Do Patents Foster International Technology Transfer? Evidence from Spanish Steelmaking, 1850-1930.

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International technology transfer is the conveyance of processes, goods, and new ways of organizing production from one country to another. Throughout history, late industrializing countries have relied on sundry methods to acquire technology from the industrial frontier. Among the most time-honored measures practiced by governments and firms in developing nations, some of which date to the Seventeenth Century, are: conducting industrial espionage; enticing skilled technicians to immigrate to their shores; sending their best and brightest students abroad to identify, study, and absorb the latest innovations; importing machinery; and courting foreign direct investment (FDI). A more recent conduit of international technology transfer, dating to around the Second Industrial Revolution, is individuals and firms in developing countries signing licensing agreements with foreign patent holders in exchange for royalties and other perks.

When and why do late industrializers opt for protecting the intellectual property rights (IPR) of foreign inventors in order to facilitate technology transfer from the industrial frontier? Are patents a substitute for industrial espionage, skilled labor from abroad, imported machinery, and joint ventures? Or do they complement those measures?

This chapter addresses these questions by telling the story of when and how technology was transferred via patent licensing from the industrial frontier to Spanish iron and steelmakers. It focuses on the period between 1850 and 1929, during which foreigners' IPR were relatively well protected, as reforms to the Spanish patent system in late 1929 strengthened introduction patents at the expense of original inventors. Not coincidentally, the most important transfer of iron and steel technology to Spanish firms occurred between 1850 and 1929.[1]

Modern steelmaking was a quantum leap over previous techniques vis-à-vis scale and sophistication. In turn, this required a revolution in technology, knowledge, and skills. However, the transition to modern steelmaking was marked by a challenging process that has gone largely unrecognized by researchers: inventors had to find ways to transfer tacit knowledge to adopters that was inordinately difficult to codify, as it was arrived at via intuition and learning-by-doing.

The technical, managerial, and marketing knowhow that complements inventions cannot be disclosed in a patent itself. Provided that there is an IPR regime that protects foreigners, however, it will be willingly shared by original inventors in the industrializing frontier with licensees in the developing world. Licensing agreements outline an ongoing relationship between these parties that enables them to work together and adjust inventions to differences in raw materials and other inputs, industrial organization, and consumer tastes.

In conjunction with importing machinery, procuring technical assistance from foreign firms, and hiring skilled labor from abroad, Spanish firms used IPR to acquire, learn, and improve new iron and steelmaking technologies from France, Belgium, England, and Germany. Patents played a key role in broadcasting new steelmaking techniques to Spaniards working in that industry. Similar to the story told by Lamoreaux and Sokoloff (2003) about the United States, Spanish entrepreneurs, managers, engineers, and metalworkers scoured the patent record to learn about and acquire new inventions. Patents also helped Spaniards connect with original, foreign inventors and establish enduring relationships with them. The latter shared their knowhow and expertise with the former under the aegis of licensing agreements and brought them into their networks of suppliers and technicians. Moreover, when disruptive steelmaking innovations were patented in Spain, this spurred second generation foreign inventors to patent improvements. It also induced Spanish inventors to come out of the woodwork and contribute their own add on innovations to iron and steelmaking—inventions they themselves patented.

To tell the story, this chapter does several things. I outline the history of the Spanish patent system, which experienced four major changes that affected the ability of foreigners to protect their intellectual property and thus affected international technology transfer. I elucidate the basic political economy behind each IPR system. I identify and explain the major process inventions around modern iron and steelmaking elaborated in industrialized countries. I explore when the inventors behind these innovations obtained Spanish patents and the details behind those patents. I investigate how they transferred their knowhow to Spanish firms via patent licenses and identify follow-up innovations patented in Spain by both foreigners and Spaniards.

While I exploit a seemingly esoteric episode of economic history to shine light on key questions about international technology transfer, this is not just an academic exercise. Technology transfer can complement, or even substitute for, indigenous technological development. Indeed, it may be the most important development driver in the industrializing world (Abramovitz 1993; Robertson and Patel 2007). On the one hand, it can improve efficiency and help firms achieve economies of scale. On the other hand, it can undergird the incremental innovation that is typical of the smaller, low technology intensive firms that dominate the developing world (Santamaría 2009).

Moreover, this issue increasingly weighs on American policymakers and is splashed across the headlines. China has increasingly attracted outsized attention from U.S. politicians, if not average citizens, for its aggressive efforts to acquire cutting edge American technology. China stands accused by the Trump Administration of several transgressions around intellectual property: engaging in widespread industrial espionage; compelling American firms of enter into joint ventures that divulge trade secrets in exchange for access to the Chinese market; and conducting onerous security reviews and testing requirements, as well as deploying billions of dollars to acquire U.S. companies operating in high-tech industries, to achieve similar ends.[2]

This animated an unusually strong response by the U.S. government between 2017 and 2019: it introduced stiff tariffs on Chinese imports, threatened additional ones, imposed stringent restrictions on FDI from China and curtailed semiconductor exports to China. In turn, this spurred Chinese retaliation and a full-blown trade war.[3]

What has garnered less attention from interested publics, however, is that Chinese companies have also acquired foreign technology through copious patent licensing. Chinese companies operating in sectors such as transportation, energy, and robotics have paid top dollar to foreign patent holders to gain access to technology from the industrial frontier: Japanese and American firms have received billions of dollars in royalties in exchange for these licenses (Taplin 2018). China's royalty payments to the US grew dramatically faster than its GDP over the last two decades: IPR payments to US entities increased 25-fold while GDP (measured in constant 2017 international dollars, and adjusted for Purchasing Power Parity), increased roughly five-fold. In 2019, alone, China paid over $34 billion to rest of world for legal use of IP. The US accounted for 23 percent of this amount (on all these points see Menaldo and Wittstock 2020).[4]

Spain, a late industrializing country that only really began to converge economically with the rest of Europe during the second half of the Twentieth Century, is reminiscent of contemporary China in many respects. During the Eighteen and Nineteen Centuries, the Spanish Crown orchestrated and bankrolled wide scale industrial espionage and spirited away trade secrets from the industrial frontier by, among other measures, encouraging British and French engineers and machinists to move to Madrid, Barcelona, and Bilbao. Indeed, as late as the Franco regime, industrial espionage continued. Yet, by the middle of the Nineteenth Century, Spanish companies began to strongly rely on licensing patents from foreign inventors to obtain technology from abroad, a practice that continued into Franco's tenure and remains true today. As I will argue ahead, Spanish steelmakers are perhaps the quintessential example of this phenomenon.

This chapter continues as follows. The first section summarizes the debate around patents and international technology transfer. The second section outlines a theoretical justification for why patents should foster international technology transfer between the industrial frontier and late industrializing countries. The third section outlines the history of the Spanish patent system, which experienced four major changes that affected the ability of foreigners to protect their intellectual property and thus affected international technology transfer. Within that section, I also discuss the basic political economy behind each IPR system. The fourth section provides a general overview of modern steelmaking and the Spanish steelmaking industry between 1850 and 1929. The fifth section discusses several major iron and steelmaking innovations that occurred during this period. The first is the so-called direct Chenot Sponge Iron System. The second is the Bessemer Steel Process. Next is the Siemens-Martin Steel System. I discuss how these were transferred by original foreign inventors to Spanish firms; I identify the patents obtained by foreign inventors and their Spanish partners before their initial introduction to Spain, and also the patents associated with subsequent adjustments, improvements, and offshoots.

THE DEBATE AROUND PATENTS AND TECHNOLOGY TRANSFER

Researchers have suggested a variety of methods for transferring technology from developed to developing countries. These include cooptation and imitation—including industrial espionage—courting skilled labor from abroad, importing machinery, and conducting joint ventures under the aegis of FDI (see Odagiri et al. 2010, p. 11). Some researchers contend that, by underpinning the web of contracts that foster the commercialization of innovation, strong IPR should also help industrializing countries close the technology gap with industrialized countries (Haber 2016) and may catalyze cumulative innovation in developing nations (see Scotchmer 1991). Focusing attention on the transfer of technology from American firms to developing countries between 1982 and 1999, Branstetter, Fisman, and Foley (2006) adduce evidence for these notions.

Some scholars who study Spain's industrialization experience also corroborate this idea. Sáiz (2006) examines the 32,000 patent applications that were filed in Spain during the Nineteenth Century and breaks them down by industry, Spanish region, and the nationality of the patentee. He argues that the Spanish patent system was explicitly designed to encourage technology transfer and demonstrates that, by patenting widely in Spain, foreigners made a noteworthy contribution to industrialization in that country.[5] Cebrián and López (2004) argue that patent licensing between firms in the industrialized world and Spanish firms helped drive the so-called Spanish miracle: the rapid, unprecedented growth acceleration that Spain experienced between 1960 and 1973.[6]

Others arrive at similar conclusions by focusing attention on particular Spanish industries. Frax et al. (1996) explore the role of patents in facilitating technology transfer around ports. Cayón et al. (1999) do the same for railroads. Sáiz (2016) does so for steam boilers and steam generators.

Quite apposite to us is Quijada (1998), who indirectly blames the lack of strong patenting and licensing around steam engines for retarding the introduction of these machines to Spain, as well as their dissemination. He recounts how the Spanish Crown was complicit in infringing upon the Boulton and Watt steam engine patent when it condoned the purchase of several pirated versions by Tomás Pérez—a mining expert hired by the state to pump water from mercury mines in Almadén—from John Wilkinson. Quijada argues that this greatly delayed getting the steam engines up and running, because it meant that Boulton and Watt were not available to offer the Spanish authorities technical assistance installing and mounting the machines, which is what they would have done had the Spaniards instead purchased patented versions from them.

However, there is another, increasingly popular, literature that is skeptical that patents encourage international technology transfer (Boldrin and Levine 2008; 2013; Lerner 2002).[7] Some researchers argue that late industrializers did not rely on strong patenting to catch up to industrialized countries; instead, they simply copied existing ideas, especially process inventions (for example, Kelly 2009; Richter and Streb 2011). The so-called Asian Tigers—for example, South Korea—adopted "export-oriented industrialization models" in which they borrowed freely from industrialized countries and relied on importing machinery (Asian Development Bank 2015).

In this vein, there are also works that are skeptical that patents made that much of a difference to transferring technology to Spain. Ortiz-Villajos (2014) argues that patents did not really impact the introduction and dissemination of gas engines and internal combustion engines during the late Nineteenth and early Twentieth Centuries. Anduaga (2009) intimates the same regarding the oil industry.

Most apposite to us, Houpt and Rojo (2006) examine technology transfer in Spanish steelmaking and shipbuilding. They focus primarily on non-patent methods. Indeed, they are reluctant to admit that IPR helped Spanish steelmaking firms to acquire and improve novel methods. Similarly, Anduaga (2011) argues that Basque engineers trained in Europe were much more important than patents for transferring technology to Spain's steel industry. Ahead, I strongly challenge these claims.

Finally, other researchers who look outside of the Spanish case make a more nuanced argument. Some argue that patents complement other channels and are rarely sufficient on their own. For example, host countries with robust IPR regimes may attract greater FDI inflows and have an easier time securing imports from firms at the technological frontier; in combination, these forces drive international technology transfer (Maskus 1998).[8] Other researchers aver that patents can sometimes substitute for alternative channels, but that depends: IPR may foster technology transfer from developed to developing countries only in some industries (for example, Lee and Mansfield 1996), or under specific conditions (see Braga and Fink 1998).

WHY PATENTS ENCOURAGE INTERNATIONAL TECHNOLOGY TRANSFER

New processes and products cannot simply be transferred in a simple and frictionless process. Technologies cannot be fully codified as important elements remain tacit. The technical, managerial, and marketing knowhow that complements inventions cannot be disclosed in a patent itself. Moreover, knowhow is costly to transfer (Arora 1995). And processes and products have to be adapted by inventors and entrepreneurs to new markets. This takes time and learning.

Even the most highly skilled and accomplished entrepreneurs in the developing world cannot rely on the information available in the patent alone to put the idea it describes into service. They do not have access to the same technological, managerial, and financial resources as developed world patent holders and licensees. They simply lack the knowledge and experience accumulated by original inventors during "learning by doing". This knowledge may go beyond their command of ancillary machinery not enumerated in the patent, and include logistical and management innovations as well.[9]

Fortunately, when original, foreign inventors secure enforceable patents in developing countries, they may enjoy the right incentives and opportunities to help entrepreneurs implement and commercialize innovations. Patent licenses may outline how this critical knowhow will be conveyed from licensors to licensees (see Arora 1995). A licensing contract can specify how a licensee will gain access to the plans, goods, services, and human capital he needs to put the idea codified in the patent into practice. This may include the provision of drawings, blueprints, and machinery by the original inventor, as well as bespoke tutorials and training conducted by the inventor herself, or her envoys.

A patent licensing contract may also enjoin the licensor to take on the role of intermediary. It may obligate her to connect the licensee to a coterie of suppliers, technicians, and even customers. A patent license may thus serve as a passport into a network of upstream firms that manufacture inputs to the novel processes, and potentially downstream firms and entities too.

In light of increasing technological and managerial complexity, this has been true at least as early as the Second Industrial Revolution. No amount of industrial espionage conducted by late industrializing countries could hope to deliver the sophisticated knowhow required to introduce new processes and products tied to advances in physics, chemistry, electromagnetism, and organizational dynamics. Nor has it been enough for later adopters to lean solely on their experiences studying and working abroad, knowledge of basic science, exposure to technical literature, membership in international technical societies, and travel to industrial exhibitions.

Instead, since the mid-Nineteenth Century, original inventors who license their patents in host countries, as well as entrepreneurs and laborers acting at their behest, have travelled to distant lands to help their licensees introduce inventions to new markets, adapt them to those markets, and help with their upkeep.[10] Examples include the transfer of process innovations associated with the manufacturing of textiles, glass, pulp and paper, machinery, chemicals, electricity, the telegraph, and railroads (see Moser 2011). They also include, as we shall see shortly below, steelmaking.[11]

IPR in late industrializing countries also help undergird transnational networks that further stimulate innovation. When inventors try to introduce a process to a new country they encounter differences in raw materials and other inputs, industrial organization, and consumer tastes. To confront these types of challenges, foreign patentees, their licensees, and other entrepreneurs must adapt these processes to unique circumstances. Patents and licenses help them do that.

Consider that a patent represents a focal point around which inventors, entrepreneurs, financiers and manufacturers can coordinate, learn from each other, and build upon one another (see Kieff 2006). In this vein, it is often the case that a flurry of additional patenting accompanies the attempt by inventors to adjust their idea to new markets in the developing world—and quite often, this is undertaken by new, previously unknown inventors who use the information in the patent to piggyback on the original invention. Moreover, these improvements may eventually make their way back to the home country.[12] Therefore, international feedback loops centered on patents that undergird knowledge sharing and collaboration may foster incremental innovation.

SPAIN'S EFFORTS AT ACQUIRING TECHNOLOGY

Spain has always been a technology laggard. Throughout its history, it has exhibited an all-of-the-above strategy for acquiring technology from the industrial frontier. Patents are the most recent among several methods that Spanish governments have availed to try to catch up. Throughout the latter half of the Eighteenth Century, Carlos III opted for a diversified approach to acquiring technology from countries such as Britain and France. He hired several foreign scientists, encouraged skilled European machinists to migrate to Spain, pushed for the importation of new machinery, and sent Spanish scientists, engineers, and technicians to study abroad in a bid to improve their knowledge and skills (see Sáiz 1995, p. 49; 1999, p. 78). He also oversaw the creation of royal laboratories and scientific academies (Sáiz 1999, p. 107). Finally, he encouraged and bankrolled industrial espionage (Helguera 2011; Sáiz 1999, p. 78; p. 109). These efforts continued, albeit with less enthusiasm, under his son's reign (see Sáiz 1995, p. 40).[13]

Under both Carlos III and Carlos IV, the Spanish government also experimented with unorthodox intellectual property tools. It sponsored prizes to stimulate new inventions, mostly around efforts to boost agricultural production (Sáiz 1999, p. 108). The crown also awarded royal privileges, a precursor to patents, to inventors. While these privileges endowed inventors with exclusive rights, Spanish monarchs only granted these sparingly, capriciously, and at a high cost. They also required that inventors first prove that their innovations worked (Sáiz 1999, p. 81).

Beginning in the early Nineteenth Century, however, the Spanish government followed up these desultory policies with more deliberate, formal attempts to attract foreign technology. These were embodied in a series of evolving laws governing industrial policy and intellectual property; important reforms extended into the late Twentieth Century. In what follows, I describe Spain's numerous patent regimes and flesh out their underlying political economy.[14]

Spain's First Patent System

Spain's first (modern) patent law was decreed by Joseph Bonaparte in 1811, under French occupation. The system introduced by the French was then adopted by Spain's sovereign government in 1820, after the restoration of the Spanish Crown, and ratified with few changes in 1826 by Fernando VII through a royal decree. Spain's patent system was originally vested in the language of natural rights: intellectual property was declared to be private property.[15]

Despite these classical liberal underpinnings, however, the actual elements of Spain's Nineteenth Century patent system betray a hybrid approach. Products could not be patented, only novel processes. The system included both "invention" and "introduction" patents—legal monopolies granted to Spaniards for putting into practice processes and products that had already been invented abroad.[16] Internationally-speaking, this made Spain somewhat exceptional.[17] Also, Spanish patents had a working requirement: patentees were compelled to put their invention into practice within one year, lest their property right expire.[18]

Most patent requests were granted without much fanfare or delay by the Spanish patent office (see Sáiz 1999, p. 104). It did not administer technical examinations prior to granting a patent. Also, while patent seekers were required to explain their inventions in writing and affix drawings, or even models, it was sometimes difficult for patent officers to ascertain whether the person filing the patent was actually the original inventor. Moreover, original inventors were not treated with priority. Spanish nationals could beat foreign inventors to the punch: obtain introduction patents for the latter's inventions. Indeed, foreign inventors were not explicitly allowed to "repatent" inventions they had already patented elsewhere.[19]

In terms of duration and cost, Spain's IPR was not particularly strong during this era. Inventors could obtain invention patents for five, ten, or fifteen years (five year patents could be extended another five years). Introduction patents were granted for only five years. The fees associated with either invention or introduction patents had to be paid by patentees in full and upfront. Invention patent fees were a function of their duration, and were significantly more expensive than introduction patents. In terms of the ratio of patent costs to (yearly) unskilled wages, the cost of invention patents was always over one hundred percent during Spain's first patent regime and the cost of an introduction patent was only over one hundred percent of (yearly) unskilled wages during the early 1800s, and well below that afterward.[20]

Despite its heterodoxies, many features made Spain's first patent system somewhat strong. Patent owners were allowed to transfer or sell their patent rights to assignees, as well as license them. There were no restrictions associated with inventions related to chemicals, plants, or animals. And, as outlined above, invention patents were granted for a longer duration than introduction patents. Moreover, both inventors and the introducers of foreign inventions were instructed to focus on narrow novelty claims so that others could work around these innovations. The Spanish patent office adopted a multipronged approach to disseminating information about patents and inventions.[21] Patents were registered, archived, and publicized to anybody who sought them out, free of charge. The patent office also provided access to technical support to understand how to use machines or put new production methods into practice. Eventually, it doubled as a degree granting engineering school, stored a huge library detailing international and

Spanish inventions, and boasted a museum populated with mechanical models. Moreover, several sources widely disclosed patents throughout the kingdom.[22]

In terms of enforcement, patentees had multiple, complementary ways to redress infringements.[23] They could receive injunctive relief, in the form of an embargo placed by the courts on competing processes or products that violated their patents. They could also win monetary relief, in which infringers paid patentees a steep fine in addition to "treble" damages. Finally, in 1868 the possibility of criminal action against patent infringement was introduced by the Spanish government, a feature that lasted until 1985.

The Political Economy of Spain's First Patent Regime

Spain's 1826 to 1877 patent system was largely a response to three factors. First, by the turn of the Eighteenth Century, it became increasingly hard for the kingdom to gain access to cutting edge technology through industrial espionage, encouraging skilled workers to migrate to Spain, and importing machinery. Second, during French occupation (1808 to 1814), Napoleonic forces had experimented with modernizing reforms, including the introduction of a patent system. Third, after it secured its independence from France, Spain faced an unprecedented economic, fiscal, and political catastrophe. Liberal reformers sought to remedy several crises by promoting economic development; a patent system was only one of several measures they undertook.

In 1719, Britain imposed a ban on the outmigration of skilled labor in response to attempts by French and Russian firms' efforts to recruit skilled British labor.[24] Over the course of the Eighteenth Century, the English Crown honed its countermeasures and tightened their enforcement. Englishmen who emigrated abroad to work incurred stiff fines, lost their rights to land and other assets, had their citizenship revoked, and were imprisoned. This ban was in place until 1825.

Similarly, throughout the Eighteenth Century, Britain increasingly banned the export of machines. In 1750, this included the "tools and utensils" used in its wool and silk industries. In 1774, a ban on machine exports in the cotton and linen industries was imposed by the crown. By 1781, most tools and industrial machines, including engines, were covered by the ban. This was followed with another update introduced by British authorities in 1785, which included any machinery overlooked by the previous two bans. These restrictions lasted until 1842.

In first reforming its patent system in 1811, Spain therefore followed a new regional trend that sought to circumvent British imposed barriers to technology transfer. For example, France adopted a modern patent system in 1791, with a fifteen year protection tenure for novel inventions. Other nations besides Spain that followed suit include the U.S. (1793), Austria (1810), Russia (1812), Prussia (1815), Belgium and the Netherlands (1817), Sweden (1819), Bavaria (1825), Sardinia (1826), Sweden (1834), Württemberg (1836), Portugal (1837), and Saxony (1843).[25] In short, intellectual property rights were widely used by European governments to coax British inventors to willingly introduce and commercialize their inventions.

In the Spanish case, it took the French to do the dirty work: introduce a patent system on the back of a host of liberalizing reforms that had been resisted hitherto to by the ruling elite. Joseph Bonaparte ruled Spain from 1808 to 1813. He promulgated decrees to end semi-feudalism and modernize commercial codes; they included rights to conduct free trade within Spanish territory and standardizing customs. He complemented these measures with a modern IPR regime.

What did this mean for Spain's exiled government in Cádiz? On the one hand, it had to compete with the Napoleonic reformers in Madrid for hearts and minds, and modernization was part of a broader propaganda war aimed at the Spanish public. On the other hand, Bonaparte's reform efforts were a welcome opportunity: for the most part, Cádiz insurgents were frustrated liberals whose reform agenda had been repeatedly blocked by the crown before Bonaparte arrived. Thanks to French occupation, a coalition of lawyers, intellectuals, bureaucrats, merchants, and modernizing army officers (see Ringrose 1996, p. 326) now had a chance to make a difference.[26]

The Cádiz Court imbued Spain's 1812 Constitution with Enlightenment principles. The charter called for a constitutional monarchy vested in the separation of church and state. It abolished the Inquisition and eliminated noble prerogatives. It codified equality before the law, free speech, private property, and the freedom to contract. It also introduced universal suffrage. Spain's reformers sought to end the *ancien régime's* absolute monarchy, feudalism, and mercantilism. They believed a radical break from the past was necessary because Spain had become a peripheral, backward, and vulnerable country. On the eve of Napoleon's invasion, Carlos IV's kingdom found itself in a death spiral.

Consider the country's dire fiscal situation.[27] Spain had accumulated a huge debt load associated with the kingdom's participation in countless wars; yearly deficits were common. By 1808, Spain's sovereign debt had risen to over 150 percent of GDP (Tedde de la Lorca 1994, p. 530). Not that the crown found it easy to borrow, however: it had defaulted on its debt several times and endlessly debased the currency, which stoked inflation and invited repeated bankruptcies.

The Spanish kingdom was fiscally vulnerable. It had come to rely excessively on volatile revenues from its Latin American colonies that were no longer available after the collapse of the Spanish Empire. [28] What remained of the country's own fiscal base was taxed by Spanish authorities in a grossly inefficient manner. Several time-honored sources of revenue had run dry.[29] By 1814, government revenues were reduced by more than a third (Ringrose 1996, p. 324).

It did not help matters that Spain had fallen behind the rest of Europe economically (Harrison 1985, p. 15). Its largely informal economy was overwhelmingly agricultural. It produced commodities and food inefficiently, and could barely feed its people. Moreover, the country was quite sparsely populated, predominantly rural, and economically Balkanized.

Political problems also abounded. As political factions turned to violence to settle their differences, unrest beset both the cities and countryside. The military services were riven with internal strife. The Navy was rendered a shell of its former self, and the military was depleted and demoralized. Popular resistance to conscription was growing.

These problems were themselves a symptom of deeper institutional and cultural deficiencies. Spain failed to liberalize and modernize its government and economy before 1800. There was never a Magna Carta type moment or Glorious Revolution in which the monarchy was tamed by a bill of rights, let alone an independent judiciary or representative legislature. Therefore, Spain's monarchs did not seek to protect individual liberties and were not prevented from indulging in overzealous spending and inflationary finance.

In many ways, the Enlightenment passed Spain by. The Church continued to have an outsized political influence. Spain largely missed out on the scientific revolution. It lacked great universities. Nor did it produce great scientists. Therefore, unlike in the Netherlands, Britain, Belgium, or even France and Germany, Spain did not cultivate the seeds of a commercial revolution, let alone an industrial one (see Mokyr 2016).

Finally, a host of new issues that arose during the bloody and protracted guerilla war to dislodge the French army compounded the problems outlined above. Large stocks of physical capital were destroyed, including workshops, factories, and laboratories. Also, skilled laborers fled the scene, and undisciplined French troops indulged in plunder and shakedowns (Esdaile 2002).

After the Peninsular War, the liberal coalition that was holed up in Cádiz emerged to reform the country. They sought to foster a more stable and prosperous Spain that could produce greater tax revenues. They believed that economic development and a stronger military could serve as a bulwark against the country's European adversaries. The humiliating Napoleonic era was seared deep into the nation's consciousness.[30]

Reformers wanted to stimulate economic development by increasing economic exchange, modernizing agriculture, and nourishing domestic manufacturing. Beyond the patent system, these goals would be achieved by "dismantling the legal basis of a society of estates" (Ringrose 1996, p. 327), which would in turn create and lubricate markets for tradable goods. Reformers therefore began by bolstering secure and tradable property rights to land.

This meant putting an end to Spain's peculiar rural political economy. They abolished the Mesta in 1836, quasi-feudal (seigneurial) land rights in 1836-1841, and the tithe in 1841.[31] Reformers also passed new mining laws (in 1849 and 1859) that abrogated the crown's ownership over Spain's subsoil and sold off scores of mines to private actors (Berend and Ránki 1982, p. 38).

To stimulate commercial exchange, reformers pursued a multipronged approach. They sought to integrate the kingdom's fragmented market by eliminating internal tariffs and local restrictions on domestic trade. They also sought to create a modern labor market, and thus eased restrictions on labor mobility. A cognate agenda was to establish a competitive and more liquid financial system, with private banks organized as limited liability corporations and endowed with the ability to issue notes, discount bills, make loans, and undertake investments.[32] This included judicial reforms that improved contracting and reforms to public finance intended to increase and improve tax collection and provide public goods.[33] Finally, and despite strong pushback and many false starts, reformers liberalized cross border trade (Tortella 2000, p. 196).

In short, Spain's first patent system was a creature of the times. It drew inspiration from a larger liberal movement, and from patent systems introduced in other European countries during that era. Intellectual property rights complemented a bid by reformers to strengthen property rights.

Spain's Second Patent System

Both before and after Napoleon's invasion, the Spanish Crown's oligarchic supporters included municipal government officials, high placed Church officers, and seaport merchants involved in the Spanish Empire's Atlantic trade routes (see Ringrose 1996). They also included a motley crew of provincial, landholding aristocrats with special property rights; for example, loosely organized Castilian cereal producers, the Barcelona association of cotton producers (see Tortella 2000, pp. 196-197), and shepherds who were members of the Mesta.

What these groups shared in common is that they depended on the state for privileges and rents. These were centered on barriers to entry and arbitrage opportunities: high import tariffs, archaic mercantilist practices such as a flag tax on merchandise delivered by foreign vessels, and the outright banning of goods such as cotton cloth, wool, and cereals (see Tortella 2000, pp. 195-196).

Because these special interest groups never truly disappeared after the Peninsular War, Spain's Liberal Revolution was a one step forward and two steps back process. To be sure, the crown and its economic allies seemed to agree that technology could play an instrumental role in driving industrialization and growth; thus, they did not threaten the patent system. Yet, whenever the so-called absolutists returned to power on the back of armed interventions or subterfuge, they watered down or abandoned other liberal reforms. And they were challenged at every stop by reformers with their own supporters within the military and greater society.

To put this political-economic tug of war in perspective, consider Spain's numerous Nineteenth Century revolutions and counterrevolutions. Upon returning to the throne in 1814, Fernando VII abolished the 1812 Constitution. However, the charter was revived between 1820 and 1823 after a military revolt. Its recrudescence was accompanied by radical reforms such as abolishing the guilds and confiscating monastic lands (Berend and Ránki 1982, p. 35). Between 1824 and 1835, however, reactionary forces were again able to beat back liberal reformers.[34]

While a reinvigorated Fernando VII again brushed aside the 1812 Constitution, as did his daughter Isabela II after she succeeded him in 1833, this time around the crown largely tolerated the modernization efforts spearheaded by reformers. Indeed, the liberal charter was again restored in 1834, after yet another revolution. And a revolt spearheaded by absolutists and fanatical Catholic bishops (the Carlist War) was snuffed out in 1839, further buoying reformers. Yet, in another twist, the 1850s saw another reactionary backlash by the Church and landed oligarchs. The pendulum thus swung towards neo-feudalism and rent-seeking once again.[35]

But this was not to last either. In 1873, Spain's "First Republic" came into existence on the heels of the abdication of King Amadeo I, who was affiliated with the House of Savoy. This Italian carpetbagger had replaced Isabela II, in 1870, after she was deposed in a military coup in the wake of a revolution, which broke out in 1868. The revolt was spearheaded by reformers—both within the armed forces and outside of them—upset with the country's direction: Isabela, like her father before her, had not fully committed herself to the country's liberal agenda.

Spain's republican experiment proved stillborn, however. The monarchy was quickly restored in 1875. That year, Isabela's son, Alfonso XII, ascended to the throne. This marked the second restoration of the Bourbon monarchy in less than a century.

Yet, Alfonso accepted the strictures of parliamentary government, including a new constitution that echoed the 1812 charter. The charter called for a bicameral legislature whose seats would be contested by competitive political parties. It also codified free speech and free assembly, jury trials, and universal suffrage. Citizens were now equal under the law and had the ability to have a say over taxes and public spending (see Tedde de la Lorca 1994).

During the ensuing era, known as "The Restoration," conservatives and liberals struck a political pact to share power in the legislative branch; they therefore took turns controlling the cabinet under parliamentary monarchy. Many economic changes were promulgated by reformers. They included the Bank of Spain obtaining the sole right to emit currency.[36] They also included a national system for regulating railroads and a new commercial code. By the second half of the Nineteenth Century, the Spanish labor market was fully integrated on the back of further liberalizing measures (Rosés 2003, p. 1000). More tax reforms also followed. Finally, so did trade liberalization: the government appreciably reduced tariffs and Spain signed commercial treaties with Europe's major powers, including England (Tortella 2000, p. 199).

Patent Changes Mirror the Consolidation of Liberal Reforms

It should therefore be unsurprising to readers that IPR also became stronger during this period. Specifically, in 1878 an important series of reforms were made by lawmakers to Spanish patent law.[37] This included reducing the costs of patenting, strengthening invention patents, and bolstering foreigners' patent rights.[38] While invention patents were extended to twenty years, the law explicitly recognized that original, foreign inventors had the right to patent their inventions in Spain for ten years, even if they had already obtained a patent in their home country and/or other countries.[39] The working requirement was also extended to two years, thus allowing inventors/entrepreneurs more time to put processes and products into place.[40] Perhaps more importantly, the government weakened the verification process employed by authorities to evaluate that patents had been put into practice and sanction non-compliers (see Sáiz 2013). Finally, inventors/entrepreneurs acquired the right to patent products, not only processes.[41]

Spain's Third Patent System

In 1929, Spain's patent system again experienced reform under a new law governing industrial property.[42] This time around, however, policymakers' main goal was to strengthen introduction patents; this was coupled with efforts aimed at speeding up industrialization at the expense of invention patents. Needless to say, this was a rebuke of the previous patent regime.

Several changes highlight the new patent system's "mercantile" DNA. The cost of acquiring an invention patent increased significantly. While the same was true for introduction patents,[43] their duration was extended from five to ten years. Patentees now had only one year to put inventions into practice. Also, inventions not associated with industrial applications faced restrictions: products could not be patented—only processes. The 1929 law also introduced "utility model patents" for minor inventions: a twenty-year protection for products manufactured in Spain for the first time. It also introduced "exploitation patents," which granted monopoly rights to entrepreneurs who sought to introduce a whole new industry to Spain rather than a particular invention; these were to be granted by the government for ten years.[44] Finally, policymakers restored the strict system used to verify whether patents had been put into practice (Sáiz 2013).

In short, a new IPR regime centered on rewarding domestic entrepreneurs who sought rents, if not monopoly profits, emerged. Original inventors, especially foreign ones, were hurt.

The Political Economy of Spain's Third Patent Regime

What explains this sharp turn away from relatively strong IPR? It was years in the making. Cartels of nascent manufacturers, most prominently textile producers, were able to capture successive Spanish governments during the last decade of the Nineteenth Century. They secured a slew of protectionist measures that ramped up import substitution industrialization. The Spanish government levied tariffs on imports in 1891, 1906, and 1922.[45] They also passed non-tariff laws that subsidized domestic manufacturing in 1907, 1909, 1917, 1918, and 1922 (Rosés 2003, p. 999).

A political takeover by Miguel Primo de Rivera consolidated the new normal. He ruled as a dictator, and used the rhetoric of nationalism and self-sufficiency as a smokescreen to erect further barriers to entry and pick winners and losers.[46]

Francisco Franco later put this "development model" on steroids during the 1940s. With the support of the so-called Falingists, he adopted a cascading tariff structure, quantitative import restrictions via licenses, and foreign exchange controls with multiple exchange rates. Franco also nationalized several private enterprises under the auspices of the *Institute of National Industry*, a state holding company. This served to promote rapid industrialization and employment growth. What remained of the private economy was heavily regulated to achieve national investment and employment goals, as well as to boost the earnings of industrial sector wage earners.[47] Tax breaks and subsidies were doled out by the Spanish government to a host of manufacturing industries, including textiles, domestic appliances, and vehicles.[48] The state also encouraged mergers to "help firms reach economies of scale" (de la Torre and Garcia 2014, p. 169). FDI was part of this process, albeit under the umbrella of stringent local content requirements: The Franco government was bent on achieving the domestic production of intermediate inputs (de la Torre and Zuniga 2014, pp. 167-169).[49]

Spain's Fourth Patent System

Spain democratized in 1977. It then joined the European Union (EU) in 1986. These political developments set off a cascade of economic reforms. They included (further) reductions in barriers to trade and foreign investment and reforms to the financial system intended to make it more competitive. By 1991, Spain's capital account was fully open.[50]

It is no surprise, therefore, that in 1986 the Spanish patent system saw reform again.[51] The government sought to harmonize the system with international best practices. Lawmakers therefore strengthened invention patents by introducing a technical examination process and eliminated introduction patents. They allowed products to be patented once more.[52] They retained protections for utility models, however (their duration set at ten years), as well as working requirements—inventors now had four years to put their innovations into practice.

These changes were foreshadowed by international agreements. Since 1973, inventors can receive a patent from the European Patent Office, which is valid across as many EU countries as they care to designate, including Spain after 1986, the year it signed the Munich Convention. In 1989, Spain joined the Patent Cooperation Treaty; since then, inventors can include Spain within the group of countries for which they may obtain a "universal" patent from the World Intellectual Property Organization.

SPANISH IRON AND STEELMAKING: TECHNOLOGY TRANSFER VIA PATENTING

Steel is pure iron that contains carbon, which hardens it. It contains less carbon than cast iron, however, which makes it both more malleable and stronger than the latter. Steel is produced by skilled laborers from iron ore, which is a compound of iron, oxygen, and earthy material. Steel comes in several varieties that depend on the mixture of pig iron and different alloys and metals.

During the Second Industrial Revolution, the mushrooming demand for new products that employed cast iron and steel drove several innovations in metallurgy and stimulated an increased production scale. What ultimately emerged was a vertically integrated system of steel production that used heavy machinery, new technologies, and an assembly line technique in which skilled laborers choreographed a ballet of seamless motion: from smelting iron ore to creating finished products such as laminated steel or steel bars and ingots.

It is useful for readers to consider all of the steps involved. First, hot blast furnaces powered by charcoal or coke (converted coal) convert iron ore to molten pig iron with the help of limestone. These furnaces reduce the iron ore as it comes into contact with carbonic oxide and separate out the earthy matter. After this smelting process, Bessemer converters or Siemens open hearth furnaces convert pig iron into purified iron. Third, metalworkers soak, roll, cool, and cut the metal in rolling mills, where they give it its final shape. Across these processes, they employ equipment of various kinds to cool, manipulate, reheat, and polish the metal.

Modern steel mills are characterized by much greater efficiency vis-à-vis the traditional ironworks they replaced. Steelmakers obtain cost savings in several ways. First, by reducing the use of heat. Second, by increasing coordination across each step in the chain. Third, by reaching economies of scale that eliminate duplicate efforts.

It should therefore not surprise readers to learn that the fabrication of steel in large amounts and for different uses under one roof requires sophisticated human capital. On the one hand, the adoption by steelmakers of sophisticated technologies calls upon skilled laborers to acquire and hone knowledge of material sciences, chemistry, and engineering. On the other hand, it entails organizational innovations and thus skilled and nimble managers.

Spanish Steelmaking: Historical Overview

Modern steelmaking in Spain had its roots in Bilbao, a port city off the Bay of Biscay, in Basque country (northcentral Spain).[53] Ironworkers, and later steelmakers, located there because there were substantial iron ore deposits in the vicinity. Indeed, many of the companies that first produced Basque steel were capitalized by their founders with revenues from iron ore exports.

During the second half of the Nineteenth Century, and into the beginning of the Twentieth Century, Spain experienced a mining boom. It was catalyzed by the elimination of export tariffs by the crown in 1849, which coincided with a huge inflow of FDI and new technologies. The Biscayan iron ore industry consequently took off during the mid-1800s. Its life and success were due largely to FDI from Britain (see Maluquer de Motes 1988, pp. 18-20). The

Spanish mining code was liberalized by the government in 1868, encouraging an even greater amount of FDI.

This accompanied the introduction of new mining technologies by foreigners who obtained numerous Spanish patents. For example, English inventors acquired several patents to protect methods for extracting low quality ores buried deep underground, including the so-called flotation system (Madrid Correspondence 1919). Foreign mining firms also imported sophisticated machinery, which also aided technology transfer (Fernández de Pinedo 1983, p. 19).

Biscayan mining thus experienced a period of modernization followed by exponential growth. Because the area's hematite lacked phosphorous, it was exported to England in massive quantities to feed Bessemer steelmaking.[54] Between 1880 and 1913, 91 percent of Basque iron ore was exported—the vast majority to England (see Riera i Tuebols 1993, p. 150). Figure 1 graphs Spain's (real) Iron Ore Income between 1830 and 1929 and recounts the story I told above: first a piecemeal, steady ascent, followed by a palpable boom that begins to peter out around 1908.

INSERT FIGURE 1 ABOUT HERE

Transition to Ironmaking and Steelmaking

During the 1850s, Biscayan iron ore began to be used by Basques to fabricate sweet iron and steel in Bilbao. Besides the presence of copious amounts of high-quality iron ore, agglomeration effects had a positive impact on the emergence and consolidation of steelmaking in and around Bilbao. The colocation of several firms dedicated to iron ore mining and metallurgy meant that a relatively deep pool of engineers and skilled laborers could be drawn on by employers. This fostered a relatively rapid spread of knowledge, technology, and innovations.

Basque steel production surged between 1879 and 1889 (see Figure 2). This is because, by the 1880s, large, integrated steel mills in and around Bilbao were producing plentiful amounts of steel. These included San Francisco de Mudela, Altos Hornos de Bilbao (Baracaldo), and La Vizcaya (Sestao). The latter two firms merged in 1901, creating Altos Hornos de Vizcaya. This hegemon began its life with a capital stock that exceeded 32 million pesetas; it eventually produced over 60 percent of Spanish steel (Gárate 2000, p. 160).

INSERT FIGURE 2 ABOUT HERE

In terms of its commercial success, Spanish steelmaking falls into roughly two eras during the period under study. The first era was when a respectable portion of Basque steel was exported to European countries. The second was when it was produced mostly for the Spanish market.

The "export oriented" period corresponds roughly to between the early 1860s and late 1880s (see Fernández de Pinedo 1983, p. 16). In the face of tough competition from imported steel and insufficient domestic demand, Basque steelmakers sought foreign outlets for their product. The most important export markets included England, France, the Netherlands, Belgium, Italy, and Germany. Between 1881 and 1890, 30 percent of Biscayan steel was exported (Escudero 1999), a feat that required Bilbaon firms to import substantial amounts of coal and coke from Britain, as it was relatively cheap to ferry this fuel from Cardiff on the same vessels that shuttled iron ore from Biscay to that English city (see Fernández de Pinedo 1983, p. 13).[55]

The second era of Spanish steel's commercial success was when Basque steelmakers revved up production to satisfy new sources of internal demand between 1888 and 1914. This phenomenon was mainly driven by trade protectionism; without it, Biscayan steel could simply not compete. For example, in the wake of the 1855 law that ushered in the construction of Spain's rail network, the French companies involved in building railways and railroads found that it was cheaper and more practical to employ French steel during the production process.

And this protectionism was in large part propelled by Spain's major steelmakers, which had formed the Asociación de la Industria Siderúrgica (which was later replaced by the Liga Vizcaína de Productores in 1894) to lobby for tariffs, both for steel and for the products manufactured by Spanish firms that were composed of steel. [56] Due in part to their alliance with cereal producers and Catalan textile producers, they achieved several victories (see Sáez-García 2017, p. 166). In 1889, Spain imposed stiff tariffs on imported machinery of all kinds, and slapped tariffs across most imported inputs and products, including iron and steel, in 1891 and 1896. Also, in 1896 the government rescinded the tariff exemption that railway firms had secured in 1855. Even more tariffs were adopted by Spanish authorities in 1906 to stoke import substitution.

Moreover, the Spanish armed forces' procurement policies were intended to benefit the domestic steel sector and machinery industries. As early as 1883, the Spanish Navy invited Biscayan firms to supply 1,200 tons of laminated steel for the construction of cruisers (Fernández de Pinedo 1983, p. 17). This was followed by the navy's requisition in 1887 that Spanish companies supply the materials for the construction of six warships. Another round of tenders by the navy to manufacture warships followed in 1907, again benefiting the domestic steel industry (Sáez-García 2017, p. 166).

Tariffs on imports and "nationalistic" procurement policies by the Spanish army and navy continued into the Twentieth Century, and were complemented by increased spending by the government on public works during the late 1920s (Sáez-García 2017, p. 167). These policies represented a reliable source of demand for Biscayan steel that lasted decades. In turn, a host of domestic firms sprung up to manufacture agricultural and industrial machines and tools; they used iron and steel produced in Bilbaoan mills to do so (Fernández de Pinedo 1983, pp. 18-19).

These metals were also used to fabricate steel pipes, railway bars, bridges, ship boilers, cranes, sundry metal structures, including warehouses and ports, and ships, arms, and tanks. The upshot is that Altos Hornos de Vizcaya, Spain's leading steelmaker at the turn of the Twentieth Century, clocked impressive growth: "the production of coke increased between 1913 and 1929 by 60 percent; that of cast iron by 46 percent; that of steel by 71 percent and that of rolled steels by 56 percent" (Sáez-García 2017, p. 167).

Figure 2 graphs raw steel production between 1842 and 1929. While it traces a trajectory that corresponds to the events discussed above—a steady ascent that really booms in the 1880s—there are other interesting patterns to note. Spanish steelmaking experienced another boom during World War I, on the back of the country's neutrality during the Great War: Spain steeped in and exported steel to countries that were formerly supplied by Britain, Germany, and France (see Aldcroft 2016, p. 129). Yet, by 1920, with the war related boom at an end, and the onset of an international recession, Bilbaoan steel experienced a crash. This was followed by a healthy recovery, and yet another crash due to the Great Depression that is not shown in the figure.[57]

Biscayan Steel: A Story of Technology Transfer from Europe

In cursory ways, the technological innovations that shaped the Biscayan steel industry paralleled those taking place in the rest of the world; more fundamentally, however, technology transfer occurred with an appreciable lag. For example, it took until 1848 for a charcoal blast furnace to be fired for the first time, let alone a blast furnace powered by coke. And while pig iron was smelt in a furnace using coke for the first time in 1856, it took several years for this practice to spread. Spanish firms instead extended their reliance on the direct processing of iron ore, which in any event only really began to bear fruit as late as 1859, and puddling techniques, which made their belated arrival in 1860.[58]

However, modern steelmaking did eventually arrive in Basque country. And its rise paralleled that of iron-ore mining, which several technology transfer measures complemented each other. Both industries employed a large stock of imported machinery. Both relied on Spanish engineers who had studied abroad. Both also employed the services of foreign-born engineers, chemists, smelters, machinists, and boiler stokers.[59] Indeed,

> …technical transfer in (Spain's) steel processing plants is not much different from the previous mechanisms of transfer of iron techniques. Foreign trained engineers and foreign consultants determined the items to be transferred, they chose among various machine factories or designing engineers from abroad and the process or installation was brought to Spain with technical supervision from the constructing or designing firm. Foreign staff was hired during a training period or contracted if their specific diagnostic skills were required over longer periods (Houpt and Rojo 2006, p. 340).

And, like with iron-ore mining before it, patenting by foreign inventors was also a key vehicle for transferring technology and knowhow about modern steelmaking to Spanish firms. On the one hand, there was widespread patenting by foreign steelmakers in Spain. On the other hand, Basque and foreign-born engineers and skilled laborers employed by San Francisco de Mudela, Altos Hornos de Bilbao, and La Vizcaya, as well as smaller firms, took a lead role in identifying patents that would increase steel production or cut costs. They then secured patent licenses and drew up contracts with foreign inventors that guaranteed technical assistance. Biscayan firms also adapted new technologies to the conditions on the ground, and sometimes engineers and steelworkers made noteworthy innovations themselves in the midst of learning by doing—many of which were subsequently patented in Spain.[60]

Before going into details, we should note that, at least in regards to steelmaking, the evidence points to the fact that it may not have mattered much that Spain's 1826 patent law did not explicitly allow foreign inventors to patent their inventions after already acquiring a patent in their home country. Sáiz (1995, p. 126) argues that foreign inventors found ways to circumvent this restriction before 1878 and obtained numerous invention patents in Spain. In terms of iron and steelmaking, I corroborate this claim below across several process innovations.

The Chenot Process

Direct steelmaking refers to several distinct methods in which iron or steel is oxidized by applying carbon and other alloys. This calls on heating iron ore to extremely high temperatures below its melting point. Cementation involves packing wrought iron in charcoal and heating the resultant slab inside of stone boxes, removing and breaking up the iron bars, and repacking and reheating them again. This removes impurities such as manganese and silicon. The crucible steel process involves melting the “blister steel” produced after heating and oxidizing wrought iron via cementation, while also adding a flux that further removes slag.

The Chenot process is a refinement of the crucible steel process. It was developed by Adrian Chenot, a French engineer, during the 1830s and 40s. He designed it to produce sponge iron in a modified, rectangular blast furnace that contains only the upper, “reducing” region.

The steps are as follows. Ironmakers vertically array pieces of iron ore by size within a twenty-five-foot-high retort (reduction chamber), and follow this step by adding a reducing agent composed mostly of charcoal. They then heat the retort’s brick interior until its walls are red hot using a coal fired oven that runs parallel to the retort, and that communicates with it through horizontal and vertical channels. Ironmakers proceed to wait for the sponge iron to cool inside a hermetically sealed cylinder directly below the retort—to prevent over-oxidation—and blast it with cold air. They then remove the sponge iron and use magnets to separate the earthy matter.

The result is a process that, between the reduction of iron ore and the removal of the sponge iron after cooling, takes six days. Four tons of fuel translate into one ton of iron for a loss of about 45 percent of the iron. Steelmakers can then convert the sponge iron into steel by carborizing it through cementation with charcoal (and sometimes magnesium), compressing it into cakes, and fusing it in a crucible.

Bilbao was the first place on earth where Chenot steel was produced in commercial quantities; patents played an instrumental role in introducing the process to Spain, perfecting it, and spreading it to other countries.[61] Chenot first acquired an invention patent in France in 1846 for his direct sponge iron technique. He then acquired a five year introduction patent in Spain that same year (#310: Método para el tratamiento de los óxidos metálicos o de sus compuestos llevados a tal estado, etc.). Chenot followed this with another Spanish introduction patent in

1850 for an improvement he had previously patented in France (#522: Método para el tratamiento de los óxidos metálicos o de sus compuestos).

But these initial patents were merely false starts: the Spanish patents he actually commercialized were invention patents of longer duration. In 1854, Chenot acquired two separate fifteen year invention patents in Spain for his now almost ten year old process (#1199: Sistema para la fabricación de acero, hierro, fundidos, soldados y moldeados; #1200: Sistema de normalización, enriquecimiento, generación y empleo general de los gases en los usos metalúrgicos).[62] These later patents caught the eye of the Baracaldo steel mill, which was owned and operated by a family of Biscayan mine owners and iron ore traders, the Ybarras. Along with their business partner, José de Vilallonga, a French trained engineer who had previously travelled throughout Europe to acquire knowledge about new advances in iron and steel making, they were on the constant lookout for new techniques (see Anduaga 2011).

The Chenot direct steelmaking process was the first of many they experimented with and adopted in their mills. The Ybarras and Vilallonga acquired these patents from Chenot and tailored their Baracaldo plant to the inventor's process, which had achieved international attention after Chenot won a gold medal in 1851 at London's Universal Exposition. In exchange, the French inventor was entitled to 25 percent of the profits associated with the steel produced by his invention. In the same contract, Chenot committed himself to providing the Spaniards with technical assistance, including setting up a laboratory to test the quality of the iron and steel produced by his method (see Morlán 2002, p. 88; Uriarte 1998, p. 21).

Despite his help, the technology transfer experience vis-à-vis Chenot's process was protracted. While experiments with Chenot ovens were carried out in the Ybarras' Guriezo plant as early as 1855 under the French inventor's guidance, Chenot furnaces were only fully installed and actually running at the Baracaldo factory in 1859.[63] In the run up to the factory's completion, Vilallonga, Juan Maria Ybarra, and Jose Antonio Ybarra toured Belgium and France to gain exposure to steelmaking developments that could inform them about how they should best set up production. They also went there to hire engineers and skilled laborers to staff the new plant.

Other inventors then went on to make numerous improvements to the Chenot process. They also patented these additions in Spain and took an active role in putting them into practice there.

Consider Ernesto Tourangin. Between 1859 and 1865, he obtained three fifteen year invention patents that eliminated or simplified many of the steps enumerated above, including reducing the amount of total fuel needed by ironmakers by switching the source of fuel to wood charcoal.[64] They also improved the design of the retorts and parallel heating ovens. Tourangin's innovations were: #1999: Horno para la desoxidación de los minerales de hierro; #2271: Procedimiento para convertir la esponja de hierro en hierro de comercio; #4028: Procedimiento para la fabricación directa del hierro. The Frenchman then disseminated his process throughout Biscay and undertook adjustments centered on the idiosyncrasies he encountered in each ironwork along the way.[65]

Another notable improvement to the Chenot process was contributed by Chenot's son, Alfred. He registered it in Spain as a fifteen year invention patent in 1865 (#3063: Procedimiento para obtener el hierro dulce y el acero directamente del horno alto). Alfred then licensed it to the Ybarras and provided them with technical assistance to implement it in Baracaldo.

The Bessemer Process

During the first half of the 1850s, Henry Bessemer invented a steelmaking process centered on a converter—a tiltable, pear shaped receptacle. Here is how it works: A steelmaker pours molten pig iron into the converter, allowing her to control and shape the flowing mass. The iron is then purified by steelmakers who blow cold, compressed air into the convertor, thus reducing its carbon content and stripping out any silicon because the air combines with the carbon and induces the iron to boil and burn until the carbon is reduced. After this oxidation process is completed, a steelmaker pours the converter's contents out and preps them for rolling. This only takes about 20 minutes.

The Bessemer process was revolutionary. It obviated the need for steelmakers to mix liquid cast iron and carbon, a much more onerous and energy laden process. This meant that no outside fuel was needed by steelmakers to make steel, which considerably reduced costs and preparation time. Basically, the Bessemer process could create thirty tons of high quality (strong) steel in thirty minutes. This led to its widespread adoption of Bessemer steel by machinemakers, railway barmakers, bridgemakers, and shipbuilders.

During the second half of the 1850s, Henry Bessemer & Company, a firm founded by Bessemer in London, acquired patents associated with his steelmaking process in both the U.K. and across several European countries.[66] It then widely licensed this patent to metalworkers and other manufacturers who had access to blast furnaces.[67] But selling a license to foreign steelmakers was only the beginning of the relationship between the company and its licensees.

Mastering the Bessemer technique is no small task. It requires workers to obtain considerable knowledge and skills centered on controlling temperatures, movements, and sequences. When pouring the molten pig iron into the converter, manipulating it through tilting and blowing, and pouring it out of the converter, it is paramount that steelmakers exercise the right technique and judgment, lest the oxidation process fail or the pig iron lose its malleability.

While much of this can be learned through experience, the accumulation of knowledge around Bessemer steelmaking involved considerable trial and error. Over time, the diagnostic and calibration skills honed by Bessemer steelmakers grew increasingly sophisticated. This led to vast improvements in efficiency and cost reductions.

Consider the following example. As a first step, Bessemer steelmakers melt iron ore in a blast furnace powered by coke. To ascertain that the pig iron they used had obtained the right consistency before introducing it into the converters, the first generation of Bessemer steelmakers cooled it after removing it from the blast furnace and then re-melted it in cupola furnaces. Over time, however, steelmakers learned how to manipulate the iron ore during the melting process itself, allowing them to pour the resulting pig iron straight into preheated converters. Finally, the Bessemer process involves rolling and shaping the cooled metal with utmost precision and care; a skill that takes steelmakers considerable time to learn and perfect.[68]

To help his licensees learn what was an elaborate and delicate process that was constantly evolving, Bessemer deployed engineers and other skilled laborers abroad; sometimes, he himself was directly involved.[69] They took an active role in calibrating the disparate processes outlined above with whatever raw materials they found *in situ*. Bessemer and his envoys taught their licensees the analytic and diagnostic tools associated with each step in the process. This included not only the oxidation process, but also blast furnacing and rolling and shaping—how to manipulate the malleable metal to make it the right size, shape, and strength.[70] They often shared insights with their licensees that they had acquired through learning-by-doing.

The introduction of the Bessemer steelmaking process to Spain was precocious. In September 1856, a mere months after acquiring his British patent, Henry Bessemer acquired a fifteen-year invention patent for his steelmaking technique in Spain (#1510: Procedimiento para mejorar la fabricación del hierro y el acero). He then demonstrated his process in London to José de Vilallonga and Jose Maria Ybarra. Bessemer sold his Spanish patent to the Ybarras in 1857 for £5000, which was supposed to be paid in four installments: the first upfront and the next three spread over the subsequent three years.

Importantly, Bessemer and the Ybarras signed a contract that committed the English inventor to provide the Spaniards with technical assistance in exchange for his Spanish patent rights. This included sharing plans and knowhow not included in the patent itself (Morlán 2002, p. 93). Consequently, between 1857 and 1858, Bessemer oversaw the installation of a converter in the Ybarras' ironworks facility in Guriezo (see Pretel and Sáiz 2012, p. 102; p. 112, endnote 14; Morlán 2002, p. 95). Moreover, while the storied inventor committed himself to sharing any improvements to his process with the Ybarras, they were obligated to reciprocity: they were to report to Bessemer any advances they innovated while making steel through his process.[71]

In this way, Bessemer was implementing a playbook he used in other countries. The Swedish example should prove instructive to readers.[72] Similar to the Spanish case, Bessemer was granted a patent in Sweden only months after filing his original British patent, and he immediately granted a license to a Swedish metalworking firm. This was accompanied by the migration of skilled workers who were familiar with the Bessemer process from Yorkshire England to Stockholm and other Swedish cities. While the Englishmen began to help their Swedish counterparts implement the new process as early as 1857, it took them about a year of challenges and experimentation to achieve success. Along with having to teach their Swedish licensees how to heat, tilt, mix, and cool the molten pig iron and other additives, the British were also tasked with installing and operating a sophisticated hydraulic system and other supporting machinery.

Unlike in the Swedish case, however, the Spaniards decided to delay putting Bessemer's process into widespread use. This, despite the fact that Bessemer steel had been produced in Basque country a mere sixteen months after the English inventor had introduced his revolutionary process to the world, and despite the fact that the Ybarras had already paid £2000 of the £5000 they owed Bessemer & Company for the patent rights (Houpt and Rojo 2006, p. 326).

Instead, the Ybarras decided to double down on the Chenot process, the centerpiece of their new ironworks plant in Baracaldo, where they had already spent five million reales and put in over three years of construction under the guidance of French engineers (Houpt and Rojo 2006, p. 327; Morlán 2002, p. 96). The Chenot process as applied to the Baracaldo steel mill ultimately proved uneconomical, however (see Fernández de Pinedo 1983, p. 14). It was abandoned in 1871.

It was not until the late 1880s, therefore, and well after the Bessemer invention patent had expired, that Bessemer steel was produced in Spain in commercial quantities—and despite additional trials outside of Bilbao in Trubia (1861) and El Pedroso (1865).[73] This first occurred in San Francisco de Mudela in 1885, a mill that was, originally, a subsidiary of a British firm, John Brown Company, and was able to exploit four coke fired blast furnaces previously imported into Spain by its parent company.[74] Then two new firms, La Vizcaya and Altos Hornos de Bilbao (AHB), followed suit in 1886.

La Vizcaya was founded in 1882 as a limited liability company by three Basque engineers trained in Belgium and England: Víctor Chávarri, his brother Benigno, and José A. de Olano. The new firm was capitalized with 12.5 million pesetas.[75] Their plan was to manufacture steel using modern, indirect techniques to service the construction of railways and steel hulls for shipbuilding (Taylor 1978, p. 74). La Vizcaya invested in blast furnaces fueled by coke and the infrastructure required to fabricate Bessemer steel, including five lamination trains. To procure the technology and expertise it needed to produce steel at a large scale, La Vizcaya contracted with a Belgian firm named Cockerill. Federico de Echevarría was named manager of the Sestao plant and charged by the firm with overseeing its launch. He received help from several Belgian engineers, foremost among them A. Greiner, and sent workers to Cockerill headquarters, in Seraing (Liege), to gain the necessary technical knowhow (Portilla 1985, p. 42).

However, because AHB had already secured a patent for Bessemer steelmaking—as we shall discuss below—La Vizcaya turned to an alternative, Bessemer like process known as "Robert" invented by a Frenchman named Gustave Louis Robert (see Houpt 2003, p. 362; Portilla 1985, pp. 63-64). He obtained a twenty year invention patent in Spain in 1888 (#8321: Un procedimiento para la fabricación de hierros finos y aceros fundidos mediante el aparato destinado a este efecto) and licensed it to La Vizcaya in 1891.[76] Echevarría erected five Robert converters in Sestao under Robert's tutelage and steel production using his process began in 1892 (see Houpt 2003, p. 363).

Finally, we come to the last of the big three: in 1882, the Ybarras helped to create—and control—AHB, a limited liability company. The new firm combined their assets in Guriezo and Baracaldo and was capitalized with 12.5 million pesetas.[77] Its purpose was to adopt Bessemer steelmaking techniques in a refurbished Baracaldo mill, and they budgeted 1.75 million pesetas

(203,000 pounds sterling) towards that goal (Portilla 1985, p. 78). The new firm also hired specialized human capital from Germany, France, Belgium, and England to do so. AHB installed the new process with the help of a French engineer, Alexandre Pourcel, who had worked at the Terre Noire ironworks in France; the mill was then put under the direction of Edward Windsor Richards, a famed English engineer and expert in Bessemer steelmaking who had been the manager of the Eston ironworks in England (owned by Bolckow, Vaughan & Company).

AHB saw fit to patent several modifications to the Bessemer system that were especially suited to the Baracaldo factory's specifications. This included a five year invention patent in 1884 that improved blast furnace heating through the use of so-called Cowper stoves (#3732: Uso de las estufas Cowper, destinadas a calentar el viento que se inyecta en los altos hornos con aprovechamiento de sus gases). It also included another five year invention patent obtained in 1886 that allowed AHB to monopolize the Bessemer technique within Spain according to the modifications they made to it (#5837: Procedimiento "Bessemer" para convertir el hierro colado en acero o hierro dúctil haciendo uso de los convertidores giratorios de su sistema). While the Ybarras could no longer lean on the licensing agreement they had agreed to with Henry Bessemer decades earlier, they sent some of their most trusted employees to train with Bessemer steelmakers at Eston to get the system up and running (Houpt and Rojo 2006, p. 336).

The result was Spain's most impressive integrated steel mill to date. The Baracaldo facility eventually boasted coke making ovens, two coke fueled blast furnaces, two Bessemer converters, three reheating furnaces, two large cupolas, three small cupolas, and rolling mills.

The Siemens Brothers Open-Hearth Process

The invention of the open-hearth steelmaking process in 1863 by William Siemens, a German born inventor residing in England who was helped by his brother Friedrich, represented another revolution in the fabrication of cheap and reliable steel at a large scale. This process calls for steelmakers to slowly boil a mixture of iron ore or scrap metal into molten pig iron, thus reducing the latter's carbon content via oxidation. Steelmakers melt these materials in a dish like open bath heated by a regenerative gas furnace fueled by either coal or natural gas.

The open-hearth conversion process differs from Bessemer's in four key ways. First, it uses the gases generated during the coke making process (which fuels the blast furnace that melts iron ore into pig iron) to fire the furnace, as well as reuses the escaping hot waste gases emitted during the steelmaking itself to preheat incoming fuel and air used to melt the steel and its additives. Second, the process spans hours, therefore allowing the steelmaker to repeatedly evaluate the metal's chemical and physical features along the way, and make any needed modifications. Third, it enables the production of greater amounts of steel, albeit over a longer period of time. Fourth, it allows for the possibility of using recycled scrap metal. Taken together, these advantages translate into much cheaper, higher quality steel.

Like the Bessemer process before it, the Siemens-Martin system was both sophisticated and supremely delicate. For the steelmaking process to operate smoothly,

> it was necessary to take into consideration the proper charging of the furnace, and the proper distribution of the materials in it; also, whether it was a furnace which under all circumstances had every part of it exactly adapted in the best possible manner to the work that had to be done, whether the hearths were the proper size, whether the boshes were

right, whether too steep or too flat, and many other points, any of which would interfere with perfect results (Iron and Steel Institute 1874, p. 51).

As in the case of Bessemer steelmaking, patenting and licensing was a critical pathway by which William Siemens disseminated his open-hearth process.[78] He first patented his invention in the U.K. and immediately licensed it to several manufacturers across that country. Siemens also licensed his patent across the European continent and the U.S.

The terms that appear throughout the licensing contracts entered into by Siemens and his licensees adduce the technology transfer mechanisms that this chapter has stressed.[79] They prominently discuss how Siemens will convey his licensor with the knowhow needed to operate the open-hearth furnace. These contracts also obligate a long-term relationship between Siemens and his licensors. Specifically, they compel Siemens to transfer knowledge of any new innovations that may arise over time to his licensors.

Let us now consider how the open-hearth process was introduced to Spain. As early as 1863, William and Friedrich acquired a ten year invention patent that codified the regenerative furnace used in the open-hearth process (#2669: Perfeccionamientos introducidos en la disposición y calentamiento de los hornos). William then registered, in 1872, a ten year invention patent for the Siemens steelmaking process itself (#4902: Procedimientos de tratamiento de minerales de hierro, en la fabricación del acero fundido, y en sus aparatos).

After the open-hearth process was introduced to Spain by the Siemens' brothers, they and others conveyed knowhow on the back of patent licenses that proved critical to consolidating and disseminating the invention. Specifically, Friedrich was instrumental in helping La Vizcaya implement the open-hearth process in its Sestao ironworks, which took several years to finalize.

Under the aegis of his Spanish patents, Friedrich helped the Spaniards install and learn to use the Siemens steelmaking process in exchange for royalties.[80] By 1889, La Vizcaya finished construction on three Siemens-Martin ovens—it set aside 350,000 pesetas that year to install those ovens (Portilla 1985, p. 63)—and added another in 1890 (Houpt 2003, p. 361), for which it spent another 82,823 pesetas (Portilla, 1985, p. 63).[81]

Between 1884 and 1907, Friedrich obtained ten additional invention patents in Spain. They codified follow up improvements to either his regenerative heating process or the Siemens steelmaking process.[82] These patents were put into practice in Sestao and other Bilbaon steel mills. By 1919, the Sestao mill boasted ten Siemens-Martin ovens that could produce twenty tons of steel (Houpt 2003, p. 362).[83]

Moreover, between 1895 and 1929, inventors from Belgium, Germany, Italy, France, and the U.S. also patented close to twenty follow up inventions to the Siemens steelmaking process in Spain.[84] After 1901, they were adopted by Altos Hornos de Vizcaya in Sestao and Baracaldo.

CONCLUSION

This chapter shows that, between 1850 and 1930, foreign inventors who made major innovations in the iron and steelmaking industry patented their inventions in Spain, licensed these to Spanish firms, and helped the latter acquire the knowhow to put these inventions into practice. This helped new processes from abroad transfer to Spain. It also fostered further adjustments and improvements by both foreigners and Spaniards. These were tailored to the challenges and idiosyncrasies they encountered on the ground and were themselves patented in Spain.

Cutting edge inventions associated with steelmaking in modern, integrated mills probably could not have been appropriated by Spanish entrepreneurs through espionage or copying. Instead, because they were complemented by a deep substrate of tacit knowledge, original inventors' willing consent and ongoing cooperation were required. Since Spanish authorities granted foreign inventors and their representatives patents that were enforceable, this underpinned the licenses that spelled out mechanisms by which technology would be transferred. In turn, this gave them the incentives and opportunities to introduce their steelmaking innovations to Spain.

These insights should encourage policymakers interested in promoting economic development. Developing countries that register low levels of spending on R&D and low levels of human capital may nonetheless grow their economies if they can acquire state-of-the-art international technology (Abramovitz 1993). That is, if they can enforce patent regimes that incentivize, and create opportunities for, the transfer of innovative processes from the technology frontier. This may also stimulate cumulative innovation associated with learning-by-doing. And some of these innovations may even make their way back to the developed world.

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[1] As I will discuss below, the Spanish system was reformed once again in 1986 to again strongly protect foreign investors. By then, however, most of the major innovations that drove the modernization of iron and steel had already taken place and transferred to Spain. Therefore, it makes sense for me to narrow attention to the previous period.

[2] On all of these points see Navarro (2018). Chinese firms also attempted to secure American technology by recruiting computer engineers and data scientists in Silicon Valley. According to the FBI and US Joint Chiefs of Staff, the Chinese government is behind the theft of billions of dollars of US companies' trade secrets across a wide swath of sectors, including aviation, pharmaceuticals, and extractive industries.

[3] Beijing imposed tit-for-tat tariffs on U.S. exports and increased regulation of American firms doing business in China; for example, Chinese antitrust authorities' decision to nix the attempt by Qualcomm to merge with Dutch chipmaker NXP. See Eliot and Davis (2018). American politicians have, in turn, complained about Chinese tariffs on American imports, China's supposed currency manipulation, its subsidies of state-owned enterprises, and its flooding of the international market with cheap industrial goods such as steel.

[4] This reflects China's manifold improvements in protecting IPRs. Beijing has joined all major international IP conventions and ramped up its enforcement capacity. Between 2006 and 2011, foreign companies brought 10 percent of patent infringement cases in China and won over 70 percent of those. In 2018, injunction rates averaged around 98 percent (see Menaldo and Wittstock 2020).

[5] Others reach similar conclusions. They include Ortiz-Villajos (2004) and (2006); Sáiz (2014) and (2016); Sáiz and Pretel (2013); Sáiz and Castro (2017).

[6] They argue that, despite the fact that Spain's IPR were relatively weak during this time, patents helped technology transfer take place in combination with increased imports of foreign machinery on the heels of trade liberalization circa 1960.

[7] Moser (2013) is bearish about patents fostering innovation; yet, she is oddly bullish about their ability to fuel technological diffusion and, by implication, technology transfer across borders.

[8] Although see Hall and Helmers (2018), who analyze the effects of accession to Europe's regional patent office, which afforded joining countries membership in the European Patent Convention. They find that FDI did not materially increase in joining countries during the post accession era, despite investors' access to a seemingly stronger IPR regime.

[9] On these points, see Arora (1995). And see Moser (2013, p. 39), who offers the instructive example of the chemical industry; she recounts how, after the outbreak of World War I, US Winthrop Chemical Company struggled to apply Bayer patents for drugs it acquired from the U.S. government. The latter expropriated these from the original patentee, but in doing so deprived the American firm from accessing critical, uncodified knowledge from Bayer.

[10] Of course, the international transfer of technology can be non-linear and complicated by a host of factors. For example, younger workers may choose to make specific human capital

investments in older technologies—such as training to operate dated machinery—if a critical mass of older workers have also made those investments; in turn, this may slow down the diffusion of new technology across borders (see Chari and Hopenhayn 1991). Moreover, the diffusion of new processes may depend on the degree to which an industry is competitive, the capital costs of initial investments, and managerial incentives to take risks (see Mansfield 1961).

[11] For an account of how technology was transferred to Scandinavia by foreigners patenting and disseminating their inventions across these sectors see Bruland and Smith (2010).

[12] For example, during the latter part of the Nineteenth Century, German and French inventors who improved upon English steelmaking inventions after acquiring licenses from them then turned around and obtained patents in England to protect their follow up innovations.

[13] These measures paralleled what was done in other countries to acquire advanced machinery and knowledge from Britain, the leading technological power at the time. Other measures experimented with across European capitals included bestowing private firms with imported machinery and setting up model factories, as well as giving them financial incentives to use more advanced technology: rebates and exemptions on import duties (see Landes 1969, p. 150-151). Ironically, long before the industrial revolution, Henry VII tried to lure skilled wool weavers from the Netherlands and Venice to England to acquire new technologies (see Reinert 1995).

[14] Before going into details, it behooves us to put Spain's relative technological backwardness in perspective, however. During the 1880s, the number of invention patents awarded in Spain was somewhere north of 2,000; over the same time period, this number was closer to 30,000 in the U.K. Also, the patenting gap between Spain and the U.K., as well as between Spain and other developed countries, widened over time. See Ortiz Villajos (2004).

[15] Terms such as “property” and “rights” were dropped in 1826, and replaced with language denoting royal “prerogatives” and “privileges”. Despite these semantic changes, Spain’s patent system remained centered on protecting temporary property rights to ideas (see Sáiz 1995, p. 95).

[16] Readers should note that if an introduction patent was granted by the government to an entrepreneur to manufacture a new invention in Spain, this did not bar others from importing it into Spain. In practice, however, this happened on a de facto basis if import tariffs were high.

[17] While Spain granted introduction patents until 1985 (more on that below), the U.K. abolished them by 1852. Moreover, the U.S. never had any; nor did France or Germany. Other countries with introduction patents were the Netherlands (before they abolished patents) and Austria.

[18] Spanish authorities stringently enforced this stricture between 1849 and 1877 (see Sáiz 2013).

[19] Foreign inventors found ways around this restriction and patented their original inventions in Spain after patenting them elsewhere; indeed, as we shall soon see, this was the case for French and British inventors working in the steel industry during the mid-Nineteenth Century.

[20] To calculate these figures I used data on patent fees from Sáiz (1995). I deflated them using the producer price index available in Taylor (2016). The wages data are from Williamson (1995).

[21] On all of the points contained in this paragraph, see Sáiz (1995; 1996; 2013).

[22] In 1886, the patent office began to print a journal that disclosed and publicized patents called *Boletín Oficial de la Propiedad Intelectual e Industrial*. Before that, other magazines and periodicals regularly broadcast new patents.

[23] On all of these points, see Sáiz (1995, p. 95).

[24] These next two paragraphs build on Chang (2003) and Harris (1996).

[25] See Penrose (1951, p. 13). Holland had a very weak patent system—with no disclosure of inventions, introduction patents, the nullification of foreign patents in favor of domestic ones,

and with wide latitude for infringement—and abandoned it in 1869. Switzerland did not adopt a patent system until 1888, and it was a rather weak one until reforms in 1907 (Chang 2003).

[26] Fernando VII had quickly abdicated in the face of France's 1808 invasion and occupation and, in a sense, had countenanced Spain's takeover by a foreign empire. The Cádiz Court soon filled the political void, as did provisional regional Juntas, and was able to gain popular support.

[27] This paragraph builds on Tortella and Comín (2001).

[28] To be sure, the crown liberalized trade between the mainland and its colonies and among the colonies in the late 1700s; this contributed to a short-lived boost in revenues. However, rising military expenditures largely offset these new revenues; besides, trade liberalization was rendered moot when Latin American countries won their independence.

[29] Consider, for example, tax receipts associated with the Mesta: the French army had laid waste to the once-valuable sheep trade, therefore killing what was once a government fiscal cow.

[30] On the struggle faced by Spanish authorities to finance both external defense and internal security after the Peninsular War, see Tortella and Comín (2001, p. 164).

[31] At the end of the Eighteenth Century, most Spanish land could not be sold, even if its owner wanted to sell it, because it was tied up in "special" holdings that faced strong sale and use restrictions. This was true for land that belonged to the Catholic Church and municipal governments, or land that was held by the nobility in entail. Moreover, many tracts were held in common by villagers. Finally, the crown bestowed privileges to the Mesta—a powerful sheep owners' organization—which monopolized pasturing rights over huge swaths of land in exchange for taxes levied on the lucrative wool trade (see Simpson 1995, p. 64; Tedde de la Lorca 1994, p. 531).

[32] On paper, distinctions were made between savings banks, mortgage banks, and investment banks; in practice, these distinctions were not always respected (see Tortella 2000, Chapter 6).

[33] On Spain's fiscal and budgetary reforms, see Tortella and Comín (2001, pp. 161-173).

[34] Ironically, this time around they had the support of the French, who (once again) occupied Spain to help Fernando VII cling to power.

[35] While absolutists were, for the most part, aligned with landed interests who sought trade protection, their alliance was complicated by the fact that some agriculturalists sought protection from imported foodstuffs and commodities while seeking duty free fertilizers and machinery. And nascent Spanish industries often sought protection from imports, even though their economic interests coincided with that of liberal reformers over matters such as access to a free, mobile labor force, credit, and cheap energy (Tortella 2000, pp. 193-4). As we shall see ahead, this was the case for the steel industry.

[36] In 1874, the Banco de España was made the sole issuer of legal tender; in 1885, it established the first nationwide network of bank branches. The bank acted as a lender of last resort, but mandated no capital requirements from banks and demanded only minimal disclosure requirements. There was free entry for non-issue commercial banks until 1920. See Martín-Aceña, Pons, and Betrán (2014). I should note, however, that the central bank had an outsize influence on the economy, focusing much of its energy on financing the country's explosive sovereign debt; also, the Spanish financial system remained quite underdeveloped in comparison to the rest of Europe (Tortella 2000).

[37] Rather than a decree, it came in the form of legislation proposed and authored by reformers in the Spanish Parliament. Specifically, it was crafted by a joint committee of the country's two

legislative chambers (see Sáiz 1995, p. 125). I should also note that Spain introduced a system of trademark registration and enforcement in 1850.

[38] While the total price tag for an invention patent increased, patent fees were now due in installments, rather than upfront in one lump sum. The amount owed by a patentee increased progressively over time. This meant that a greater number of inventors/entrepreneurs could afford a patent and smooth out the amortization of their IPR.

[39] This implied that, for the first time, foreign inventors had a priority over the Spanish nationals who might have sought to introduce these previously existing inventions to Spain. Foreigners had up to two years after first obtaining a patent abroad to patent their invention in Spain. Moreover, in 1884 Spain joined the *International Union for the Protection of Industrial Property* (IUPIP) as a founding member. Signatories obliged themselves to respect a priority right: the filing of an application for a patent in one country gave the applicant the right to obtain a recognition of her claim in all other IUPIP members. However, readers should keep in mind that the IUPIP was vested in a non-reciprocity approach: foreign citizens were entitled to receive the same treatment as nationals, but signatories were not required to accord foreign citizens—nor their own citizens, for that matter—the same rights they enjoyed in their own countries.

[40] I should note that, as a share of total patents, corporations began to patent in Spain at increasing rates around this time, paralleling a trend seen throughout the industrialized world. The majority of these companies were foreign multinationals (Ortiz Villajos 2004; Sáiz 2016).

[41] Spanish patent law now explicitly barred the patenting of "naturally occurring" things, as well as pharmaceuticals, and gave original inventors priority when patenting further additions to their inventions. And further patent reforms were made by Spanish lawmakers in 1902. Foreigners were afforded the same twenty-year protection for their invention patents as Spaniards, even if

they had previously patented their inventions in their home country or elsewhere; the working requirement was extended to three years; temporary patents were given, at no cost, to inventors who debuted their innovations at international expositions; the patent office was required to keep inventions with national security implications secret; and the state could use eminent domain to “expropriate” patents if doing so advanced the national interest (see Sáiz 1995, pp. 144-147).

[42] See Sáiz (1995, pp. 152-162; 1999, pp. 95-96) on all of the following points.

[43] These increased fees were introduced by the government in 1924 (see Sáiz 1995, pp. 153).

[44] Exploitation patents were abrogated in 1930, however (see Sáiz 1999, pp. 96). There were other, less important, changes made by the Spanish government to the patent system under the 1929 law; this included a host of regulations governing “addition patents” (see Sáiz 1995, pp. 165).

[45] Some researchers argue that these tariffs were not protectionist per se, and that they instead served as revenue generating measures (Berend and Ránki 1982, p. 106; Tortella 2000, p. 201; Tortella and Comín 2001, p. 179).

[46] De Rivera was a military general who had the support of King Alfonso XIII. He lasted in office six years; after he gave up power, Spain’s Second Republic was ushered in.

[47] There were two reasons for this. First, Franco included important labor unions in his coalition. Second, the regime feared political instability associated with labor militancy.

[48] On all of these points, see Pons (2002).

[49] This crony capitalist system relied on financial repression and concomitant economic distortions. The government restricted entry into the banking system and capped interest rates, so credit was artificially rationed. The upshot was a highly concentrated, inefficient financial system centered on five big banks. In exchange for barriers to entry and associated market power

rents, these banks held controlling stakes in important industries, many of them state-run enterprises, to which they directed subsidized credit. These oligopolistic banks also held the government's debt at below market rates, which helped the latter fund large budget deficits.

[50] Trade liberalization began in 1959 a part of a stabilization plan. The government reduced quantitative restrictions on external trade and tariffs reductions (see Tortella 2000, pp. 431-3).

[51] On all of the following points, see Sáiz (1999, pp. 97-98).

[52] The government barred scientific discoveries from being patented, along with software or innovations centered on plants, animals, medicine, and food. In 1992, Spain allowed chemical substances to be patentable once again, however (see Chang 2001, p. 306).

[53] While the rest of this chapter focuses on post 1850 steelmaking in that region of Spain, there was considerable "pre-modern" iron and steelmaking in other parts of Spain: Andalusia, on the Southern, Mediterranean coast, and Asturias, in northwest Spain, where there were abundant coal reserves; there were two additional, albeit tiny, enclaves in Barcelona and Toledo. See Nadal (1970) for the etiology of iron and steelmaking in these regions, as well as their relative contribution to overall Spanish steelmaking until 1868. There were also failed modern steelmaking experiments undertaken by firms and the Spanish state in Andalusia.

[54] The first generation of the process required phosphorous free iron ore. In 1878, Sidney Gilchrist Thomas and Percy Gilchrist innovated a way to remove phosphorous from the iron during Bessemer steelmaking, however: they added limestone to the converter and then removed the resulting slag. This significantly reduced the selling power of Biscayan iron ore.

[55] To be sure, there were substantial coal deposits to Bilbao's west, in Sama de Langreo, Asturias. Yet, the lack of infrastructure linking these two regions made transportation costs, and thus the costs of shipping that coal east, prohibitive (see Riera i Tuebols 1993, p. 150).

[56] Escudero (1999, p. 199) offers several reasons why Spanish steelmakers were uncompetitive vis-à-vis European ones and thus sought protection: the advent of the Thomas Gilchrist adjustment to Bessemer steelmaking—which allowed convertors to use pig iron with phosphorous—meant that Biscayan iron ore lost its competitive edge; Bilbaoan steelmakers were unable to achieve economies of scale; and countries such as Italy and Germany adopted tariffs on imported steel.

[57] It is important to note that, internationally speaking, the Spanish steel industry never achieved the size one would want to write home about; nor was it ever really all that competitive on world markets (Aldcroft 2016, p. 128). Between 1882 and 1922, Spain only produced 0.69 percent of world iron and steel output (Houpt and Rojo, p. 329). Several hypotheses have been put forth by economic historians to explain this. They include lackluster internal demand, high levels of protectionism that stifled competitiveness, and rent-seeking. Also, a civil war that raged between 1873 and 1876 deterred investors from building and expanding Biscayan mills (Nadal 1970).

[58] For the onset of each of these techniques see Fernández de Pinedo (1983) and Houpt and Rojo (2006, pp. 324-25). See Nadal (1970, pp. 220-21, Table 4.3) for a list of Spanish iron and steelmaking establishments in 1865, and the technologies possessed by each of these.

[59] See Anduaga (2011) and Houpt and Rojo (2006). Unlike in the iron ore industry, however, the nascent steel industry had a low level of foreign direct investment, so FDI did not play much of a role, if any, in facilitating the transfer of technology.

[60] I exploited electronic access to the actual patents through the Spanish Patent and Trademark Office (OEPM); they were put into a searchable database by Patricio Sáiz and his collaborators.

[61] Chenot steelmaking then spread to Belgium, France, Italy, and Russia (see Uriarte 1998).

[62] Later that year, Chenot followed this with a five year introduction patent for steps that complemented his steelmaking process (#1212: Procedimiento para el tratamiento de los óxidos metálicos o sus compuestos llevados a tal estado).

[63] The plant eventually boasted eight Chenot ovens, several blast furnaces, and several puddling furnaces (see Fernández de Pinedo 1983, p. 13; Morlán 2002, p. 88).

[64] Tourangin first obtained a French invention patent in 1853, followed by a Spanish introduction patent in 1855 (#1275: Procedimiento de fabricación del hierro por el método catalán haciéndolo mas rápido, económico, y lucrativo).

[65] For a description of these inventions and how Tourangin spread them, see Uriarte (1998).

[66] Bessemer's basic steelmaking patent was granted in 1856. Over the years, he also patented improvements upon his original process. In the U.S., William Kelley obtained a patent for the same technique in 1857: an American court ruled he discovered the process independently.

[67] Within the first year of acquiring his patent, Bessemer collected £107,000 in royalties (Morlán 2002, p. 91). Bessemer collected royalties from three sources. First, he sometimes transferred his patent to a foreign agent outright. Second, he sometimes charged a fee for its general use. Third, he sometimes earned royalties on each unit of steel that was produced by a licensee.

[68] On all of these points, see Nuwer (1988).

[69] Patenting and licensing complemented other methods by which foreign steelmakers became aware of, and acquired knowledge about, the new process. The latter included Bessemer's attendance at international exhibitions, conferences about iron and steel, and seminars organized by the *Institution of Mechanical Engineers*. There, he and other metallurgists discussed their experiments, inventions, patents, and products.

[70] This paragraph builds upon Houpt and Rojo (2006).

[71] This was similar to the patent licensing agreements that were often made between multinationals and Spanish subsidiaries (see Sáiz 2016 for the case of Babcock and Wilcox).

[72] This paragraph draws strongly on Bruland and Smith (2010, p. 87).

[73] Several theories have been put forth to explain this delay, in particular, and the overall reluctance of Basque firms to adopt blast furnaces powered by coke, despite their eagerness to learn about and even acquire these technologies early on (see Fernández de Pinedo 1983; Morlán 2002; Houpt and Rojo 2006, p. 328; Uriarte 1998). One popular theory is that Basque iron ore was of such high quality that Spanish ironworkers could "afford" to continue to rely on direct methods that yield sponge iron. Another is that internal demand was too low to achieve the necessary cost efficiencies associated with economies of scale. Still another reason is the relatively low quality and reliability of Bessemer steel before the advent of add-on innovations such as the Mushet system, which helped prevent over-oxidation by reintroducing some carbon.

[74] It was purchased by a Spaniard, Francisco de las Rivas, in 1879. I have not been able to ascertain whether this firm continued to produce steel after 1886 using Bessemer convertors. If it did so, it was infringing on the patent rights that were locked up by AHB that year (see below).

[75] Major shareholders included miners and merchants from Bilbao, Barcelona, and London. For a complete list, see Portilla (1985, p. 41).

[76] I should also note that La Vizcaya obtained a 5 year invention patent in 1887 (#7479, Hornos para acero en solera, "Sistema Bech") that codified some of the modifications that its engineers made to the Sestao blast furnaces in order to accommodate indirect steelmaking techniques.

[77] For a list of original investors, shareholders, and the capital each invested, see Morlán (2002, pp. 122-124).

[78] In 1864, under Siemens' guidance, a French licensee named Pierre-Émile Martin was able to find a way to add scrap metal and wrought iron to the furnace in order to complement pig iron, thus reducing costs to an appreciable degree. It is for this reason that the open-hearth process came to be referred to the world over as Siemens-Martin steelmaking.

[79] For an example of one of these contracts in English that can be accessed online see Great Britain, Parliament, House of Commons (1872).

[80] William died in 1883, but not before bequeathing his patents and the royalties associated with the open-hearth inventions to Friedrich. Niebel (2009, p. 60) recounts how Friedrich offered critical technical assistance to Federico Echevarría during the implementation of the Martin-Siemens process in Sestao. As discussed above, he was La Vizcaya's manager; he then went on to own and operate his own metallurgical firm and later became a senator in the Spanish parliament. Several biographies of Echevarría's life echo this account about his relationship with Siemens.

[81] Fernández de Pinedo and Uriarte (2013, p. 225) report that AHB erected a Martin-Siemens oven in 1887. However, I could not find any records of a license granted by Friedrich to AHB, or his involvement in transferring knowhow to that firm. This does not entail that AHB infringed on his patents, however, as Friedrich's brother, William, had only obtained a ten-year invention patent in 1872. Similarly, I could not ascertain exactly what patent was connected to the licenses he granted to La Vizcaya; by implication, I could not identify whether Friedrich transferred knowhow under the auspices of a contract connected to any patent(s). Instead, as noted in the previous footnote, I am relying on overlapping accounts about this phenomenon that include Niebel (2009) and other Federico Echevarría biographers.

[82] These were registered in 1884 (#4562: Un nuevo método de operar con hornos de hogar abierto para la producción de lingotes de hierro y acero), 1885 (#5518; Perfeccionamientos introducidos en la construcción y funcionamiento de los hornos, gasógenos y hogares de calderas calentadas por el gas), 1889 (#9922: Un procedimiento para utilizar los gases perdidos y demás productos gaseosos de la combustión por la mera construcción de un horno para el calor regenerado que permite alcanzar dicho objeto y cuya construcción puede emplearse también de la manera usual), 1890 (#10441: Perfeccionamientos introducidos en los hornos para gas de calor regenerado), 1897 (#20422: Mejoras en hornos regeneradores de gas), 1898 (#23383: Perfeccionamientos en los hornos de gas de calor regenerado), 1902 (#30583: Mejoras en los hornos regeneradores de gas), 1903 (#32035: Mejoras en los hornos de gas recuperadores para recalentado), 1904 (#33194: Mejoras en hornos regeneradores de gas), 1906 (#38973: Mejoras en los hornos de gas recuperadores para recalentado).

[83] By this time, La Vizcaya and AHB had merged to form Altos Hornos de Vizcaya.

[84] Details can be obtained through the Spanish Patent and Trademark Office (2018).