Research Note

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Green Innovation from the Global South: Renewable Energy Patents in Chile, 1877–1910

This research note uses the case of nineteenth-century Chile to argue that the phenomenon of early green entrepreneurship was not confined to the United States and Europe. It focuses on Chile-based inventors who pursued intellectual-property protection in solar, tidal, wave motion, water flow, and wind power. The backgrounds and careers of these inventors are examined. The case contests the popular assumption that knowledge always originated in the developed North and flowed southward. Instead, at least in the case of renewable energy, knowledge emerged endogenously in Chile and sometimes even flowed northward. This research note argues that the circulation of knowledge was strongly linked to the mobility of individuals rather than to the mobility of patents between North and South.

Keywords: patents, Chile, nineteenth century, renewable energy sources

The relationship between the progress made by civilizations and the human use of available energy sources has been increasingly scrutinized by scholarship, and some studies go back as far as antiquity.[1] Scholarly researchers are also engaging with depictions of the progress made during the past centuries regarding the development of technologies that used available energy sources.[2] Recent studies that examine the relationship between energy use and social progress between the

[1] Vaclav Smil, *Energy and Civilization: A History* (Cambridge, MA, 2017).

[2] Christopher F. Jones, *Routes of Power: Energy and Modern America* (Cambridge, MA, 2014); Astrid Kander, Paolo Malanima, and Paul Warde, *Power to the People: Energy in Europe over the Last Five Centuries* (Princeton, 2013); Thomas P. Hughes, *Networks of Power: Electrification in Western Society, 1880–1930* (Baltimore, 1993).

Business History Review 93 (Summer 2019): 379–395. doi:10.1017/S000768051900062X
 ISSN 0007-6805; 2044-768X (Web).

nineteenth century and the present have highlighted the role played by pioneering actors who pursued sustainable agendas in renewable energy and organic food, among other sectors. This literature is heavily focused on the developed world.[3] The same bias is evident in studies of contemporary sustainable business.[4]

The term "green entrepreneurship" has been used by Geoffrey Jones and others to label such pioneers.[5] The term has similarities to the concept of "sustainable entrepreneurship," used for contemporary forms of environmentally friendly entrepreneurship.[6] Both terms refer to businesses that engage in for-profit ventures designed to enhance rather than degrade sustainability. Contemporary studies of green entrepreneurship are heavily focused on developed countries.[7] Jones's historical study, too, is heavily focused on Germany and the United States, at least before World War II. Regarding the postwar decades, he does identify cases in Japan, Egypt, and a number of other countries, including Brazil and Costa Rica, from the 1980s.[8]

This research note seeks to trace the history of green entrepreneurship in developing countries, particularly Latin America, to before World War I. Its focus is on entrepreneurial endeavors in Chile in the late nineteenth and early twentieth centuries, including several cases of novel industrial technologies that sought patent protection for the use of

[3] Julia Adeney Thomas, "Historia económica en el Antropoceno: Cuatro modelos," *Desacatos* 54 (May–Aug. 2017): 28–39; Kristina Söderholm, "Environmental Awakening in the Swedish Pulp and Paper Industry: Pollution Resistance and Firm Responses in the Early 20th Century," *Business Strategy and the Environment* 18, no. 1 (2009): 32–42; Geoffrey Jones, *Profits and Sustainability: A History of Green Entrepreneurship* (Oxford, 2017); Geoffrey Jones, *Varieties of Green Business: Industries, Nations and Time* (Northampton, MA, 2018).

[4] Martin Jänicke argues that only a handful of countries are pioneering environmental policy leaders (Sweden, the United States, Japan, Denmark, Finland, France, Germany, the Netherlands, the United Kingdom, and Canada. Jänicke, "Trend-Setters in Environmental Policy: The Character and Role of Pioneer Countries," *European Environment* 15, no. 2 (2005): table 1. In the European context, Reinhard Haasa, Christian Panzera, Gustav Rescha, Mario Ragwitzb, Gemma Reecec, and Anne Held report that Austria is the leading EU country in terms of consumption of energy generated by renewable sources (over 60 percent). Haasa et al., "A Historical Review of Promotion Strategies for Electricity from Renewable Energy Sources in EU Countries," *Renewable and Sustainable Energy Reviews* 15, no. 2 (2011): 1007, fig. N. 6.

[5] Jones, *Profits and Sustainability*.

[6] "Sustainable entrepreneurs" refers to businesspeople who combine economic, social, and environmental value creation with an overall concern for the well-being of future generations; see Pablo Muñoz and Boyd Cohen, "Sustainable Entrepreneurship Research: Taking Stock and Looking Ahead," *Business Strategy and the Environment* 27, no. 3 (2018): 300–22.

[7] Although most of the contemporary case studies concerning *sustainable entrepreneurship* focus on developed countries, a few case studies have analyzed experiences in developing countries. David Wheeler, Kevin McKague, Jane Thomson, Rachel Davies, Jacqueline Medalye, and Marina Prada, "Creating Sustainable Local Enterprise Networks," *MIT Sloan Management Review* 47, no. 1 (2005): 33–40.

[8] Jones, *Profits and Sustainability*.

renewable energy sources. The patent applications filed between 1877 and 1910 in the Chilean patent office form the basis of the study. It is already known that there was considerable interest in both solar energy and sea wave energy in the nineteenth century, but all from inventors in the developed West.[9]

This research note begins with the first industrial development of solar distillation at a nitrate plant in the Atacama Desert named Las Salinas in the 1870s.[10] It goes on to examine two other distillation plants, established in the Sierra Gorda and Domeyko nitrate production facilities.[11] The inventor of this technology was Charles Wilson, a European engineer immigrant who settled in Chile and obtained a local patent in 1877.[12] This note explores whether Wilson's endeavor was a singular occurrence or, rather, if he was a harbinger of a larger entrepreneurial trend occurring in Chile at the time.

This level of innovation might be considered surprising, since Chile's economy was still primarily focused on commodity exports, especially nitrates, minerals, and agricultural products.[13] However, as several

[9] David Ross, *Opportunities and Uses of the Ocean* (New York, 1978); David Ross, *Energy from the Waves* (Oxford, 1981).

[10] Josiah Harding, "Apparatus for Solar Distillation of Fresh Water from Salt Water," *Scientific American Supplement* 405 (Oct. 1883): 6461–62; "Apparatus for Solar Distillation," *Minutes of the Proceedings of the Institution of Civil Engineers* 73 (June 1883): 284–88.

[11] W. Bollaert was perhaps the first to report the use of distilled water in Iquique: "On leaving the port of Iquique, (at which place there is no water, excepting that distilled from the ocean) … The scene is one of absolute sterility." Bollaert, "On Common Salt: The Sources from Whence Obtained, and the Processes Involved in Its Manufacture – With Observations on the Origin of Salt and Other Saline Bodies," *Journal of the Society of Arts* 1, no. 39 (1853): 478. Josiah Harding, in "The Desert of Atacama (Bolivia)" (*Journal of the Royal Geographical Society of London* 47 [1877]: 250–53), noted that all water that was needed was distilled from wells, but later described the plant. Nelson Arellano-Escudero, "La ingeniería y el descarte artefactual de la desalación solar de agua: Las industrias de Las Salinas, Sierra Gorda y Oficina Domeyko (1872–1907)" (PhD diss., Universitat Politècnica de Catalunya, 2015).

[12] Wilson's invention of solar distillation technology was reported by Maria Telkes, "Fresh Water from Sea Water by Solar Distillation," *Industrial & Engineering Chemistry* 45, no. 5 (1953) pp. 1109. ; A. S. E. Ackermann, "The Utilisation of Solar Energy," *Journal of the Royal Society of Arts* 63, no. 3258 (1915): 538–65; and Julio G. Hirschmann, "A Solar Energy Pilot Plant for Northern Chile," *Solar Energy* 5, no. 2 (1961): 37–43. See also, more recently, Soteris A. Kalogirou, "Seawater Desalination Using Renewable Energy Sources," *Progress in Energy and Combustion Science* 31, no. 3 (2005): 242–81; Arellano-Escudero, "La ingeniería."

[13] Nitrate soda was the chief commodity export in the late nineteenth century. Frederick R. Clow, "South American Trade," *Quarterly Journal of Economics* 7, no. 2 (1893): 193–204; Carmen Cariola Sutter and Osvaldo Sunkel, *La historia economica de Chile: 1830 y 1930. Dos ensayos y una bibliografia* (Madrid, 1982); Marc Badia-Miró and José Díaz-Bahamonde, "The Impact of Nitrates on the Chilean Economy, 1880–1930," in *The First Export Era Revisited: Reassessing Its Contribution to Latin American Economies*, ed. Sandra Kuntz-Ficker (London, 2017), 151–88. In the twentieth century, and to date, it was copper. B. S. Butler, "Copper," *Annals of the American Academy of Political and Social Science* 89 (May 1920): 103–110; José Antonio Ocampo, "Commodity-Led Development in Latin America," in *Alternative Pathways to Sustainable Development: Lessons from Latin America*, ed. Gilles Carbonnier, Humberto Campodónico, and Sergio Tezanos Vázquez (Leiden, 2017), 51–76.

recent studies have documented, Chile was an early adopter of the patent system—its first patent law was passed in 1840.[14] The system was open to most inventions, and patent fees were relatively cheap.[15] Chile was a small patent jurisdiction representing less than 0.07 percent of worldwide patent grants between 1830 and 1914.[16] However, it is known that some of this patenting was significant, including the cases of the female inventor Laurencia Collangues de Solminihac and Edison's electricity patents.[17]

The note is organized as follows: section 2 looks briefly at the role of patents in innovation; section 3 discusses the patent database used in this study; section 4 presents the evidence of Chilean patent data; and section 5 concludes.

Patents and Knowledge Creation in Chile

Debate about the costs and benefits of patent systems, particularly for developing economies, began in the late eighteenth century and continued through the nineteenth century.[18] Despite these historic disagreements, patent systems are usually regarded by contemporary economists as a healthy public policy that promotes economic and technical progress, although there are many dissenters.[19] The value, or otherwise, of

[14] Bernardita Escobar Andrae, "An Early Patent System in the Developing World: The Chilean Case, 1840s–1900s," in *Fashioning Global Patent Cultures: Diversity and Harmonization in Historical Perspective*, ed. Graeme Gooday and Steven Wilf (Cambridge, UK, forthcoming); Bernardita Escobar Andrae, "The Doctrines and the Making of an Early Patent System in the Developing World: The Chilean Case, 1840s–1910s" (FEE Diego Portales University Working Paper 58, Santiago, 2014); Padro Alvarez Caselli, "Inventar en el fin del mundo: Orígenes de la propiedad industrial y el sistema de patentes de invención en Chile, 1840–1880" (PhD diss., Pontificia Universidad Católica de Chile, 2017).

[15] Josh Lerner, "150 Years of Patent Protection" (NBER Working Paper 7478, Cambridge, MA, 2000). Table 3 highlights that patent fees were relatively cheap, and table 1 shows that patents for chemicals, food and medicines were allowed.

[16] Ian Inkster, "Patents as Indicators of Technological Change and Innovation — An Historical Analysis of the Patent Data, 1830–1914," *Transaction of the Newcomen Society* 73 (2003): 179–208. Chile was one of the first countries to establish patent protection in Latin America. Over two thousand patents were granted between 1840 and 1910. Arturo Montero, *Rejistro Jeneral de Patentes de Invención: Que comprende todos los privilejios, ya sean de invención o de introducción concedidos por el gobierno de Chile hasta 1912* (Santiago, 1913).

[17] Bernardita Escobar Andrae, "Mujeres inventoras en Chile hasta el centenario: ¿Particularidad o emprendimiento?," in *Empresas y empresarios en la historia de Chile: 1810–1930*, ed. Manuel Llorca-Jaña and Diego Barría Traverso (Santiago, 2017), 293–311; Carlos Donoso Rojas, "De la compañia chilena de telefonos de edison a la Compañia de Telefonos de Chile: Los primeros 50 años de la telefonia nacional, 1880–1930," *Historia* 33 (2000): 101–39. Collanges de Solminihac's patent had expired by the turn of the twentieth century, because of lack of use, whereas Edison's was used extensively after it was granted.

[18] Fritz Machlup and Edith T. Penrose, "The Patent Controversy in the Nineteenth Century," *Journal of Economic History* 10, no. 1 (1950): 1–29.

[19] Notably, Michele Boldrin and David K. Levine, "2003 Lawrance R. Klein Lecture: The Case against Intellectual Monopoly," *International Economic Review* 45, no. 2 (2004):

https://doi.org/10.1017/S000768051900062X Published online by Cambridge University Press

using patent statistics as an index for innovation activity is also much debated. Petra Moser has recently argued that patent statistics are an imperfect way to capture innovation because they tend to discourage applications, for several reasons.[20] However, the fact that Chile had an early patent system—relatively cheap, regardless of the origin of the application; open to most technologies; and with publication requirements that did not disclose technical aspects of the subject matter—suggests that Chilean patent law was less likely than other patent systems to discourage innovators from using the system. Therefore, patent information seems like a useful guide to the innovation dynamics taking place in Chile.

While there is evidence that the Southern Hemisphere was a source of knowledge creation, the history of technological innovation in the region is not well known.[21] Nevertheless, it is clear that technological development in Europe and in European colonies and ex-colonies in Asia and Africa was a more interactive, culturally nuanced, multisited process than traditionally acknowledged.[22] European scientists traveled to and wrote about Chile during the eighteenth and nineteenth centuries, noting particularly technologies for spinning, dyeing, and weaving cloth and for extracting gold from ore.[23] American scientists reported on the

327–50; "The Economics of Ideas and Intellectual Property," *Proceedings of the National Academy of Science of the United States of America* 102, no. 4 (2005): 1252–56; *Against Intellectual Monopoly* (Cambridge, UK, 2008). Different arguments against patents are laid out in James Bessen and Michael Meurer, *Patent Failure: How Judges, Bureaucrats, and Lawyers Put Innovators At Risk* (Princeton, 2008).

[20] Petra Moser, "Patents and Innovation in Economic History," *Annual Review of Economics* 8 (2016): 241–58. She argues that technology fairs displayed innovations that better mirrored innovation dynamics of countries because they attracted innovations that would otherwise avoid using patent systems. Among the reasons for not using patent systems are the high fees, the need to disclose technology through publication requirements, and the presence of discriminatory fees charged on the basis of the applicant's country of origin.

[21] Carlos Sanhueza, *La movilidad del conocimiento científico en América Latina: Objetos, prácticas, instituciones, siglos XVIII–XX* (Santiago, 2018); Eden Medina, Ivan Da Costa Marques, and Cristina Holmes, eds., *Beyond Imported Magic: Essays on Science, Technology, and Society in Latin America* (Cambridge, MA, 2014); Mine Kleiche Dray, *Les ancrages nationaux de la science mondiale, XVIII^{e}–XXI^{e} siècles* (Paris, 2018).

[22] D. Arnold, "Europe, Technology, and Colonialism in the 20th Century," *History and Technology* 21, no. 1 (2005): 85–106.

[23] Some examples are the reports by eighteenth-century physicians such as Louis Feuillee and Amadeo Francis Frezier and those by Darwin and others in the nineteenth century, Ricardo Cruz-Coke Madrid, *Historia de la Medicina Chilena* (Santiago, 1995). In spite of the country's socioeconomic inequality and backwardness, several traditional indigenous techniques used in South America, and in Chile in particular, were worthy of mention in scientific journals. For example, William Bridges Adams stated, "I have seen Patagonian women, with a loom formed of pegs stuck in the bare earth open to the sky, on their knees plying the shuttle to form a poncho of the brightest of wool, dyed and spun by themselves, and capable of turning any amount of rain water better than the best wool of Leeds or Manchester; and I have seen the Chilé gold crushing mills at work, made of native wood and native granite, with not five pounds weight of iron in their whole composition, extracting gold more effectually than by all the

abundant solar radiation in the central and northern regions of Chile and its use in the manufacture of *charqui* and raisins.[24]

The Patent Data

In order to examine the evolution and use of the Chilean patent system for registering renewable energy inventions, we relied on patent application data rather than patent grants published by Montero.[25] We chose to do so because the set of patent grants is too reduced, in that it excludes data related to unsuccessful applications. The data about applications that were not granted patents provides valuable information about the types of technologies that were being pursued and the kinds of protections inventors sought for themselves and their families within the economy. We built a database using the information concerning patent applications published in the *Official Gazette* between March 1877 and December 1910.[26] We found the relevant information by carrying out searches of the words "*privilejio*," "*invento*," and "*invencion*" in the search engine of the *Official Gazette*. Once the name of the applicant and key words of the invention were identified, we organized the information such that each entry in the database would mimic and contain what is normally part of a patent application file.[27] We completed the gaps for missing data with additional ad hoc searches for each entry in the database corresponding to patent applications.

The technologies of interest for this research were identified through the terms most commonly used for different categories of energy sources. Thus, we later identified the patent application descriptions,

powers hitherto used by more civilised people." Adams, "On the Culture of Food," *Journal of the Society of Arts* 7, no. 321 (1859): 119.

[24] William Bridges Adams, "Proceedings: The Food Committee," *Journal of the Society of Arts* 17, no. 839 (1868): 118–23; C. G. Abbot, "The Smithsonian 'Solar Constant' Expedition to Calama, Chile," *Proceedings of the National Academy of Sciences of the United States of America* 4, no. 10 (1918): 313–16; C. G. Abbot, Walter Knoche, Alfred F. Moore, and Leonard H. Abbot, "The Smithsonian 'Solar Constant' Expedition to Calama, Chile," *Science*, n.s., 48, no. 1252 (1918): 635–36.

[25] Montero, *Rejistro Jeneral*.

[26] The *Official Gazette* is the paper that communicates content of a legal nature to the public and by doing so fulfills the publicity requirements that govern the action of the public administration. It normally contains new legislation and petitions of private parties made to the government that may affect third parties' interests, such as trademark and patent applications. At the time, it also contained third-party oppositions to the latter applications. During the period of study, the gazette published various decisions made by the government regarding these types of procedures. Nonetheless, the plans and designs regarding the subject matter were not published in the gazette.

[27] The database singles out patent applications, some decisions made by the government regarding each of them, and any opposition by third parties to applications. However, the gazette does not normally contain information regarding the appointment of patent examiners.

through their contents, using terms such as "*viento*," for wind power; "*mar*" and "*olas*," for wave and tidal power, which were also aggregated with the fewer cases that used run-of-river as the energy source; and "*solar*" and "*salobre*," for solar energy.[28] Identifying applications required distinguishing and excluding the applications that had nothing to do with the use of renewable energy sources or were likely to confound the patent applications dealing with the use of such energy sources with steam and combustion power, which were the dominant energy sources at the time.[29]

In several cases, the communications from applicants published in the *Official Gazette* included information about their national origin and place of residence. This information allows for the identification of immigrants, a feature of patent applicants that is not available in Montero's list.

Evidence from the Chilean Patent System

Table 1 summarizes the patent application data collected for the period. A total of 3,650 applications were collected for the period from 1877 to 1910, as compared to over 2,000 patents granted between 1840 and 1910.[30] Overall, eighty patent applications (2 percent) were related to renewable energy and the evidence shows that the large majority of renewable energy applications originated in Chile (74 percent), and the rest in foreign countries.

Taking the 1880s as a basis, renewable energy applications tripled by the end of the decade, regardless of their origin. However, relative to other technologies, renewable energy applications originating in Chile grew more dynamically. The opposite occurred with foreign applications: renewable energy applications grew more slowly than other types of patent applications.

An estimated 8 percent of domestic patent applications were filed by immigrants who had settled in Chile. In general, the evidence suggests that Chile had a dynamic economy that required the protection of new technological developments using renewable energy, both Chilean and foreign. Innovation originating in other countries was becoming

[28] We did not include force of gravity, because it was deemed too difficult to separate the cases we were seeking from those that used the term "gravity" in a different manner or with a different meaning.

[29] For example, technologies related to underwater devices were common in the period, but they are of no interest for this study. To exclude these cases from the applications that we sought to select, we explicitly excluded applications using nouns related to means of transportation, such as ships, vessels, and boats.

[30] Montero, *Rejistro Jeneral*. An analysis of such data reveals that 1,826 patents were granted between 1873 and 1908. Escobar Andrae, "An Early Patent System".

https://doi.org/10.1017/S000768051900062X Published online by Cambridge University Press

Table 1
Patent Applications for Renewable Energy Sources (RES) in Chile by Residents and Nonresidents

	Nonresidents		*Residents*						*Resident and Nonresident*				
	RES	*Other*	*RES*	*% Migrant*	*Other*	*% Migrant*	*Total*	*% Migrant*	*RES*	*Other*	*% Migrant*	*Total*	*% Migrant*
1877–1880	1	43	6	17	135	19	141	18	7	178	26	185	14
1881–1890	3	174	11	18	324	12	335	13	14	498	42	512	8
1891–1900	6	451	10		770	6	780	6	16	1,221	49	1,237	4
1901–1910	10	761	33	6	912	4	945	4	43	1,673	38	1,716	2
Total	20	1,429	60	8	2,141	7	2,201	7	80	3,570	155	3,650	4
%	1	99	3		97		100		2	98	4	100	

Source: Authors' calculations based on data retrieved from the *Official Gazette* between Mar. 1877 and 31 Dec. 1910.

increasingly more frequent, but indigenous innovations maintained a leading position, with most patent applications being submitted by non-migrants (92 percent of resident applications). Moreover, the table reveals that the proportion of immigrant applicants declined during the period, from 18 to 4 percent in the final decade. These features reveal a limited role played by innovators from developed countries in the knowledge creation reflected in patent activity in Chile.

Table 2 shows the distribution of renewable energy patent applications, revealing that the majority of applications concerned water energies—wave, tidal, water flow, and currents (72 percent of all renewable energy applications)—and that this percentage was slightly higher among applications originating in Chile than from nonresidents (74 compared to 65 percent of renewable energy applications, respectively). Solar technologies followed at 19 percent, and wind energy represented the remaining 9 percent. Only 17 percent of applications related to wind energy originated in Chile, which made wind technologies the least-frequent domestic source of energy.

It is difficult to benchmark these figures, as we have found no comparable evidence for other countries. Nonetheless, technologies related to renewable energy account for 2 percent of all patent applications in Chile during the period, a small though not negligible figure. Eighty technologies applied for protection in thirty-three years, sixty of them originating in Chile, which is an average of 1.8 applications per year, equivalent to an average of one renewable patent application per million inhabitants per year.

Table 3 presents the number of applicants applying for renewable-energy patents according to their origin. Applicants may have participated in the application process several times during the study period, acting in different roles (namely, applicant, examiner, agent, or opponent of an application). We tried to identify them by name and to determine the first year in which they appear as actors in the database, regardless of the role they played at the time. Since an application may have more than one applicant, and an applicant may apply for more than one patent, figures for applicants may differ from the actual number of applications. The table shows that the eighty renewable energy source applications (RES) involved ninety-two individuals (applicants, opponents, or examiners). Most of these actors (seventy-three, or 80 percent) were residents, and sixty-three were patent applicants. Compared to nonresidents, resident actors were less specialized in renewable energy technologies: RES technologies represented approximately 42 percent of the applications filed by resident actors during the period. By contrast, renewable energy applications represented 65 percent of applications by nonresidents. These figures indicate that these

https://doi.org/10.1017/S000768051900062X Published online by Cambridge University Press

Table 2
Renewable Energy Source (RES) of Patent Applications by Residents and Nonresidents

	Nonresident RES				*Resident RES*					*Total RES*				
	RES	*Solar*	*Wind*	*Wave Current*	*RES*	*Solar*	*Wind*	*Wave Current*	*Solar& wave*	*RES*	*Solar*	*Wind*	*Wave Current*	*Solar& Wave*
1877–1880	1	0	0	1	6	5	0	2	1	7	5	0	3	1
1881–1890	3	2	0	1	11	2	1	9	1	14	4	1	10	1
1891–1900	6	1	2	3	10	2	0	8	0	16	3	2	11	0
1901–1910	10	1	1	8	33	4	3	27	1	43	5	4	35	1
Total	20	4	3	13	60	13	4	46	3	80	17	7	59	3
%	25	24	43	22	75	76	57	73		100	100	100	100	
(1)	100	20	15	65	100	19	7	74		100	19	9	72	

Source: Authors' calculations based on data retrieved from the *Official Gazette* between Mar. 1877 and 31 Dec. 1910.
(1) RES applications that qualify in two categories (solar & waves) are subtracted in equal parts from each category to compute percentages.

Table 3
Patent Applications by Residence Status of Applicants

	Nonresidents				*Residents*				*Total*			
	Persons	*RES*	*Other*	*% RES*	*Persons*	*RES*	*Other*	*% RES*	*Persons*	*RES*	*Other*	*% RES*
1877–1880	1	1	0	100	13	11	29	28	14	12	29	25
1881–1890	3	3	0	100	13	14	33	30	16	17	33	34
1891–1900	4	5	5	50	18	14	31	31	22	19	36	35
1901–1910	10	11	6	65	29	36	11	77	39	47	17	73
Total	18	20	11	65	73	76	103	42	92	96	115	45
%	20				80				100			

Source: Authors' calculations based on data collected from the *Official Gazette*. Note that the table overrepresents the aggregates because of those applicants who applied for the same patent. Such cases would be counted as many times as the applicants had applied for the patents.

individuals, particularly the residents, were active innovators engaged in technological development, in both sustainable energies and other technologies. Twenty-eight resident applicants applied for more than one patent each, and renewable energy applications tend to correspond to their first incursion into the patent system. Thirty-five other applicants applied for only one patent, which was a renewable energy application.

Table 4 summarizes the data of the twenty-eight resident applicants participating most actively in the patent system. The ones selected corresponded to those who had the largest number of RES applications and filed one other patent application and/or played at least one other role in the patent application system (as opponent, examiner, or agent of other patent applicants). We searched for available information for these individuals and found that at least two of them had obtained a U.S. patent for a similar or related RES technology after having first applied for a patent in Chile, and one obtained a patent in the United Kingdom after he had obtained a patent in Chile. We also found that six applicants had made publications and that all of them, except for Liborio Brieba (a prolific author of the time), published after they had first applied for a patent in Chile. It is also noteworthy that eleven of these applicants had been active opponents of third-party patent applications and four had also been examiners of patent applications.

The preliminary evidence regarding these individuals suggests that they were active businesspeople engaged in the public life of their time. Many were founding investors in new firms, some related to energy production and distribution. The exemplary case of Juan Tonkin Thomas is revealing. He obtained a patent to produce energy using water in 1897, as well as several other patents later on. He sold the first patent to a foreign firm and later invested in pioneering companies that developed hydroelectricity (Compañía Nacional de Fuerza Eléctrica) and urban electricity distribution (Compañía Chilena de Electricidad). He was more than an investor and inventor. He was also an active patent activist, vigorously opposing potentially competitive technologies seeking patent protection. He sat on the boards of these large energy companies until the 1930s.

The case of Victor Vargas Gamallo is also interesting. Even though less evidence exists of his investment and corporate activities in Chile, he is known to have exported his technology abroad. He owned a patent for the use of solar energy in the production of honey and later obtained other related patents. In addition to obtaining a patent in the United States thereafter, he published content regarding his invention

Table 4
Characterization of a Sample of Renewable Energy Sources (RES) Patent Applicants

Patent applicant	*No. of times other roles played*		*No. of patent applications*		*Year of first application*		
	Opponent	*Agent*	*Total*	*RES*	*Chile patent*	*Publication*	*U.S. patent*
Eusebio Naranjo	1		7	6	1901		
Tomas Wilson			6	3	1886		
Ana Augusta Weihers			5	3	1901		
Eulogio Allendes Cuadra		2	3	3	1899		
Erik Knut Ekwall	1		4	2	1901		
Enrique Bogdan			3	2	1903		
Teófilo Reszka	7		10	1	1879	1893	
Víctor Vargas Gamallo			8	1	1886	1900	1913
Eugenio Lahaye			7	1	1896	1901	
Julio A. Morandé	2		6	1	1887		
Pedro Enrique Perez M.	1	1	6	1	1880		
Alberto Zégers Fernández			5	1	1899		
Juan Eleodoro Allende			5	1	1882		
Domingo Urzúa Cruzat	1		5	1	1896	1904	1898
Liborio E. Brieba	2		5	1	1880	1869	
Aníbal Labarca Feliú	1		4	1	1900		
Marcial Gatica		1	4	1	1891		
Juan Tonkin Thomas	6		4	1	1897	1937	1900
Carlos E. Wilson B.			3	1	1877		
Carlos Enrique Plisson			3	1	1880	1884	
Arturo Besa	2		3	1	1879		

Continued.

Table 4
Continued

Patent applicant	*No. of times other roles played*		*No. of patent applications*		*Year of first application*		
	Opponent	*Agent*	*Total*	*RES*	*Chile patent*	*Publication*	*U.S. patent*
Emilio Frame			2	1	1879		
Emilio Saner			2	1	1887		
Juan Murray			2	1	1901		
Julio Figueroa			2	1	1893		
Narciso Carvallo			2	1	1878		
Juan Luis Ariztía	1		2	1	1897		
Manuel Martínez Otaegui		1	2	1	1902		

Source: Selection made by the authors of RES applicants with the largest number of interventions in patent applications throughout the period.

in Chile and later in Cuba.[31] His invention was reported by others in Central America through Spanish diplomatic reports to the mainland.[32]

These individuals had diverse origins. We found evidence of patent holders who had immigrated to Chile at some point before they made their applications and continued living in Chile thereafter, such as Charles Wilson, the European national who established Las Salinas.[33] Other immigrants included Dr. Erik Knut Erwall, a radiologist/physician who emigrated from Sweden; Eugenio Lahaye, a Belgian engineer who became a prominent professional in the mining sector; Teofilo Reszca, a German engineer who filed many patent applications; and Charles Plisson, a French engineer who had previously published in a scientific journal in Chile. The case of Ana Augusta Weihers is also remarkable. While we found no evidence about her origin, her surname suggests that she might have migrated from Europe or been born to a migrant family (as was Juan Tonkin Thomas). She was one of the few women filing patent applications at the time and the only one seeking protection for the use of RES. She was a multiple patent applicant; unfortunately, and unlike many of the other individuals on the list, not one of her patent applications was granted.

Yet, as previously mentioned, many applicants were Chilean born, like Domingo Urzúa Cruzat, Liborio Brieba, Eulogio Allendes, and Eusebio Naranjo, among others. Most of them were members of the elite, intellectuals (such as Brieba and Urzúa Cruzat), and patent examiners (like Allendes, son of a politician and well-known university professor).

The above evidence suggests a multidirectional trend in the flow of knowledge and technology. Patents were filed by individuals who migrated from the northern hemisphere and stayed in Chile (e.g., Knut Erwall, Lahaye, Reszca); they originated in the Southern Hemisphere and flowed or travelled northward (Vargas Gamallo, Urzúa Cruzat, Tonkin Thomas; they emerged in Chile and stayed within its borders, with some formal dissemination (Brieba). There were also cases with little evidence of use or dissemination of technology at that stage (e.g., Naranjo). These individuals are not easily characterized as similes of the "green entrepreneurs" depicted elsewhere.[34] They appear to have been engaged as businesspeople and technicians; many

[31] Victor Vargas Gamallo, *La Apicultura nacional* (Santiago, 1900); *Nuevo sistema de colmenas de barras movibles* (Havana, 1914).

[32] Pablo de Benito, "Memoria sobre la situación económica de la República de Guatemala en el año de 1911" *Memorias diplomáticas y consulares e informaciones* 387 (1913):1-59.

[33] Harding, "Apparatus for Solar Distillation" (Oct. 1883); "Apparatus for Solar Distillation" (June 1883).

[34] Jones, *Profits and Sustainability*.

https://doi.org/10.1017/S000768051900062X Published online by Cambridge University Press

of them originated in Chile; so far there is no evidence of them being naturalists as early green entrepreneurs; and in some cases they migrated in person to export and expand their business.

Conclusion

This research note has examined patent-applicant data from a new database tracing evidence of interest in developing technologies using renewable energy in Chile between 1877 and 1910.

Starting in the 1870s, with the almost forgotten case of the solar distillation initiative at the Las Salinas nitrate plant in the North of Chile, we found significant evidence of technological development in Chile, engaging in different uses of a variety of renewable energies beyond solar, including wave, hydro, tidal, and wind power. We found eighty patent applications filed in this period and over ninety individuals engaged in the application process, mostly as applicants. Three-quarters of these actors were Chilean nationals, and their patent applications were primarily related to water energy sources. Some patent applicants living in Chile had immigrated from Europe. The preliminary analysis reveals that many patent applicants became authors of written works relating to their inventions in Chile and abroad after they filed the first patent application. Several individuals were investors and founders of companies, mostly after they applied for the corresponding patents. The three inventors who also obtained patents abroad were active businesspeople who developed an industry either in Chile or abroad.

The evidence examined in this research note suggests that the creation of renewable energy technology in Chile originated largely in Chile and was part of a business-led endeavor. While some of the actors involved in technological development had previously migrated from Europe, European participation decreased over time. There are examples of Chilean nationals successfully developing renewable energy technologies and exporting them to other nations. However, there are some cases in which we could not determine whether they were successfully implemented in the marketplace. In sum, we found mixed evidence regarding the origin and direction of the flows of knowledge. Mostly, knowledge originated in Chile, with inputs from migrants and Chilean nationals alike. We found evidence of the exportation of knowledge to the United States and Britain through foreign patents, as well as to other developing countries such as Guatemala and Cuba.

The evidence examined in this note suggests that Chile was in the process of developing new, novel, and "green" technologies much earlier than the 1960s. The evidence examined here suggests that Chile was forging a new and early path of sustainable economic development

by using clean energy sources within a framework of an open global economy, thus exploiting their comparative advantages. However, this trajectory may have been halted by subsequent global developments, notably World War I, and the subsequent collapse of the nitrate industry and the economic crisis of 1929.

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