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Putting Spanish steel on the map: The location of Spanish integrated steel, 1880–1936

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By contrasting the optimal with the actual location of Spain's main production centre in Bilbao, we have tried to resolve the enigma that mislocation introduced an important welfare loss in Spain's industrialisation. This analysis considers the optimal location for integrated steel mills in Spain from their origins (1880s) until the Spanish Civil War (1936–39). The first part of this article introduces the relevant aspects for formalising a model, while Section 2 applies the methodology. The numerical results show how the major technical change – the reduction of coal consumption – affected each of the alternative sites. They also allow us to identify 'the overall optimum site', which was not Bilbao. Our final conclusions confirm that the actual centre of iron and steel production during the period considered was a second-best location. The cost in terms of direct welfare loss, in terms of captive markets and rent-seeking used to maintain this second-best solution, and the ultimate consequences of mislocation, point to an inefficiency which has changed the course of modern Spanish industrialisation.

Introduction

The age of mass steel production began between 1865 and the early 1870s with the diffusion of the Bessemer steel process. As both the Bessemer method and its immediate successor – the Siemens acid open hearth – could only use low-phosphorus iron ore, the limited supply of such ore in Western Europe during the steel and railway booms sent investors off into the European periphery in search of low phosphorus iron ore mines. This supply constraint was to be overcome in the latter decades of the nineteenth century by two parallel developments. The Martin-Siemens process introduced a new production method, which recycled iron scrap. The Thomas process and the application of its principles to the Siemens open hearth furnace allowed other ores – with high and medium phosphorus content – to be processed into steel.[1]

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[1] Abstracting from other ore qualities, we can maintain that iron ores with a phosphorus content below 0.1 per cent were appropriate for Bessemer and acid Siemens open

These four mass steel processes were introduced with different intensities in the leading European steel producing nations. In Germany, basic technologies, which used medium and high phosphorus content ores, became dominant after the mid 1880s. Great Britain remained tied to acid technologies – which required low-phosphorus ores – well into the twentieth century. National supply constraints on available home ores and falling transport costs allowed Lorraine and Sweden to become major phosphoric ore suppliers to the emerging industry in Germany, and introduced Spain to the British markets where it supplied nearly 80 per cent of all imported ore between 1871 and 1914.[2]

The important amount of non-metallic debris – 40 to 60 per cent – which was transported in the form of ore to steel centres in Western Europe, the almost unlimited access to charcoal in Sweden and the abundant coal deposits in Spain, raise the question of why these peripheral ores were not processed directly in their countries of origin and sold as higher value added products. As Spanish contemporary Pablo de Alzola put it in 1897:

> With two tons of mineral worth 18 pesetas, one ton of pig iron worth 64 pesetas is produced; if this is transformed into rails then the value is enhanced to 140 pesetas; [rolling it into plates it reaches a price of 210 pesetas] with the evident result that if we export the greater part of our minerals for the infinitesimal price of 9 pesetas, we imitate Esau in selling his birthright for a mess of pottage.[3]

The Basque iron and steel industry, centred around Bilbao, grew at a substantial rate during the period we are examining. The three modern mills which were erected there in the 1870s and 1880s used 'state of the art' technology which they obtained through their ore export ties with Wales and the north-east coast of England. But the industry grew at a much lower rate than its European counterparts and had established a dominant firm oligopoly by the turn of the century – much earlier than similar concentration movements in other countries. What draws attention to the Spanish case is not the existence of cartels and pressure groups, but the intensity and speed with which they eliminated competition. This has been explained by the

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hearth processing, those between 0.1 and 1 per cent for basic open hearth, and for those between 1 and 3 per cent Thomas processing was applied. Higher concentrations of phosphorus damaged linings seriously and were lowered by mixing with ores with a lower concentration (Temin 1964, p. 145 and Rodriguez Alonso 1902).

[2] Flinn (1955, p. 84, 1n). Over 20 per cent of all ore smelted in Great Britain between 1890 and 1915 came from Spain. Advisory Council Department of Scientific and Industrial Research (1918), *Report on the Sources and Production of Iron and other Metalliferous Ores used in the Iron and Steel Industry*. London.

[3] Sánchez Ramos (1945, p. 226). Translation taken from Flinn (1955, p. 89).

proneness of Spain's institutional framework to generate this kind of economic interventionism.[4]

State and steel – heavy industry – are two of the basic foundations for Alexander Gerschenkron's theories of development in backward countries. Everything points to Spain as a likely candidate in which to find Gerschenkron's patterns of backward development: with strong state policy to promote initially inefficient heavy industry.

Surprisingly, export figures before the early twentieth century protectionism identify Spanish pig iron and raw steel products as competitive. Spanish producers exported 27 per cent of the pig iron they produced between 1881 and 1894, and 10 per cent between 1895 and 1915. The cost price of Bilbao hematite pig iron remained below the market price for Cleveland # 3 pig iron – the cheapest pig iron sold on world markets – well into the first two decades of the twentieth century. Rail cost prices in Spain were 30 per cent lower than market prices in Great Britain, Germany and the USA during the same period.[5] The literature states that mislocation and closing the economy to free trade was what stopped Spain from developing a buoyant export-based steel industry in the long run.[6]

Wrong location and protectionism are two issues which are easily separated and our analysis will concentrate on the former, the question of the mislocation of integrated steel mills in Spain at the end of the nineteenth century and during the first third of the twentieth century.[7] Identifying the correct location of Spain's main production centre is aimed at resolving the enigma that mislocation introduced inefficiencies and redundant costs, and weakened the competitiveness of Spain's potential products on international markets. At the same time this analysis will move in a dynamic context and will attempt to assess whether the optimal site varied, as substitutes for coal – one of the main factors of production – were found throughout the period studied, and how this affected Spain's steel industry.

The suspicion that Bilbao – the centre of Spanish steel production – was not the ideal location has been commented on by a number of Spanish historians and economists. Nadal (1989) called it 'a twist of logic' which situated the centre of gravity of the Spanish iron and steel industry near Biscay's ore mines rather than on Asturian coal fields.[8] Tortella (1994), given the lack of coking coals and the strong competitiveness of its ores, situates 'competitive Spanish iron and steel industry outside the country: in Cardiff, Newcastle, Essen, or Pittsburgh and not in Bilbao, Avilés, Málaga or

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[4] Fraile (1991, pp. 118, 134, 143, 146 and 159).

[5] See Houpt (2000) for a detailed discussion of the competitiveness of Spanish iron and steel products.

[6] Fraile (1987, pp. 242–5), Sanchez Ramos (1945, p. 291).

[7] The loss of competitiveness due to protection will be addressed in a separate analysis. See Houpt (2000).

[8] Nadal (1989, p. 134).

[9] Tortella (1994, p. 74).

Sagunto'.[9] Tamames (1992) refers to the choice of Biscay as 'a site that did not prove rational in the long run, [but that] followed a certain logic in its origins.'[10]

Elsewhere, location analyses have been applied to the iron and steel industry: Isard (1948), Isard and Capron (1949) and Hekman (1978) for the United States or Altman (1986) for Canada. These studies have focused on explaining shifts in the location of the industry, the criteria these shifts have been determined by or the rivalry between different steel producing regions. The existence of the steel industry's mislocation has not been examined, nor have the criteria affecting the particular case of Spain been formally exposed.

With this proposal in mind, the first part of this article will introduce a general model for locating integrated steel and include some specific considerations for the case of Spain. The integrated plant will be considered our unit of analysis due to the externalities and positive economies to which it is susceptible. Section 2 will show the methodology applied, that is, the underlying assumptions, the model of transport cost minimisation and the calibration of parameters. The numerical results presented in the following section are the result of combining the two alternative sources of coal with the different feasible iron ore sources. At the same time these tables will show how the reduction of coal consumption – the predominant technical change in this period – affected each of these alternative combinations of inputs. The results will also allow us to identify 'the overall optimum site', given the trend to reducing the weight of coal as an input.

The preliminary results will be scrutinised by introducing different aspects originally excluded from the model. Uniform transport costs will be questioned. The alternative of sea transport will be contemplated. Scope economies, such as port capacities, ore transportation facilities, labour and capital availability will be considered to discuss the results obtained. Our final conclusions will show that Bilbao – the actual centre of Spanish iron and steel production up to the late 1950s – was a second-best location.

The relevance of these results is important. A correct location of the steel industry would have changed the course of Spain's industrial development. With the installation of the steel industry on a major coal site, heavy industry would have agglomerated near coal deposits, iron and steel could have been provided at a much lower price, and the material cost of industrialising and providing cheap energy would have been reduced. Given the importance that backward countries designate to iron and steel as a strategic sector for industrial development, the ultimate consequences of mislocation are even more devastating. The DUP activities, rent-seeking and cartelisation which maintained mislocation in Bilbao would not have characterised the industry to the same extent as they in fact did. Industrial growth, in gen-

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[10] Tamames (1992, p. 322).

eral, could have been far more extensive, both in volume and geographical spread and Spanish industrial development would have taken a completely different course.

Location theory

Walter Isard's selected papers include a thorough discussion of Alfred Weber's (1909) model of industrial location based on transport cost, fixed technical coefficients, and cost minimisation.[11] Weber's model provides the ideal framework for determining the optimal location of high volume, input-reducing industries with a low degree of permissible factor substitution, as is the case of the steel industry. In the rest of this section we will motivate, define and calibrate the application of the Weberian model to our problem of location. To begin with, and following Isard's patterns of location in the iron and steel industry since the early nineteenth century, we can identify four predominant and determining factors: the location of coal, iron ore, markets and scrap.[12]

The supply of raw materials in high volume transformation industries, such as iron and steel processing, is a vital factor affecting site selection given the incidence of transport cost on total costs.[13] But producers do not only apply a rationale related to acquiring resources. Especially with the progress of communications, they need to counterbalance these forces of attraction with those related to the proximity of their markets. The mobility of factors and processing technology reduces the exercise of cost minimisation to choosing the minimum transport cost site. We can assume that a specific plant using a fixed set of inputs and distributing its products to known markets can be set up in any location.

Besides the procurement costs of high volume inputs and the distribution of final products discussed above, optimal location must also consider direct labour costs, overhead costs such as interest payments, rents, royalties, maintenance and depreciation, taxes and other conventional expenditures. For the iron and steel industry, these additional factors combine to form a very low percentage of the final cost, and their price differentials between one region and another usually lack the magnitude to make them relevant in determining the cost-minimising optimal site. Only when total transport costs vary little between alternative locations will these other processing costs become the key elements in location.

In the case of iron and steel transformation we can define an optimal site as the geographical co-ordinates which, given a vector of prices and decision variables, minimise costs for a firm.[14] The iron and steel industry uses two

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[11] Isard (1990, pp. 56–60).

[12] Isard (1948).

[13] See Lüth and König (1967, pp. 141–2); Haven (1954, p. 347); Isard (1948); Day and Nelson (1973); Hekman (1978).

[14] These variables can be distance, supply delay times and factor quality variability.

main material factors – raw iron and coal – and one minor material input – flux. Given the 'state of the art' technology being used, we can assume that all other production factors have very small price and quality differentials from one region to another and need not be included as decision variables. Raw iron can initially be assumed to be iron ore, although ore as the prime source of iron and steel was increasingly replaced by scrap iron after the end of the nineteenth century. This meant that works reduced the proportion of their steel obtained from smelting ore to pig iron and then processing it to steel. Steel was increasingly obtained by refining scrap in open hearth furnaces. In the United States, by 1933 less than 50 per cent of semi-finished iron and steel was obtained from smelted pig iron.[15] As the autochthonous supply of scrap iron was generally scarce in industrially backward countries – they had less to scrap – and the increasing world demand for scrap drove prices higher, in the 'late follower' countries scrap had a lower presence in open hearths compared to pig iron.[16] For the Spanish factories analysed, open hearth steel production was very secondary to Bessemer processing. Similarly to the Dowlais Iron Co., these plants installed open hearth furnaces only to meet naval contract specifications and fed them with their own Bessemer scrap. Scrap was not a viable raw iron substitute for these factories.

For the purposes of our analysis, this narrows the important factors down to three – coal, flux and iron ore. Given that for the type of ore to be processed in Spain, flux is mainly limestone, which is a very commonly found material, we can concentrate the exercise on coal and iron ore. A number of relevant mines can be considered for both raw materials in Spain. The exact criteria for their selection are exposed in the calibration of the parameters in the discussion of the model.

The alternative supply of ores or coal from outside Spanish territory is not considered in this exercise. The case of British coking coal is especially relevant. There are numerous reasons for excluding this possibility. Spain imposed increasingly nationalist economic policies and, by the end of the period examined, Spain emerged into complete economic autarchy for almost twenty years. At the same time, the coal price hikes from the 1890s on, supply cuts during the two world wars, and post-war restrictions, forced Spanish producers to switch to Spanish coke in the long run. Mixing techniques and chemical knowledge made this increasingly feasible.

Even though the added weight of coal and ore consumed worldwide totalled more than three tons per ton of final steel product up to the middle of the twentieth century, we can observe that iron and steel plants have not

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[15] Isard (1948, p. 214) and Burn (1940, pp. 473–5).

[16] In a period as late as 1925 to 1936, Spain obtained two thirds of its scrap for steel transformation from imports. In the 1920s the market price for scrap was still 15 per cent higher per ton than pig iron produced in Bilbao. Merello Llasera (1943, p. 149).

Table 1. *Geographical examples of oriented location.*

Orientation	Location
Coal	Pittsburgh, Pennsylvania, US Youngstown, Pennsylvania, US South Wales, GB Ruhr, Germany Durham, GB
Iron ore	Lorraine, France Duleth, Great Lakes, US Bilbao, Spain Cleveland, GB
Limestone	Volta Works, Brazil
Coal and ore	Birmingham, Alabama, US Teeside, GB
Transhipment points	Cleveland, Ohio, US Buffalo, Indiana, US Gary, Indiana, US
Coastal or waterside	Sparrows Point, Baltimore, US Stettin, Germany Sagunto, Spain
Market	Ford Steel Plant, Detroit, US

always been located strictly by the criterion of proximity to either or both resources.

One general trend in the leading iron and steel companies could be the key to understanding sites which were not situated on coalfields. The amount of coal being employed to produce a ton of pig iron was gradually and persistently reduced. Iron ore input remained fairly constant, oscillating between 1.6 and 3 tons, depending on its metallic content.[17] But coal input was steadily reduced from 8 to 10 tons in the 1750s to an average of 1.67 or 1.27 in 1938 for Great Britain and the United States respectively. This reduction was due to the introduction of hot-blast techniques, the improved homogeneity standards of the coal used, and other improvements in the furnaces' practices. By the middle of the 1880s most of these coal savings in pig iron production had been attained in the modern mills set up in Biscay. They used an average 1.5 tons of coal.

Therefore we will limit ourselves to analysing energy savings obtained in other areas of production. Integration of coking, blast furnaces, steel

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[17] Yields for pig iron are usually expressed in coke per pig iron but the conversion to coal is fairly easy. For Great Britain and the US the average coke yield per ton of coal ranged between 60 and 70 per cent. Isard (1948, p. 206) quoting US Bureau of Mines, Mineral Yearbook, annual issues and Burnham and Hoskins (1943, Appendix III, pp. 303–313).

processing and rolling, provided heat economies because downstream processes used upstream waste gases for heat and motive energy. Both coke oven and blast furnace waste gases were used to generate the energy needed for blasting machinery, for providing motion and heating to the rolling mills and for transportation of materials and products. A similar set of energy-saving economies became available as liquid iron was directly converted into steel, or when fresh steel, which had soaked out heat evenly in a pit, was immediately rolled into its intermediate and final shape, hardly needing to be reheated. In the latter cases substantial reheating costs were avoided. Even greater savings in coal consumption were introduced with the gas-driven electrification of motors in the 1920s. These considerations applied to the leading steel technologies at that time, namely Bessemer, Siemens, Siemens-Martin and Thomas. Those heat economies which can be attributed to vertical integration in iron and steel processing also justify the integrated steel plant as the organisational unit of analysis to be considered.

Nonetheless, coal reduction was a very gradual, input-specific process. As late as 1953, ENSIDESA – the public owned steelmill in Asturias on the north-west coast of Spain – calculated a minimum of 1.43 tons of coal for processing iron ore to a ton of pig iron. An additional 3–3.5 tons would have been needed to process the necessary amount of pig iron into structural steel, using coal as caloric input.[18] The real total amounts to consider are significantly lower. Theoretically, waste gas production in coking and pig iron processing would fully cover the heat requirements without using any additional coal in the later stages of transformation. Even though waste gases were being used as a source of heat and motive power in Spanish plants before the Spanish Civil War, we cannot consider coal as being fully replaceable in the processing of iron into steel and steel into its final rolled form. A reasonable 'guesstimate' for the total amount of coal employed in rolled steel products would be between 1.5 and 4 tons of coal per ton of finished product. An amount between 2.5 and 4 tons, however, would be much more reasonable for the period under study. The amounts for iron ore needed would lie between 1.6 and 2.2 tons, depending on the iron content of the ores – see Table 2 below.

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[18] See INI Ensidesa – Proyecto de la Fábrica de Avilés, June 1953. The technical coefficients take the input quality differences into account by calibrating a mill production function, which is equally applicable to any of the technologies being used to process them. The minimum coal weight reflects the maximum amount of coal chemically necessary for reducing the lowest quality of these five ores to pig iron, and the maximum coal weight reflects the highest minimum amount of coal necessary for the complete process of transformation from ore to structural steel for the highest coal consuming combination – León ores and basic Siemens. The declining discrete amounts we assume between these amounts reflect the gradual replacement of coal in all areas of transformation except pig iron processing and the lower initial maximum amounts of coal that may be necessary for any of the hematite ores processes with a different steel technology.

Table 2. *The weight of Spanish iron ore in steel products.*

Iron ores from	Iron content %	Ore (tons) needed for 1 ton of steel product
Bilbao – Castro Urdiales	49	2.05
Sierra Menera	53	1.90
Almería – Granada	55	1.80
Ponferrada, León	50	2.00
Riff, Morocco	64	1.60

Source: Apraiz (1978, pp. 262–4).

Our model should therefore establish the correct location of an integrated steel plant which combines the different cokeable coals in amounts between 1.5 and 4 tons with any of the important ores, in order to produce and distribute final structural steel products at a minimum cost.

The model

The model we will formulate mathematically can be visualised abstractly as taking a board with the shape of Spain's map with holes for the different raw material sites and consumption points. We can introduce different sets of strings from the bottom of the board to a nodal point on the surface – one string for coke, one for ore and one for each consumption point. The length of each string is proportional to the transportation costs of the raw material or final product to be transported. Each set of strings represents a specific combination of raw materials with the final consumption points. We would then tie weights proportional to the weight of raw materials or final product transported from or to this specific point to each corresponding string. If we drop all weights at the same time the nodal point or knot will then come to rest at the cost-minimising site for that specific set of strings. This is the basic idea behind the Weberian model we propose. Our exercise is based on the assumptions included in Weber's original model and others will be added in order to make it applicable to this specific case.[19]

The presence of economies of scale in iron and steel production justifies the abstraction of production to one firm to some degree, but we can also assume this single firm to be representative of the industry as a whole, if we did not find a single firm of this size realistic in this context. The allocation of consumption is a function of the regional distribution of population and economic activity which we must assume subject to minor variations for the moment. The model will propose the uniformity of transport which does not truly reflect reality, but will be re-examined when discussing results. And finally, the rigidity of input combinations in metallurgic processes fully

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[19] See Paelinck and Nijkamp (1978, p. 34) for a summary.

supports a Leontief-type definition of production. Formalising these ideas using Weber's original model we can formulate the following assumptions:

Assumption 1: We are looking at a single representative firm that produces a known amount of product.
Assumption 2: We have predetermined the weighted *loci* of consumption and the points of origin of raw material are known points in space.
Assumption 3: Transportation costs are uniform along each transportation vector.
Assumption 4: The production function is Leontief with fixed technical coefficients.
Assumption 5: The consumption distribution is known and remains invariable to changes in the location of the production centre.

The generalisation of Weber's original location triangle can be defined as the following points O_i (x_i, y_i) the iron ore mines, C_l (x_l, y_l) the coalfields and B_k (x_k, y_k) which we have generalised for $(k = 1, 2, \dots J)$ multiple consumption points.[20] The combined 'distance'–'transport cost'–'fixed material weight' pull of each of these points will co-determine the optimal production site in terms of transport cost minimisation. Mathematically this can be expressed as follows:

Total transportation cost T.

$$T = \sum_{i=1}^{I} t_i d_i a_i q + \sum_{k=1}^{K} t_k d_k q_k \tag{1a}$$

$$= \sum_{j=1}^{J=I+K} t_j d_j a_j q$$

for $j = (1, 2, \dots, I, I+1, \dots, I+K)$

and $\exists\, a_j$ such that $a_j q = q_k \; \forall\, j > I$ and $\forall\, k$

$$d_j = \sqrt{(x_j - x)^2 + (y_j - y)^2} \; \forall\, j \tag{1b}$$

$$q = \sum_{k=1}^{K} q_k \tag{1c}$$

Variables: q_k the amount of product distributed at consumption point B_k.

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[20] Originally the model was taken from Launhardt (1882), but Kuhn and Kuenne (1962), Cooper (1967), Nijkamp and Paelinck (1973) and Paelinck and Nijkamp (1978) have used this methodology.

q	the total volume of product.
r_i	the raw materials at O and C, ($i = 1, 2$)
d_i	the distance from the unknown production location to the raw material sites.
d_k	the distance from the unknown production location to the consumption centre B_k.
a_i	denotes the weight volume of raw material required to produce one weight unit of final product.
t_i	is the unit transportation cost per ton kilometre for raw material.
t_j	is the transportation cost per ton kilometre for finished products.
$a_i \times q$	is the total requirement of input r_i used to produce one unit of final product.
$T_i = t_i \times d_i \times a_i \times q$	is the total transportation cost of raw material r_i.
$T_k = t_k \times d_k \times q_k$	is the total transportation cost of final products q_k.

The optimal location will be found by minimising an unknown set of coordinates with respect to the unknown location – see Appendix, First Order Conditions.[21] In order to define a transport cost minimum, the transport cost function T should be convex. As T is the sum of distance functions d_j, it will be sufficient to show that d_j is convex for all j, that is, if its Hessian matrix is semi-definite positive – see Appendix, Second Order Conditions.

Convexity of the distance functions verifies when the eigenvalues of the determinant are non-negative. Using the properties of quadratic expressions: $| H - \lambda I | = (h_{11} - \lambda) \times (h_{22} - \lambda) - h_{12} \times h_{21} = \lambda^2 - (h_{11} + h_{22}) \times \lambda + h_{11} \times h_{22} - h_{12} \times h_{21}$, the λ's will be non-negative if:

(1) the trace of the Hessian is positive, that is $h_{11} + h_{22} \geq 0$, and
(2) the determinant of the Hessian is non-negative, that is $h_{11} \times h_{22} - h_{12} \times h_{21} \geq 0$.

These two conditions can be shown to be true and any local optimum of T will be a unique global minimum of this transportation problem – see Appendix: Minimisation. Based on this property, the first order conditions provide a system of non-linear equations that require a solution algorithm, which will generate a numerical solution for the optimum in a finite number of stages.

The next step is the calibration of the parameters to be used in the model. The iron ore mines and coalfields for the exercise have been determined by their degree of past importance, the reserves available and the quality of their minerals. Fernández-Miranda (1925) identifies both the coalfields and

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[21] See Appendix 2A in Paelinck and Nijkamp (1978).

iron ore mining districts using the previous criteria.[22] We have chosen the coalfields near Mieres in Asturias [N] and La Robla, León [N] – mainly because of their sufficient coking suitability, but also due to their steam and heat qualities, and their availability.[23] We had indicated that the amount of coal consumed for one ton of final steel product was an amount between 1.5 and 4 tons per ton of final output – even though we said that a lower bound of 2.5 would be more realistic.[24] The model will consider locations for discrete amounts of coal – between 1.5 and 4 tons – being employed per ton of final steel product made.

The choice of the ore mining districts includes the mines around Bilbao [NE], the Sierra Menera mines in Teruel and Guadalajara [E], the mines in Almería and Granada [S], the mines near Ponferrada in León [NW]. As a remote option, we have added the Riff mines in Morocco [S] given their relative proximity and their Spanish protectorate status until 1956. Whereas the most important ore fields for hematite ores suited for acid processing were located in Biscay [NE], Teruel [E], Almería [S] and the Riff mines in Morocco [S]. León [N] ores had a slightly higher phosphorus content which made them more appropriate for the basic Siemens open hearth. The weight of the iron ores in the finished products has been determined with much greater precision. As normal processing losses are compensated by a small per centage of shop scrap added in steel processing, the various ores have only been adapted to reflect their different iron contents.[25] Table 2 shows the minimum amount of each ore used to obtain one ton of pig iron.

A *caveat* must be added concerning some of the ores considered. Although the ores from Almería/Granada and Teruel were hematite and appropriate for acid steel processing, a high percentage of the ores screened from both

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[22] Fernández-Miranda Gutiérrez (1925, p. 21) shows the major coal producing areas in 1922, the maximum amount produced in one year, their probable reserves and the coal classes available. Fernández-Miranda Gutiérrez (1925, pp. 66–7) shows regional iron ore production between 1913 and 1922 by provinces. Apraiz Barreiro (1978, pp. 122–24), complements that with a description of the most important iron ores used at that date, their chemical composition, annual production, and reserves.

[23] Merello Llasera (1943, pp. 80 and 88), defines the mines around Mieres and La Robla as the only coal mining districts capable of supplying coal for coking and steel processing purposes. During absolute economic autarky after the Civil War these remained the only two fields capable of providing metallurgic coke in Spain.

[24] Between 1.4 and 1.5 tons of coal are necessary to reduce them to one ton of coke. Approximately 0.9 tons of coke were used to process ore to pig iron. Further processing of pig iron to steel and steel to its final form used energy equivalent to 3.5 tons of good quality coal. We assume that at least one ton of coal energy had been already replaced by waste gas energy which gives us the upper bound, a four ton total consumption for one ton of steel product. The lower bound assumes that gradually all coal consumption with the exception of coking coal could be substituted for waste gas energy, leaving us with a minimum requirement of 1.5 tons.

[25] Data on the iron content were taken from Apraiz Barreiro (1978, pp. 122–4).

these regions was too small in size for blast furnace processing until the early 1920s when they could be agglomerated by sintering or other methods of concentration. Until then, they were mixed with other ores. Without considering these limitations, none of these sites is dominant under the assumptions of our models. But by including them in the contrast we have measured their effect on optimal location once sintering techniques became available.

The major consumption points used in the exercise were projected from the regional steel demand schedule provided by París Eguilaz (1954) for 1953. The co-ordinates used in the algorithm concentrate the regional consumption figures in the region's capitals. This is the earliest regional breakdown of steel consumption we have been able to find. The demand schedule is probably biased by over a decade of economic autarky and below the maximum production of steel – one million tons – obtained in 1929, but it is indicative of the average

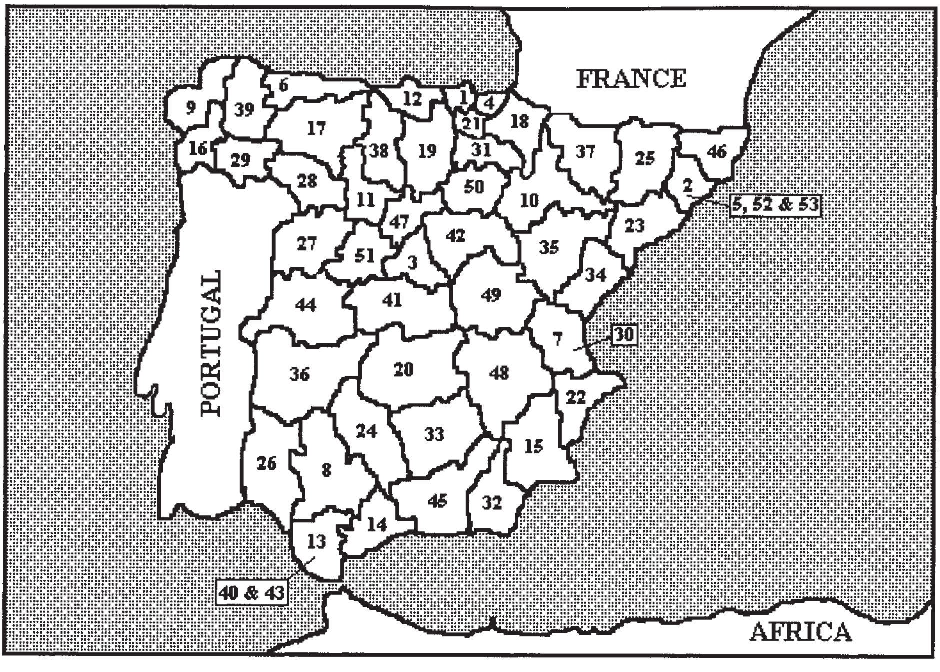
Table 3. *Breakdown of Spanish steel product demand in 1953 by provinces.*

Provinces	Per cent	Tons	Provinces	Per cent	Tons
1. Biscay	24.508	140,186	29. Orense	0.259	1,481
2. Barcelona	14.103	80,669	30. Palma	0.258	1,476
3. Madrid	10.609	60,683	31. Logroño	0.248	1,419
4. Guipuzcoa	9.787	55,982	32. Almería	0.197	1,127
5. Foreign Sales	8.189	46,841	33. Jaén	0.146	835
6. Oviedo	5.954	34,057	34. Castellón	0.143	818
7. Valencia	3.265	18,676	35. Teruel	0.135	772
8. Seville	2.894	16,554	36. Badajoz	0.127	726
9. La Coruña	2.046	11,703	37. Huesca	0.121	692
10. Saragossa	1.739	9,947	38. Palencia	0.112	641
11. Valladolid	1.635	9,352	39. Lugo	0.108	618
12. Santander	1.473	8,426	40. Tenerife	0.089	509
13. Cádiz	1.376	7,871	41. Toledo	0.087	498
14. Málaga	1.205	6,893	42. Guadalajara	0.073	418
15. Murcia	1.186	6,784	43. Gran Canaria	0.070	400
16. Pontevedra	1.140	6,521	44. Cáceres	0.058	332
17. León	0.975	5,577	45. Granada	0.049	280
18. Navarra	0.882	5,045	46. Gerona	0.047	269
19. Burgos	0.778	4,450	47. Segovia	0.036	206
20. Ciudad Real	0.750	4,290	48. Albacete	0.012	69
21. Alava	0.682	3,901	49. Cuenca	0.008	46
22. Alicante	0.432	2,471	50. Soria	0.008	46
23. Tarragona	0.363	2,076	51. Avila	0.004	23
24. Córdoba	0.345	1,973	52. Morocco	0.017	97
25. Lérida	0.307	1,756	53. Guinea	0.017	97
26. Huelva	0.301	1,722			
27. Salamanca	0.286	1,636	TOTAL	99.904	571,451
28. Zamora	0.265	1,516			

Source: París Eguilaz (1954, p. 42).

consumption patterns for steel products in industry, transport and construction for the period of time in question. We can safely assume that relative population distribution and the previously existing economic structure remained virtually unchanged after the economic crisis suffered in the twenties and thirties, the Spanish Civil War and the first decade of severe economic autarky. The annual breakdown of production at Altos Hornos de Vizcaya – the dominant firm before and after the war – shows the same structure of production of rolled steel products for the early 1950s as the 1910s. Although some degree of bias is introduced, given that we are measuring the demand schedule more than a decade after our period of study, we can safely assume that there was very little change in the fundamental aspects of the existing economic structure of Spain which, in turn, is what determined the demand schedule for steel.

The algorithm was originally normalised to one unit of production and later generalised to a production of half a million tons of steel products.[26] Nevertheless, the geographical solutions are insensitive to production levels. However, introducing this scale of production was instrumental for calcu-



Map 1. *Spanish provinces and extra-peninsular demand allocation.*

Note: See Table 3 for legend.
Source: Original map provided by Blanca Sánchez Alonso.

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[26] Barreiro Zabala (1943) shows steel products around that level between 1925 and 1931 and later in 1940/1. This figure has been chosen arbitrarily but within the capacity of the production centres.

lating both the total cost of transport and the total ton-kilometres transported.

The last set of parameters to be defined is transport costs. High total terminal costs, both in shipping and rail transport, impose widespread discrimination in rates, usually in favour of raw materials and against final products.[27] Discrimination is introduced to compensate the terminal costs of lines with low traffic. The pattern of transport price discrimination usually reflects the lower unit added value of material inputs and the greater demand elasticity for this kind of transport. These price distortions give a greater force of attraction to markets.

A unique transport cost was assigned to coal, ore and final products. Therefore origin and destination of goods do not affect transport cost in any case. As a benchmark we have used the 1894 rail fare for one ton of coal from Mieres, Asturias [coalfield] to Bilbao [orefield] – 15 pesetas – which represents a fare per ton/km of around 0.049 pesetas.[28] Official tariffs were published throughout the period by the different railway companies. But reliable rail transport prices based on the real prices being applied to large consumers for all of the items are to date only available for southern Spain. The company records of the major company operating in southern Spain – Madrid-Zaragoza-Alicante – show a discrimination of prices similar to the structure assumed below.[29] Given the few observations we have for only one company and the partial coverage – southern Spain – we have opted for obtaining transport cost differentials using a different method.

We have indexed railway freight price differentials for coal, iron ore and steel products for the United States in 1932, in the middle of economic depression. Rail freight rates themselves may not be considered strictly comparable as distances, rolling stock, demand, and so on, differ considerably from Spain. Nonetheless we can consider these depression-year figures as indicative of the added value and elasticities which determined the discriminated fares of each of these bulk transports. These ratios, 1.27 for ore to coal and 2.26 for finished steel products to coal, are used to extrapolate the ton/km fares of coal, iron ore and finished steel products which maintain these relative price ratios and are close to our benchmark.[30] Coal fares are fixed at 0.0442 pesetas per ton and kilometre, iron ore at 0.0564 pesetas and steel products at 0.1 pesetas.[31]

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[27] Terminal costs include maintaining line services, railway stations, warehouses and communications.

[28] Ojeda (1985, p. 221).

[29] Biblioteca Fundación Ferrocarriles Españoles, Carpetas D433/04, D434/01, D435/01, D094/05 and D585/01.

[30] Berger (1951, Appendix C, table C-1, pp. 196–7).

[31] This has been biased slightly downward to allow for some adjustment to higher quantities being transported. But the criteria has been to normalise final product transportation to 25 per cent above the average transportation cost for all goods on the

Discussion of results

Using the two alternative coals as the basis for two separate exercises, each of the two coals has been combined alternately with each of the five iron ores and the proposed demand schedule. At the same time the amount of

Table 4. *Optimum locations using Asturian coal.*

	Coal Asturias tons	Co-ordinates X	Y	Transport cost million ptas	Total distance 000 kms	Location
Ore Biscay	4	4.0	11.0	42.2	35.58	Mieres
	3.5	6.0	10.8	40.9	33.13	
	3	6.7	11.0	37.9	33.83	
	2.5	6.8	11.0	34.7	33.83	
	2	6.8	11.0	31.5	33.83	
	1.5	6.8	11.0	28.3	33.83	Bilbao
Ore Teruel	4	3.9	11.0	57.5	36.04	Mieres
	3.5	5.1	10.2	56.7	31.21	
	3	5.9	9.6	54.5	28.94	
	2.5	6.5	9.0	51.4	27.58	
	2	7.3	8.2	47.1	26.72	
	1.5	8.2	7.3	41.5	27.32	Setiles
Ore Almería	4	3.9	11.0	77.0	36.08	Mieres
	3.5	4.3	10.4	76.8	33.05	
	3	5.0	9.4	75.3	29.06	
	2.5	5.5	8.3	72.5	26.55	
	2	6.1	6.6	68.0	24.97	
	1.5	6.1	6.3	62.5	25.06	Getafe-Madrid
Ore Ponferrada	4	3.9	11.0	34.2	36.08	Mieres
	3.5	3.9	11.0	34.2	36.08	
	3	3.9	11.0	34.2	36.08	
	2.5	3.8	10.7	34.1	35.12	
	2	3.6	10.3	33.5	34.20	
	1.5	3.1	9.9	32.4	34.50	Ponferrada
Ore Riff	4	3.9	11.0	72.1	36.08	Mieres
	3.5	3.9	11.0	72.1	36.07	
	3	4.5	10.1	71.7	31.89	
	2.5	5.1	9.2	69.8	28.38	
	2	6.0	8.0	66.7	25.99	
	1.5	6.1	6.6	61.8	24.97	Madrid

Caminos de Hierro del Norte de España [$\mu = 0.076$; $\sigma = 0.0086$] and the Ferrocarril Madrid-Zaragoza-Alicante [$\mu = 0.071$; $\sigma = 0.0036$] lines between 1886 and 1918. Rail tariffs for this calculation were taken from Tedde de Lorca (1978, p. 99, table IV-17 and p. 207, table IV-58). The 25 per cent differential between average product fare and steel product fare is taken from the US data taken from Berger (1951, p. 199).

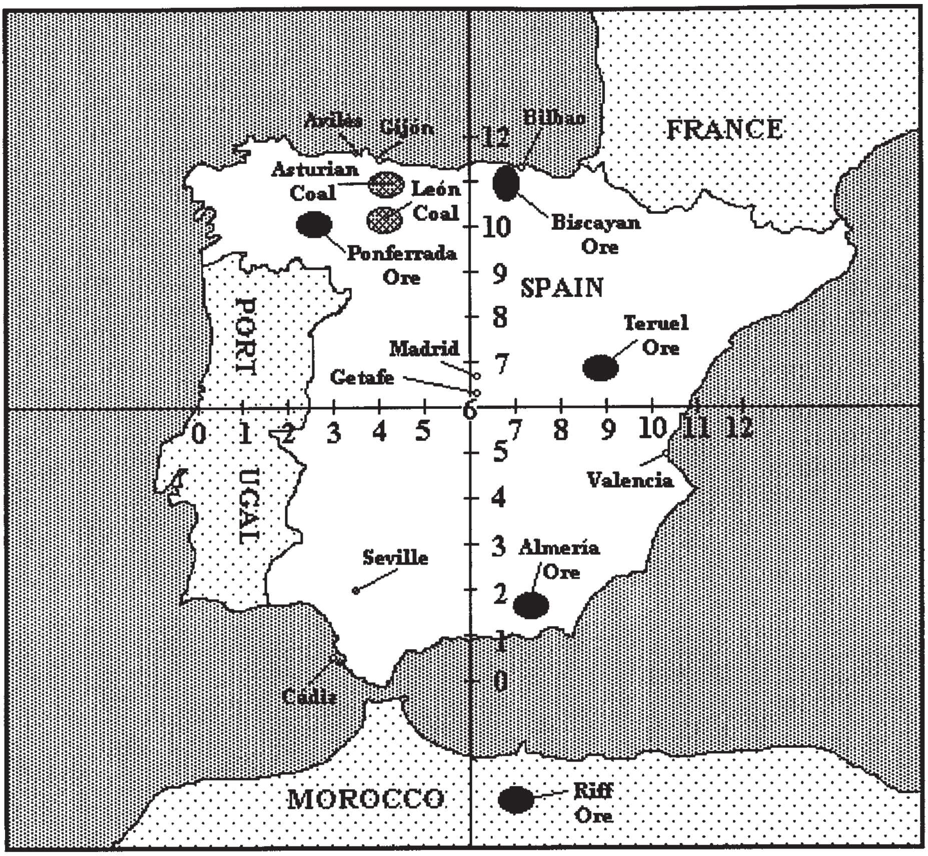
Table 5. *Optimum locations using León coal.*

	Coal León tons	Co-ordinates		Transport cost million ptas	Total distance 000 kms	Location
		X	Y			
Ore Biscay	4	3.9	10.1	41.4	32.88	La Robla
	3.5	5.3	10.3	40.7	31.67	
	3	6.6	10.9	38.4	33.29	
	2.5	6.7	11.0	35.1	33.83	
	2	6.8	11.0	31.8	33.83	
	1.5	6.8	11.0	28.5	33.83	Bilbao
Ore Teruel	4	3.9	10.1	53.2	32.90	La Robla
	3.5	4.8	9.7	52.9	30.13	
	3	5.7	9.2	51.2	27.99	
	2.5	6.4	8.7	48.4	26.89	
	2	7.2	8.0	44.7	26.46	
	1.5	8.2	7.2	39.7	27.33	Setiles
Ore Almería	4	3.9	10.1	71.2	32.90	La Robla
	3.5	4.0	10.1	71.2	32.54	
	3	4.7	9.1	70.4	28.62	
	2.5	5.4	8.0	68.3	26.23	
	2	6.1	6.6	64.5	24.97	
	1.5	6.1	6.2	59.9	25.14	Aranjuez
Ore Ponferrada	4	3.9	10.1	30.3	32.90	La Robla
	3.5	3.9	10.1	30.3	32.90	
	3	3.9	10.1	30.3	32.90	
	2.5	3.9	10.1	30.3	32.90	
	2	3.9	10.1	30.3	32.90	
	1.5	3.8	10.1	30.3	32.89	La Robla
Ore Riff	4	3.9	10.1	67.0	32.90	La Robla
	3.5	3.9	10.1	67.0	32.90	
	3	4.1	9.8	66.9	31.60	
	2.5	5.0	8.8	65.8	27.86	
	2	5.6	7.7	63.4	25.71	
	1.5	6.1	6.6	59.2	24.97	Madrid

coal used in processing one ton of steel products was reduced in stages from 4 tons – the upper bound we established for the late nineteenth century – to 1.5 tons – the lower bound established by the state of the art in the 1950s.

Both Tables 4 and 5 clearly show that Bilbao is not the optimal site in terms of transportation cost minimisation for high to moderate coal consumption, which was the level of consumption in Spanish steel mills at their origins and probably up to the late 1950s. The absolute minimum in terms of transport cost minimisation is obtained in Bilbao for 1.5 tons of Asturian coal followed very closely by Bilbao for 1.5 tons of León coal. But using better-founded assumptions – between 2.5 and 4 tons of Asturian coal and León coal – the optimal site is not Bilbao! The optimal locations are the coalfields in Mieres and La Robla respectively. The savings for these coal sites with respect to Bilbao oscillate between 22 and 1.5 pesetas per ton of steel for León and between 16 and 1.2 pesetas for Asturias. Within the framework of the model, we are talking about a lost saving of up to 23 per cent on the cost price of steel rails or 15 per cent on steel plates. The amount of direct welfare loss involved alone, is serious enough, without even taking into account the secondary effects of this mislocation.

Given the magnitude of the economic welfare loss we have calculated with our model, careful re-examination of some of the model's assumptions seems necessary before formulating final conclusions. The first important assumption to be re-examined is the formalisation of transportation cost. We have assumed transport cost to be uniform, that is, equivalent in any direction, and that the distance paid will be the shortest distance between two points, that is, a straight line. There is some evidence of different tariffs for different railway companies in Spain. We have been able to calculate a 7 per cent tariff differential for the average km-ton fares of the two major



Map 2. *Location of resources and optimal sites.*

rail companies operating in Spain at this time. The railway company operating in the north of Spain had slightly higher prices than the company operating in the south and centre of the country. This is mainly due to the more mountainous terrain in the north. But even so, the existing differential is small enough to maintain our assumption of uniform transport cost.

Assuming that things can be moved in a straight line creates more problems. Railway tracks were far from being linear connections, due mainly to mountain barriers. As a consequence of mountainous inland terrain, interprovincial transport used up to the Spanish Civil War was usually a combination of coastal shipping and rail transportation. Spain's topography shows that land transport is difficult because of the rise and fall of the sierras surrounding the two central mesetas. Sea transport to a point of easy inland access, combined with rail transport to the final destination was often preferable to overland rail transport.

Given these possible objections, we have readapted the previous parameters for a seaboard-rail model. All inland steel demands have been allocated in the following way:

(1) The dominant criterion has been to choose the port which provides the minimum number of railway transhipments on the way to the final destination for each factor and final product demand. One-haul railway routes were chosen where possible.
(2) If equivalent transhipment hauls existed, the port which minimised the distance to the final destination was chosen.[32]

We have maintained the freight differentials between coal, ores and final products used above, given that we assume the same added value differentials and elasticities. We established the per-ton and kilometre sea freight for coal at 0.015 pesetas, less than a third of the rail fare.[33] Sixteen major ports were chosen based on their importance as a final consumption point or as transhipment points to inland demand. They were ordered along a straight line according to the distance between them. Almost all the non-port consumption points had unique optimal land routes, with the exception of Madrid with various alternative routes. Demand from the Spanish islands and foreign locations posed additional problems. The consumption of the Balearic Islands was included with Valencia, that of the Canary Islands was added to Cádiz. Madrid and foreign sales were finally assigned to Barcelona as a strong bias against northern ports, which is where coals were located.

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[32] Transhipment cost can include recomposing trains, or unloading, storing and reloading.

[33] We have used freights for Asturian coal to Barcelona and Bilbao to regress the fixed component of freight, between four and five pesetas, and the variable component, which depends on distance, between 0.015 and 0.022 pesetas per km. These calculations are for 1890 and 1895. As 1890 was a year of exceptionally high English coal prices in Spain which may have biased Spanish coal freights we chose the second benchmark. Our railfare benchmark was for 1894 so this is quite coherent.

We can assume that the decision rule taken for assigning transport to its optimal port minimises its remaining transport cost. In each case we have chosen a combination of shipping and rail transport which reduces transhipment cost. Any alternative route would be more expensive as it involved more transhipments. Using this assumption, we can abstract the transport cost minimisation problem to that of reducing the cost of sea transport.[34] Table 6 below shows the results.

The first result to be underlined is that Asturias – its port in Gijón – comes

Table 6. *Optimum locations for coastal transport.*

	Coal Asturias tons	Co-ordinate y	Transport cost million ptas	Total distance 000 kms	Location
Ore Biscay	4	4.5	34.69	36.35	Gijón
	3.5	4.5	34.69	36.35	
	3	4.5	34.69	36.35	
	2.5	4.4	34.69	36.35	
	2	1.1	34.20	41.27	
	1.5	1.1	32.95	41.28	Bilbao
Ore Teruel	4	4.5	81.60	36.35	Gijón
	3.5	4.5	81.60	36.35	
	3	4.5	81.60	36.35	
	2.5	4.5	81.60	36.35	
	2	22.8	78.11	26.93	Seville
	1.5	34.9	67.85	34.86	Valencia
Ore Almería	4	4.5	72.30	36.35	Gijón
	3.5	4.5	72.30	36.35	
	3	4.5	72.30	36.35	
	2.5	4.5	72.30	36.35	
	2	23.5	67.91	26.93	Cádiz
	1.5	28.9	58.87	28.47	Almería
Ore Ponferrada	4	4.5	28.17	36.35	Gijón
	3.5	4.5	28.17	36.35	
	3	4.5	28.17	36.35	
	2.5	4.5	28.17	36.35	
	2	4.5	28.17	36.35	
	1.5	4.5	28.17	36.35	Gijón
Ore Riff	4	4.5	65.33	36.35	Gijón
	3.5	4.5	65.33	36.35	
	3	4.5	65.33	36.35	
	2.5	4.5	65.33	36.35	
	2	8.8	65.17	32.91	La Coruña
	1.5	28.9	58.87	28.47	Almería

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[34] Supposing transhipment and rail transportation costs to be the same in all Spanish ports is a strong assumption because the orography of Spain distorts uniformity considerably.

out in a much stronger position than in the previous exercises. The coal coefficient has to drop below 2.5 tons per ton of steel product to break Gijón's grip on minimum transport costs for any of the iron ores used. The absolute minimum of 28.17 million pesetas – for Ponferrada ores and 1.5 tons of coal – in Gijón tends to reaffirm the correct location of the Spanish public-owned integrated mill, ENSIDESA, in the late fifties. State intervention in iron and steel production in post-Civil War Spain was inspired by the necessity of providing cheap basic raw material, by the lack of coking coals and by the presence of a dominant private firm – Altos Hornos de Vizcaya – which produced below capacity and had stopped innovating in the late 1920s. The integrated publicly owned mill projected in the 1950s sought to provide solutions to these pending problems and state technicians located it in Avilés near Gijón.

Conclusions

As in the case of overland transport, the seaboard model strengthens the view of Bilbao as an inefficient location and strongly questions its status as the overall optimum location. The depletion of Biscay's ore reserves in the 1920s, and its falling ore grades throughout the period examined, reinforce this conclusion. All numerical exercises for well-founded coal consumption have been conclusive in determining coalfields as the optimum site for the Spanish steel industry in terms of minimising domestic transport of products and inputs. With mislocation established beyond doubt, two other important questions arise. On the one hand, what were the economic consequences of this mislocation? And on the other hand, why and how did Spain's mislocated steel centre retain its position over time?

The immediate consequences of this mislocation are its serious negative impacts on industrial development and the significant welfare loss it produced. The location of the steel industry on or near coalfields would have reinforced the centripetal location forces of establishing Spain's industrial centre where cheap energy supply was – this is the thesis proposed by Ojeda (1985). The expansion of Spanish steel production and downstream transformation industries right up to the 1970s was limited and distorted by the dominant and mislocated Basque firm. On the one hand, a major input cost for industry was inflated – the cost of steel – and on the other hand, transformation industry was attracted by the steel centre in the Basque country rather than by coalfields in Asturias which distorted their energy costs *via* transport considerably.

As downstream industries such as metal transformation, shipbuilding, household appliances, the automotive and aeroplane construction industries developed, the higher price of steel and the extra cost of transporting coal became all the more relevant. For the model we have used, the transport savings alone which could have been attained by locating steel production in Gijón, were around five million pesetas a year or 14.5 per cent of sea transportation cost. For a production of half a million tons of finished products, this means up to 10 per cent of finished steel products' cost price. The magnitude of the ultimate consequences of mislocation remain hard to establish, but the distortion effect on heavy industry's development was very considerable.

This raises the second question. With the production inefficiency and welfare effects involved, why and how did Spain's mislocated steel centre retain its position over time? Adopting the role of the devil's advocate, a few arguments can be raised in Bilbao's defence. Some of them are technical, such as the overall reduction of coal consumption in industry, while others are more structural – the lack of scrap iron in Spain's backward economy, excellent port installations, qualified labour markets, and easy access to investment capital. And definitively, the most determinant and supporting elements of mislocation were of an institutional nature. The speed at which Spain's iron and steel industry had cartelised in the early twentieth century, and the ease with which it had attained state protection, are a clear reflection of these political and social ties between Basque mining and steel entrepreneurs and Spain's political oligarchy.

Starting with the weaker arguments, the lack of iron scrap for open hearth ovens retained Bessemer technology as a predominant steel processing method in Spain. The Bessemer converter used virtually no coal for processing and this reinforced the orefield location of the industry in Bilbao. Nevertheless, the advance of waste gas recovery and its application for heating Siemens open hearths invalidate this technical restriction.

Turning to the structural arguments, the potential for commercial expansion in Bilbao was backed by a modern harbour. The Bilbao port had not only modernised its installations to admit higher tonnages, but its lighting and signalling services allowed boats to navigate day and night and had provided an extensive waterfront with docking and loading facilities. The significance of the positive economies which derive from the iron-ore exporting sector in the area, gave Bilbao clear advantages over Gijón. For Bilbao, the average annual port movement was 4.5 million tons a year.[35] Between 1878 and 1920 port movement averaged 385,000 tons per year for Gijón.[36] Gijón's limited harbour facilities have always been considered one of the serious impediments to expanded coal production in Asturias at the turn of the century.[37] Gijón's harbour installations were limited to ships with a gross tonnage of around 300 tons, one fifth of average British tonnage

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[35] Churraca (1951, Table 8). These figures have been contrasted with data obtained from the Spanish Foreign Commerce data presented by Puerta Rueda (1994, Table 13, p. 127), for these decades and similar results for those reference points are obtained.

[36] Frax Rosales (1981, pp. 93 and 102). Standard deviations are 275,000 and 260,800 respectively, due mainly to a significant increase in coastal shipping volume during World War I.

[37] Ojeda (1985, p. 229).

towards the end of the nineteenth century. The water line dropped below navigation limits at low tide twice a day. Gijón failed to modernise its harbour throughout our period of analysis. But surely a correct location of the heart of Spain's steel and transformation industry would have provided the incentives to modernise its port installations earlier.

An additional defence mechanism could be the scope economy found in the availability of capital and potential investors in the Bilbao area. González Portilla (1974) tried to quantify profits from iron ore mining and the importance of these funds for reinvestment in the iron and steel industry. Although Valdaliso (1988) has questioned the total amount reinvested by mine owners and mining companies in major iron and steel processing enterprises, his figure is still considerable – 25 per cent of iron and steel capital came from mining profits. Furthermore, the infrastructures and economic activity created by Bilbao's mining boom attracted investors. Increasingly large capital injections from outside the steel industry were needed to overcome the liquidity constraints faced in an industry characterised by production scale economies. Over two billion pesetas were invested in incorporated companies in Bilbao between 1900 and 1936. That is 14 times as much as the dominant Basque steel mill, Altos Hornos de Vizcaya, invested over the same period.[38] Even so, there were no impediments to investing these sums of money elsewhere. Indeed, large sums of Basque companies' capital originated from Madrid, Catalonia and Andalusia, and we find that Spanish – even Basque – capitalists had no prejudice against investing in other parts of Spain.[39] A deficiency of capital in the coal provinces could also have been made good by foreign investment. It was the institutional framework which prevented this from happening. The existing industrial concentration and cartelisation, combined with its DUP activities and rising protectionism, explain why foreign capital increasingly avoided Spain.[40] Additionally, growing economic nationalism from the 1920s onwards limited the direct participation of foreign investors in Spanish industry. Yet, it is safe to affirm that foreign capital would have beaten a path to an optimal location, had that opportunity existed in a liberal competitive economic framework.

Iron-ore mining activity had other positive externalities in Bilbao. Over 80 per cent of Biscayan iron ore in the period considered was exported and foreign demand created the transportation infrastructure for bringing these minerals into the port.[41] Acquisition costs of ores were lowered considerably for riverside

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[38] Churraca (1951, pp. 108–110) and Houpt (1998, vol. II, p. 436).

[39] There is an important investment diversification of the leading Basque family fortunes into other provinces: Echevarrieta, Chávarri, Salazar, Rivas, Ibarra, and so on.

[40] Fraile (1991, ch. 5) and González Portilla (1985, pp. 189–235).

[41] The port of Bilbao had been improved to allow for a more fluent export of iron ore for which there was a high demand in Great Britain, but at the same time this provided import facilities and the possibility of applying backhaul rates for returning ships.

mill locations.[42] Massive iron ore extraction also attracted workers from surrounding provinces to the nearby mining district; the estimated workforce for the area surrounding the river port grew from 26,700 to 72,200 workers between 1877 and 1900 – a 270 per cent increase.[43] In 1896 around 4,000 workers were employed in Bilbao's steel mills.[44] By 1909 that number had increased to 5,620 and by 1924 to 6,982 for the Altos Hornos de Vizcaya factories alone.[45] But these same labour and transport externalities could have been present in the coal mining districts, had they developed a thriving steel industry there earlier.

The only really distinctive element that permitted its dominant firm – Altos Hornos de Vizcaya – to persist as an oligopolistic leading firm over time, was the accumulated collusive behaviour of the Biscayan merchant capitalist and capitalist *bourgeoisie*. The rent-seeking and captive market strategy that Biscayan capitalists adopted is what established the firm's hegemony. Collusive behaviour in the iron industry can be traced back as far as 1827 when the four major ore merchants merged into a single firm to control Biscayan iron inputs for foundries. This joint venture monopolised ore trade and avoided competition between its partners until the first modern blast furnace was erected in 1843.[46] Similarly, from the very first moments of mass production – the pig iron sales cartel dates back to 1886 – the modern steel firms in Biscay imposed cartels for different products.[47] By 1907, Altos Hornos de Vizcaya had organised and completely dominated a national sales cartel for virtually all iron and steel products. Discipline within the cartel was imposed by a three pronged fork, the overcapacity of the dominant firm, its technological superiority in terms of unit costs, and the splendid profits it distributed among the members of the cartel. At the same time its political influences combined with the general protectionist movement in other sectors – agriculture and textiles – to keep foreign competition away from home markets.[48] Pressure groups in Biscay, Catalonia and Castile

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[42] The five major ore railways had their loading bays in the direct neighbourhood of the Altos Hornos de Vizcaya factories.

[43] Shaw (1977, p. 95). Iron ore production rose from 432,418 m tons in 1876 to 4,691,000 m tons in 1887 and to 5,361,796 m in 1900. Population in the mining areas grew from 40,159 persons in 1857 to 105,728 in 1887 and 167,680 in 1900. González Portilla (1974, pp. 53, 81 and 82).

[44] Shaw (1977, p. 98).

[45] *Monografía de la Sociedad Altos Hornos de Vizcaya de Bilbao* (1909). Barcelona: Thomas, p. 55; and *Monografía de las industrias siderúrgicas propiedad de la Sociedad Altos Hornos de Vizcaya* (1924), p. 34.

[46] Díaz Morlán (1999, pp. 18–24).

[47] The first cartel for iron products dates back to December 1871. Saéz García (1999, pp. 124–5).

[48] The chairman of the board of Altos Hornos de Vizcaya, Pablo de Alzola, was appointed chairman of the tariff *ad hoc* committee for the 1906 tariff reform, its vice-chairman, Faustino Rodríguez San Pedro, was a member of the Cabinet and six of its board members were members of parliament.

united in a common effort to raise barriers against foreign products. High tariffs reinforced their capacity to capture home markets. And so, Altos Hornos de Vizcaya's consolidated its institutionalised grip on the sector. Its position as a dominant firm could not be broken, even when the all-powerful industrial Spanish state holding INI set up a gigantic steel complex on Spain's coalfields in the late 1950s in an attempt to correct mislocation.[49]

The analysis of Spain's steel industry contains all the elements of Gerschenkron's economic backwardness theory. But basic heavy industry, unbalanced growth and state intervention combined in a way he had not predicted. The foreign demand for Bessemer-apt iron ores and the collusion of the Biscayan steel industry – previous to Spain's industrial revolution – established a mislocation which the institutional framework consolidated and maintained until industrial reconversion and entry to the European Union in the 1980s. And Spain's captured markets were able to resist direct and indirect state intervention throughout all of this period.

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[49] See Fraile Balbin (1993).

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Appendix

First Order Conditions

$$\frac{\partial T(x, y)}{\partial x} = -\sum_{j=1}^{J} t_j a_j q \cdot \frac{x_j - x}{d_j} = 0 \qquad (2a)$$

$$= -\sum_{j=1}^{J} \frac{t_j a_j q}{d_j} \cdot x_j + \sum_{j=1}^{J} \frac{t_j a_j q}{d_j} \cdot x = 0$$

$$\therefore\ x = \frac{\sum_{j=1}^{J} \frac{t_j a_j q}{d_j} \cdot x_j}{\sum_{j=1}^{J} \frac{t_j a_j q}{d_j}}$$

$$\frac{\partial T(x, y)}{\partial x} = -\sum_{j=1}^{J} t_j a_j q \cdot \frac{y_j - y}{d_j} = 0 \tag{2b}$$

$$= -\sum_{j=1}^{J} \frac{t_j a_j q}{d_j} \cdot y_j + \sum_{j=1}^{J} \frac{t_j a_j q}{d_j} \cdot y = 0$$

$$\therefore\ y = \frac{\sum_{j=1}^{J} \frac{t_j a_j q}{d_j} \cdot y_j}{\sum_{j=1}^{J} \frac{t_j a_j q}{d_j}}$$

Second Order Conditions

$$H = \begin{bmatrix} \frac{\partial^2 d_j}{\partial x^2} & \frac{\partial^2 d_j}{\partial x\, \partial y} \\ \frac{\partial d_j}{\partial x\, \partial y} & \frac{\partial^2 d_j}{\partial y^2} \end{bmatrix} = \begin{bmatrix} d_j^{-1} - (x_j - x)^2\, d_j^{-3} & -\,(x_j - x)(y_j - y)\, d_j^{-3} \\ -\,(x_j - x)(y_j - y)\, d_j^{-3} & d_j^{-1} - (y_j - y)^2\, d_j^{-3} \end{bmatrix} \tag{3}$$

Minimisation

$$d_j^{-1} - (x_j - x)^2\, d_j^{-3} + d_j^{-1} - (y_j - y)^2\, d_j^{-3} = \tag{4a}$$

$$d_j^{-1}\, [1 - (x_j - x)^2\, d_j^{-2} + 1 - (y_j - y)^2\, d_j^{-2}]$$

d_j^{-1} is positive, and

$$[(x_j - x)^2 + (y_j - y)^2]\, d_j^{-2} < 2$$

$$d_j^2 \cdot d_j^{-2} < 2 \qquad \text{q.e.d.}$$

$$[d_j^{-1} - (x_j - x)^2\, d_j^{-3}]\, [d_j^{-1} - (y_j - y)^2\, d_j^{-3}] - [-\,(x_j - x)(y_j - y)\, d_j^{-3}]^2 \geq 0 \tag{4b}$$

$$d_j^{-2}\, [1 - (x_j - x)\, d_j^{-2}]\, [1 - (y_j - y) d_j^{-2}] - (x_j - x)^2 (y_j - y)^2\, d_j^{-6} \geq 0$$

$$d_j^{-2} - [(x_j - x)^2 + (y_j - y)^2]\, d_j^{-4} + (x_j - x)^2\, (y_j - y)^2\, d_j^{-6} - (x_j - x)^2\, (y_j - y)^2\, d_j^{-6} \geq 0$$

$$d_j^{-2} - d_j^2\, d_j^{-4} \geq 0 \qquad \text{q.e.d.}$$