of information which could be used by competitors to deprive LMIC inventors of their IP rights. Therefore, the main challenges which emerged during the patent application process in LMIC are corruption and an unexperienced legal system.

Ensuring protection in case of infringement is a second aspect that policy makers should tackle. If protection is not guaranteed, investors are disincentivised to invest in the technology, while inventors choose alternatives to patents (Barros, 2015). In several LMIC courts possess limited IP experience and lawyers with international knowledge are scarce, resulting in difficulties to enforce the patent globally.

The third area which should be covered by an effective patent system is a better support for developing strong patents. This requires more experienced and trained patent attorneys, lawyers, and drafters to write patents with effective claims that cannot be easily invalidated.

Any inefficiency of the national patent system in one of these three areas force inventors to rely on external support, increasing the overall cost of owning a patent. A possible explanation for the underdevelopment of the national patent system in LMIC might be the poor R&D: the low number of inventions does not incentivise the establishment of an effective patent system, as its utilisation is not significant to justify investments for its improvement.

5.1.3 Diffusion of CCAT inventions

According to the literature, the diffusion of inventions should be improved by the global visibility and the support in negotiations obtained through patents (Levin, et al., 1987, de Rassenfosse, et al., 2016).

From the interview data, facilitating the diffusion of inventions emerged as a frequent patenting motive, with inventors aiming at developing inventions which have a positive impact in their

communities. In this scenario, the role of patents for technology diffusion appeared to be unclear. In fact, patenting is not the only IP strategy and, depending on the context, other alternatives might appear more suitable (Cohen, et al., 2000; Aaboen & Holgersson, 2016).

In favour of patenting, a patent can boost technology diffusion by attracting the private sector, which is knowledgeable of the market. However, if the market for an invention is not significant or its profitability is limited, even with a patent the private sector would not be sufficiently incentivised to invest. Therefore, developing partnerships and publications in the field could increase the interest toward the technology, favouring a growth of the market and consequently the technology diffusion.

On the other hand, some inventors argued that patents can discourage collaborations because of the lack of IP knowledge in LMIC and of the concerns about the legal implications of patenting. In this case, an alternative could be patenting the invention in other countries to establish collaborations with more IP-experienced companies. This problem could be tackled by national and international institutions by providing education and consultation, and aligning the patenting standards to fast-changing growing industries in LMIC (Maskus, 2014).

Given the local nature of many CCAT inventions, an alternative to global collaboration for technology diffusion could be the establishment of IP "areas" (i.e. regions, groups of countries) with similar standards and regulations (Maskus, 2014). These IP areas could support the development of a south-south technology transfer mechanism, which represents an opportunity for the diffusion of CCAT inventions particularly. The role of patents in this technology transfer mechanism appears to be fundamental to guarantee the rights of LMIC inventors, who could otherwise see their inventions replaced by similar ones imported from other countries.

5.2 International organisations

The increasing awareness of the economic effects of climate change is bringing CCAT to the agenda of many international organisations. During the interviews, both CTCN and WIPO GREEN mentioned new projects in this field, involving IP to support the creation and diffusion of new technologies, especially in LMIC.

From the interviews it emerged that the patenting barriers appear well-known to these organisations, and overall aligned with the findings of this study. However, what is currently missing is an implementation framework to improve the national patent systems, support local innovation, and guarantee the protection of IP rights in LMIC.

The results of this research suggest focusing on capacity building, such as continued efforts to raise IP awareness and increase IP education, to train patent attorneys, lawyers and drafters, and make inventors aware of the different IP strategies they have to protect inventions. As mentioned by one of the interviewees, establishing partnerships between universities and technology transfer offices in developed and developing countries could be an effective approach to accelerate the transfer of IP knowledge into LMIC. Moreover, supporting the participation of delegations from LMIC at international conferences could create opportunities to raise investments for LMIC inventors. In fact, even though many inventors claimed a lack of support from international organisations, WIPO GREEN highlighted two support mechanism which are not widely utilised: WIPO Technology and Innovation Support Center

(TISC), which supports the patent search task, and WIPO Inventor Assistance Program (IAP), an initiative in partnership with the World Economic Forum which provides pro-bono patent attorney services for small companies in LMIC countries. The main reason for why LMIC inventors are not taking advantage of these opportunities seems to be the lack of awareness. Therefore, a closer collaboration between CTCN and WIPO GREEN could result in an easier achievement of the results, improving IP education and the utilisation of the available services.

A second aspect which international organisations might want to pay more attention to are the national patent systems in LMIC. According to the director of CTCN, the development of effective national patent systems should be at the heart of any project which aims at supporting CCAT inventions. Effective patent systems would guarantee protection to inventions through a transparent patent application process, the development of strong patents, and trustworthy enforcement. All these aspects enable trust and the utilisation of patents as a business tool, attracting investments from companies which can rely on effective support in case of infringement. The CTCN Director also claimed that lack of protection is one of the main issues that emerged during their projects, and it affects the patent application of endogenous ideas. This concept was confirmed by LMIC inventors, who participated in our study. They stated that protection is a patenting motive, but at the same time mentioned several challenges in ensuring this protection after obtaining the patent. Despite the weaknesses in national patent systems in LMIC, some inventors still decide to patent, relying both on the national patent system and on the support of developed countries. This highlights the potential role of patenting for CCAT inventions developed by LMIC inventors.

Finally, the impact of new technology transfer mechanism more suitable for LMIC should be further investigated. This research highlighted a positive attitude of LMIC inventors we interviewed towards a south-south technology transfer mechanism. This could complement the existing north-south technology transfer, reducing the barriers usually faced by imported technologies during the adoption stage. Moreover, this mechanism would be more aligned with the local nature of CCAT issues, maximising the impact of local solutions (Lee & Mwebaza, 2020). This concept also emerged at COP26, in which a call for endogenous innovation was made. However, negotiations about IP in LMIC still appear quite divisive at international events, forcing CTCN to work around the issue continuing with a north-south technology transfer.

6. Conclusions

6.1 Findings

This study examines patenting motives, benefits, and barriers as perceived by LMIC inventors developing CCAT. Based on 13 interviews with local inventors from 10 different LMIC, we developed six propositions which have been validated through 2 interviews with experts from CTCN and WIPO GREEN. These propositions are clustered in three aggregate dimensions: national patent system, global support, and complementary skills and resources for IP.

Regarding the national patent system, in LMIC the lack of experienced lawyers, patent drafters, and examiners hinders the patent application for new technologies. Moreover, corruption, dishonesty, and courts which are not used to the infringement procedure affects IP protection, which is one of the main patenting motives. A weak patent system makes it more difficult to attract investments from the private sector, hindering the technology diffusion.

In the global support dimension, the first result is that LMIC inventors seek investments for their inventions also in other countries. Attracting investments is the most frequent patenting motive, as with patents inventors can attract the private sector and other kinds of investors, like venture capitalists. Moreover, national and international institutions have a significant role in directing investments toward LMIC, as they can play as technology matchmakers, bringing companies and LMIC inventors together at international conferences, and implementing technology transfer mechanisms. South-south technology transfer appeared to be supported by LMIC inventors and could become a valuable alternative to local innovation to increase the market for CCAT.

Finally, for what concerns the dimension of complementary skills and resources for IP, the lack of IP understanding emerged from the interviews, which could be divided into lack of experience, poor confidence about the novelty and patentability of the invention, and lack of skills to assess the market for the invention. This generates uncertainty about the role of patents in supporting or hindering the diffusion of the inventions.

National and international institutions can play a role in supporting local innovation, promoting IP awareness and education for LMIC inventors and training attorneys, lawyers, drafters, and examiners to improve national patent systems. Supporting LMIC participation in international conferences and developing partnerships between universities in LMIC and HIC countries could spread IP knowledge in LMIC and distribute the load of this task to a wider range of organisations. Moreover, international organisations could support with technology transfer mechanisms targeted for LMIC, especially considering the local nature of CCAT.

6.2 Limitations and future research

To the best of our knowledge, this is a first study that interviewed LMIC inventors developing CCAT, that experience the greatest risk of the negative impacts from climate change. While we believe that the paper lays the foundation for more research in the field, this study naturally has limitations. The core assumption of this research is that the insights collected through the interviews were generalisable for the LMIC category and were not affected by the specific context of each country. Future research should thus investigate the differences among LMIC

more closely, to also capture differences across national patenting motives, benefits, and barriers. Starting from the six propositions of this research, future studies could focus on the assessment of a single proposition, gathering more qualitative and quantitative data, and developing case studies which consider the specific IP environment of a single country. This could provide a more effective guidance to LMIC inventors of that country.

A second limitation is that the findings of this study were not divided in terms of technology, applicant type, or lower/upper middle-income country. According to Sattar et al. (2013), lower and upper middle-income countries have different channels for technology transfer, while Arundel & Kabla (1998) stated that different industries have different patent propensity. Therefore, these variables might also introduce some differences in terms of patenting motives, benefits, and barriers. Moreover, the Y02A classification included some patents which were poorly related to CCA, making it more difficult the identification of relevant patents.

Finally, the last limitation is related with the sampling methodology to identify interviewees. First, we decided to only include USPTO patents as a quality filter to enable a comparison across LMIC, but this approach excluded inventors who patented using their national patent offices. Moreover, LMIC inventors who decided not to apply for a patent were not included in the interview sample, resulting in a possible bias towards patenting. Therefore, future studies should include these categories by adopting a different sampling methodology.

Future research could also support the development of an implementation framework to improve IP education, develop the national patent system in LMIC, and boost local innovation and technology transfer mechanism. This could be part of a future collaboration with international organisations to identify the best opportunities to address these findings in a real context.

6.3 Conclusion

Overall, this paper offers a contribution to better understand patenting motives and barriers for LMIC inventors when developing CCAT, hence contributes to the IP and innovation literature. Understanding the role of IP in supporting local innovation represents a valuable opportunity for the development and diffusion of effective CCAT, particularly in LMIC which experience a great risk from the negative impacts of climate change.

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