Globalization and Technological Capabilities: Evidence from Mexico's Patent Records ca. 1870-1911

Globalización y capacidades tecnológicas: evidencia de los registros de patentes de México ca. 1870-1911

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Abstract

Using a new database of all patents issues in Mexico between 1870 and 1911, this paper explores the impact of the vast wave of technology imports into Mexico during the nineteenth century period of globalization. Historians have established that massive technology imports made possible sustained economic growth and early industrialization during this period, but have not systematically explored the degree to which the skills and know-how embodied in new imported technologies stimulated adaptive and inventive activity in Mexico. Did imported technologies stimulate local technological creativity, or were Mexican technicians largely isolated from the adoption and use of imported techniques? The evidence shows that imports did stimulate patenting activity by Mexicans, although this response was modest in relation to increased patenting by inventors from North Atlantic countries. In general, Mexican inventors focused on activities outside the core technical advances on the global frontier, and often on activities that were more entrepreneurial than technical, although we can observe several important exceptions. These findings support the argument that technological capabilities were scarce in Mexico and local technicians had few opportunities to engage with and learn from imported know-how.

Key words: *Technology, capabilities, patents.*

JEL Classification: *F69, N76, O14, O34.*

Resumen

Usando una base de datos nuevos, compuesta por todas las patentes que fueron concedidas en México entre 1870 y 1911, este artículo se enfoca en el impacto que tuvo en México la gran importación tecnológica que caracterizó la intensa época de globalización del siglo XIX. Los historiadores han argumentado que la importación masiva de tecnología tuvo un impacto directo en el crecimiento económico y el desarrollo industrial que caracterizaron este periodo, pero

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hasta ahora, no se ha explorado cómo y de qué manera el conocimiento y la destreza de esta nueva tecnología se desarrollaron en México. ¿Se generó una nueva creatividad tecnológica en México? La evidencia nos demuestra que las importaciones tecnológicas tuvieron un impacto positivo en el registro y crecimiento de nuevas patentes en México, pero, en comparación con los países del Atlántico norte, el impacto fue relativamente mínimo. En términos generales, los inventores mexicanos se enfocaron en actividades fuera de los avances de la frontera global, y, con algunas excepciones importantes, se dedicaron más a las actividades comerciales. Las capacidades tecnológicas eran escasas en México, y por lo tanto, los técnicos mexicanos tuvieron muy pocas oportunidades para generar sus propios inventos y aprender del conocimiento importado.

Palabras clave: *Tecnología, capacidades, patentes.*

Clasificación JEL: *F69, N76, O14, O34.*

1. Introduction

Historians have long recognized that Mexican economic growth from the 1870s to 1910 was intimately tied to expansion in the broader Atlantic economy, driven primarily by industrial growth in the countries of the North Atlantic. Rising demand there for industrial raw materials and foodstuffs, falling oceanic and overland transportation costs, and expanding North Atlantic exports of investment capital and technologies all provided the external conditions for late-century economic growth in Mexico and much of Latin America.

The most visible manifestation in Mexico of an expanding Atlantic economy was an increasing flood of foreign direct investment and the widespread adoption of foreign technology. "Technology" is here understood in the broadest sense: as knowledge and capabilities ("know-how") embodied in (1) physical hardware like tools and machinery as well as in (2) human beings and (3) print materials. We can easily observe the historical record of machinery and tool imports in commercial trade records, as well as in secondary works and as the rusting relics of industrial archeology (Nickel, 2005). Although less easily quantifiable, the other two venues for the importation of new technologies from the North Atlantic offered equally dynamic sources of new knowledge and skills. Alongside the hundreds of millions of dollars invested in technical hardware, tens of thousands of Americans and somewhat lesser numbers of British, German, French, and Belgian citizens came to Mexico from the 1870s to 1910. Some came on work assignments of a few weeks or months; others came and settled and stayed for a decade or a lifetime. Most of these could be considered immigrant technicians, carriers of accumulated technical know-how in their roles as investors, entrepreneurs, managers, engineers, mechanics, and skilled workers (Gómez-Galvarriato, 2013). At the same time, hundreds of pounds of print materials arrived daily aboard ships or trains, or via telegraph. Ranging from newspapers and commercial trade journals to blueprints, textbooks, advertising materials, and patent applications, print materials carried another form of technical knowledge that was quickly consumed in Mexico's cities, towns, and in more distant mining camps.

What was the impact of the imported technologies that flooded into Mexico ca. 1870-1911? On one hand, imported knowledge embodied in machinery, people, and print was installed in work settings across the country–in factories, construction sites, mines and mineral refineries, commercial farms and elsewhere. In each of these settings, technology imports expanded productive capacities and boosted productivity. On one hand, the adoption of new technologies critically underlay economic growth during the Mexican "Porfiriato" (1876-1911). New technologies were also, of course, intimately entwined in the economic and social changes that dislocated lives, but the distribution effects of late century technological change are a separate, though no less important, story.

On the other hand, the widespread adoption of new technologies says little about the impact of imported technical know-how on local, Mexican capabilities. Did imported knowledge stimulate local technological creativity–efforts to imitate, adapt, modify or improve? Or were Mexican technicians relatively isolated from the adoption and use of imported techniques, with few opportunities to work with and learn from new machines and processes and products? As a result, did imported know-how stymie local creativity, with little positive affect on Mexican capabilities? The broader literature on technology transfer suggests two opposing possibilities.

First, massive technology imports might bypass or actively displace opportunities for local, Mexican contributions. If domestic demand for technological innovation was satisfied primarily by foreign imports of machinery and technical personnel–whether for reasons of cost, quality, or cultural preference–then there may have been only a modest space for local responses to new opportunities. There would be little reason for Mexicans to devote their energy to technological invention, little incentive for local entrepreneurs to invest in the production of technological hardware, and few opportunities for Mexican engineers and mechanics to work in new enterprises. Historians have often argued, at least implicitly, that new technologies left only a weak imprint in Mexico. They posit a landscape sharply divided between a relatively small modern sector and the deeply traditional, largely static nature of Mexican life and culture. They focus on a deep chasm between foreign technology and Mexican culture, between elite visions and common experiences, between urban and rural Mexico, between industrial and artisanal practices, between a *México moderno* and an essentialized *México profundo* (Bonfil Batalla, 1996).

Alternatively, however, technology imports might stimulate local interest, engagement, and technological learning. In this scenario, technology imported as hardware or embodied in personnel or print materials might represent new opportunities to assimilate new knowledge and expertise and to stimulate a local engagement with global trends. New ideas and expertise embodied in technology imports might "spill over" to local entrepreneurs and technicians as they learned of or worked with new techniques. Potential inventors and mechanics might seek to imitate, adapt, or improve on imported techniques. Did the widespread adoption of new technologies in fact yield a local assimilation of new technical knowledge and skills? Did technology imports, in other words, yield effective technology transfer?[1]

Which of these two scenarios prevailed depended in large part on the extent of technological capabilities in Mexico.[2] What was the extent of local capacities to engage the central technological advances of the late nineteenth century: the mechanics of large-scale automated production, metal working, machine building, industrial chemistry, mineral refining, and electricity? Was the gap in technological know-how between foreign and local capabilities too large for local technicians to easily bridge, or were they able to creatively interact with and learn from imported knowledge? Policy makers of the era were pessimistic. They did not hope for a "Mexican Edison", nor did they do much to support the development of local ingenuity and innovation (Tenorio-Trillo, 1996). Reforms to the technical and engineering curricula in Mexico's schools of higher education were relatively modest, and new patent laws in 1890 and 1903 did not offer local technicians the kinds of formal opportunities to engage foreign invention and to legally protect their contributions that were found in the patent laws of many other late developers (Bazant, 1993; Beatty, 2001). Historians have generally asserted that technological capabilities were scarce in Mexico, but we do not yet have careful industry-level studies.

Although the scale and scope of technological change across Mexico's economic landscape between 1870 and 1910 has long been recognized, and although we get glimpses of this change in the secondary literature, we have few systematic histories of technology for this period.[3] None of the recent major works on Mexico's economic history treat technology in any explicit manner, despite its centrality to any explanation of economic growth and development.[4] And we have few firm-level studies that focus carefully on technology choices, and even fewer at the household level.[5] My book *Technology and the Search for Progress in Modern Mexico* (2015) offers one effort to examine patterns and consequences of technological change in nineteenth century Mexico. Building on several case studies (transport, steam power, and iron working early in the century, and sewing machines, glass bottle manufacturing, and precious metal refining late in the century), I argue that widespread adoption of new technologies did not yield significant assimilation of technological capabilities (Beatty,

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1 There is a vast literature on technology transfer in the post-war world; see, for instance, Rosenberg (1970) and (1982), Ruttan and Hayami (1973), and Katz (1985).

2 On "technological capacity" and "absorptive capacity" see Cohen and Levinthal (1990), Criscuolo and Narula (2008), Keller (1996), Solo, (1996) and for a Latin American application, Strassman (1968).

3 For the best extant treatments of technological change during this period, see Sánchez Flores (1980), Soberanis (1989), Blanco and Romero Sotelo (1997), Corona Treviño (2004), and Concha and Calleros (1996). For industry specific accounts that provide some coverage of technological change, see Keremitsis (1973), Gómez Galvarriato (2000), Velasco Avila et al. (1988), Bernstein (1964), Haber (1989), and Tortolero Villaseñor (1995).

4 See Bulmer-Thomas et al. (2006), Coatsworth and Taylor (1997), Haber (1997), Cárdenas et al. (2000), Kuntz Ficker (2010), and Cárdenas (2003).

5 For exceptions, see Gómez-Galvarriato (1990), Womack (2012), Kuntz Ficker (1995), and Guajardo (2010).

2015). This paper extends and modifies that argument by utilizing new evidence drawn from Mexico's patent records.

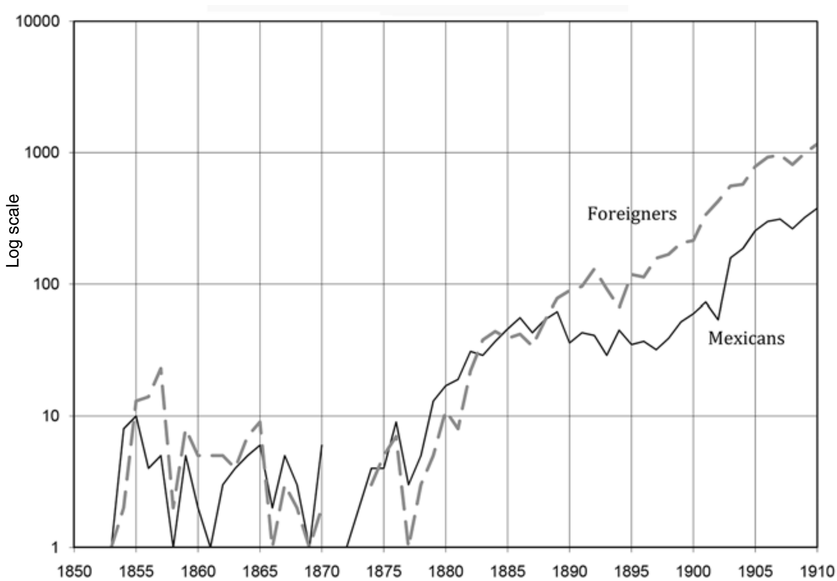
2. Mexico's Patenting Evidence

Patents provided one venue for technology imports in nineteenth century Mexico, carrying in their documentation a kind of announcement and technical description of new advances. For many in Mexico, patents provided first notice of inventions in the North Atlantic. Although patents offer a problematic window onto the history of technology generally, they can provide novel avenues of research onto the relationship between foreign technologies and local capabilities (Pavitt, 1988; Griliches, 1990). Mexico's Secretaría de Fomento issued about 14,000 patents from the middle of the nineteenth century to 1911; the vast majority of these issued over the last two decades of this period. However, the files housed in the *"Patentes y Marcas"* collection in the Archivo General de la Nación contain documentation on less than two thousand of this total (Soberanis, 1989). Using the patent notices printed in the annual and monthly publications of the Secretaría de Fomento, in the Gaceta Oficial de la Nación (before October, 1903), and in the Gaceta de Patentes y Marcas (after October, 1903) I have compiled a comprehensive digital database of the roughly 14,000 patents issued by Mexico through the long nineteenth century.[6] This paper represents a first effort to utilize this database to examine the impact of technology imports on local innovation.

Patenting in Mexico rose rapidly through the late nineteenth century. Rare before the 1870s (averaging less than five yearly), applications grew ten-fold between 1880 and 1890, and ten-fold again by 1905, reaching a 1907 peak that would not be reached and sustained again until the 1950s! Increasingly, most patent applications came from North Atlantic inventors and firms (Figure 1). Mexico conceded roughly 10,000 patents to foreign applicants compared to about 4,000 to Mexicans over sixty years (again, mostly between 1890 and 1910). Although the ratio varied over time, by the turn of the century roughly 80% of Mexican patents were being issued to foreign inventors, and roughly 20% to Mexicans. This ratio is roughly consistent with trends in other late developing countries. It should not be surprising, given that Mexican patent law after 1890 treated all patent applications equally, regardless of country-of-origin, and that almost 90% of patents across the globe came from a small handful of countries in the North Atlantic (the United States, Great Britain, France, Germany, and Belgium; see Figure 2). For firms in the North Atlantic, the practice of taking multiple foreign patents went hand-in-hand with broader strategies of foreign investment and intense competition to capture foreign sales markets. Mexico's patenting experience through this era of globalization differs little from the experience of Argentina, Brazil, and Chile (Beatty, Pineda, and Sáiz, 2015). Foreign patent applications provide one rough indication of the scale and scope

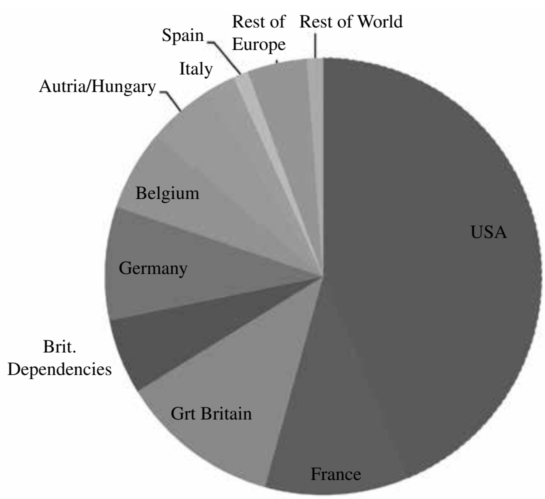
[6] For sources and further discussion see Beatty (2002) and Beatty and Sáiz (2007). The database will soon be available from the author at ebeatty@nd.edu or through the website http://www.ibcgrou.es/.

FIGURE 1
ANNUAL PATENTING BY MEXICANS AND FOREIGNERS IN MEXICO, 1850-1910 (LOG SCALE)



Notes: All patent data derived from the author's database of roughly 14,000 patents issued in Mexico 1850-1910.

FIGURE 2
DISTRIBUTION OF PATENTS GRANTED BY COUNTRY OF ORIGIN: THE WORLD TO 1912



Notes: Derived from Inkster (2002).

of new technical knowledge available to investors and consumers in Mexico–the so-called advantage of late development.

3. The Local Impact of Foreign Technology Imports

Patent records offer one window through which we can explore the extent to which Mexicans engaged with newly introduced foreign technologies. Recall our two opposing possibilities: foreign imports constrained opportunities for Mexicans to participate in technological activity, or foreign imports stimulated Mexican capabilities and offered new opportunities to invent, adapt, and modify. The patent records offer one way to glimpse the relative likelihood of these two paths.

To examine this issue we identify a number of Mexican industries that experienced between 1890 and 1910 an abrupt change in production methods with the introduction of new, large-scale automated machinery or production systems from the North Atlantic–what Joel Mokyr calls "macro-inventions (Mokyr, 1990). The manufacture of glass bottles, for instance, was revolutionized with acquisition of automated glass bottle blowing machinery after 1905; the cigarette industry expanded dramatically with the introduction of large scale cigarette rolling machines in the 1890s; and silver and gold mining experienced a major boom with the adoption of industrial-scale cyaniding plants to refine ores around the turn of the century. In these and other industries, we can locate the discrete moment(s) of technological change both in the narrative history of these industries and in the annual series of Mexican patent records. And in these and other industries, abrupt technological change began with the adoption of new production technologies from the North Atlantic.

How did Mexican engineers, mechanics, and tinkerers respond? Did they have the ability and the opportunity to work with and otherwise engage newly imported production technologies? Did major changes in production technology stimulate local efforts to imitate, modify, adapt, improve, or to otherwise engage in inventive and innovative activities related to the activity or industry in question? By examining the activity of Mexican patentees in the months and years following the introduction of the paradigm-shifting technologies in each case, we can begin to see the extent to which local capabilities were stimulated (or not) by technology imports. If local capabilities were scarce, or if the gap between local capabilities and foreign technologies was large, and if Mexican's had few opportunities to engage with and learn from the knowledge embodied in new technologies, we would expect to see little change in patterns of Mexican patenting before and after the introduction of a major new production technology from abroad. If, conversely, local capabilities were present, and local technicians were able to engage with and assimilate the know-how embodied in technology imports, we would expect to see the introduction of major new advances followed by a stream of local patents. This "stimulation effect" provides one indication of the impact of imported technology on local capabilities.

This paper presents a first look at several cases of Mexican industries that experienced dramatic change in production methods in the late nineteenth century. We locate the moment of disjuncture–the invention of a new production process in the North Atlantic, or its introduction in Mexico–and then examine

Mexican patent records in that field for evidence of a distinct shift in the level or patterns of patenting before and after. Ideally, we would assess the presence and significance of any shift in level and trend using statistical tests. Several factors, however, mitigate against this. First, the "moment" of introduction of a macro-invention from abroad is typically not as exact as it might seem. It is, in other words, not always clear what would be the appropriate date: the initial invention, or the first patent abroad; when the invention is first noted or advertised in Mexico; when it is first introduced or imported in Mexico; or when it is actually put into production, or into the market. What we are looking for is the moment when the new technology makes an impact in Mexico–when it gets noticed, attracts attention, and begins to stimulate new market opportunities. Our judgment here relies more on an understanding of the historical context than the exact moment of an act, and deserves the qualifier "roughly". Second, the annual level or number of patents in Mexico in any patent class (e.g. glass products, tobacco products, mineral refining) can be very low. Before the 1890s, annual numbers rarely exceeded single digits and often fell to zero, too low for robust statistical testing of trend lines. At the same time, as we will see, the "before" and "after" levels of patenting shift markedly in each case, often by a factor of ten or more, roughly correlated with the "introduction" of a new macro-technology. It is not difficult, in other words, to make a rough, eye-ball level assessment: does the appearance of a new macro invention stimulate a one-time change in local patenting activity, and if so, in what ways?

3.1. Glass & Glass Bottles

In 1903, Michael Owens of the Libbey Glass Company in Toledo Ohio patented the world's first fully automated glass bottle blowing machine. Although bottle manufacturers in the US and Europe had been working on automating the bottle making process for decades, Owens' machine represented a revolutionary jump over prevailing methods, and those gathered for its first public demonstration were reportedly "thunderstruck".[7] A newly organized Toledo Glass Company followed Owens' initial US patents with applications in Europe and, still in 1903, patents #3904 and #3271 in Mexico.

In Mexico as elsewhere, the greatest demand for glass bottles at the turn of the century came from beer brewers, as urban working and middle class Mexicans increasingly chose bottled beer over pulque and other alternatives (Gauss and Beatty, 2014). As a result of rising demand and the high cost of hand-blown glass bottles, two of the country's largest breweries raced to acquire the Mexican rights to the Owens system from Toledo Glass. Their directors had learned of the new machine shortly after its US debut through transnational business networks, and at least one had seen it exhibited at the St. Louis World's Fair in the Fall of 1904. By September 1905 the owners of the Cervecería Chihuahua had a deal with

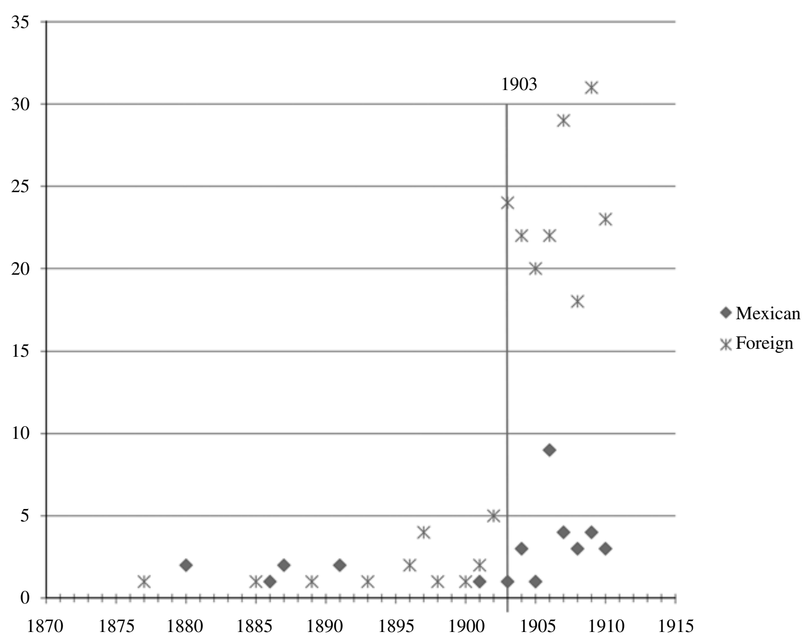
[7] Scoville, Revolution, 103-64, also the Toledo Glass Company, record book #1, 263. The story of the Owens machine in Mexico is drawn from the files of the Toledo Glass Company held at the University of Toledo, and the Juan Brittinghman archive at the Universidad Iberoamericana, campus Laguna. See also Scoville (1948), pp. 103-164 and Beatty (2015), chapter 5.

Toledo Glass, though it would take until 1912 and a partnership with the larger Cervecería Cuauhtémoc in Monterrey to commercialize the process in Mexico.

But news of the revolutionary Owens system in Toledo quickly stimulated an international wave of innovative activity related to glass bottles. We can see this reflected locally in a sharp discontinuity in patenting activity in Mexico (Figure 3). Before 1903, patenting of glass-related inventions in Mexico had averaged under two per year. But after 1903, the annual average immediately leapt to twenty-seven yearly. Whatever international market existed for glass bottle techniques before 1903, it had not yet touched Mexico. The appearance of the Owens machine changed this nearly overnight as a rapidly expanding North Atlantic market for glass bottle-related technologies quickly spilled over into Mexico. 87% of glass and glass bottle patents conferred in Mexico beginning in 1903 were taken by foreign applicants. The nearly two hundred foreigners who sought Mexican patent protection in the wake of the original Toledo Glass Company patents included 127 Americans, 17 Frenchmen, 16 Spaniards, and five or six from Germany, Britain, and Belgium, among scattered others (the country-origin ratios closely match the nationality distribution in the full Mexican patent database, with the British underrepresented in the glass bottle field and the Belgians overrepresented). Whether or not any of these worked directly to capitalize on their Mexican rights, they were all conscious of a new era in

FIGURE 3

ANNUAL PATENTS IN GLASS & GLASS BOTTLES, MEXICO 1870-1910



Notes: All patent data derived from the author's database of roughly 14,000 patents issued in Mexico 1850-1910.

which international markets for new technologies and their products would be an essential part of the glass business everywhere.

Did the appearance of the Owens machine stimulate Mexican invention as it did inventive activity in the North Atlantic? The numbers suggest at least a modestly significant response: from just eight domestic patents over the preceding four decades to nineteen over the eight years 1903-1910. Figure 3 separates Mexican and foreign patentees among the glass bottle patents. A closer examination of the nineteen Mexican patents offers a glimpse of the local response.

Most of the new patenting activity by Mexicans after 1903 targeted ancillary processes or design opportunities newly raised by the automated mass production of glass bottles. Developing new ways to easily and automatically cap glass bottles comprised by far the largest sub-category (see Table 1). Tops, caps, corks, seals, and processes to apply them dominate the Mexican patents, with over fifty percent of the total.[8] New designs for bottles were also prevalent, as were assorted systems and ancillary processes for washing, sterilizing, filling, and labeling bottles. Although the distribution of patents among these different sub-categories is roughly similar for Mexican and non-Mexican patentees, several distinctions are evident. First, foreigners took over twenty patents related to the actual manufacture of glass bottles while Mexicans took just one. Judging from the published descriptions, nearly all these foreign patents represent claims for mechanized bottle manufacturing, or improvements to the component parts thereof (new tank designs, automated blowing processes, conveying systems, etc.). Machinery design and manufacturing constituted the most technologically sophisticated branch of the industry, requiring a combination of large-scale and finely-tuned machine building skills and the ability to solve technical problems of design and operation that characterized much of the new automated technologies of production in the North Atlantic's so-called second industrial revolution. As a result, the majority of patents in this area originated from North Atlantic countries with strong, longstanding local traditions of both machine building and glass bottle manufacturing. While a few Mexican firms had produced glass bottles for generations–by hand–there was virtually no domestic expertise in machine building (Beatty, 2015, chapters 3, 7).

Second, Mexican's comparative advantage relative to foreigners lay not in the automated manufacture of glass bottles, but in the commercial challenges of using them. We can see in Table 1 a significant difference in the direction of patenting between foreigners and Mexicans in the glass bottle field. Many of the Mexican patents after 1903 sought to "*apagar y decorar*", apply "*esmalte o barniz*", or otherwise proposed new external decorations and designs. Capping and bottle design were the only two areas where the relative weight of Mexican innovation exceeded the relative weight of foreign innovation. We can observe, in other words, a modestly significant Mexican response to the opportunity represented by the Owens macro-invention, as Mexicans sought patents that circled around the core mechanical challenges of manufacturing. The evidence suggests that Mexicans responded to the new market opportunities created by

[8] *Tapas, cubiertas, casquetas, tapones, corchos, cerraduras, cierres, etc.* There are also many patents for capping, covering, and enclosing systems in class M.IV, "*Envases*", although most if not all of these do not apply to narrow necked glass bottles.

TABLE 1
Patenting Subclasses within Glass & Glass Bottles, Mexico 1870-1910
(Percentages)

Sub-classes	Mexican (%) (N=36)	Foreign (%) (N=208)
A. Glass manufacture	6	6
B. Bottle manufacture	3	9
C. Bottle design	17	11
D. Bottle capping	56	51
E. Other	19	22

Notes: All patent data derived from the author's database of roughly 14,000 patents issued in Mexico 1850-1910.

the introduction of the Owens technology and sought their own space in the rapidly expanding international market. In fact, Mexican patents in the glass field increased on by four-fold almost immediately after the Owens introduction. The particular nature and technical requirements of the automating glass bottle production meant that Mexicans were not well equipped to engage the manufacturing process directly, and as a consequence sought opportunities in complementary products and processes.

3.2. Cigarette Manufacturing

Cigarette manufacturing, like glass bottle production, underwent a revolutionary disjuncture in production technology at the end of the nineteenth century. Until the 1880s, cigarettes in Mexico and elsewhere were produced by hand in workshops and factories, each rolled individually by workers (usually women) sitting at tables or desks, with children (often young girls) regularly refilling boxes of cut tobacco and rolling papers. In 1883 James Bonsack developed the first viable automated rolling machine, installed the following year in the factories of James Duke in North Carolina. The Bonsack Machine company took its first Mexican patent in 1889 for improvements in its machine to manufacture cigarettes. At the same time, Anatolio Decouflé developed an automated machine in France, quickly patented there and in the United States. Two years later Mexico issued a patent to Decouflé for his "perfected machine to make cigarettes without glue", which competed directly with the Bonsack machine.[9] Over the next decade the Bonsack company would take at least six more Mexican patents for various improvements in its machine, while Decouflé's company took two more, one as late as 1907. Mexico's "Buen Tono" cigarette company, established by Ernesto Pugibet and others in 1894, imported and installed a number of Decouflé

[9] The first Bonsack patent recorded is May 27, 1889, without number; the first Decouflé patent is September 24, 1891, #160. We do not yet have a good history of the modernizing tobacco industry during this period; for partial accounts, see Haber (1989) and Bunker (2012).

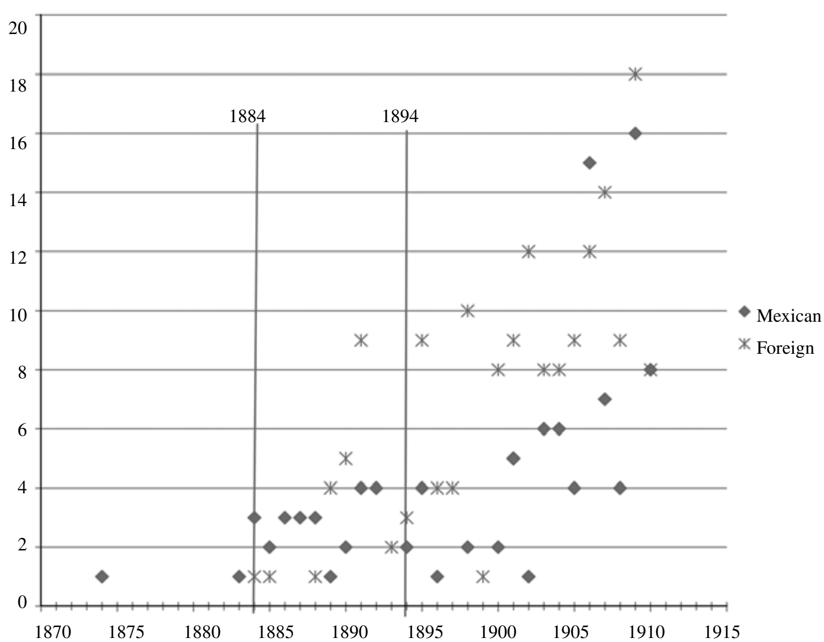
machines in its Mexico City factory, while competing tobacco firms imported and installed Bonsack machines in the 1890s.

These automated machines yielded an extraordinary leap in worker productivity and the cigarette industry's output capacity everywhere they were adopted, and subsequent improvements increased the machines' efficiency and scale. Over the following decades, inventors working on ancillary devices and processes further contributed to the mechanization and efficiency of the industry in the United States and Europe: conveyor belts to carry inputs to the machine, the design and manufacture of boxes and cartons, and methods to pack them with cigarettes; the production of cigarette paper, tipping, and filters; the placement of filter tips on cigarettes; the printing and folding of labels for cartons; and of course the stemming, trimming, flavoring, and cutting of the tobacco itself.

As with automated glass bottle technology, patents for tobacco and cigarette technologies were nearly absent before the invention of the Bonsack machine. Until 1884 there was only one patent in the class, for the "manufacture of fiery cigars and cigarettes". Foreign patent applications begin trickling into Mexico after 1884, although the numbers remain low until the early-to-mid 1890s (Figure 4). Patents from Mexicans, which also had been extremely scarce before 1883, appear regularly in each year thereafter. Though the numbers are low, Mexican patents outnumber foreign patents for tobacco products before 1894, one of the

FIGURE 4

ANNUAL PATENTS IN TOBACCO & TOBACCO PRODUCTS, MEXICO 1870-1910



Notes: All patent data derived from the author's database of roughly 14,000 patents issued in Mexico 1850-1910.

few such cases in the country's broader patenting history. In fact, both Mexicans and foreigners took more tobacco-related patents relative to other fields than in any other subperiod of the late nineteenth century.

Patents for tobacco products experienced two distinct jumps, one about 1884 and one about 1894, each corresponding closely with important moments in the technology history. The first matches the invention and international innovation of the Bonsack machine, while the second follows immediately on the founding of the Mexican firm that would import the Decouflé machine and go on to dominate the Mexican industry. El Buen Tono installed the Decouflé automated cigarette machines in order to compete directly against its main rival, La Tabacalera Mexicana, holder of the Bonsack patent rights The Bonsack company immediately brought an infringement suit against Buen Tono, which dragged through the Mexican courts for several years. After losing in a District court in 1898, the Second Circuit court upheld Buen Tono's Decouflé patent in 1899 and the company increased its capital by 150% to build a second factory. A year later, the Mexican Supreme Court confirmed the decision to uphold the Decouflé patent and judged the Bonsack patent to be an infringement. Once the uncertainty created by the legal conflict had passed, tobacco-related patenting surged again, with increased numbers of patents taken by both foreigners and Mexicans. In sum, before 1885 there had been no market for tobacco product-related technology in Mexico, despite the long history of manufacturing enterprises in the country. By the first decade of the new century that market had expanded from under two patents yearly to nearly twenty.

In contrast to the glass bottle industry, in tobacco products the direction of Mexican and foreign patenting aligned much more closely. Though foreigners took nearly twice as many patents as Mexicans, roughly half of all Mexican and foreign patents claimed advances in processes or equipment related to the actual manufacture of cigarettes and cigars (see Table 2). Mexicans were only slightly less represented in the manufacturing sub-class than were foreigners (in both relative weight and in absolute number: 47% (or fifty two patents) compared to 54% (or ninety four patents). The relative strength of Mexican's participation in the manufacturing dimension is significantly stronger than in the

TABLE 2
PATENTING SUBCLASSES WITHIN TOBACCO & TOBACCO PRODUCTS, MEXICO 1870-1910

Sub-classes **	Mexican (%) (N=110)	Foreign (%) (N=169)
A. Tobacco treatment	6	9
B. Cigarette & cigar manufacturing	47	54
C. Cigarette packaging	16	16
D. Cigarette paper	12	2
E. Matches	5	6
F. Other	13	12

Notes: All patent data derived from the author's database of roughly 14,000 patents issued in Mexico 1850-1910.

glass bottle industry. Mexico, of course, was both a producer of tobacco leaf and had a long tradition of tobacco manufacturing, based primarily in the colonial tobacco monopoly as well as in hundreds of small scale, often home-based and entirely artisanal manufactories (Deans-Smith, 1992). This long history provided an environment where, it seems, a relatively larger number of Mexicans were ready to participate as innovators in the modernization of the productive process.

Ernesto Pugibet and his Buen Tono company together account for nineteen of the fifty-two Mexican patents in this field. Pugibet's individual patents all come after the initial Bonsack patent but before the first Decouflé patent, and focus on ancillary processes like cutting tobacco and boxing cigarettes as well as on machine manufacturing. Buen Tono's patents begin in 1895, one solicited together with Decouflé, and continue through 1910, ranging from various improvements in the manufacturing process (7 of 14) to mechanisms for absorbing tobacco dust, cigarette mouthpieces, and industrial models of cigarette cases. In other words, Pugibet and El Buen Tono produced an intriguing string of patents both before and after the original Decouflé macro-invention, suggestive of some kind of in-house research and development capacity, if yet informal and ad hoc. However, we do not yet have a good firm-level account of Buen Tono's operations that would tell us who was developing these improvements and exactly what their relationship was to the original Decouflé technology.

As in the glass business, the tobacco products subfield with the highest concentration of Mexican participation was one of the less technologically sophisticated: patents in cigarette paper, including methods to manufacture, sanitize, and otherwise prepare the paper. In general, however, the percentage growth in tobacco-related patenting by both Mexicans and foreigners after the 1890s are smaller than the percent growth of patenting by each group, across all economic activities. The evidence in Figure 4 suggests that the dramatic modernization of the global tobacco industry in the 1880s and 1890s stimulated a sharp expansion in the market for tobacco product technologies across the Atlantic world. Though inventors and firms in the North Atlantic would dominate this market–as they did in the glass business–Mexican inventors and entrepreneurs proved able to respond, to engage the new technologies, and to take advantage of new market opportunities.

3.3. Gold and Silver Refining

Across the globe in the nineteenth century, miners utilized several different methods to separate gold and silver from less valuable rock. Where the precious metal was loose and oxidized, crushing and gravity-based sluicing sufficed to do the work. Smelting ore in furnaces dominated practice in other places, especially where fuel costs were not prohibitive. But for three hundred years, the dominate refining method in the Americas and in many parts of the world was the mercury amalgamation process, first developed in Mexico in the 1550s. In Mexico and elsewhere, mercury amalgamation (the "patio" process, after the broad patios where crushed ore and mercury were mixed, often by mules or sometimes human feet) still refined most ore in the late nineteenth century. However, by then most of the easily accessible, high-value silver and gold ores had been exhausted, and the rising costs of ever deeper shafts and tunnels and ever lower and more recalcitrant ores pushed costs above yields and profits.

In Mexico, and in many global mining districts, precious metal mining found itself in crisis and in desperate search for new methods (Velasco Avila et al., 1988; Beatty, 2015).

Two chemists working in Britain for the Cassel Gold Extraction Company succeeded in developing a new refining process in the late 1880s, using cyanide: the MacArthur-Forrest cyanide separation process. Developed to address the challenge of refining low grade gold-bearing ores, the process was pushed by the proprietary firm to gold districts in South Africa, Australia, New Zealand and, a bit later, in the United States. News of the process spread in Mexico quickly, by the early 1890s, with some experimentation and early, partial adoption in a few gold mines. But Mexican ores were overwhelming silver heavy, and silver had been the dominant product of the country's industry since the sixteenth century. Into the early years after 1900, miners working in Mexico remained deeply skeptical about the potential of adapting the cyanide process to silver ores. Yet extensive experimentation in the Guanajuato district and elsewhere yielded new techniques that, by 1904, allowed the application of cyanide to silver, and the process quickly diffused through the country, pushing mercury amalgamation nearly to extinction.

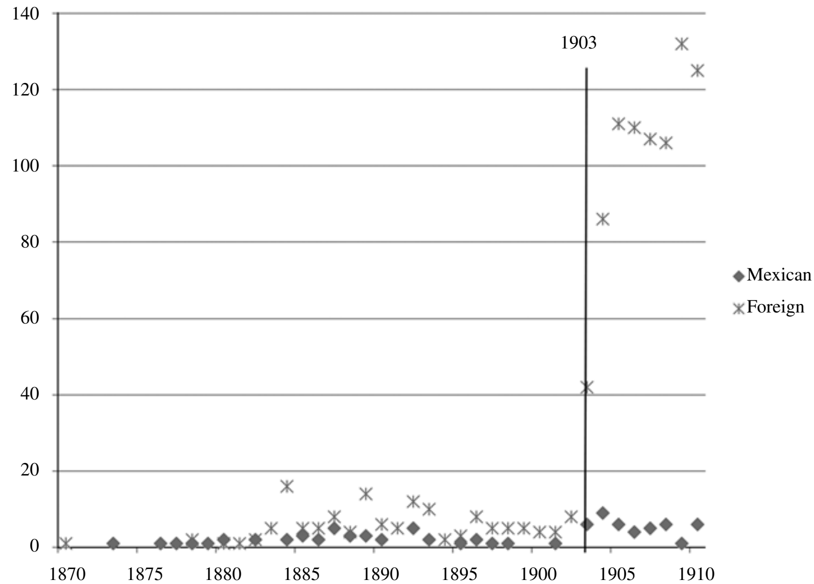
We can see this history clearly reflected in Mexico's patent records. The patent subclass for gold and silver refining techniques had long been an active one, with over one thousand total patents between 1870 and 1910. Through the last decades of the nineteenth century, annual patents numbered about ten yearly. Early discussion and experimentation of the MacArthur-Forrest process did not immediately affect patenting in Mexico. The Cassel Company set up a subsidiary in Mexico–the Mexican Gold & Silver Recovery Company–and took two patents in 1893 and two in 1896, but for a decade there would be no significant change in annual patenting levels. This changed dramatically and nearly overnight with the successful adaptation of the cyanide process to silver ores and the diffusion of the process in Mexican districts through 1904-1906. Annual patenting jumped from its hitherto steady level of about ten yearly to nearly fifty and then around one hundred twenty yearly through the rest of the decade (Figure 5).

But the dramatic expansion of patents for new techniques related to the refining of gold and silver ores was wholly the result of foreign patenting. Mexican technicians, miners, and mining engineers played no part. This is striking, given the proud history of mining expertise in the country that produced the dominant refining technology three centuries earlier. In the late eighteenth century, Mexico was home to the first technical school in the Americas–the Royal Mining College, and its proud graduates played prominent roles in national life through the nineteenth century. As late as the 1870s and 1880s, Mexican miners and engineers directed the majority of the nation's mining and refining activity. What had happened?

The patent records ratify the story we can piece together from the archival records. In short, the cyanide process and other new mining and refining techniques of the 1890s were very much products of the second industrial revolution: large, industrial-scale process heavily dependent on the nearly emergent fields of industrial chemistry, electricity, and machine building. Those who proved able to engage these fields were trained in mining colleges of the United States, Britain, and Germany. Mining was no longer a game of chance bonanzas or

FIGURE 5

ANNUAL PATENTS IN PROCESSES TO REFINE GOLD & SILVER, MEXICO 1870-1910



Notes: All patent data derived from the author's database of roughly 14,000 patents issued in Mexico 1850-1910.

rule-of-thumb judgment, but an industrial science. Experimentation and adaptations–the "micro-inventions" that, for instance, succeeded in adapting the cyanide process to silver ores–required both high levels of formal training and information-sharing, via connection to global networks of mining engineers through journals like the *Mining and Scientific Press* and the *Engineering and Mining Journal*. Mexican engineers could simply not compete, and we can see this in the sharp separation in national patenting trends in Figure 5. Over the full period, Mexicans took just 85 patents to the 960 taken by foreigners in this subclass, with most of this large gap coming after 1903. The introduction and diffusion of the revolutionary new cyanide separation process, in other words, had little or no capacity-building impact on Mexican mining technicians except to wholly squeeze them out of the industry.

4. Conclusions

This paper has examined Mexico's response to the globalization of markets and technologies at the end of the nineteenth century. Mexico's increasing exposure to North Atlantic technologies generated economic growth and new opportunities for investment and innovation. Did this process include new opportunities for Mexican inventors? Did it yield experiences of local learning and acquisition of technological knowledge and skills, stimulating local, Mexican efforts to imitate, adapt, modify, and improve foreign advances, or to otherwise respond creatively? The evidence presented here is only suggestive, and needs further extension in several directions. First, we need to extend this analysis to other activities and sectors. We have presented just three cases here, but similar patterns appear to be present in other activities and industries as well: in the processing of agricultural products, in preserved foods and food products that benefited from refrigeration, in some chemical fields, and of course in the generation and application of electrical power for lighting and motive force. Second, we need to look more closely at the experience of individual Mexican patentees and inventors within particular industries, activities, and firms. We need detailed case studies of experiences "on the shop floor" and within patentee's workshops. At present, however, we can offer several tentative conclusions.

First, the introduction of new "macro-inventions" in the North Atlantic clearly stimulated increased patenting activity by Mexicans, although this response was modest in relation to the increase in patenting by inventors in the North Atlantic. Second, Mexicans did not tend to work and patent in technical areas related most directly to the core advances of global frontier technologies. Without any local foundation for precision metal working and machine tooling (for example), Mexican technicians often turned their attention to areas further from the technical core. In the glass bottle industry, increased patenting by Mexicans was directed toward the activities of capping, filling, cleaning, and labelling bottles. In the cigarette industry, Mexican technicians were apparently able to work with the mechanics of automated production, but also worked in ancillary activities of manufacturing paper and matches, for example. In the mining sector, however, Mexican technicians appear to have been entirely shut out of the market for innovations: despite a dramatic expansion in that market following the diffusion of the new cyanide separation process, the level and direction of patenting by Mexicans remained unaffected.

Overall, we can observe both technical and entrepreneurial responses to the introduction of new macro-inventions. In some areas, Mexicans were able to directly engage the central core technologies and components of new, large-scale and automated production machinery and systems. This was the case, for example, in automated cigarette manufacturing, but not in the automated glass bottle system. Until firm-level histories can reconstruct what went on inside the workshops of El Buen Tono and other firms in this and other industries, we can only speculate what these patents represent. When the technological capacities to directly engage new systems were relatively scarce in Mexico, local technicians sought to engage new opportunities in ancillary aspects of the production process, or in activities linked upstream or downstream from the core of the new advance. Mexicans were clearly quick to identify the potential new markets and opportunities generated by imported technologies. They were quick to respond to these market signals, sometimes in anticipation of major new investments. Even when technical expertise at the global frontier was scarce, entrepreneurial instincts were not, and focused local attention on technical challenges and opportunities within reach of local capabilities. Nevertheless, the technology gap between local and foreign technical knowledge and expertise loomed large.

Mexico's experience was in some ways not at all unique in the late nineteenth century world. The dramatic expansion of the North Atlantic industrial economies between about 1870 and the 1920s pushed investment capital and new technological know-how across the globe, embodied in tools and machinery, in the bodies of engineers, mechanics, and skilled workers, and in print materials like patents. Only rarely were those on the receiving end able to engage, assimilate, and learn from novel technology imports, thereby establishing a foundation of local capabilities to imitate, adapt, modify, improve, and in the long run invent and innovate independently of imported expertise. Japan is of course the canonical case. Nearly everywhere else, the constraints to engaging and learning proved substantial. In Mexico, the engagement we can observe in the patent records happened in spite of substantial obstacles to learning.[10]

First, interactions between imported technologies and local workers and technicians were often limited. Given the relative scarcity in Mexico of experience working with technologies of the global frontier, it was cheaper and easier for investors to hire foreign expertise to install and operate new machinery than to train Mexican workers. Local workers' interaction was often limited to relatively simple tasks of operation, performing ancillary activities, and perhaps simple maintenance and trouble shooting. In contrast, the spillover of products, technologies, and expertise embodied in thousands of young men from the North Atlantic substituted for local scarcity, but it also displaced opportunities for local engineers and workers. As a result, most opportunities for interaction with new knowledge and thus for technological learning were monopolized by foreign technicians, and Mexico lost the opportunity that technology imports might have stimulated even deeper forms of local learning and enhanced domestic technological capabilities.

Second, the gap between technical know-how in Mexico and in the North Atlantic proved too great to easily bridge. Late nineteenth century inventions drew heavily on new scientific knowledge and forms of technological expertise honed over a century of industrial growth in the North Atlantic. Metallurgy, machine tooling, the chemical industry, and the generation, distribution, and application of electricity lay at the center of the second industrial revolution. But Mexico had missed much of the earlier wave of industrial and mechanized technologies of the first industrial revolution. As a result, the country had only a weak foundation of expertise with which to engage the new onslaught of advances it faced in the North Atlantic market. Few cases illustrate this better than the very slow diffusion of steam power and iron working capabilities through the nineteenth century. Without local expertise in the operation, adaptation, repair, and replication of these basic foundations of the industrial experience, Mexican technicians had limited capacity to assimilate the technical know-how embodied in a wholly new generation of late century technologies.

Third, technical education programs proved unable to supply the engineers and technicians who might have worked to bridge the gap between Mexico and the North Atlantic. Despite some investment in new programs and curricular reforms, graduates numbered only a relative handful and did not fill the capacity of new programs. This was true for both basic training programs for workers as well as for the country's engineering schools. Few alumni of the latter played a major role in applied work, in mastering the know-how at the center of new

[10] See Beatty (2015) for a more complete account of these five issues.

advances and working out–in the field or on the shop floor–the technical challenges of adopting and adapting imported technologies to local settings. From the perspective of investors, hiring the know-how from abroad was cheaper in the short run, reinforced by the kinds of ethnic preferences that so frequently marked divisions between skilled and unskilled labor in Mexican mines, in factories, and throughout the economy.

Fourth, even when Mexican entrepreneurs and technicians acquired new knowledge about foreign technologies, there were few local or national networks for sharing that knowledge. On the one hand, the nineteenth century witnessed a flowering of government-sponsored and privately organized societies and associations for the promotion of science and commercial enterprise. Both the government and business associations sponsored scientific and technical expositions and diverse publications that presented recent advances within the country. Although we need further research on the nature and operation of these kinds of associations, few provided effective venues for the diffusion of knowledge and expertise in Mexico. This was especially true for the vertical diffusion of knowledge and skills through society, from the small number who acquired advanced education and training to the majority of engineers, technicians, and especially mechanics and workers. The few glimpses we have in the secondary literature of the social relations of work within mines and factories suggest that constraints to skill sharing and to learning outweighed facilitating factors.

Finally, government policies did little to directly promote technological learning. Trade policies persistently favored access to capital and technical hardware from abroad instead of promoting local learning at home. Although tariffs increasingly sought to protect many domestic manufacturing industries, protection was limited to consumer goods and some basic producer goods like cement, structural iron and steel, and paper. There was no sustained debate about the desirability of supporting the domestic manufacture of tools and machinery. Indeed, the principle consumers of technological hardware across the economy made it abundantly clear that their success depended on free and easy access to the new machinery available in the North Atlantic. Both formal policy and informal norms favored the employment of US or European engineers and technicians over their Mexican counterparts, even if the latter were available, capable, and more economical. The political economy of technological change, in other words, overwhelmingly favored borrowing while it undermined opportunities to develop domestic expertise.

References

Bazant, M. (1993). *Historia de la educación durante el Porfiriato*. Colegio de México.

Beatty, E. (2001). *Institutions and Investment: the Political Basis of Industrialization in Mexico before 1911*. Stanford University Press.

Beatty, E. (2002). "Patents and Technological Change in Late Industrialization: Nineteenth Century Mexico in Comparative Context". *History of Technology,* vol. 24; 121-150.

Beatty, E. and P. Sáiz (2007). "Propiedad industrial, patentes e inversión en tecnología en España y México (1820-1914)". In R. Dobado, A. Gómez-

Galvarriato, and G. Márquez, eds. *México y España ¿Historias económicas paralelas?* Fondo de Cultura Económica.

Beatty, E. (2015). *Technology and the Search for Progress in Modern Mexico*. University of California Press.

Beatty, E.; Y. Pineda and P. Sáiz (2015). "Technology in Latin America's Past and Present: New Evidence from the Patent Records". Manuscript.

Bernstein, M. (1964). *The Mexican Mining Industry 1890-1950: A Study in the Interaction of Politics, Economics, and Technology*. State University of New York.

Blanco, M.and M. Romero Sotelo (1997). *Cambio tecnológico e industrialización*. DGAPA-FE-UNAM.

Bonfil Batalla, G. (1996). *México Profundo: Reclaiming a Civilization.* University of Texas Press.

Bulmer-Thomas, V.; J. Coatsworth, and R. Cortés Conde, eds. (2006). *The Cambridge Economic History of Latin America, Vol I: The Colonial Era and the Short Nineteenth Century* and *Vol. II: The Long Twentieth Century*. Cambridge University Press.

Bunker, S. (2012). *Creating Consumer Culture in the Age of Porfirio Díaz.* University of New Mexico Press.

Cárdenas, E.; J. Ocampo, and R. Thorpe, eds. (2000). *An Economic History of Twentieth-Century Latin America*, 3 vols. Palgrave Macmillan.

Cárdenas, E. (2003). *Cuando se originó el atraso económico de México: la economía mexicana en el largo siglo XIX, 1780-1920.* Biblioteca Nueva.

Coatsworth J. and A. Taylor, eds. (1999). *Latin America and the World Economy Since 1800*. Harvard University Press.

Cohen, W. and D. Levinthal (1990). "Absorptive Capacity: A New Perspective on Learning and Innovation". *Administrative Science Quarterly*, vol. 35; 128-152.

Concha G. de la and J. Calleros (1996). *Los Caminos de la Invención: Inventos e inventores en México*. Instituto Politécnico Nacional.

Corona Treviño, L. (2004). *La tecnología, Siglos XVI al XX*. Universidad Nacional Autónoma de México.

Criscuolo P. and R. Narula (2008). "A novel approach to national technological accumulation and absorptive capacity: Aggregating Cohen and Levinthal". *The European Journal of Development Research*, vol. 20; 53-73.

Deans-Smith, S. (1992). *Bureaucrats, Planters, and Workers: The Making of the Tobacco Monopoly in Bourbon Mexico*. University of Texas Press.

Gauss, S. and E. Beatty (2014). The World's Beer: The Historical Geography of Beer in Mexico, in M. Patterson and N. Hoalst-Pullen, eds. *The Geography of Beer: Regions, Environment, and Societies*. Spring; 57-66.

Gómez-Galvarriato, A. (2013). *Industry and Revolution: Social and Economic Change in the Orizaba Valley, Mexico*. Harvard University Press.

Griliches, Z. (1990). "Patent Statistics as Economic Indicators: A Survey". *Journal of Economic Literature*, vol. 28, December; 1661-1707.

Guajardo, G. (2010). *Trabajo y tecnología en los ferrocarriles de México*. El Centauro.

Haber, S. (1989). *Industry and Underdevelopment: The Industrialization of Mexico, 1890-1940*. Stanford University Press.

Haber, S. (1997). *How Latin America Fell Behind: Essays on the Economic History of Brazil and Mexico, 1800-1914*. Stanford University Press.

Horacio Gutiérrez Crespo, H. (1980). *Historia del azúcar en México*. Fondo de Cultura Ecónomica.

Inkster, I. (2002). "Patents as Indicators of Technological Change and Innovation - An Historical Analysis of Patent Data 1830-1914". Paper presented at the Meeting of the Newcomen Society, London.

Katz, J. (1985). "Domestic Technological Innovations and Dynamic Comparative Advantages". In N. Rosenberg and C. Frischtak, eds. *International Technology Transfer: Concepts, Measures, and Comparisons*. Praeger; 127-166.

Keller, W. (1996). "Absorptive Capacity: On the Creation and Acquisition of Technology in Development". *Journal of Development Studies*, vol. 49; 199-227.

Keremitsis, D. (1973). *La industria textil mexicana en el siglo XIX*. SepSetentas.

Kuntz Ficker, S. (1995). *Empresa extranjera y mercado interno: el Ferrocarril Central Mexicano, 1880-1907*. Colegio de México.

Kuntz Ficker, ed. (2010). *Historia económica general de México*. Colegio de México.

Mokyr, J. (1990). *Lever of Riches: Technological Creativity and Economic Progress*. Oxford University Press.

Nickel, H. (2005). *Vestigios de las haciendas henequeneras de* Yucatán (siglo XIX y XX). Instituto Ibero-Americano Berlin.

Pavitt, K. (1988). "Uses and Abuses of Patent Statistics". In A. Van Raan, ed. *Handbook of Quantitative Studies of Science and Technology*. Elsevier Science Publishers; 509-536.

Rosenberg, N. (1970). "Economic Development and the Transfer of Technology: Some Historical Perspectives". *Technology and Culture*, vol. 11; 550-575.

Rosenberg, N. (1982). *Inside the Black Box: Technology and Economics*. Cambridge University Press.

Ruttan V. and Y. Hayami, (1973)."Technology Transfer and Agricultural Development". *Technology and Culture*, vol. 14; 119-151.

Sánchez Flores, R. (1980). *Historia de la tecnología y la invención en México: introducción a su estudio y documentos para los anales de la técnica*. Fomento Cultural Banamex.

Soberanis, J. (1989). "Catálogo de patentes de invención en México durante el siglo XIX (1840-1900). Ensayo de interpretación sobre el proceso de industrialización del México desimonónico". Tesis de Licenciatura, UNAM.

Solo, R. (1966). "The Capacity to Assimilate an Advanced Technology". *American Economic Review,* vol. 52, Nº 1-2; 91-97.

Strassman, P. (1968). *Technological Change and Economic Development: the Manufacturing Experience of Mexico and Puerto Rico*. Cornell University Press.

Tortolero Villaseñor, A. (1995). *De la coa a la máquina de vapor: Actividad agrícola e innovación tecnológica en las haciendas mexicanas 1880-1914*. Siglo XXI.

Velasco Avila, C.; E. Flores Clair, A. Parra Campos, and E. Gutiérrez López. (1988). *Estado y minería en México (1767-1910).* Fondo de Cultura Económica.

Womack, J. (2012). *El trabajo en la Cervecería Moctezuma.1908.* Colegio de México.