USING MACHINE LEARNING TO ANALYZE CLIMATE CHANGE TECHNOLOGY TRANSFER (CCTT)

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ABSTRACT

The objective of the present paper is to review the climate change technology transfer. This research proposes a method for analysing CCTT using patent analysis and topic modelling. A collection of climate change mitigation related technology (CCMT) patents from patent databases would be used as input to group patents in several relevant topics for climate change mitigation using the topic exploration model in this research. The research questions we want to address are: how have the patenting activities changed over time in CCMT patents? And who are the technological leaders? The investigation of these questions can offer the technological landscape in climate change related technologies at the international level. We propose a hybrid Latent Dirichlet Allocation (LDA) approach for topic modelling and identification of relationships between terms and topics related to CCMT, enabling better visualizations of underlying intellectual property dynamics. Further, we propose predictive modelling for CCTT and competitor analysis to identify and rank countries with a similar patent landscape. The projected results are expected to facilitate the transfer process associated with existing and emerging climate change technologies and improve technology cooperation between governments.

1 INTRODUCTION

The Intergovernmental Panel on Climate Change (IPCC) defines technology transfer (TT) as "a broad set of processes covering the flows of know-how, experience, and equipment for mitigating and adapting to climate change among different stakeholders such as Governments, private sector entities, financial institutions, nongovernmental organizations (NGOs) and research/educational institutions."(IPCC, 2000). Schnepp et al. (1990) define technology transfer as ‘‘A process by which expertise or knowledge related to some aspect of technology is passed from one user to another for the purpose of economic gain’’. In the case of the transfer of CCMT, the economic benefits include the reduction of the future costs associated with climate change and other benefits to the countries involved in the transfer process. Technology transfer is not only about the exchange of device or know-how across national or international frontiers, but also about the complicated processes of sharing knowledge and adapting technology to meet local scenarios.

1.1. NEED FOR CCTT

Agenda 21 that resulted from the United Nations Conference on Environment and Development recognizes that “there is a need for favourable access to and transfer of environmentally sound technologies, in particular to developing countries, through supportive measures that promote technology cooperation and that should enable transfer of necessary technological know-how as well as building up of economic, technical, and managerial capabilities for the efficient use and further development of transferred technology” (United Nations, 1992). The Johannesburg Plan of Implementation (JPOI) that resulted from the World Summit on Sustainable Development calls upon governments and relevant regional and international organizations to take action on development, dissemination and deployment of affordable cleaner energy, energy efficiency and energy conservation technologies and the transfer of these technologies to developing countries (DSD, 2015). Figure 1 highlights Intellectual property landscape in the field of climate change technologies. Drawing upon new extractions from the Worldwide Patent Statistical Database (PATSTAT), The International Energy Agency (IEA) and Organisation for Economic Co-operation

and Development (OECD) have found that while patenting of innovations in climate change mitigation technologies (CCMT) related to power generation, transport, buildings, manufacturing, and carbon capture and storage (CCS) had generally been increasing much faster than other technologies in the period up to 2011-2012 (IEA, 2019). However, there has been a notable drop-off in the number of these patents since 2015 as represented by Figure 1.

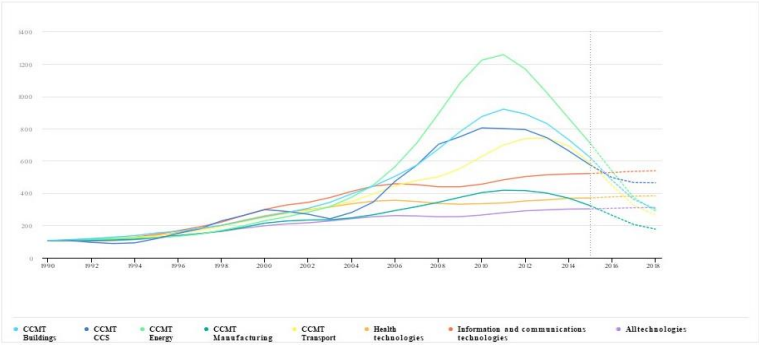

Figure 1 Global patent applications for climate change mitigation technologies Source: (IEA, 2019)

2 METHODOLOGY

Studies indicate that most of the technology transfer that takes place is among developed countries (Stewart, 1992). The rate of global patenting on the climate change mitigation technologies is essential for dissemination of knowledge globally. For analysing climate change patents transfer data we propose a step by step methodology as represented in Figure 2.

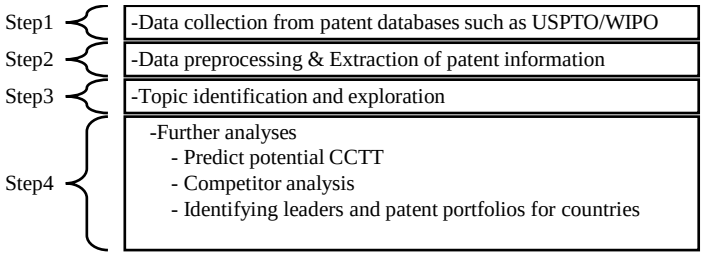

Figure 2 Proposed methodology

2.1 STEP 1: DATA COLLECTION

The patent documents related to climate change technologies will be collected from the United States Patent and Trademark Office (USPTO)'s online database. The data source is appropriate for exploring technological trends because it is a representative patent database containing an enormous number of patents from all over the world and covers the most advanced technologies (Kim & Lee, 2015). However, country wise comparisons to the climate change technologies poses a further challenge (Schmoch, 2008). The proposed search query for the data collection consists of terms dealing with climate change mitigation technologies, combined with climate change domain ontology and domain terms such as *biodiversity, carbon, climate, ecology, environment, emission, ICT for climate change mitigation, energy storage, sustainable, etc.*

2.2 STEP 2: DATA PREPROCESSING

The collected patent documents represent an unstructured text format. Therefore, in step 2 the data would be pre-processed and transformed into a structured format for further analyses. The pre-processing procedure will be performed using the document parsing techniques. The relevant items, such as the title, abstract, assignees, filing year, register year, classification code, and citation will be extracted from documents. For this purpose, the abstract in a free-text format will be required for further pre-processing tasks with natural language processing techniques, including tokenization, lemmatization, stop-word removing, and vector-space representation. Among these

text items, the abstract will be used as the input to lda2vec to identify topics because it essentially includes the main problem addressed by the patented technology.

2.3 STEP 3: TOPIC IDENTIFICATION AND EXPLORATION

The research question we will be addressing by this step is: what is the topic landscape of patents filed for climate change mitigation technologies? We propose topic identification and exploration using lda2vec to address the question. Topic modelling is a statistical approach for discovering topics that occur in a document corpus (Blei et al.,2003). Lda2vec (Moody, 2016) combines the power of word2vec (Mikolov et al., 2013) with the interpretability of LDA. Based on the per-topic distribution, each patent document will be assigned to one of k topics exhibiting the highest probability. In this step we have the following objectives—

(i) grouping patent documents with similar topic probability distributions;
(ii) increasing the understanding of the latent topic structure by producing a term distribution over each topic;
(iii) label the k identified topics in the climate change mitigation - related patents.

2.4 STEP 4: FURTHER ANALYSES

In this last step, the identified topics are further explored from two aspects: trends in patenting activities over time and assignees in each topic. The research questions are as follows: how have the patenting activities changed over time? and who have been technological leaders in climate change related patents? The investigation of these questions can offer the technological landscape in climate change related technologies at the international level.

After the investigation of patent landscape, we further propose to build predictive models based on our patent analysis for technology transfer among countries. We would like to highlight few prior studies that used predictive modelling based on patent information. Mogee, (1991) used patent families to analyze R&D planning, international patent activity, and patent indicators. Wu *et al.* (2010) constructed a predictive model based on international patent classification (IPC) codes to assess possibilities of patent registration. Kim et al. (2013) proposed a hierarchical analysis model of the decision-making process in order to predict technology transfer policy directions. There are plenty of predictive algorithms that can be applied to our study. We propose a SNA based analysis for this step. The predictive model can be constructed by using SNA, regression analysis, decision trees, etc. There are various techniques to analyse patent data. Among them we would use SNA, because SNA is an efficient approach to analyse the patent data (Jun & Park, 2013). The information based on IPC codes, citation information, and so on will be fetched to SNA graphs. Social network structures contain a number of nodes consisting of information for a particular targeted technology such as Number of forward citations, Novelty, Number of backward citations, Number of INPADOC Family patents, Patent duration (Expiration date – Registered date), Number of forward citations, Number of IPC codes extracted, and so on. The results from the SNA graphs will be used all together to explore meaningful relationships to build predictive models for predicting factors that aid technology transfer.

To facilitate the process of technology transfer, we further propose competitor analysis between countries. It would be very useful for countries to know what the trend of a competitor's technology development is. Based on the topic modeling results, we propose competitor analysis using techniques such as word-based similarity (WBS) and Topic-based divergence (TBD). WBS represents countries by a vector of words, and it would rank the competitors based on (Cosine) similarity between countries. TBD represents each country's patent portfolio using the topic distribution and ranks the competitors by the KL-divergence.

3 PROJECTED RESULTS

In general, the transferred technologies are important nationally and internationally for improving their technological competitiveness. Using the methodology proposed in this study, we aim to give investors, governments and policy makers recommendations based on following projections:

(i) Analysis of patent portfolios for disclosed regarding climate change related topics using hybrid LDA;

(ii) Find which countries are addressing the threat of climate change in their patent portfolios;

(iii) Aid developing countries for capacity building for climate change technology development and transfer;

(iv) Aid policy makers in creating new programmes such as the Clean Development Mechanism (CDM), Asia Pacific Partnership for positive advances in the case of international technology transfer;

(v) Providing a predictive model of technology transfer by collecting patent data and applying text mining techniques for pre-processing.;

In conclusion, we proposed a model that promotes developed countries to concretely pursue technology transfer with developing countries in the field of climate change related technologies.

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