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Technology Transfer in Spanish Heavy Industry, 1856-1936©

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Resumen en castellano

El objetivo de este trabajo es descifrar los factores específicos que determinaron la transferencia de tecnología desde la Europa industrial a España entre 1856 a 1936. Esta primera versión presenta algunos primeros resultados. El análisis se centra en la industria pesada que tiene un especial interés dada su intensidad de capital, el carácter autoritario de su gerencia, la magnitud de su producción, el coste de parada de su instalaciones de semiflujo y sus elevadas inversiones en capital fijo. De momento se ha analizado la industria siderúrgica moderna y la industria de la construcción naval.

El trabajo se divide en cuatro partes. La primera de ellas define los elementos que intervienen en la transferencia de técnicas. La siguiente da una descripción breve de la evolución tecnológica de los sectores tratados. El apartado tercero aplica el marco teórico desarrollado previamente incluyendo un análisis de casos y la última parte expondrá las conclusiones.

Las conclusiones identifican unas pautas comunes para la transferencia de la tecnología siderúrgica. En ambos casos existen personas vinculadas a las burguesía mercantil con educación técnica en el extranjero que sirven de bisagra en el proceso de transferencia. Sus contactos y conocimientos técnicos sirven de filtro para elegir las innovaciones que se producen en Europa. Los mecanismos de transmisión velan por la garantía técnica del proceso introducido. Entre las formas que se adoptan se encuentran los contratos de llave en mano, la garantía del constructor, los patentes pero sobre todo el personal cualificado que transmite sus conocimientos o los pone al servicio de la empresa española.

La construcción naval muestra pautas distintas que pueden remontarse a su promoción por parte del Estado. Los concursos de construcción de las escuadras premiaban la creación de empresas *joint venture* con el sector armamentístico extranjero. La rápida sucesión de tecnología en este sector y la falta de industria secundaria en España impuso un elevado grado de dependencia de estas empresas.

Introduction

Some attempts have been made at bringing the cultural and geographical differences of Mediterranean societies into the stylized facts on growth and development we have for explaining the wealth and poverty of the nations. Tortella's book on development in contemporary Spain introduced such elements with a Latin growth model which establishes fiscal imbalances, soil quality and weather, subsistence agriculture, land distribution, dictatorial governments as some of the factors that determine the backwardness and distinct economic growth of the Western Mediterranean.[i] Along with these specific geographical and political settings we might also include other common traits such as paternalism, corporatism, *caciquismo* and clientelism which have formed an important part of the social patterns of these societies for centuries and until more recent times. Even to this day, these information, transaction and dominance mechanisms are present in Mediterranean economy, i.e. the predominant management model is the authoritarian one, family and acquaintance promotion criteria remain in place and male dominance patterns are stronger than in other Western countries.[ii]

The hypothesis that we would like to discuss in this paper is the influence of specific factors in determining the adoption of technology and thereby of the pattern of technological change in Spain. The paper will identify different patterns of innovation: buying capital embodied technology, hiring foreign technicians, investment in technical education and buying patent rights. Our analysis will focus on Spain's heavy industries where apart from strong social mechanisms of discipline and authority there are aspects of precision, magnitude, and the enormous cost of holdup related to their semi-continuous flow production processes or the high fixed capital overhead which determine unique technology paths. Steel, ship-building are the sectors analyzed to date, mechanical engineering and land transport shall be added in the near future.

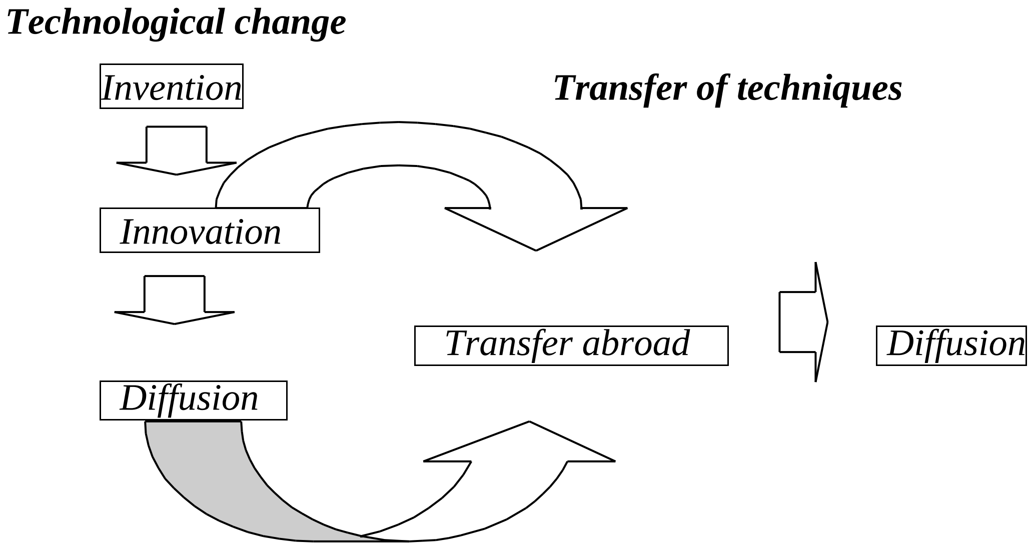
The paper will be divided into four parts. A first section will define the elements involved in the transfer of technique. The following section will give short descriptions of the technical evolution of the two sectors we have chosen to analyze. Section three will apply the theoretical framework developed in section one to the two sectors including more specific case studies and the last part of the analysis will draw the relevant conclusions.

The transfer of techniques

The usual definition of technological change includes three phases: invention, innovation and diffusion. It thereby distinguishes the conception, the viability and spread of know-how. Opposed to this, the process of technology transfer or transfer of techniques is more concerned with the spread of this technical change abroad, i.e. transfer and diffusion. The transfer process is concerned with emulating, replicating or adapting a given practice to the circumstances present in another country. The chart below tries to visualize these differences.

It may also be necessary to distinguish between macrotechniques and microtechniques, in parallel to the nomenclature of macroinventions versus microinvention adopted by Mokyr to distinguish far-reaching breakthroughs from minor adaptations of these breakthroughs. In most of the cases we analyze, the

Chart 1. *The processes of technological change and transfer of techniques.*



techniques transferred to Spain will be macrotechniques which change the production mode significantly. The process of technical transfer involves a number of aspect which Naziol (1996) tried to summarize in a similar way to what we have put together in table 1.

Table 1. *Aspects involved in technical transfer*

Agents	Firms, inventors, engineers, investors, speculators. (donors, middlemen and recipient).
Impetus	Economic motivation, strategy and reputation.
Content	Innovation.
Mode	Legal contract, patent rights, royalties, design, construction and set up (turnkey plants), espionage, capital embodied.
Method	Channels of transmission: commerce, correspondence, journals, societies, travel, import, expatriates.
Outcome	Diffusion rates, effects on production levels & sales levels, levels of capability, failure rates, legal disputes, setup time.

Source: inspired by Niziol (1996), p.3.

Niziol also underlines a range of peculiarities involved in the process of technology transfer: He finds that normally there is no smooth handing over and that the interplay between the two sides has been fraught with distrust. This is a not one-sided story, sometimes the recipients are not as passive as we might imagine them to be – they can even be more aggressive than the donors. On the other hand, even though the motivation for transfer is usually profit, it can also be political or an ambiguous mixture of the two. The modes of transfer in the past have always been similar to what they are today: patents, direct foreign investment, joint ventures, licensing agreements, etc. What has varied over time is the share of each modality in the total. This has changed together with the enforceability of property rights and the accumulated business practice. We can generalize the existing modes into the following way, whatever it is, it can either be provided, purchased, or acquired through indigenous effort.

Specifically studies have shown that the initiatives by recipients are what decide the success of assimilating foreign techniques and stimulating indigenous innovative capabilities. At the same time, donors are usually on the long side of the fulcrum which allows them to control modes and extent of transfer through legal property right arrangements and reap large profits. We see this in the behavior of multinationals which have been reluctant to release technology until late in its life cycle.

In the sectors we are going to examine and analyze for technical transfer we have observed the following pattern of know-how appropriation: In the case of steel works, the key national figures involved in technology transfer received engineering education, some abroad, they usually proposed or initiated the process of transfer. First contacts with foreign companies or engineers were usually made through business partners Additionally national technicians traveled to visit of other factories in Europe to calibrate the kind of installations which were most appropriate. Bringing new technologies usually involved various stages: a first round of deliberations to see which foreign engineer could draw up the necessary project and recommended a competent engineer to carry out construction. Once installations were in place, the project engineer inspected the construction and guaranteed technical assistance until installations were functioning properly. The next stage involved contracting of foreign engineers and technicians to run installations during its initial phase. At the same time their national counterparts received training and experience to take over operations.

For the shipbuilding industry we have observed a slightly different pattern. Whereas foreign engineer projects clearly dominate the construction of new installations, joint ventures with foreign companies for constant technology transfer was more common in the operation phase. The projects are usually initiated via contacts through shipping companies. The long tradition of autochthonous navy shipyards and repair dock facilitate the contracting of qualified workers from previously existing establishments, technical apprenticeships were institutionalized much earlier within the factories and from the 1920’s on, the industry counted with a body of engineers preceding from the Spanish Naval engineer school as a viable alternative to foreign engineers. The dominance of foreign engineers was limited to a much shorter period during set-up and operation.

Modern steel and shipbuilding

In iron and steel processing technical and organizational change brought about important increases in productivity throughout the nineteenth century. These gains in productivity were attained mainly by reducing the cost of heat through a better coordination of the successive stages of transformation, by increases in scale that improved energy efficiencies and by a better calibration of processes and procedures that reduced redundancies and waste. Many of these advances were tied to higher demands for new products such as cast iron, puddled wrought iron and steel. But a greater part of these achievements was obtainable only after combining the new processes for the different stages of transformation into a single mill.

By definition, the modern integrated production of iron —as later that of steel— implied combining three process: 1) charcoal or coke hot blast furnaces 2) puddling facilities for producing wrought iron —later these were replaced by Bessemer and Siemens steel processing installations— and 3) rolling mills.[iii] In some cases establishing modern mills included backward integration into coal and iron ore mining, transportation and coking and forward integration into product distribution and metal transformation industries. Neither of these additional degrees of integration was strictly necessary for attaining the productivity gains we have mentioned before, they were more concerned with guaranteeing input regularity and markets.

The necessary technology for these modern installations and their organization were modern hot blast furnaces, puddling furnaces, Bessemer steel converters, Siemens open hearth furnaces, rolling mill trains and an innumerable amount of ancillary equipment for reheating, handling, finishing off and transport. Even though many of these technologies were firmly embodied in the physical installations they were issued patents for, their successful application depended to a high degree upon the input regularity and the diagnostic skills of the workers in charge of their operation.[iv]

In the case of the shipbuilding industry, which became a downstream sector of iron and steel industry in the nineteenth century, technical advance brought about two major changes in ship construction: the replacement of wood with iron and steel as the predominant construction material and a parallel movement of engines and turbines replacing sails as means of propulsion. The treatment of steel plates, the framing ships with steel beams and "sewing" them together with rivets were thus fore some of the important material changes introduced in the construction of ships in the 19th century.

The propulsion of ships suffered other important advances on both sides in a prolonged battle between sail and steam. Initially steam gained terrain in river and canal navigation, this was followed by its introduction in coastal and short distance line shipping and it completely dominated transport as coal requirements for long journey were reduced drastically with newer engines. Our list of shipbuilding developments in civilian constructions include the introduction and improvement of steam engines, diesel engines, propellers and to a small extent turbines. The construction of machinery, pumps, rudders, and other mechanical parts posed additional problems.

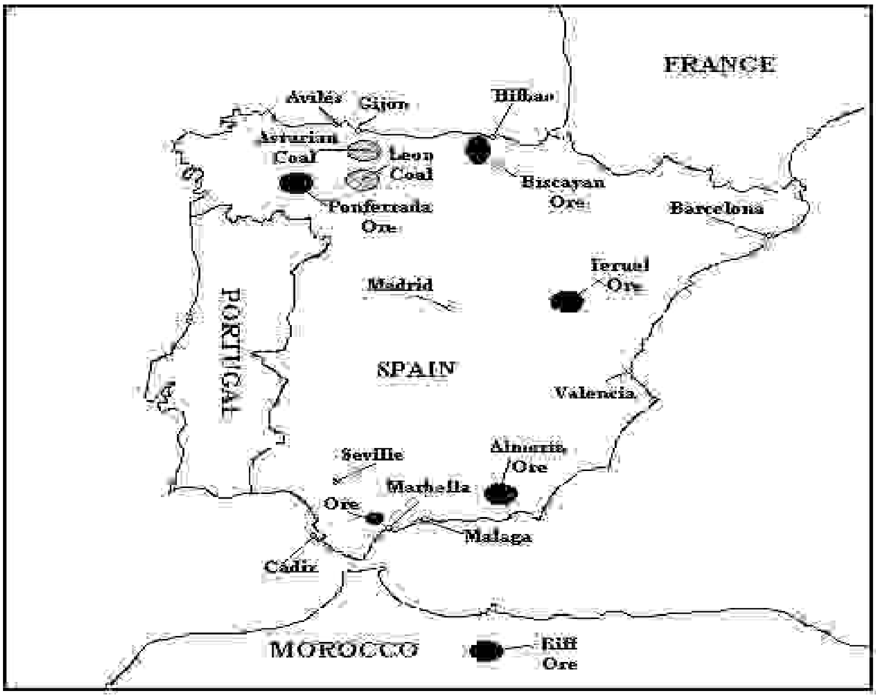
In the case of shipbuilding, steel hull construction was a skill-embodied technology combined with the necessary tools and materials. Machinery and boiler construction was more complicated as it involved a much higher degree of engineering skills, was highly dependent on the quality of materials and high precision workmanship. In addition to this, the industry shows a number of specific traits that distinguish it clearly from other heavy industries. Its products cannot be mass produced, they are unique pieces of manufacture. The production cycle can extend over very long periods and construction involves high variable costs, high fixed capital investments and layouts.

Technical advance and transfer to Spain

Following the production stream direction, progress in iron and steel preceded those in shipbuilding. The macrotechnique patterns of nineteenth century technical and organizational innovation of the Spanish iron industry have been analyzed by Luis María Bilbao (1988). He has observed that innovative early nineteenth century Spanish iron producers adopted a continental pattern of modernization similar to that of Germany and France. These Spanish mill owners innovated more heavily in the less expensive secondary refining techniques —such as puddling and rolling mills— and improved existing primary transformation processes —such as charcoal blast furnaces or more traditional processes for obtaining raw iron— only slightly.[v] Their reluctance to adopting coke blast furnaces was motivated by the higher relative cost of the investment, its scale dependency and the technical difficulty of calibrating input ratios to obtain an equal quality product to that of their former charcoal based processes. Improving refining techniques and final transformation was less costly in relative terms. It did not depend on such a high throughput volume in order to write off the investments incurred and at the same time these improvements were sure to increase the quality of final output

A second aspect of the industry's pattern of technical change throughout the nineteenth century in Spain has been elaborated by Emiliano Fernández de Pinedo (1985) based on earlier work by Jordi Nadal.[vi] Both have identified technical changes, which altered the composition of raw materials used in best practice technology, as determining shifts in regional supremacy throughout the nineteenth century. [vii] The first shift from direct processing systems for obtaining wrought iron to indirect systems, a second shift from charcoal to coke blast furnaces and a final shift from puddling to Bessemer provoked locational changes of the center of Spanish iron production.

Map 1. *Distribution of resources and metallurgic centers in Spain*



A third aspect to underline for Spanish iron production is that throughout most of the nineteenth century traditional methods coexisted with more modern installations. As in the case of Sweden —based on a very similar ore specificity— more traditional techniques were able to survive over a longer period of time than in most other European countries. Traditional processes incorporated very little of the new technological methods, but as they provided a product of higher quality, which in "markets where metallurgical technology was little developed, [was more suitable] than puddled iron to treatment by simple work-up techniques," they were able to survive with minor changes.[viii] The specificity of Biscayan ores and the low degree of market integration thus retained direct processing methods in the northeast of Spain during the first three-quarters of the nineteenth century.

A last recurring pattern to be observed all throughout the nineteenth century is the use of foreign engineers, technicians and workers —or national counterparts educated in the iron and steel centers abroad. Their skills were needed especially for setting mills up, which involved calibrating the different processes with the existing raw materials, and running them in their initial phases until they had transmitted enough analytical and diagnostic skills the professionals they had been matched with.

How exactly these industrial innovation patterns relate to technical transfer in the iron and steel industry, is the question we will try to answer in the two following subsections.

The introduction of blast furnaces, puddling and rolling mills

The Heredia firm was a pioneer at establishing more modern works in Spain. It introduced hot-blast charcoal furnaces, puddling furnaces and rolling mills in Andalusia in the 1830's. As in the case of other early industrialization processes, the Heredias were local merchant capitalists, who set up modern mills with trading capitals and technical assistance from abroad. Their first contacts with engineers and technicians in Great Britain were established through business partners, the Heredias contacted with the Bristol producer Randell, who provided them with an engineer, Lionel Brough, and the necessary workmen and technicians.[ix] Nonetheless the key figure in running their mill was Francisco Antonio Elorza. Elorza as an exiled liberal party Spanish artillery officer had studied metallurgy at the University of Liege between 1823 and 1824. During that time, he established an ongoing friendship with the future director of the Liege cannon factory, General Frederix. He went on to finish his studies at the Science School in London and visited iron mills in France, Great Britain, Belgium and the Harz region before returning to Spain in March of 1829. He set up the blueprints for smelting and processing cast and puddling pig iron in both of the Heredia mills —La Concepción in Marbella and La Constancia in Malaga— as later in La Pedrosa, one of the Seville factories which imitated the Heredia's integrated production model.[x]

The Heredia's began smelting its pig iron at La Concepción in Río Verde, Marbella where the company had erected charcoal blast furnaces as early as 1833. Charcoal was an expensive input in southern Spain, which had a low supply of hard wood. For this reason, the owners had set up a second site, La Constancia, on a coastal location near Málaga in order to reduce procurement costs for coal. These second installations were used for puddling and rolling; thereby limiting the use of charcoal to pig iron smelting. A first attempt at establishing an integrated iron mill with coal blast furnaces in La Constancia was made in 1843. The mill owners tried in vain to introduce anthracite blast furnaces there, buying hot blast equipment from Great Britain, which was to be combined with Welsh anthracite. This could have lowered the price of pig iron significantly given that charcoal was expensive and anthracite had a high density with a comparatively lower unit transport cost. After numerous failed attempts with anthracite the new blast furnaces were finally fired and fueled with more expensive charcoal. Even so this first modern mill integrated charcoal blast furnaces, puddling installations and rolling mills successfully over a period of 22 years.[xi] Three other companies in the south followed their example and founded similar mills in Malaga and Seville.[xii]

The product of the Andalusian mills was of a lower quality than the Basque products it was substituting on Spanish markets. We must therefore assume that the southern mills had attained their dominant position mainly due to the Carlist War (1833-

37), which had paralyzed metallurgic activity in the northeastern provinces. The dearth of iron forced consumers to accept lower quality iron for some time. But long after the war had ended, the south of Spain remained the center of Spanish iron production, even up to 1864. The post Carlist war fiscal status of the Basque provinces imposed tariffs on their products when introduced into the rest of Spain. And so internal tariffs, perhaps the lack of market integration and the aftermath of the Carlist war in the north allowed southern producers to retain their position for decades. Their large scale production processes had succeeded to some extent in substituting low quality irons and Basque producers reluctance to produce with similar methods was mainly because these newer processes could not provide high quality irons traditionally produced there.

From Andalusia in the south, the center of Spanish iron production moved on to the north in Asturias —one of the most important coal mining districts of Spain— in the mid sixties of the nineteenth century. The main obstacles to having established installations on Spain's most important coalfields beforehand were the small-claim mining legislation and lacking transport infrastructures. Mining legislation until 1868 delimited concessions, which were below feasible company scales and the mining districts lacked both road and railway facilities to send coal or bulky final products to other parts of Spain.

The first attempt to build a modern ironworks in Asturias dates back to 1832. At that time John Cockerill together with a group of Belgian and Spanish businessmen negotiated the concession of vast coal claims in Asturias and iron ore claims in Biscay in exchange for establishing a modern factory in Spain. The preliminary field study designated Asturias as the ideal site for the works. After the French invasions, the Spanish Government was interested in setting up a modern industry as a development strategy and to promote national defense autarchy. They generously offered the promoters of the project a 25-year company tax exemption, exceptions to Spanish mining law on claim size and number, and a tariff exemption for all the elements that needed to be imported for the construction of the factory. For unknown reasons, Cockerill backed out of the project and his partners found it difficult to establish the iron mill on their own.[xiii]

Twelve years later, in 1844 Francisco Antonio Elorza was appointed director of the rehabilitated arms factory in Asturias, La Fábrica Nacional de Cañones de Trubia, there he was finally to succeed in smelting iron in a coke blast furnace. He designed a modern integrated mill in Trubia. Its coke blast furnace was fired in April of 1848 and by 1853 Trubia had installed five puddling furnaces and a rolling mill. The factory had a limited success due to the high transport costs for coal. It shut down its blast furnace in 1860 and used pig iron from surrounding mills instead. [xiv]

Six months after Trubia's first coke blast pig iron, the Fábrica de Mieres was the first civilian enterprise to successfully smelt ore to pig iron in a coke blast furnace, with the help of English and French technicians.[xv] The owning enterprise, the Asturian Mining Company, had been promoted by an English engineer, John Manby, and the British Consul in Asturias, John Kelly, and was registered in London in September of

1844. The installation of puddling ovens and rolling equipment completed the requisites for an integrated mill within the span of a year.

Duro y Compañía founded in 1858 is perhaps the first commercially successfully integrated iron mill in Spain. Again, this factory was designed with some help from Elorza and his technicians from Trubia. By 1860 the mill had two coke blast furnaces, two puddling furnaces —16 furnaces by 1863— and four commercial-bar rolling trains. Five months earlier and in the same valley, Gil y Cía installed coke blast furnaces with the help of Elorza producing pig iron for further transformation mainly in Trubia. Duro and Gil both had railway locations, which facilitated the arrival of superior Biscay ores and the shipment of their products to their points of final destination. These first integrated mills were to loose their predominant position two decades later.

From 1879 on, the main production center of Spanish iron and steel made a final and definitive shift from Asturias to Bilbao in the northeast. From the early 1880's three mills increased national pig iron production substantially from the estuary of Bilbao: San Francisco de Mudela, Altos Hornos de Bilbao and La Vizcaya. Their origins are linked to the massive hematite ore mining in the area which was a consequence Bessemer steel production in Europe.

Early precedents of adopting modern technology in Bilbao were Santa Ana de Bolueta which had fired Biscay's first successful charcoal blast furnace in June of 1848. The Bolueta factory had backward integrated into pig iron production following the Spanish pattern of modernization —puddling and rolling combined with pig iron imports or traditional iron ore processing. The company had been floated in June of 1841, it was constructed by a French engineer. and in 1844 commenced its activity refining English pig iron in 4 puddling furnaces using Asturian coal. They had gone on to produce commercial bars from their own charcoal-blast pig iron and local forgery wrought iron using a rolling train moved by water power which they received from Liverpool.

The first mill to coke smelt pig iron in Biscay was La Fábrica de El Carmen established in 1856. Among its founders, the Ybarras were important Biscayan mine owners and ore merchants, who had established an iron mill in the nearby Santander province ten years earlier.[xvi] Their first mill had been a rather fortuitous refloating of an earlier enterprise owned by a debtor, the then illiquid Marquis de Miravalles. Chance and growing competition had determined a site whose poor communications limited the potential of the iron enterprise. The mill in Santander, La Fábrica de Hierro de Nuestra Señora de la Merced de Guriezo, had originally been set up with fair supply of charcoal, excellent iron ore mines close by and an irregular supply of water power especially throughout the summer. Ybarra, Mier y Compañía had constructed a charcoal blast furnace there in 1847, and combined it with 5 puddling furnaces and three small rolling trains.

The Ybarra sons and sons-in-law had projected their second factory closer to their rich mine holdings in Baracaldo, Bilbao in 1854. It had a port location and would be connected to the iron ore mining district by a number of mining railways and to the rest of Spain by rail and water.[xvii] In addition to the first coke blast furnace the mill owners set up in 1856, which they fed alternately with coal and charcoal, they continued to use the blast furnace they owned in Guriezo, and installed Chenot sponge ovens by 1859 which directly processed iron ore to sponge iron.[xviii] They maintained these Chenot ovens for high quality wrought iron at least until 1873, even though two charcoal blast furnaces had been added in 1865 and 1872, and 10 puddling furnaces had been additionally adopted in 1860. They integrated production on site and became Spain's most important high quality commercial iron merchants up to the 1880's. Even though they might have become even more than that.

Henry Bessemer's paper read at the Cheltenham meeting of the British Association for the Advancement of Science was published three days later, on August 14th, 1856 in *The Times* announcing his steel processing method to the world. Only 26 days later, the Ybarras and one of their sons-in-law José Vilallonga applied for a five year introduction patent for Spain. On September 25th José María Ybarra and José Vilallonga assisted a trail at Bessemer's bronze factory at St. Pancras und negotiated the terms of acquiring the patent rights for his invention in Spain. By December of 1857 Ybarra Hermanos y Cía. had built Spain's first Bessemer converter in Guriezo. Together only with Sweden's early Bessemer trails, the blasts performed there in December of 1857 and February of 1858 were both successful. The Ybarras backed out of their patent contract with Henry Bessemer. Their massive hematite mining interests —one third of the concessions— and the early adoption of the Bessemer system, which could have been the key to establishing Europe's prime Bessemer steel center in Biscay, failed. The Ybarras had reconsidered adopting the process on a large scale after having paid £2,000 for patent rights and with £3,000 pending.[xix] Instead they continued fitting their new riverside works in Bilbao with a sponge iron direct processing technology which had won a rather dubious prize at the World Fair in Paris.[xx] At the time of their decision, the costs —around 5 million reales— and efforts —three years of construction with French engineers and operators— already incurred in the Chenot ovens being installed in their new factory in Bilbao tilted the balance in their favor. Especially as news of Bessemer's initial problems in adopting his process with ores other than those used in his primitive experiments reached Spain. Paradoxically Spain —and especially the Ybarras— went on to provide the major European steel companies with the greater part of the ore which these based their Bessemer steel production on.[xxi]

Ybarra family had forward integrated their mining and ore merchant activities into iron production towards the middle of the century. Again there was a key person for the necessary technological transfer involved in this integration. The technical knowledge for this strategy was provided by their son-in-law Jose Vilallonga. Vilallonga came from a iron mill owing family in Catalonia, had studied industrial engineering —probably in Barcelona— and had traveled through Europe to learn about the latest advances in metallurgy before becoming the Ybarra's business partner in the 1840's. Traveling, foreign assessment through business partners in Paris and London and family training became the three-prongs which the Ybarras based the management of their technological transfer on. Vilallonga was key in this process. His technical knowledge combined with frequent travels to France and Great Britain oriented the innovation path of their factories. Chenot technology was transferred via patents and through contacts between Vilallonga and the Chenot family. Vilallonga recruited the first director of the Baracaldo factory in France. He patented Bessemer's invention in Spain, negotiated with Bessemer, and supervised and evaluated both trials. Diáz Morlan's description summarizes Vilallonga's position in the Ybarra's businesses: wide knowledge, rational optimism and entrepreneurial ambition impregnated his view of the business [and] the Ybarra's recognized that they never took a decision without consulting Vilallonga beforehand.[xxii]

With the scarce evidence at hand, most of the conclusions we can draw in this subsection are based on rather shaky foundations. We find that the initiative for bringing British iron processing practices to Spain came mainly from merchant capitals —Heredias, Ybarras, Duro—, the transmission of coke blast furnaces techniques took place primarily due to one single key figure, Francisco Antonio Elorza. Elorza brought sufficient skills back from Belgium, France, Germany and Great Britain to put coke blast furnace technology in place in Asturias. Even so his first attempts to use coal in Andalusia had failed. The Andalusian furnaces have been designed and constructed by Elorza and British technicians, and the remaining furnaces not constructed by Elorza were put in place by foreign engineers.

We have very little to base the transmission of puddling and rolling techniques on. The Heredias took out patents for puddling furnaces. They received technical personnel from Bristol. We do have evidence to metallurgic workmen migration in Spain similar to that described by Fremdling for puddler craftsmen.[xxiii] But we have no direct evidence of how these technologies reached Spain and how they were transmitted.

A fact, which is surprising, given Spain's backwardness in terms of income per person or in terms of economic development during this period, is the speed of adopting these new technologies. Within the continental pattern of technological transfer —puddling and rolling first— Spain's lag at adopting new technologies is minimal.

Table 2. *Spain's lag in the technological transfer of iron and steel processes.*

Macrotechnique	**Invented (Ready for diffusion)**	**Used in GB/D/USA**	**Used in Spain (patent)[years]**	**Lag Diffusion**	**Lag Followers**
Coke Blast furnace	Darby 1709 (1750)	1780	1848 Asturias	98 years	68 years
Hot blast Regenerative	Nielson 1829 Cowper 1857 Whitwell 1865	1830 – 1850	1843 Malaga 1885 AHB 1885 La Vizcaya	14 years 27 years 20 years	3 years

Puddling	Cort 1784 (1800)	1820 – 1830	(1832)[22]1839	32 years	7 years
Bessemer	Bessemer 1856 (1862)	1862 – 1873	(1856) [15] 1886	24 years	20 years
American layout	Holley 1872 (1874)	1874 – 1880	1886	12 years	9 years
Siemens-Martin	Siemens 1863 (1880) Martin 1864 (1880)	1880 – 1890	(1872)[10] 1887 (1867)[10]	7 years	2 years
Universal mill	Arrowsmith 1829 (1840)	1845-1855			
Mixer	Holley 1874 (1878)	1885 – 1895	1906	28 years	16 years
Stack charger		1895 – US	1926		31 years

Sources: Burn (1940), Carr and Taplin (1962), Houpt (1998), Minutes BoD, AHB, La Vizcaya, AHV, Ojeda (1985), Díaz Morlán (1999), Wengenroth (1984).
Notes: Bessemer – 1857 trial Guriezo, 1861 attempt Trubia, 1879 attempt Sevilla

Modern steel plants: coke blast furnaces, steel processing and rolling mills

Spain's first fully integrated modern iron mill was created with a lag of about 70 years with respect to blast furnace practice in Great Britain and less than 10 years for puddling and rolling facilities[xxiv]. Part of the lag in adopting blast furnaces can be explained with the input specificity of high quality irons produced in the north of Spain. The high grade of ores in Biscay allowed producers in northeastern Spain to postpone the adoption of coke blast furnaces and puddling works and introduce transitional 'modern' direct processes such as Chenot and Gurlt-Tourangin which produced sponge iron instead.[xxv] So by 1865, with Bessemer's innovation well under way in Europe, iron works in Spain were still disputing the primacy of coke blast furnaces. Only four firms had operating coke furnaces to that date. The lag in fully integrated steel mills was similar. With a lag of 20 years, the first Bessemer steel works was created in 1886, although Spain successfully produced its first Bessemer steel, 16 months after the invention had been made public.

Bessemer processing still remained the key to Spain's and especially Biscay's integration into the world iron and steel production during the last quarter of the nineteenth century and through the early twentieth century. Bessemer steel processing converted Spain in a major world iron ore supplier. The ores being mined in Spain were mainly hematite —low phosphorous— the only type of ores that Bessemer steel could be made of. Around seventy percent of these iron ores extracted between 1876 and 1936 was mined near the north coast, in Biscay and the adjacent Cantabria. Both regions had the cost advantages of coastal proximity and low-cost open cast, i.e. surface layer, mining. This set of circumstances helps explain why Spain mined an average 8.05 % of world iron ore between 1882 and 1922.

The importance of Spanish iron ores grew with the scarcity of low-phosphorous ores in countries with high demand such as Great Britain, Germany, and Belgium. The liberalization of Spanish mining legislation in 1868 had helped remove some of the legal barriers on property rights, commerce and investment. And finally, the exploding Bessemer steel rail demand after the mid-1860's provided incentives and opportunities for expanding mining activity in Spain.

Spain's small but relevant role as an iron ore miner, comparable to that of Belgium or half of that of Germany, did not carry over to the further transformation of iron and steel, where Spain's total industry produced a mere 0.69 % average of total world output over the same time period. With such a specific asset and knowing that Spain had fair sized coal reserves moderately close to Biscay's rich ore deposits, it is hard to understand why ores were exported and why Biscayan entrepreneurs conformed with their meager role in world iron and steel production. Spanish contemporaries were well aware of the steel industry's potential for comparative advantage and even modern day economic historians have maintained the hypothesis of lost opportunities for this sector.[xxvi] Its failure has been attributed to the lack of internal demand, e.g. railways were built using mainly foreign iron and steel exempt from duties, or the erection of high levels of protectionism which sheltered the sector from the efficiency of world economy and instilled the associated mechanisms of rent-seeking.[xxvii]

The industry's potential —based on the high quality and specificity of its iron ores— is reflected by the early attempts made by foreigners to set up processing plants on Spain's coal fields in Asturias. Cockerill's failed enterprise in 1832 has already been described. Besides the British venture initiated in 1844 in Fábrica de Mieres —already mentioned as an attempt at creating an integrated mill—, two other French ventures in the second half of the century were slightly more successful. Minas y Fábrica de Moreda y Gijón was formed in Paris in 1878 , and the Compañía de Asturias of La Felguera was created in Paris in 1894 and absorbed by Duro in 1900.[xxviii]

The Third Carlist War (1872-1876) and the social and economic turmoil it caused, especially in northern Spain, prevented a second wave of projects to install iron and steel mills in Bilbao in the Bessemer plants' boom years. Processing ores to steel on ore sites had become feasible with secondary innovations made to the Bessemer steel making process. The idea of processing ores to pig iron and steel in Bilbao and shipping coke or coal as a return freight became an important strategy to consider with the rise of direct processing, i.e. taking carefully produced liquid pig iron directly from the blast furnace into the Bessemer converter with the consequent savings of reheating cold pig iron.

The Bessemer process removed remaining impurities from pig iron in a 15-20 minute interval with virtually no coal or coke. Its resulting steel quality depended very much on the pig iron input. Until the 1870s, Bessemer pig iron was cooled down, analyzed and combined to be remelted in cupola furnaces in order to obtain the adequate mixture for converter processing. Starting in the mid-seventies, iron masters in France and Belgium calibrated blast furnace input and monitored furnaces carefully enough to directly obtain the adequate mixture of pig iron for Bessemer processing. Pig iron ran out of the furnace into ladles and was poured straight into preheated Bessemer converters with no reheating requirements. This technique was adopted quickly by English and American works.

Among others, "Krupp was very impressed by the news Alfred Longsdon [Krupp's English partner] brought him from England about the successful implementation of the process [direct Bessemer processing from the blast furnace: Wengenroth's note] and he proposed constructing blast furnaces in Essen, or, as a radical alternative, erecting a completely new works in Spain on his iron mines there." [xxix] Lower transport costs gave British firms processing Biscayan Bessemer ore a clear advantage over Krupp, especially because many of them were located on coal sites, which allowed them to send return freights. This is what motivated Krupp's project of building a plant with six blast furnaces in Bilbao to process and ship out Bessemer pig iron as a return for the coking coal sent from Germany used for the furnace. Krupp's saving per ton of Bessemer pig iron was calculated to be £ 3. 9 ch. 3 d. or more than a 40 % saving on cost price in 1873. A financial strait at Krupp in 1873 hindered the project from being put into practice and by 1878, when it was reconsidered, savings had been reduced to 1 ch. 6 d. —a negligible difference, which was more than compensated by set-up costs and acquired expertise in Germany. The considerable drop in freight rates was responsible for the loss of opportunities.[xxx]

A second major steel producer had considered this strategy two years earlier, in 1871 the John Brown Co had set up its subsidiary —the Bilbao River and Cantabrian Railway Company Limited— and bought plots in Sestao (Bilbao) to construct blast furnaces and process iron ore from the nearby Galdames mines they owned, which was to be transported by a factory owned railway they started building that same year.[xxxi] The railway was finished in 1876 and blast furnaces had been completed in 1873. The political climate —the third Carlist War [1873-76] and its aftermath— are one of the reasons which motivated the company to abandon the blast furnace project and sell the installations to the Duke of Mudela —Francisco de las Rivas— in July of 1879. The second and more important reason for selling its processing plant was the fact that ore deposits in Galdames were significantly less than prospected. Mudela's nephew and mine owner —José María Martinez de las Rivas— took on the management of the iron works and the furnaces were finally fired up in October of 1880. The new company, San Francisco de Mudela, profitably produced and exported cast , foundry and Bessemer pig iron until the end of the century.[xxxii]

These projects show that foreign entrepreneurs coincided at some moment with Spanish contemporaries in identifying potential profits from Bessemer pig iron and steel mills in Spain. Nonetheless, from what we know, foreign capitals concentrated on safeguarding their ore supplies by buying or participating in mining companies rather than investing in processing plants in Spain. Both Charles Cammell and John Brown had initially invested in mines in Galdames near Bilbao, Bolckow, Vaughan & Co. had invested in Luchana Mining, Consett, Dowlais, and Krupp in Orconera Iron Co. Ltd.; Cockerill, Denain et Anzin, and Montataire in Société Anónyme Franco Belge des mines de Somorrostro.[xxxiii] In iron processing industries, foreign investment in mining seemed plentiful whereas investing in processing was scarce. One important reason for not investing in proceesing plants may have been the limited size of home and regional markets in countries like Spain, as has been pointed out by Chandler.[xxxiv]

Even so, Spanish iron and steel production suffered a number of radical changes during the early 1880's. Three new modern highly competitive factories arose in the Bilbao Ría. John Brown's mill, San Francisco de Mudela, received its blast furnace technology as a subsidiary between 1871 and 1873 and the bulk of its physical technology was transferred on an intrafirm basis. Very little evidence of this process has survived in Spain. Our analysis will concentrate on the other two Bilbao mills, Altos Hornos de Bilbao in Baracaldo and La Vizcaya in Sestao.

The Baracaldo mill had been designed and constructed by E. Windsor Richards at that time the manager of Bolckow, Vaughan and Co. and the Sestao mill was a turnkey project constructed by Societé Anonyme Cockerill of Seraing. Between the two factories, they concentrated more than 50 % of all pig iron and steel production between 1885 and 1936 and their archives provide the data necessary for applying a thorough examination of the technological transfer which took place in constructing and running them.[xxxv]

The Sestao mill is easier to explain. It was designed as an emergency outlet strategy for Biscayan iron ores when the Thomas-Gilchrist process threatened to replace hematite ores with cheaper phosphorous ore.[xxxvi] It's original plan included two phases of construction. Phase I was to cover the construction of four blast furnaces for Bessemer pig iron, Whitwell hot blast stoves, Bessemer processing installations and a rolling mill for shaping bars, rails, wheels, axis, construction beams and everything necessary for construction and railways. Phase II was to go on constructing four more blast furnaces, two of these to feed puddling furnaces and a ship plate mill and the other two for cast iron and a foundry. It's initial project was a turnkey contract with the Belgian steel company, Societé Anonyme Cockerill from Seraing for two Bessemer pig iron blast furnaces.

The contract stipulated the construction and inspection of all the necessary components of the Seraing factory in 6 and a half months after its signing, and firing the blast furnaces 18 months after signature. It included the following technical warranties: a replacement guarantee on all parts during 6 months after lighting the furnaces, Belgian personnel to construct and operate the plant until it is fully functional (in both cases their salaries, housing and travel was paid by the Spanish firm), and a 3% recharge for delay's in delivery .

The key figure for technical transfer in this case are the Chávarri brothers, Victor and Benigno. Their father has been one of the major Biscayan ore merchants from the middle of the nineteenth. Both studied engineering in Liege adjacent to Seraing in

Belgium. Victor Chávarri negotiated the contract with Cockerill and became the company's first manager and director of the board. Chávarri was elected member of parliament in May of 1886 and substituted as managing director with Spanish mining engineers from then on, Mariano Zuaznavar (May 1886 – November 1889) and thereafter Guillermo Pradera. Even so Chavarri remained tied to the company as a major shareholder and technical adviser.

Table 3. *Foreign staff at La Vicaya during working phase, 1885-86.*

Operation staff	**Position held**	**Annual pay**
Alfredo Hacha	ing., Production manager	1.000
Pedro Smal	Chemist	300
Latin	Smelting foreman	650
Lecocq	First smelter	400
Germain	First smelter	400
Bruyére	Second smelter	325
Pataz	Second smelter	325
Luarent	Furnace stacking foreman	350
Brass	Furnace stacking foreman	350
Rumelot	Boiler stoker	300
Brocken	Boiler stoker	300
Crêppe	Foreman mechanical section	400
Coussaint	Foreman mechanical section	350
Macheroux	Assistant	300
Schanfheid	Assistant	300
Dounay	Stacking machinist	325
Coomans	Stacking machinist	325
Jean Toassin	Blast engine machinist	350
Aubert (Damas)	Blast engine machinist	350
Dieudonne Fresón	Mason	350

Adolphe Greiner, the manager of the Seraing mill in Belgium received a three month leave from his company during the first months of 1885 to supervise the final construction and fine tuning of the furnaces. Furnace 1 was fired in June of 1885, i.e. 18 months after the signature and furnace 2 was fired in December. The personnel contracted by La Vizcaya for this preliminary phase of operation are listed in table 3. They were gradually substituted with their Spanish counterparts before the compromise with Cockerill extinguished. Foreign blast furnace masters remained a necessity. In October of 1886, the director of blast furnaces, León Goffart, is replaced with the engineer and Saint Nazaire director of blast furnaces Beck given the poor performance of furnace no. 1. Greiner travels to Bilbao to study the problems in the furnace together with Zauznavar, Chávarri and Beck. He approves the changes in the profile of the furnace proposed by Beck although he attributes the poor performance of the furnace to the use of small size coke.

Contract Beck:

Fixed salary	FF 12,500		
Production bonus	FF	0.75	per ton per furnace per 24 hours over 90 t

Production minus	FF	2	per ton per furnace per 24 hours less than 90 t
Coke bonus	FF	0.01	per kilo less than 1:1 ratio pig iron and coke
Coke minus	FF	0.03	per kilo over 1:1 ratio pig iron and coke
Monthly settlement			

The case of Altos Hornos de Bilbao is slightly different. The origins of this company go back to the former Ybarra mills in Guriezo and especially in Baracaldo. The complete installations, mining contracts, water rights and staff are passed on to this limited company in 1882. The Ybarra family remains closely tied to the company. José de Vilallonga was President of the Board of Directors until his death in 1898. José Antonio de Ybarra Arregui, a member of the second generation, studied engineering in Liege and went on to become the key person in the company controlling technical transfer. Fernando Luis de Ybarra complemented this with legal consulting and representing the company's interests in the Spanish Tariff Comission.

The mill's new installations were an important part of the strategy of the new company. San Francisco de Mudela's furnaces were functioning since 1880.Their forward integration into steel processing and rolling supposed a clear menace to the Ybarra's markets for finished products in Spain. The board of directors decided to close this front by constructing a Bessemer steel mill, two new coke blast furnaces, two Bessemer steel converters and steel rolling mills for rails, plates, sheets, strip steel, etc. These installations were designed to complement two of the charcoal blast furnaces, the puddling installations and wrought iron rolling mills they already had in place. The board's deliberation produced a list of possible candidates for designing the new mill.[xxxvii]

Feranando Luis Ybarra used his contacts with the Krupp family to file a report on Helmholtz, manager of the Bochum factory, José Antonio Ybarra asked for reports on the French engineer Ponsard at Denain et Anzin and contacts Snelus, the chemist at Dowlais and manager of West Cumberland in Workington, and writes to Windsor Richards, the manager at Bolckow Vaughn, for advice on possible candidates. Other possible candidates are Greiner manager of Cockerill; Stein, chief engineer at a machine construction factory in Belgium; Ljudic at Besseges, France; E. Williams, director of Ebbw Vale; Gadgrey, factory director of Bolckow; and Murdock factory director of Barrow Hematite Steel Works.

Windsor Richards, an authority on Bessemer steel works in Europe, offered himself as a designing engineer with the sufficient warranties to accept a second British engineer Jenkin Lewis to carry out construction. Windsor Richards accepted a modest fee of £ 300.- per year for his drafts, supervision and consulting. He remains a consultant of the company over the years with an annual fee of £ 250.- per year. He visits the new installations before construction is initiated and shortly after they are operating. But he continues to visit the Baracaldo factory on a number of occasions to resolve technical questions and advise the technical staff on the operation of new machinery or new installations. In December of 1900 the Spanish government distinguished Richards with the Great Cross of Isabel la Católica (Isabella II) for his merits and contributions to the promotion of the Spanish steel industry.[xxxviii]

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[i] Tortella (1994), chap. 1.

[ii] Dye and Galassi Galassi

[iii] Fremdling (2000), Landes (1979), pp. 193-200.

[iv] Nuwer (1988).

[v] See Fremdling (2000) for an extensive explanation of this behavior.

[vi] Nadal (1970), (1970a) and (1989)

[vii] Sánchez Ramos (1945), p. 121, Nadal (1970), pp. 228-33, Nadal (1970a), pp. 376-9 and 396, Nadal (1989), pp. 170-181, and specially Fernández de Pinedo (1985).

[viii] Söderlund (1960), p. 60.

[ix] Díaz Morlán (1999), p. 49.

[x] Fernández Penedo (1964), pp. 449-53.

[xi] Patents for puddling furnaces were taken out by Agustín Heredia in 1832 (5 years) and 1839 (15 years). Oficina Española de Patentes y Marcas, Archivo Histórico, Privilegios de invención, no. 98 and no. 144.

[xii] Nadal (1989), pp. 168-9.

[xiii] Ojeda (1985), pp. 14-5.

[xiv] Ojeda (1985), pp. 49 and 56, Nadal (1970), p. 225 and Nadal (1989), pp. 167-8.

[xv] George Lambley and Edward Fettyplace were its managers during the first years and T. Lambert was responsible for erecting its first coke blast furnace. Ojeda (1985), pp. 61 and 63. Sánchez Ramos (1945), p. 141.

[xvi] They had considered establishing a mill in Asturias with technical advice from Brough and Randell through a recomendation with the the trading house Aguirresolarte y Murrieta of London. Díaz Morlán (1999), p. 49.

[xvii] The regional government owned the Triano mining railway which was finished in 1865, the Bilbao Iron Co. railway was finished in 1876, the Orconera company railway in 1877, the Franco-Belga company railway in 1880 and the Luchana Mining company railway in 1887. The Bilbao-Portugalete branch line and the Bilboa-Tudela line connected the factory to the rest of Spain’s railway transportation network. Towards the end of the century Bilbao gained direct rail-access to coal mines in León by the Robla railway.

[xviii] The Chenot process was a sophistication of traditional forgery techniques —direct processing ore to obtain a high quality raw iron. It could only be applied to the high quality ores —rubios— which the Ybarras had been selling to forgeries for decades. The decline of forgeries may have motivated them to adopt this technology as an outlet for their otherwise excess supply high quality ores.

[xix] Díaz Morlán (1999), pp. 63-69. Dowlais had paid £ 10.000 for a license of 20.000 t plus a farthing a ton. Bessemer (1897), chapter 12.

[xx] Uriarte (1999), p. 781.

[xxi] The information on this episode is taken mainly from Díaz Morlán (1999), p. 63-69, also from Henry Bessemer’s autobiography, chapter 12 and Carr and Taplin (1962), chapter 1.

[xxii] Díaz Morlán (1999), pp. 69-70, free translation.

[xxiii] Raveux (1994), Fremdling (1991).

[xxiv] Abraham Darby II developed coke smelting for forge iron in 1750 and Henry Cort applied the puddling process and rolling to wrought iron in 1784.

[xxv] Uriarte (1998)

[xxvi] Alzola refers to exporting Biscay ores instead of processing them as "imitating Esau who sold his birthright for a mess of pottage", Alzola y Minondo (1896), p. 55. See also Adaro Magro (1885), p. 175.

[xxvii] Nadal (1989), p. 183 "La demanda ferroviaria, menos intensa que en otras épocas, acuñó, en los últimos años del siglo XIX, el nacimiento del acero español. Esta constatación refuerza, a fortiori, la tesis de la gran oportunidad perdida treinta años antes por la industria del hierro colado y del hierro afinado, como consecuencia de la franquicia al material extranjero acordado por la ley de junio de 1855." see also pp. 158-165, and 187. Fraile (1991), p. 202 "Lo que realmente diferenciaba a España de la mayoría de sus vecinos era la proclividad del marco institucional a generar y mantener a lo largo del tiempo estructuras de oferta con un marcado carácter restrictivo y monopolista que tendían a separar a la industria española de la competencia internacional por medio de la protección arancelaria. Con un marco institucional adecuado, los empresarios industriales españoles eligieron una estrategia de maximización acorde con los precios relativos de los factores y las tasas esperadas de beneficios. Para un mismo nivel de beneficios, la facilidad de obtener rentas del estado (...) hacia más atractiva la asignación de recursos en búsqueda de rentas."

[xxviii] Adaro Ruiz-Falcó (1968) and Memorias de Central Siderúrgica de 1924.

[xxix] The reference to his mines there are the Ybarra mining concessions he participated in as a shareholder of the renting company, the Orconera Ltd. Correspondence on the 4th of May, 1876, Wengenroth (1994), p. 90.

[xxx] Wengenroth (1998), pp. 4-5.

[xxxi] The company was originally floated under the name of Bilbao Iron Ore, which it changed in 1876. Escudero (1998), p. 39.

[xxxii] See Bahamonde Magro (1989) pp. 576-7; Escudero (1998), pp. 31-2, Montero (1990), p. 68 and Montero (1995), p. 70.

[xxxiii] For Charles Cammell and John Brown see Wengenroth (1986), p.185; for Consett, Dowlais, Krupp, Cockerill, Denain and Anzin in AHV (1902), pp. 53 and 69, Díaz Morlán (1999), pp. 82-95.

[xxxiv] Chandler (1990), p. 139, "None of the American companies invested in a plant abroad if an extensive capacity already existed in that area (...) the investment required to achieve minimum scales would have created massive overcapacity in the region in which the new plant was built." and idem, p. 491, "Like the Americans, the German steelmakers rarely built works abroad to support their marketing organizations, for the capacity required to compete with existing plants in those markets was too costly and would have increased output too much to be worth the investment."

[xxxv] The company they both merged into in 1901, Altos Hornos de Vizcaya, has preserved the minutes of the board of directors and annual shareholder meeting memoranda from the origins of both companies until the present.

[xxxvi] *Memoria descriptive de las instalaciones para una fábrica de hierro y acero proyectada en las marismas de Sestao por la Sociedad de metalurgia y construcciones Vizcaya*, January 24th, 1883. Archivo Histórico de Altos Hornos de Vizcaya, Baracaldo.

[xxxvii] MboD AHB, Vol. I, pp. 11-17. The Board of Directors was well aware of the specialization of foreign engineers for design and construction on one hand and operating mills on the other.

[xxxviii] MboD AHB, Vol. IX, p. 236.