The role of technology transfer for the development of a local wind component industry in Chile

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ABSTRACT

This paper contributes to the debate about climate change technology transfer by analysing barriers and enablers for a Chilean company starting up the production of wind blades. Literature on the role of technology transfer for the development and deployment of local renewable energy technologies in developing countries often refers to success stories in Brazil, India and China. Instead, this case study highlights the different challenges faced by smaller emerging economies. The paper argues that successful technology transfer in a smaller economy like Chile requires: a minimum internal demand and access to regional markets to attract foreign knowledge providers; a focus in the types of technologies where the recipient country or company have a competitive advantage; and active learning processes by the recipient company. Lessons are drawn for improving the design and implementation of technology-push and market-pull policies in small or medium emerging economies.

Keywords:
Technology transfer
Renewable energy
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1. Introduction

Developing countries are experiencing unprecedented levels of growth. As a result they will be responsible for most of the future growth in energy demand and Greenhouse Gas (GHG) emissions (International Energy Agency (IEA), 2010a). The largest, fast growing countries, such as Brazil, China and India will cover most of this growth.

Curbing GHG emissions in developing countries has therefore become one of the cornerstones of a future international climate change agreement under the United Nations Framework Convention for Climate Change (UNFCCC). However, setting caps to developing countries' GHG emissions has faced a strong resistance in the current negotiations. Continued economic growth that allows poverty eradication is still the main priority of most developing countries and caps are perceived as a constraint to future growth prospects. The development, transfer and use of low carbon technologies have more positive connotations than caps to emissions and are more widely accepted among developing countries as a way to achieve sustained growth without compromising the climate. Inadequate empirical evidence exists to guide policy making in the area of international low-carbon Technology Transfer (TT). This paper provides new evidence for policy makers by analysing the TT process in the specific case of an emerging low-carbon industry in Chile.

Since its inception, the UNFCCC has recognised the importance of TT to achieve stabilisation of global emissions. In the 13th Conference of the Parties (COP-13) in Bali, technology became one of the four pillars of an expected post-2012 climate change regime. The debate on Intellectual Property Rights (IPR) was one of the thorniest issues within the TT negotiations up to COP-16 in Cancun. It divided developed and developing country positions showing their different political discourses on development and diffusion (Ockwell et al., 2010). The issue of IPR was finally left out of the Cancun Agreements, which decided to establish a Technology Mechanism (TM) that contains a Technology Executive Committee and a Climate Technology Centre and Network. The objective of the TM is to enhance clean technology development and diffusion. Funding availability for the TM and the mechanisms to allocate these funds are still under discussion. Also, eligibility criteria for countries and technologies have not yet been addressed.

To date, the UNFCCC has attempted to promote TT through several means: an Expert Group on Technology Transfers (EGTT), Technology Needs Assessments (TNA), and two financial mechanisms: the Clean Development Mechanism (CDM) and the Global Environment Facility (GEF). The EGTT will be replaced by the TM, as decided in the Cancun Agreements. TNA systematically identify, evaluate, and prioritise climate change technologies for developing countries (United Nations Development Programme

(UNDP), 2009). The CDM was created by the Kyoto Protocol to reduce the cost of compliance for Annex I countries by taking advantage of cheaper emission reduction opportunities in non-Annex I parties, and to support sustainable development in non-Annex I host countries. The GEF is the financial mechanism of the UNFCCC as well as other UN Conventions. It provides grants to developing countries and countries with economies in transition for projects related to biodiversity, climate change, international waters, land degradation, the ozone layer and persistent organic pollutants. Neither the CDM nor the GEF were created with the aim to fund TT; however, they have done so indirectly.

The success of UNFCCC efforts to promote TT has been limited. The EGTT has been criticised for delaying difficult but necessary decisions to enhance TT and for the lack of expertise of its political representatives (South Center (SC) and Center for International Environmental Law (CIEL), 2008). TNAs have identified potential projects but have failed to implement them. The GEF has only a limited budget which has resulted smaller in scale than the market-based CDM. A recent study shows that 40% of CDM projects accounting for 59% of estimated emission reductions (roughly 335 $MtCO_2$/year) claim to involve TT[1] (Seres et al. 2010). The CDM has contributed to technology diffusion, reducing the payback period and improving the internal rate of return (IRR) of clean technology projects (Hansen, 2008; Ang, 2009). However, the CDM as a vehicle for technological change has been widely criticised in the literature. Firstly, it has not reached the scale required to meet the stabilisation challenge (United Nations Framework Convention on Climate Change (UNFCCC), 2008; McKinsey&Company, 2009). Secondly, its project-based nature does not foster large scale deployment of mitigation technologies or the promotion of innovation in host countries (Staley and Freeman, 2009). Thirdly, many of the emission reductions achieved by the CDM are not "additional", meaning that they would have happened anyway and should not be financially supported (Wara, 2009). Several studies of TT in Chinese, Indian, Brazilian and Malaysian CDM projects show that income from carbon credits was rarely the primary reason why the projects were developed, because of the uncertainty of carbon income and the long CDM registration time lags (Hansen, 2008; Wang, 2010; Lewis, 2010; Hultman et al. 2010; He and Morse, 2010). Finally, CDM projects were concentrated in the largest emerging economies, while African countries and other LDCs have been largely left out (UNEP Risø Centre, 2010).

The new TM could benefit from a better understanding of the drivers and enablers of successful TT to improve UNFCCC performance to date. TT are inherently difficult to define and measure, which has placed some limitations to the existing econometric studies of climate change TT (Dechezleprêtre et al., 2008; Doranova, 2009; Seres et al., 2009, 2010; Hascic and Johnstone, 2009; Dechezleprêtre et al., 2010; Frankel and Rose, 2002; Mielnik and Goldemberg, 2002; Cole and Elliott, 2003; Cole, 2006; Ang, 2009; Hubler and Keller, 2010). Case studies can show the actual TT process and provide a focused, localised, empirical and qualitative approach to understanding the variables that govern successful TT.

Case study literature on TT is scarce and has mostly focused on the success stories of BRIC economies,[2] such as the emergence of leading wind turbine manufacturers in India and China (Lewis, 2007; Wang, 2010; Zhang et al., 2009); the world-leading Chinese photovoltaic technology (de la Tour et al., 2010); or Brazilian biofuels production (Hira and de Oliveira, 2009). However, these countries do not represent the average developing economy. China, India and Brazil offer potential investors the prospect of large profits and have an advanced domestic technological base that allows rapid adoption of foreign technologies. Smaller developing countries would struggle to replicate BRIC countries' success stories given their smaller bargaining power towards foreign technology providers. Further case study research is needed to identify the national policies and business strategies that have worked or failed in non-BRIC economies.

This paper contributes to the TT debate with a new case study of a Chilean company needing foreign technologies to start up the production of wind blades. Selecting Chile is relevant to show the challenges faced by companies in non-BRIC countries to attract and successfully absorb foreign technologies. The case study provides empirical evidence about what constitutes successful TT and what are the key factors that enable them. It highlights the particularities of low-carbon TT in the context of a relatively small developing economy with limited resources. The final aim of the paper is to provide policy recommendations that complement those found in the existing literature mostly based on empirical evidence from BRIC countries. Chile is, nevertheless, a special country due to its sustained growth, stable macroeconomic conditions, liberal economy and OECD membership, which may limit the extrapolation of our results to other developing countries.

The paper is structured as follows. Section 2 provides the conceptual and theoretical basis on what constitute TT and its enabling environments. Section 3 presents the country context, defining the Chilean preconditions for successful TT. Section 4 introduces the case study of a Chilean start-up for the production of wind blades. Section 5 discusses the theoretical framework about the concept of TT and its enabling factors in the light of the evidence provided by the case study. The conclusion summarises the major arguments in the paper and suggests further areas or research.

2. Theoretical framework

2.1. Conceptualising technology transfer

The term "technology transfer" has been defined and measured in many different ways by a wide range of disciplines. Early research provided a narrow definition of technology as scientific and engineering knowledge and blueprints. The transfer of this codified knowledge then constituted TT. This concept has evolved and now technology is defined in broader terms, as encompassing the corporate capacity to operationalise and effectively use this knowledge in production (Cantwell, 2009). Technology in the second case is tacit and refers to firm-specific competence in production. Its transfer involves an internal learning process in the recipient company.

Several authors have distinguished three different flows of transferred technological content, from lower to higher impact on the technological capabilities of the recipient. The first flow encompasses capital goods and equipment, it increases the production capacity of the recipient, but on its own does not enable the recipient to efficiently use the imported facilities or to generate technological change. The second flow includes skills and know-how for operating and maintaining equipment. It places the human resources of the importer at the technological level required to efficiently operate the imported technology but without indigenous efforts, does not enable technological change. The third flow encompasses knowledge and expertise for

[1] Data in Seres et al. 2010 about TT in CDM projects rely on TT claims made by project participants in the Project Design Documents (PDDs) of 4984 projects that were in the CDM pipeline as of 30 June 2010. These claims are subject to uncertainty as they are not based on a common definition of TT and they have not gone through verification unless they belong to the additionality test. Also, they refer to projects often at the design stage, which may not be successfully implemented and hence may not deliver emission reductions.

[2] The term "BRIC countries" was coined by Goldman Sachs to refer to Brazil, Russia, India and China as a group of large and fast growing economies.

generating and managing technological change. It creates new technological capacity through the transfer and the active independent learning, creation and innovation of the recipient (Bell, 1997; Wei, 1995; Ockwell et al., 2008).

In the field of climate change, the Intergovernmental Panel on Climate Change (IPCC) provides a frequently quoted definition of climate-change TT as "a broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change amongst different stakeholders such as governments, private sector entities, financial institutions, non-governmental organisations, and research or education institutions" (Intergovernmental Panel on Climate Change (IPCC), 2000). Under this broad definition, TT could provide the recipient country the capacity to install, operate, maintain and repair imported technologies; produce lower cost versions of imported technologies; adapt imported technologies to domestic markets; and circumstances, and develop new technologies, whilst respecting relevant intellectual property rights (United Nations Framework Convention on Climate Change (UNFCCC), 2009).

Given the tacit nature of technology in its broader sense, measuring TT is inherently difficult. Some publications in the field of climate change have attempted to measure TT using as proxies the import of foreign equipment or knowledge in CDM projects (Dechezleprêtre et al., 2008; Doranova, 2009; Seres et al., 2009, 2010) or the number of filed foreign patents related to climate change technologies (Hascic and Johnstone, 2009; Dechezleprêtre et al., 2010). However, these studies present a narrow perspective of technology as equipment or engineering knowledge and cannot be taken as an indication of the level of skills and knowledge that have been transferred alongside. Case studies can provide a more detailed, qualitative account of the technology flows and the extent of knowledge spillovers beyond the equipment transferred.

2.2. *Enabling environments for technology transfer*

Discussions between the public and private sector often conclude that enabling frameworks are needed to accelerate technology diffusion to developing countries (World Business Council for Sustainable Development (WBCSD), 2010). Evidence based literature shows that the main enabling elements for successful TT are:

(1) Adequate institutional and economic frameworks.
These include stable policies, transparent investment regulation and conducive local conditions (WBCSD, 2010). For certain technologies an important element is the establishment of an appropriate intellectual property right protection to enhance their transfer (Alliance for Clean Technology Innovation (ACTI), 2009). A liberal trade policy allows engagement in international economic activities, mostly imports and FDI that can channel climate change technologies. Uncoordinated energy policies, uncertainty of institutional frameworks, excessive bureaucracy or inappropriate power purchase agreements (PPA) are behind some TT failures in Ghana and South Africa (Gboney, 2009; Grant, 2009).

(2) Appropriate absorptive capacity.
A minimum threshold of human capital and infrastructures is required for the efficient operation of transferred technologies and the subsequent generation of advanced local technological capabilities. This requires a functioning education system, targeted capacity building programs and capacity at all levels of implementation of the technologies: technical, financial, business development and regulation (Gboney, 2009; WBCSD, 2010). Countries with significant technological capabilities would have the ability to absorb the most innovative technologies and develop an endogenous technological base. On the other side, countries with low capabilities would target more mature technologies and would have a stronger dependence on foreign equipment.

(3) Large and stable demand. The private sector, owner of most climate change technologies and responsible for most TT, is attracted by the prospect of a large and stable demand. The success of China, India and Brazil in attracting and deploying foreign technologies and growing domestic renewable energy industries seems to confirm this point. A large market allows technology businesses to build a significant production scale and achieve lower production costs as a result of economies of scale and technological learning curves (Wei, 1995; Stern, 2007). It also provides scope to develop a wide portfolio of low-carbon technologies. Countries with a small demand would instead be expected to have a narrower portfolio, focused in the technologies where they have significant competitive advantages.

(4) Supportive policies for low-carbon technologies, which help to bridge the gap between low carbon solutions and their commercial viability. Technology policy is commonly divided into market-pull and technology-push policies. Technology push policies are those influencing the supply of new knowledge, increasing the absorptive capacity of the recipient country and hence reducing the cost of TT. The most common examples of technology push measures are government sponsored R&D, tax credits for companies to invest in R&D, support for education and training, infrastructure development and funding demonstration projects (Nemet, 2009). Market pull policies influence the demand of technologies expecting cost reductions through a variety of learning processes as the installed capacity increases (Grubb, 2004). Common examples of market pull policies in the field of climate change include: carbon markets, tax credits and rebates for low-carbon consumption, energy efficiency standards, feed-in tariffs, renewable energy portfolios and taxes on competing technologies, intellectual property protection, government procurement or technology mandates (Nemet, 2009; de Coninck et al., 2008). Both demand-pull and technology-push are complementary and a mix of them is necessary for technological development (Mowery and Rosenberg, 1979). Experience in China, India and Brazil has shown that in addition to a large demand, successful TT responded to governments' strong signals and incentives favouring low-carbon growth (Lewis, 2007; Ockwell et al., 2008; Ribeiro and De Abreu, 2008; Wang, 2010; Zhang et al., 2009).

3. Country context: Chilean enabling environments for TT in the wind industry

3.1. *Institutional and economic framework*

An enabling environment for investment contributes to the Chilean attractiveness for receiving TT. Chile's investment framework is characterised by high economic growth, the sharp drop of public debt, the stabilisation of external accounts and the favourable conditions for international trade, amongst others. The economy has experienced a fast recovery from the global recession and the damage caused by the earthquake in 2010. Growth rates of up to 5% were expected for 2010 and up to 6–7% for 2011 (Bloomberg, 2010). In addition, free trade agreements allow companies in Chile to access 86% of the world's GDP (InvestChile, 2011).

All these factors have contributed to Chile's entry into the selective group of OECD members in 2010, making it the first South American member and the first country to join the organisation in ten years. In recent years incoming FDI has maintained an upward trend, helping to improve Chile's competitiveness not only through resource seeking FDI but also through technological development and specialised know-how (Chilean Foreign Investment Committee (FIC), 2011). Over the past decade, FDI has represented an annual average 6.5% of Chile's GDP, rising to an average of 8% in the period 2007–2009 (Chilean Foreign Investment Committee (FIC), 2009).

Chile was ranked 11th in the Heritage Foundation and The Wall Street Journal's 2009 Index of Economic Freedom. This score placed Chile above nearly all of the European economies and only one position behind the United Kingdom. In the Global Trade Enabling Report issued by the 2008 World Economic Forum, Chile was ranked as one of the world's most open economies in terms of international trade and investment—27th out of 118 countries (World Economic Forum, 2011). In the 2010 World Competitiveness Yearbook published by the Institute for Management Development (IMD) in May 2010, Chile took 28th place out of 58 economies.

3.2. *Absorptive capacity*

Education statistics show that Chile is well positioned among emerging and developed economies. Chile currently has the highest school internet access rate in Latin America and spends 3.2% of its GDP on education (InvestChile, 2011). Literacy rates surpass 95% of the population and the average years of schooling of local workforce is 10.5 years (InvestChile based on Mineduc and UNESCO). Secondary education has expanded dramatically and government education initiatives emphasising English-language proficiency and digital literacy are providing businesses with the necessary skills to operate internationally (InvestChile—CORFO).

However, there is a common acceptance that the quality of Chilean education lags far behind that of developed countries. According to UNESCO, in 2005 Chile had almost 1.000 full time equivalent researchers per million inhabitants (almost the same as Argentina) while countries like Australia had more than 4.000 (Consejo Nacional de Innovacion para la Competitividad (CNIC), 2008).

There is a rising consensus about the role of innovation as a driver for Chilean development. Since the mid-1980s, Chile's economy has been fuelled by natural resources based export markets with significant concentration of production in a few sectors: mining, pulp, paper and fruits. The high commodity prices allowed a 7.1% average growth rate between 1984 and 1998. However, since 1998, growth rates have decreased significantly as well as the Total Factor Productivity (TPF), which fell from an annual average of 2.8–0.4% between 1998 and 2005 (Consejo Nacional de Innovacion para la Competitividad (CNIC), 2010).

The National Innovation Council for Competitiveness (CNIC) was established in 2005 to create a national innovation strategy. Its data shows that Chile's low participation in certain electronics and transport industries explains why aggregate R&D investment rates are almost 50% lower than the OECD average, even if Chilean total investment rates are similar to average OECD countries. Some positive indicators about innovation show that during the 1990–2005 period, the number of patents per million of inhabitants grew from 10 to 40 and is expected to achieve more than 100 in 2010. In the same period, the number of scientific publications grew from 1200 to 3500. However, recent recommendations by the OECD suggest a need for a stronger link between scientific development and industry needs, as well as a diversification of the economy and the transition towards higher value added activities (OECD, 2010).

The implementing institutions of Chile's innovation policy are CONICYT (Science and Technology Council) and CORFO (the Chilean Economic Development Agency). In general terms, 2/3 of the funds to support and encourage innovation come from the public sector, while 1/3 come from the private sector. CONICYT covers individual basic research and has more than twice the budget allocated to CORFO for industrial innovation and applied R&D. InnovaChile is the implementing agency for CORFO's innovation policies. The agency supports Chilean firms to improve their competitiveness in national and international markets by promoting the development of innovative processes. Energy related small-and-medium size companies in cooperation with university research centres are some of the main beneficiaries. From 2005 to 2010 InnovaChile supported more than 120 innovation projects on Renewable Energy, allocating more than U$40 million to transfer, improve or develop technology. InvestChile is one of the instruments used by CORFO for attracting FDI to Chilean prioritised economic sectors. The instruments used include, matching grants for pre-investment, fixed capital, funding start-ups, capacity building and real estate leases.

A significant weakness for innovation in energy technologies is the lack of a clear Research, Development and Deployment (RD&D) strategy at the Ministry of Energy (IEA, 2009). The merit of individual projects is the main basis for the approval of basic research funding. As a result, activities are dispersed, collaboration between institutions is lacking, and research is project-driven rather than linked to the country's needs. Renewable energy is not considered a priority sector under the Chilean innovation strategy, rather it is considered as a transversal technology platform relevant to all niches of the Chilean economy. Using competitiveness as the only measure might be a narrow goal for future energy R&D priorities. Other factors such as environmental sustainability and energy security should also be taken into account (IEA, 2009). The Centre for Renewable Energy (CER) is currently preparing a study on skills and competences required for the renewable energy industry in the country to create a basis for a clearer strategy.

Within the country's industrial sectors, mining is a significant source of Chilean technological capabilities. It represents 19% of Chiles' GDP and 60% of its exports in average throughout the last 5 years (Sociedad Nacional de Mineria (SONAMI), 2011; Banco Central de Chile, 2010). The budget for the national innovation system, mainly the grants provided to innovative entrepreneurship and local R&D, comes directly from royalties and production taxes over mining operations. Furthermore, the mining industry is the main source of local expenditure on R&D, the fourth sector with the highest score on innovation practices, and the main patent owner of the Chilean economy (21%). The mining sector has a strong foreign presence, but significant technological capabilities have developed among local suppliers of goods and services. Local suppliers need to operate in a global market and have incentives to compete by developing world class technology.

3.3. *Renewable energy technology demand*

Chile has a population of 16.7 million and a GDP of 104.6 billion 2000 USD (IEA, 2010b). Its economy accounts for only 4% of the Chinese economy and around 12% of Indian or Brazilian economies. Chile is also significantly smaller than many of its Latin American neighbours. Brazil, Mexico, Argentina, Colombia and Venezuela have larger economies and all of them, including Peru, also have larger populations (IEA, 2010a). Accordingly, Chile's energy consumption is behind most of these larger countries, although higher energy intensity places Chilean electricity consumption ahead of Colombia and Peru. Since 1990, Chile has experienced fast growth in electricity consumption at an annual average of 7% between 1990 and 2008, well above the 3% Latin American average (United States Energy Information Administration (US EIA), 2011).

Chile's energy sector is characterised by limited indigenous fossil energy resources, unlike many of its South American neighbours. Heavy dependence on imported fossil fuels has created serious periods of electricity shortages during the first decade of this century. On the other hand, Chile's geography provides a high potential for renewable energy. Biomass and hydropower are significant primary energy sources in the Chilean energy balance. Jointly they provided 40% of primary energy consumption in 2008, when considering a calorific power for hydroelectricity equivalent to that of the Chilean electricity generation matrix (Comisión Nacional de la Energía (CNE), 2010a). In the electricity generation matrix, hydropower plants can provide up to 50% of the country's electricity needs in years with good rainfall (such as in 2006) and have 35% of the generation installed capacity (CNE, 2010b). However, the penetration of the so-called "Non-Conventional Renewable Energy" (NCRE) technologies is still low. NCRE is defined by the Chilean Government as electrical energy generated through non-conventional, renewable, primary energy sources, that has a low environmental impact, including biomass, hydropower with less than 20 MW capacity; geothermal energy; solar energy; wind; and marine power.

In December 2010 installed capacity of NCRE in Chile was 452 MW, representing 3% of the country's total installed capacity (CNE, 2010b). Grid connected wind capacity in December 2010 was 162.5 MW. It is expected that Chile will reach 202 MW of wind power installed capacity by 2020 to meet the country's renewable energy portfolio targets. This estimation considers that the most competitive NCRE, particularly hydro, would contribute to most to the target. The Chilean Congress is leading efforts to increase the share of NCRE to 20%. If legal modifications to the current regulatory framework prospered, Chile could achieve almost 1300 MW of total wind installed capacity by 2020. In any case, these figures contrast with the large expected wind capacities of other Latin American countries like Brazil, with 31.6 GW and Mexico, 6.6 GW by 2025 (HIS, 2010).

The main companies operating wind power projects, making investments or planning new wind power projects in Chile are linked to the main international power companies, such as Endesa, SN Power and GDF Suez. However, there is a recent trend for new capacity additions and new projects in the portfolio headed by the mining and chemical industries. For example, during 2010 the Canadian based company Methanex started operating a 2.34 MW wind farm to boost power production at its methanol plants, due to the rise in the natural gas price. Mining company "el Toqui" has recently started operating a 1.5 MW wind power plant for its own power consumption. Gold mining company Barrick is undergoing the construction of a 36 MW project and Australia's Pacific Hydro is planning to build wind farms for the mining operations of BHP Billiton in northern Chile. Furthermore Codelco, the main state-owned mining company and the world largest copper producer, has started the tendering process for the construction of a wind power project. As a consumer of almost 15% of energy in Chile (CNE, 2010a), the mining industry is particularly interested in taking advantage of local resources to achieve security of energy supply and comply with renewable energy regulations.

3.4. *Supportive policies for low carbon technologies*

For the past 30 years Chilean energy policy has been founded on the premise that the best ways to meet electricity demand at affordable prices are to rely on competition between private companies, regulate natural monopolies and limit the role of the state in business decisions. In 1982 Chile pioneered the privatisation of the electricity market. Since then, the average cost of technology and technical reliability have been the only relevant variables taken into consideration for decisions on capacity expansion, above other considerations such as diversifying the generation portfolio, limiting greenhouse gas emissions, enhancing local technology development or creating high skilled jobs.

The assumption that competitive markets would deliver security of supply was embedded in this private approach to the electricity system. However, heavy dependence on imported fossil fuels created serious periods of electricity shortages during the first decade of this century. The large renewable energy potential of Chile has not been fully harnessed to increase security of supply because long term planning on capacity expansion to incorporate renewable energies is not easily compatible with the existing electricity model, which is better suited for short terms decisions on dispatch through merit order.

Over the past five years, conditions for the development of NCRE in Chile have improved considerably. This has been done through new laws, the creation of instruments for direct support to investments (loans and grants for pre-investment studies), better information on renewable resources, the implementation of investment projects and the recognition of diversification of the energy mix as one of the core objectives of the current energy policy (Comisión Nacional de la Energía (CNE) and Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), 2009). The associated regulatory framework has been improved over the years, maintaining the original goal of minimising global cost. The main changes include a new market pull policy to encourage NCRE deployment in Chile. Law 20.257 that came into force on April 1st, 2008, obliges power companies selling directly to final customers to incorporate 5% of NCRE into their electricity sales. This percentage will increase gradually to 10% by 2024. Companies who do not comply with this request have to pay a penalty. However, power companies are currently indifferent about choosing to pay the penalty or to comply with the law. This could be because when large power companies cannot develop their own NCRE projects, they prefer to pay the penalty and pass the cost through their customers rather than allowing the entry of new competitors in the market (Diario Financiero, 2010). Besides, the law applies only to new contracts and therefore a large percentage of the current contracts are not affected. It is hard to assess the deadline of all current contracts and therefore difficult to estimate the future demand of new NCRE projects. This situation creates uncertainty on the real value of the renewable energy attribute and makes it difficult to implement the legislation.

The current government aspires to incorporate at least 20% of NCRE in total installed capacity by 2020. However at the date of submission of this paper, no roadmap or plan have been made public to illustrate how this aspiration would be met. Furthermore, for the local and international investors an aspiration is not a strong signal. In the Chilean competitive market it is still very hard for a new independent power producer to dispatch to the grid, especially considering the high levels of uncertainty behind the projected marginal costs of electricity. This commercial risk can only be managed by traditional large power companies who distribute the risk on a wide portfolio, and therefore concentrate most new generation capacity.

Some institutional developments favouring renewable energy are the creation of the Ministry of Energy and the Centre for Renewable Energy (CER) in 2009. The CER activities are focused in two areas: accelerating investment in NCRE and becoming a knowledge and TT hub. The CER is expected to have a lead role in promoting renewable energy technologies in the market and to serve as a clearinghouse connecting research entities and private companies to the international network of renewable energy technologies. One relevant effort from the Ministry of Energy is the ongoing bidding process of public land for wind power projects, in cooperation with the Ministry of Public Goods. As part of the bid, the government provides wind potential information based on wind measurements and mesoscale models.

4. Case study: development of an indigenous wind component industry in Chile

4.1. Introduction to the case study

This paper uses Fibrovent Wind[3] (FW), a Chilean company starting up the production of wind blades, as an example of TT in non-BRIC developing countries. FW was created as a partnership between the Spanish wind turbine provider Eozen and the Chilean company Fibrovent. The partnership had been initially conceived as a joint venture but has subsequently developed into a purely commercial relationship where Eozen will sell Fibrovent blade moulds and blade design licences. The information used to construct the case study was gathered through company documentation, two structured interviews and written communication with company representatives.[4]

Fibrovent is part of the SAME Group, a Chilean holding covering a wide range of services for the mining industry. The SAME group was founded in 1982 to provide industrial ventilation systems in Chile. In 1992, SAME developed its first project for the mining industry. Fibrovent was created in 2002 to provide the mining industry with composite materials technologies for ventilation systems. It is now the leading Chilean supplier of these technologies and has gained an international reputation after winning projects in South Africa and Laos. In 2009 Fibrovent adopted the strategic goal of becoming the first Chilean wind blade manufacturer.

Eozen is a Spanish wind turbine manufacturer founded in 1999. It is a licensee of Vensys wind turbine technology, which is characterised by its simple system concept and high reliability. Vensys technology uses direct drive permanent magnet synchronous turbines with no gear box that convert 100% of their machine power. Eozen has developed and certified its own blade technology specially designed to optimise the output of Vensys wind turbines. Eozen finalised in 2007 the construction of its production plant in Spain but was soon hit by the contraction of the Spanish wind market. It then looked for opportunities abroad to sell its wind turbines. In April 2010 Eozen announced a redundancy plan for its 90 employees and in January 2011 new shareholders entered the company, providing 31.33% of equity to avoid the collapse of the company (Alimarket, 2011).

FW plans to replicate European processes for the manufacture of blades for 1.5 and 2.5 MW wind turbines in Chile. FW expected to start operations in 2011, producing 150 blades per year to supply a wind capacity of 75–100 MW. A second production plant would start operating in 2012, producing 300 blades per year for a wind capacity of 150–200 MW. The second plant would be expanded in 2013 to produce 600 blades per year for a 300–400 MW wind capacity.

4.2. Conceptualising and structuring technology transfer

Fibrovent's idea to start wind blades production stems from business growth aspirations through new applications of composite materials. After attending an international congress on renewable energies, the company CEO was convinced that business opportunities in the wind market were large and that Fibrovent had the capability to start this new venture. However, Fibrovent lacked specific technical and market experience in the wind industry. Knowledge of wind blade production was not available in Chile and therefore foreign technological support was required.

TT in FW has taken place through several channels, with the first two in the list considered as the most significant:

- Incorporation of a Brazilian expert with more than 20 years experience in the manufacture of wind blades and generators.
- Licences of wind blade designs and blade moulds acquired to the Spanish company Eozen.
- Imports of foreign capital goods. Equipment for wind blades manufacture has been sourced from a German company. The selection was made on the basis of previous experience from the Brazilian expert and the Spanish company Eozen.
- Participation in several international congresses. Fibrovent's staff is continuously involved in international events to keep up to date with technological and market developments in the wind industry.

A Brazilian expert joined Fibrovent in May 2009, initially through a specialised consultancy assignment and subsequently on a permanent basis as a partner of FW. CORFO's InnovaChile provided funding for the consultancy appointment through its TT support line. The role of this expert has been key for the technical and organisational design of the new company, the selection of technology providers, the definition of a business plan and the capacity building among local staff. The permanent contact of the expert with Fibrovent's staff has enabled a profound TT. TT in this case has involved not only codified knowledge and blueprints but also corporate technological capabilities acquired from the Brazilian wind turbine manufacture experience. Fibrovent has gone through a process of internal learning assisted by this foreign expert.

Fibrovent had initially agreed to constitute a joint venture agreement with the Spanish company Eozen. The joint venture would give the Spanish company 50% of FW's shares and 45% to Fibrovent, with the remaining 5% allocated to the Brazilian partner. A pre-agreement was made in November 2009 defining that FW would commercialise Eozen generators and would use Eozen's licensed wind blade design at no cost. The initial target market would be Chile, but FW would expect to resume exports to the rest of Latin America and beyond after successful deployment in Chile. The new company would be partly financed with public subsidies and partly with a private loan endorsed by the SAME group. Negotiations to conclude the joint venture stalled due to the financial weakness of Eozen and to the high uncertainty of Chile's demand for wind blades. The TT was subsequently conceived as an arm's length relationship between both parties where Fibrovent would buy blade design licences and moulds from Eozen. Such an arrangement considerably reduces the risk for Eozen as well as the potential gains. It also provides

[3] Fibrovent Wind is not the real name of the new company. A hypothetical name has been created by the researchers because the final name of the wind blades producing company had not yet been decided at the date of writing this paper.Interviews to Victor Poblete, commercial manager and partner of FW, as well as Plant Manager of Fibrovent, José Francisco Antunes, partner and Technical Director of FW took place in August 2010 and November 2010. Written communication by e-mail with both representatives took place on the 2nd of February, the 14th and 15th of April, 2011.

[4] Interviews to Victor Poblete, commercial manager and partner of FW, as well as Plant Manager of Fibrovent, José Francisco Antunes, partner and Technical Director of FW took place in August 2010 and November 2010. Written communication by e-mail with both representatives took place on the 2nd of February, the 14th and 15th of April, 2011.

Fibrovent with more freedom to decide the structure of the new company and its potential market. Geographical restrictions for the exports of wind blades were among the critical issues under discussion in the joint venture agreement but have been eliminated from the current negotiation.

Fibrovent required a foreign partner to penetrate a market with strong entry barriers. An operating plant and a certified wind blade design are preconditions for commercial relationships with potential customers. Fibrovent's initial decision to structure the TT as a joint venture with foreign majority was driven by foreign participation requirements to access public financing through CORFO's instrument InvestChile. InvestChile is the best available support instrument in Chile for starting technological businesses requiring TT. It aims to attract highly specialised foreign investments providing the most generous subsidies, faster and more flexibly than any other instrument aimed at local innovation. Through InvestChile subsidies, FW was able to finance a large share of the initial equipment and human capital costs.

Eozen was one of the very few foreign technology providers that showed some interest in starting a wind blades production venture in Chile. All other potential partners were interested in penetrating larger markets such as the US, China, India or Brazil. In other cases, wind turbine manufacturers were simply not interested in sharing their knowledge. The choice of Eozen as technology partner was motivated by its openness to collaboration and by technological affinity with Fibrovent's in-house expert. After the joint venture negotiations were interrupted and replaced by a commercial relationship, more foreign parties have become interested. Fibrovent reports that now it does not fully depend on Eozen as German and Dutch companies would also be willing to sell them wind blade moulds and licences to produce in Chile. This has increased Fibrovent's bargaining power in the TT negotiation.

Eozen's initial interest in a joint venture in Chile was motivated by the decline of Spanish demand. Participation in FW would allow access to the Latin American market, with faster growth rates than Spain. Chile was perceived as a low-risk location, with stable macroeconomic conditions, low corruption, and a liberal economy welcoming foreign investors. Recent Chilean legislation to promote renewable energies signalled prospects for wind power demand growth. Not having significant international experience, collaboration with a local company would lower Eozen's entry risks to a new market. In addition, low-tax rates and free trade agreements eased wind blades production for export, at a lower cost than those produced in Spain. The subsequent preference for a purely commercial relationship was due to a desire to reduce the risk of the transaction, given its own financial weakness and the uncertainty of Chilean demand.

4.3. *Enabling environments for technology transfer*

4.3.1. *Absorptive capacity*

Fibrovent has gained critical knowledge on composite materials and their properties through its experience as a service provider for the copper mining industry. It is a pioneering company in the application of state-of-the-art injection technologies for the composite materials industry in Chile. Significant efforts have been made to systematise its processes through the implementation of certified quality procedures. This has been possible through the professionalisation of its human resources. The number of engineers has grown from one to ten since the company was born. The quality of Chilean engineering education is considered as a key enabler for the creation of endogenous technological capability in Fibrovent. However, specific capabilities on wind technology are not available in Chile, which was considered as a barrier.

Experience in the mining industry allows Fibrovent to start the new wind blades industry with a well-functioning, trusted, flexible and low-cost supply chain. Fibrovent regularly undertakes training sessions for their local suppliers to ensure quality of procured goods. Moreover, as a distributor of several foreign suppliers, it can ensure low cost materials. However, the new wind blades business requires expanding their suppliers' network, which they have been doing in the last year. Fibrovent executives consider their previous international exposure as key to entering the international wind market. The company has been exporting composite materials products for more than 5 years. It has won significant international bids, which have contributed to build credibility and self confidence. Based on this experience, the company has learnt that before competing in the global market they need to operate successfully in Chile. The steep learning curve that Fibrovent has gone through to achieve excellence in the mining industry can be now capitalised into the new wind blades business, which requires a strong level of precision and expertise.

In addition to cross-sectoral knowledge transfers, Fibrovent is actively involved in specific wind technology R&D in its own laboratories as well as in partnership with universities. The aims of these partnerships are to jointly develop patents; to create spin-offs as a result of successful research projects; and to provide research and testing services to other institutions. As an example, one of the ongoing partnerships with the Chilean Universidad de La Frontera is currently working in the design of a wind turbine for low wind speed in isolated regions.

4.3.2. *Demand prospects*

FW business plan forecasts blades production for an annual wind capacity of up to 400 MW. In December 2010, Chile had only 162.5 MW of wind capacity and only needs to reach 202 MW by 2020 to meet the regulated renewable energy targets. A significant increase in these targets or an improvement in the implementation of the legislation would be required to achieve commercial feasibility.

FW relies on the Chilean market to be able to grow and compete internationally, for mainly two reasons. Firstly, access to international markets depends on credibility gained through experience. FW blades need to be operating in a number of wind power projects before they can bid for international projects. Demonstration projects will be much easier to get in the Chilean market. Secondly, Fibrovent needs foreign partners that can provide the technological knowledge base. While potential foreign partners are not interested in creating an additional competitor in the global market, they are attracted by the possibility of penetrating a new market. The existence of a minimum local market size, as well as the possibility of entering the Latin American market has been a prerequisite for Eozen to enter in negotiations with Fibrovent.

Lack of clear demand prospects delayed and eventually stopped the formalisation of a joint-venture between Eozen and Fibrovent. Eozen preferred a less-risky commercial agreement with its Chilean counterpart. The construction of the production plant slowed down until demand for wind generation projects builds up to the planned blade production capacity. In the last five years the Chilean regulatory framework has taken some steps to support renewable energy and has declared an aspirational target of 20% renewable power production by 2020. However, flaws in the implementation of the existing renewable energy legislation and electricity price instability have prevented a significant and stable local demand. Fibrovent is actively involved in local lobbying groups requesting regulatory amendments that extend the demand of renewable energy.

In any case, the relatively small size of the Chilean market presses FW to grow internationally. While Latin America is the initial target region, FW expects to supply to other developing and emerging economies. Competition is considered too strong in Europe due to the vast number of suppliers already operating in the area. While the free trade agreement with the United States provides good opportunities to access this market, barriers of entry are higher than in South–South commercial operations. FW's executives have estimated that their blades will be able to sell at 40% less than European blades and 20% less than Brazilian ones. Sources of competitive advantage come from Chilean low taxes and free-trade agreements and Fibrovent's access to cheap raw materials.

4.3.3. *Supportive policies*

Technology-push and market-pull policies stimulated Fibrovent's initiation of a low carbon TT process. However, flaws in these policies have also slowed down the process.

Technology-push policies have had a direct impact in enabling TT. CORFO's InnovaChile financed Fibrovent's appointment of an external consultant that later on became a key member of the new company. CORFO's InvestChile support line for foreign investors provided part of the initial capital investment needs of FW. InvestChile requirement that the funded company should have a majority foreign participation made Fibrovent decide to channel the TT through a joint venture. This prevented Fibrovent and Eozen from selecting the most appropriate channel for their specific situation. Given the high capabilities of Fibrovent, the weak financial situation of Eozen, the lack of any other foreign companies interested in constituting a joint venture, and the uncertain demand for wind technology in Chile, an arms-length relationship presented a number of advantages over a joint venture. It increased the bargaining power of Fibrovent and reduced the risk for Eozen. The joint venture negotiations were eventually stopped and replaced by a purely commercial relationship. This will not have severe implications for FW's access to InvestChile's funds, because the instrument is currently being modified to allow the participation of national companies independently from foreign investors.

Demand-pull policies have also had a mixed impact on FW's TT process. FW's representatives acknowledge that Law 20.257 setting renewable energy quotas was an important factor in attracting foreign technology providers. However, the inability of Law 20.257 to spur investment in wind power plants has also been quoted as one of the main stumbling blocks in their TT negotiations. Chilean renewable energy legislation has not been strong enough to ensure the quick-start of FW's project and to raise interest among a wider group of potential partners. A more effective implementation of the renewable energy quota as well as policies providing price stability could boost wind energy demand. Price stabilisation rather than subsidies through feed-in tariffs is more likely to work in Chile, given the high price of Chilean electricity and its free market economy. The CER is currently studying different potential mechanisms for price stabilisation.

While national renewable energy policies are essential for the development of a sustained demand, FW representatives consider the CDM as irrelevant to provide demand certainty. International mechanisms are seen as part of the political framework that could enhance international demand, but are not considered in their business plan.

5. Discussion

The selected case study confirms the prescriptions set by the theoretical framework and provides additional evidence about enabling factors and policies that are specific to non-BRIC developing countries.

The case study confirms a perspective of TT as going beyond the mere acquisition of foreign equipment and knowledge. The process of TT in this case study is not limited to the use of a certified blade design, the acquisition of foreign licences and equipment or the use of the engineering knowledge of a foreign specialist. TT is rather the assimilation of foreign knowledge for the generation and management of technological change, which involves an intense learning process. Our findings ratify that success in TT is linked to the assimilation of the technology and its contribution to the dynamics of technical change of the recipient company. The process of TT experienced by FW could bring significant technological change to Chile, introducing a high value added manufacturing activity with the potential of significant spillovers. At the business level, TT structured as the recruitment of a Brazilian specialist has been particularly successful. The day-to-day contact has enabled Fibrovent's process of internal learning and subsequent capacity to implement technical change. The fact that this constituted a South–South relationship seems to have eased the transfer process, with recipient and provider acknowledging a high degree of affinity. The relationship with the Spanish technology provider appears more narrowly restricted to codified knowledge. In this case, intermittent contact, low demand prospects, a risk-averse profile of the provider and the North–South character of the transfer may have limited further knowledge spillovers.

Chile, as a medium-sized emerging economy faces particular challenges to attract and successfully absorb foreign low-carbon technologies. Its electricity consumption accounts for only 2% of China's and 9% of Brazil's. Therefore it cannot afford to implement a diversified low-carbon electricity generation matrix. It must focus instead on a reduced group of technologies to reach affordable costs through economies of scale and learning by doing. Decisions on the group of technologies that could guide Chile's low-carbon development path should take into account the country's sources of competitive advantage. Some cross-sectional sources of competitive advantage come from its open economy, low taxes, functioning institutions and low location risk. These attributes make Chile competitive by lowering transaction costs, exporting costs and labour costs. Technology-specific sources of competitive advantage are based in pre-existing knowledge, abundant and cheap natural resources and availability of skilled human resources.

The Chilean mining sector has facilitated specialisation in a number of advanced technologies, which can be transferred to some renewable energy sectors. This pre-existing knowledge allows local start-ups to become competitive faster. FW provides an example of how technological knowledge about composite materials in the mining sector can be transferred to the renewable energies sector. Other cases of cross-sectoral TT from the mining sector have taken place in the fields of geothermal and solar energy. Geothermal exploration requires expensive drilling equipment and human resources for an integral assessment of reservoirs. The mining industry shares a relevant part of this knowledge and capacities. Concentrated Solar Power (CSP) technology uses molten salts to store thermal energy during the night to provide continuous supply of power. Most of the salts used in the world's CSP power plants are provided by SQM, a Chilean company leader in the industry of fertilisers, lithium, iodine and explosives for mining companies. In the prioritisation of renewable energy technologies, small developing countries could follow this example, analysing their knowledge base and studying the possibility of cross-sectoral TT. In addition, targeted technology-push mechanisms are required to bridge the knowledge gap.

The main stumbling block in TT negotiations has been the small and uncertain demand for wind technology in Chile. A significant local demand is necessary to attract foreign technology leaders. Foreign investors are usually attracted by large markets and are willing to share knowledge assets in exchange for the large future profits that these markets can offer. Future profits in small developing countries may not compensate for the loss of competitive advantage involved in giving up some knowledge assets. Chilean demand-pull policies have not been strong enough to ensure the quick-start of FW's project and to raise interest among a wider group of potential partners. Transparent and effective demand-pull policies contribute to the feasibility of low-carbon projects in small and medium developing countries that require TT, even if this projects aim at selling to a global market.

Another option to increase the market potential of small and medium developing countries is to bundle customers, services, or markets across borders. In South America, Chile, Colombia and Peru aspire to form a common market, joined by Mexico. The three countries have a growing affinity as fast-growing, medium-sized countries with Pacific coastlines, betting on market economies, foreign investment and trade with Asia to achieve development (The Economist, 2011). A common market would facilitate bundling together products from all three countries to achieve a significant scale for exports. It would also create the possibility to bundle demand to reach the scale required by foreign investors. Access to the Latin American market through a regional base in Chile could be an incentive for foreign partners and presents a number of advantages. Firstly, being a small country facilitates creating alliances because there is no fear of creating strong global competition. Strong protection of intellectual property rights (IPR) also provides the right signals for foreign knowledge-intensive industries fearing loss of competitiveness by sharing knowledge with low-cost manufacturing companies in developing countries. Furthermore, Chile's smaller size gives technology providers the flexibility to adapt to the market's varying condition and to recover earlier from wrong design or marketing decisions before approaching the global market.

The case study also shows that when local technology recipient companies have significant capabilities, technology-push policies should be flexible enough to let them choose the most appropriate TT channel. Chile's technology-push policies to stimulate joint-ventures with foreign companies attracted only a second tier company without the financial strength required to take risks. They reduced the bargaining power of the local company, whose project depended on a single interested foreign partner. A shift towards a purely commercial relationship has increased the bargaining power of the local company and reduced the risk for the foreign company.

As regards the relevance of UNFCCC mechanisms for the TT process, evidence shows that they have not played any role in FW's business plan. New technology-related international instruments should be closer to actual needs of companies in developing countries.

6. Conclusions

This paper has provided some evidence about the country factors and business strategies that enable successful TT to a small emerging economy. A Chilean company starting up the manufacture of wind blades has been used as a case study.

This analysis shows that TT not only involves equipment and codified knowledge, but also the ability to use them to generate and manage technological change. This ability requires a certain absorptive capacity. In Fibrovent's case, it was gained through cross-sectoral TT from the mining sector and an internal R&D strategy. Small developing countries should identify such opportunities for cross-sectoral transfers. Our case study has pinpointed the importance of a minimum local demand and the access to foreign markets to attract foreign technology providers. Effective national market-pull policies depend highly on each country's circumstances. Chile's liberal economy and high electricity price made it choose renewable energy quotas as the most cost-effective policy. However, some flaws in implementation of the legislation and the uncertainty of future electricity prices have prevented growth of renewable energy and deterred TT activities. Technology-push policies should be adapted to the capabilities of local technology recipient companies and avoid forcing dependence on foreign technology providers.

The lessons learnt through our case study may not be applicable to many developing countries. Chile's OECD membership, free trade philosophy, ease of doing business and good macroeconomic indicators make it special. Further research would be necessary to describe other non-BRIC developing countries' experiences. In any case, the importance of a pre-existing knowledge base; the international dimension of local companies; well-designed technology-push and market-pull national policies; and the possibility to bundle regional markets are general recommendations relevant for all policy makers in the developing world.

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