Infant–Industry Tariff Protection with Pressure Groups

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Abstract

This paper analyzes the increasing tariff protection in the Spanish iron and steel industry over the first third of the 20th century. Learning effects are explicitly included to model a dynamic game of trade liberalization. The government chooses the tariff level while firms decide how much to produce each period. Firm's production decisions determine their future cost levels. Assuming that learning reduces only fixed costs, the dynamic game may be solved in closed form, so that the optimality and time consistency of the actual policy can be evaluated. Furthermore, the model is used to measure the relative importance of producers and consumers on the government's equilibrium tariff strategy. The model is calibrated for year 1913 and it is shown that the existence of important, unexploited, dynamic economies of scale may have justified high tariff levels at that time. In addition the results also show that the Spanish iron and steel producers behaved more competitively than what is commonly assumed, and that the government's protection policy was not significantly conditioned by steel producers. JEL: C73, F12, L61.

Keywords: Infant–Industry; Tariff Protection; Spanish Steel Industry.

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1 Introduction

Despite the widespread application of tariff policies to encourage the development of both infant and non–infant industries, very little effort has been done to measure its economic effectiveness. This type of policy has been particularly prevalent in the European iron and steel industry, a key sector in any industrializing country. However, the performance of these tariff policies was very different accross countries. For instance, while the Imperial tariff may have helped to develop the German iron and steel industry by imposing intermediate levels of protection, the prohibitive Spanish tariffs isolated the Spanish iron and steel industry from the European market. Apart from English Liberalism, most of Continental European countries applied some level of protection in order to improve their competitiveness relative to the leading English economy. In the 19th century, List and the Protectionists supported tariffs as a way to profit from the learning period in manufacturing. Protection would allow less advanced countries to acquire the general and technical know–how of all aspects of manufacturing to be able to compete in international markets [Bairoch (1993, §2)]. Bismark's *Realpolitik* meant the start of a long period of protectionism on Continental Europe. The new German tariff of 1879 generalized the use of specific duties. The same policy started in Spain with the Tariff Act of 1891.

The aim of this paper is to study the increasing protection of the Spanish iron and steel industry over the first third of the 20th century. At that time, given the stage of development of the Spanish economy, this industry could be considered an infant–industry with important potential learning effects. In order to analyze this case, I develop a simple structural model that easily characterizes time–consistent tariff protection policies. The model provides an appropriate analytical framework to evaluate the social optimality of the actually implemented protection policies. Previous evaluations of the Spanish tariff policy since the beginning of the 1890s has been characterized by a lack of theoretical structure. This is common with the analysis of many other protectionist policies. Even when it is theoretically possible to account for learning effects induced through tariff protection, there is not any suitable model to address the issue of an optimal tariff policy. Therefore, existing interpetations of the Spanish protection policy rely on normative arguments which tend to neglect either whether the actual protection policy was excessive [Nadal (1975)], or whether there still existed potential learning effects that justified a high level of protection [Fraile (1991)]. This paper is an attempt to evaluate this protection policy according to optimality criteria derived from a theoretical model.

The most common argument in trade policy in favor of protection deals with the existence of dynamic economies of scale at the industry or firm level. In this case, tariff protection induces higher domestic production and therefore cost savings which provide the domestic industry with a better cost position relative to its foreign competitors. This is also the focus of the mainstream research in this field. The reasoning is outlined in Brander and Spencer's (1983) model of strategic trade policy: in the presence of government intervention, domestic Stackelberg leadership becomes a credible strategy. Following the same line of reasoning, Brander and Krugman (1983) develop a reciprocal dumping duopoly model with static economies of scale (downward–sloping marginal cost). In this model, if the government protects its domestic market, the domestic firms will reduce costs by increasing production, and therefore, as the foreign firm has reduced its respective production, the domestic firm will be able to compete in the foreign market. As Krugman (1984) has shown all these models can be interpreted as different ways of promoting exports through import protection, whether they include static economies of scale, international R&D competition or dynamic economies of scale (learning by doing). Krugman notes that benefits from a future cost advantage may motivate government protection as many policy makers claim.

Another related stream of work emphasizes that the resulting tariff protection policy is the outcome of bargaining between pressure groups and the government. The suggestive work of Fraile (1991) analyzes how Spanish steel producers conditioned the government design of the tariff policy. This pressure group explanation is based on exogenous measures of group power. The present model does not endogenize the relative power of each group explicitly, but it makes possible to measure it at the equilibrium. The bargaining process between government and producers resembles a dynamic version of Matsuyama's (1990) model. The government wants to liberalize trade in order to maximize domestic welfare. But, due to learning effects, welfare maximization over time requires the establishment of a tariff to protect the domestic industry. The optimal tariff will depend on industry performance. Given a low learning effect, the optimal policy will reduce the tariff to increase competition and avoid excessive domestic monopoly power. And, despite the fact that domestic firms prefer a monopolistic position, the possibility of foreign competition induces them to increase production above the static profit maximization level in order to reduce costs and be able to compete later. Hence, if producers have the ability to influence the government, the government's determination to liberalize may be lower than predicted by the optimal solution. In the present model the dynamics have their origin in the decreasing speed of learning induced by a downward sloping, convex, fixed cost function over accumulated output. The government does not commit to some level of protection that firms may take as given while colluding. Instead, the tariff policy is contingent on industry performance. Excessive collusion will be compensated by lower levels of tariff protection in order to increase competition.

In order to characterize a time–consistent policy easily, the model only includes fixed cost reduction due to learning. However, this feature changes completely the way in which welfare is enhanced by tariff protection. Given the number of firms in the industry, the government is interested in protecting the industry in its early stages of development in order to enhance consumer variety and promote competition. In the case of an infant–industry, costs are so high at early stages of development that without protection, at least some firms need to exit the market. Government protection allows firms to produce in early stages by ensureing a high enough domestic price for domestic firms to cover total costs. This policy temporarily reduces consumer surplus because it induces high prices for both domestic and imported goods. However it also permanently increases variety, allowing domestic production to be profitable. Since fixed costs decline with production, the tariff level necessary to ensure profitability also falls. If tariffs do not drop off, firms will profit from the excessive market power ensured by tariff protection. Since this policy also allows all domestic firms to remain in the market, competition among them is enhanced, which ensures the lowest possible domestic price in the long run.

The paper is organized as follows. Section 2 briefly presents the model and characterizes an infinite horizon time consistent Markov Perfect Equilibria. Section 3 describes the development of the Spanish Iron and Steel Industry. It also ties these features to the theoretical assumptions of the model. In section 4 the model is calibrated for year 1913. Section 5 summarizes the main results.

2 A Concise Description of the Model

The game consists of $n+1$ players: n firms and the government of a small country. There is no entry or exit into or out of this industry. Firms ask for protection to have time to reduce total costs and later to be better positioned to compete with foreign firms. The model is structured using a continuous time specification. The only state variable of the model is the vector of accumulated outputs for each firm in the industry. Denote the realization of this vector at time t as y^t. For each player, time t strategies are contingent on the state of the game. Production is firms' only control variable. The choice variable for the government is the tariff level.[1] A firm's objective in each period is to maximize its expected discounted profits. The government maximizes the discounted weighted sum of consumer surplus, total profits and tariff revenues. Foreign firms, who produce a slightly differentiated good, are assumed to behave competitively. In addition assume that they have exhausted their respective learning processes. This assumption allows me to ignore strategic effects between domestic and foreign firms as well as the investment aspects of foreign firms' output decisions. Foreign firms compete while domestic firms supply a differentiated good in a monopolistically competitive regime and are subject to learning effects. In order to solve the model, I will specify the structural functions as follows.

2.1 Demand System

Assume that domestic and foreign production are considered imperfect substitutes for each other by domestic consumers. Domestic firms produce a homogeneous good and they compete in a differentiated product market with foreign firms. Let $X^t = \sum_{i=1}^{n} x_i^t$ denote the domestic industry production and let M^t denote imports at time t. Assume the following quadratic, strictly concave utility function for domestic consumers:

$$U(X^t, M^t) = Q_0^t + a_x X^t + a_m M^t - \frac{1}{4}\left[b_x (X^t)^2 + b_m (M^t)^2 + 2k X^t M^t\right]$$

[1] Technically, the model needs the existence of at least one state variable. An alternative interpretation of the model is that firms' total costs depend on the accumulated stock of physical or human capital. In this case, firms' strategic decision variable is the level of investment at each period.

where all parameters a_x, a_m, b_x, b_m, k are strictly positive. At each time, t, consumers maximize $U(X^t, M^t)$ subject to the monetary constraint $I^t = Q_0^t + P_x^t X^t + (P_m^t + \tau^t)M^t$, where $U(X^t, M^t)$ is a money valued utility function and Q_0^t represents the aggregate consumption of a competitive numeraire good. Let P_x^t and P_m^t represent the world price for the domestic and the imported good respectively. Since I consider only the case of an import tariff, τ^t, the necessary conditions equate marginal utilities to domestic market prices *i.e.*:

$$P_x^t = a_x - \frac{1}{2}b_x X^t - \frac{1}{2}kM^t \tag{1}$$

$$P_m^t + \tau^t = a_m - \frac{1}{2}kX^t - \frac{1}{2}b_m M^t \tag{2}$$

Let $P^t = (P_x^t, P_m^t)$. Using Cramer's rule, demands for domestically produced goods and imports as functions of the tariff level can be written as follows:

$$X^t(P^t, \tau^t) = X^t(P^t, 0) + \frac{2k\tau^t}{b_x b_m - k^2} = X^t(P^t, 0) + \mu_x \tau^t \geq 0 \tag{3}$$

$$M^t(P^t, \tau^t) = M^t(P^t, 0) - \frac{2b_x\tau^t}{b_x b_m - k^2} = M^t(P^t, 0) - \mu_m \tau^t \geq 0 \tag{4}$$

with $\mu_x > 0$, $\mu_m > 0$ defined implicitly. Finally, consumer surplus is given by:

$$CS(X^t, M^t) = U(X^t, M^t) - Q_0^t - P_x^t X^t - (P_m^t + \tau^t)M^t \tag{5}$$

2.2 Cost Function

Learning only reduces firms' fixed costs and firm costs are additively separable in accumulated output and current production, which implies that marginal cost is constant over time. The fixed cost is a positive, strictly decreasing and strictly convex function defined on $[0, y^*]$ and constant on $[y^*, \infty)$, for some large level of accumulated output y^*. In particular, I adopt the following additively separable specification:

$$C_i^t(y_i^t, x_i^t) = \begin{cases} c_0 + c_1 y_i^t + \frac{1}{2}c_2(y_i^t)^2 + c_3 x_i^t & \text{if} \quad y_i^t \leq y^* \\ \\ c_0 + c_1 y^* + \frac{1}{2}c_2(y^*)^2 + c_3 x_i^t & \text{if} \quad y_i^t \geq y^* \end{cases} \tag{6}$$

where x_i^t represents output and y_i^t represents accumulated output of firm i at time t. Fixed cost is assumed to be a decreasing and convex function of each firm's accumulated output, so that $c_1 < 0$ and $c_2 > 0$.

2.3 The Firm's Problem

In an infinite horizon game, each firm's problem is to maximize the present value of its own profits given its competitors' behavior, and the government's tariff, while considering the learning effects induced by current production. Given the production decisions of the rest of the competitors, and the particular functional specifications (3) – (4) and (6), this is a standard linear–quadratic differential game. Hence, I face a dynamic programming problem that can be solved using Pontryagin's maximum principle. The necessary conditions for this problem depend on $\hat{x}_i^t = \hat{x}_i^t(y_1^t, \ldots, y_n^t)$ and $\hat{\tau}^t = \hat{\tau}^t(y_1^t, \ldots, y_n^t)$, the optimal controls for each firm and the government's optimal tariff at time t. This formulation captures the interaction of firms' strategies and the government's policy over the game horizon. It makes firm i's co–state variable depend on the government's tariff policy and competitors' actions. The model could be solved for any industry configuration but that general solution would be useless for calibration purposes.[2] Therefore, in order to simplify and aggregate firm's first order conditions, I impose symmetry and constant conjectural variations[3] over the horizon of the game to capture strategic behavior among firm's decisions on control variables. Denoting by λ^t and $\dot{\lambda}^t$ the aggregate co–state variable and its time derivative, the firms' generalized Hamilton–Jacobi necessary conditions for this problem are:

$$0 = a_x - \frac{1}{2}\left[b_x(1+\theta) + k\frac{\mu_m}{\mu_x}\right]X^t - \frac{1}{2}kM^t(P^t, \tau^t) - c_3 + \frac{\lambda^t}{n} \tag{7a}$$

$$\dot{\lambda}^t = r\lambda^t - (nc_1 + c_2Y^t) + \frac{1}{2}b_x n[2n\theta - \theta - 1]X^t\frac{\partial \hat{X}^t}{\partial Y^t} + \frac{1}{2}k\mu_m(X^t + \tau^t\mu_x)\frac{\partial \hat{\tau}^t}{\partial Y^t} \tag{7b}$$

which uses $\sum_{j=1}^{n} \frac{\partial x_j^t}{\partial x_i^t} = 1 + \gamma(n-1)$ to define $\theta = [1 + \gamma(n-1)]/n$, the aggregated version of the conjectural variation parameter. This parameter summarizes firms' beliefs over their competitor's behavior in response to their actions. The perceived marginal revenue to each firm depends on the value of this parameter θ which represents different market conducts ranging from collusion to perfect competition. This approach is a useful way to discriminate among models of industry behavior at the calibration stage. Table 1 presents the values of each conjectural variation parameter under different competition conducts.[4]

INSERT TABLE 1

[2] The closed form solution will be more cumbersome, but time consistent solutions could also be characterized. However I should define $(n \times n)$ conjectural variation parameters. Two problems of different nature then arise: structural parameters are not identified, and data on individual firms' accumulated output is not available.

[3] This is a stronger than necessary assumption. Actually, I only need that the conjectural variation parameter be independent of players' optimal strategy so that the model could be calibrated at different moments. However I want to avoid unnecessary formulation on this issue since the market conjecture is not a truly behavioral parameter (it is not based on dynamic best responses of players). Its use is only justified as an equilibrium measure, which at the calibration stage helps to identify market conducts.

[4] An alternative interpretation of this conjectural variation approach is that parameter θ represents the level of sustainable collusion in a game between the government and the industry as a whole where production is later symmetrically divided among the firms of the industry.

2.4 The Government's Problem

The model includes explicit distributive considerations, which are taken as given for the social planner's problem. The intent is not to model government preferences explicitly as resulting from interacting pressure groups. Instead I will carry out a sensitivity analysis after I parameterize the model in order to fit the data and test the traditionally assumed existence of strong interest groups.[5] Let CS^t denote the consumer surplus derived from the demand specification, Π^t is industry profits and R^t represents the government's tariff revenues. The stage social welfare function is then defined as:

$$W^t = CS^t + \alpha^t \Pi^t + \beta^t R^t$$

where $\beta^t \geq \bar{\beta}$ is an index of government's relative preference for tariff revenues at time t.[6] Therefore, if $\beta^t > 1$ the government outweights tariff revenues. The parameter $\alpha^t \geq 0$ is an index of government's relative preference for producers surplus at time t; $\alpha^t = \beta^t = 1$ represents the standard case of a total surplus maximizing government. However, if α^t is greater than 1 or less than 1 the government is partially captured by producers or consumers respectively. By searching for the values of α^t and β^t that best fit actual values for each market structure outcome of the model, I can approximate the relative political power of pressure groups and government tariff preferences.

The government's problem is to maximize the present value of the above defined welfare function, given optimal industry production strategy and considering the aggregate learning effects induced by its tariff policy. Because of the demand and cost assumptions, this problem is also consistent with a standard linear–quadratic differential game structure given the production decisions of the industry. Now, denote by $\hat{X}^t(Y^t) = \sum_{i=1}^{n} \hat{x}_i^t(y^t)$ the optimal choice of X^t for the industry as a whole at time t. Then, the solution must satisfy the following generalized Hamilton–Jacobi conditions:[7]

$$0 = \Gamma_0(X^t(P^t, 0), M^t(P^t, 0), \alpha^t, \beta^t) + \Gamma_1(\beta^t)\tau^t + \mu_x \tilde{\lambda}^t \tag{8a}$$

$$\dot{\tilde{\lambda}}^t = r\tilde{\lambda}^t + \alpha^t(c_1 + \frac{c_2}{n} Y^t) \tag{8b}$$

[5] The political economy of pressure groups dates back at least to Olson (1968). An extensive overview of this literature and its applications to government intervention analysis is provided by Noll (1989). On the political economy of protection see also Baldwin (1984; 1985), Mayer (1984), Pincus (1977), and especially Hillman (1989).

[6] Parameter $\bar{\beta}$ is the minimum value of β^t such that government's optimal control problem is well defined. Substituting (5)–(6) into the current Hamiltonian expression for the government's problem, it can be shown [Miravete (1994)] that the government's solution is well defined by demand parameters in this study case because: $2\bar{\beta} = b_x b_m / (b_x b_m - k^2) = 1.13058 > 1$.

[7] Parameters $\tilde{\lambda}^t$ and $\dot{\tilde{\lambda}}^t$ denote the government's co–state variable and its time derivative respectively. For a complete definition of $\Gamma_0(\cdot)$ and $\Gamma_1(\beta^t)$ see the technical appendix of Miravete (1994).

2.5 Equilibrium

The pattern of production by firms and the government's design of the tariff policy is constructed to be optimal. The optimal control paths derived are dynamic best response functions for each set of agents, that is, the government and the firms as a whole. Given the government's optimal tariff policy firms choose their optimal output paths symmetrically including in such computation their symmetric, common knowledge belief on their competitors' responses. For these strategies to be a Nash Equilibrium, the government's strategy must also be the best response to firms' strategies as described above. Markov perfection requires that these strategies be a perfect equilibria for any time and state.

In solving this model, I assume perfect information, which implies that each player knows the history of the game, *i.e.*, the previous realizations of the state vectors, $y^s \in R^n$, and control variables, $(x^s, \tau^s) \in R^{n+1}$, $\forall s \leq t$. The generalized Hamilton–Jacobi conditions are a set of partial differential equations that can only be solved for very particular cases. One of these cases is the present linear–quadratic differential game, in which the motion equation is linear in the state but each player's objective function is quadratic in the state and control variables.

The solution to any linear–quadratic game is found by assuming that the co–state variables are linear in the state, so that there exists a closed–form strategy equilibria of the game:

$$\lambda^t(Y^t) = \phi_0 + \phi_1 Y^t \tag{9a}$$

$$\tilde{\lambda}^t(Y^t) = \tilde{\phi}_0 + \tilde{\phi}_1 Y^t \tag{9b}$$

As a consequence, the optimal strategies are also linear in the state:

$$\hat{X}^t(Y^t) = \frac{2a_x - kM^t(P^t, 0) - k\mu_m \dfrac{\Gamma_0(\cdot) + \mu_x(\tilde{\phi}_0 + \tilde{\phi}_1 Y^t)}{\Gamma_1(\beta^t)} - 2c_3 + \dfrac{2}{n}(\phi_0 + \phi_1 Y^t)}{b_x(2+\theta)} \tag{10a}$$

$$\hat{\tau}^t(Y^t) = \frac{\Gamma_0(\cdot) + \mu_x(\tilde{\phi}_0 + \tilde{\phi}_1 Y^t)}{-\Gamma_1(\beta^t)} \tag{10b}$$

The lack of time consistency of trade liberalization policies has been used to reject any infant–industry protection argument by theorists for a long time. However, it remains very intuitive that both the government and industry may benefit from a tariff policy that effectively promotes the competitiveness of the domestic firms. Given the shape of the learning curve, protecting the industry at the initial stages of development may be optimal for the government if the increase in aggregate profits exceeds the loss in consumer surplus. The government must also account for the future profits induced by the lower costs achieved by domestic firms and the future consumer gains from lower domestic goods prices and enhanced variety. List and 19th century Protectionists claimed for temporary protection of the domestic industries to allow them to develop. Protection was not to be generally applied to all sectors, but only to those with important learning potential [Bairoch (1993, §2)]. When an industry reaches its mature stage, there is little or no potential cost reduction at all (depending whether y_i^t is lower of greater than y^*). Thus, it is no longer optimal to protect this industry because potential loss in consumer surplus exceeds future gains. In this case protection has the negative effect of increasing domestic firms market power. Hence after learning is exhausted, liberalization becomes the optimal policy. A decreasing tariff over time, contingent on industry performance, captures this idea.

I must establish some criteria to select these time consistent equilibria among the solutions of the Riccati equations implied by (9) and (10). Time consistency means in this framework that the government has no incentive to deviate from the equilibrium strategy in later periods, for instance favouring permanent protection when previously precommited to liberalize. An MPE for a finite horizon always exists but only if the matrix of net effects of the state variables over control variables is negative semi–definite it also constitutes an MPE for an infinite horizon. Miravete (1994) shows that strategies (10) constitute an infinite horizon MPE if $\phi_1 < 0$ and $\tilde{\phi}_1 < 0$.[8] According to equation (10b), this result implies that only decreasing tariff policies may constitute a time consistent equilibria.

The intuition behind this result is simple. If a government announces an increasing tariff, this is clearly a non–optimal strategy in the long run. The objective of any tariff protection policy in this framework is to improve welfare by reducing costs of production of the domestic firms. Once firms have reduced their costs by increasing production above the static industry equilibrium output, the government has no interest in intensify this policy because it will hurt consumers more than producers could gain from little remaining costs reduction. When learning effects fall below some threshold, switching to a less restrictive trade policy is always a dominant strategy because it promotes foreign competition and increases welfare by increasing consumer surplus despite a second order producer surplus loss. Therefore the government will abandon any increasing tariff in the long run, and this policy will not qualify for Markov perfection. The same can be said of a constant tariff. As long as learning is not exhausted the optimal static tariff will not induce production above the static optimal production level. Higher constant tariffs will only allow excessive monopoly power and a less than optimal production level, while lower tariffs induce firms to produce below the static level because of the foreign competition (or shut down production). In both cases costs are not reduced more than in the static case because the optimal production is at most the static optimum level, and the government has an incentive to change that policy, so that a constant tariff does not qualify for Markov perfection either.

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[8] An asymmetric solution would require that the product of all ϕ_{1i} (one for each firm) be negative in addition to $\tilde{\phi}_1 < 0$.

The decreasing tariff result confirms List's claim that protection must only be temporary. The model allows me to check easily for time consistency since it may be solved in closed form and provide an easy criteria to choose among the different solutions of the linear–quadratic differential game at the calibration stage.

3 Protection of the Spanish Iron and Steel Industry

In this section I describe the development of the Spanish iron and steel industry until the outbreak of World War I. The features of this industry are tied to the technical assumptions of the model.

3.1 Historical Overview

The slow development of the Spanish Iron and Steel industry started in the south of Spain, at the beginning of the second quarter of the 19th century. Recovery of industrial production, once Spain's economy adjusted to the definitive loss of the colonial markets, allowed development of such business. However, the increase in the production level was insufficient to provide a basis for fast development of the sector. After fifty years of upstart attempts, the industry located finally in the Basque Country, near the French border on the northern coast of Spain. The Bessemer steel making process turned the coal endowment of the area the best of Europe because of its low phosphoric content. It was not based on the existence of an entrepreneurial class or any kind of previous capital accumulation in that area.

English production of iron and steel mainly employed the acid Bessemer converter and the acid Martin–Siemens open–heart process which could not use phosphoric iron ore.[9] This forced English firms to import iron ore from Sweden (Orebo and Norrbotten), Italy (Liguria and Elba), Algeria, and Spain. The Basque Country supplied up to one third of the English imports of iron ore (this represented up to 91% of Spanish production). Basic Bessemer steelmaking declined rapidly after 1894 which made British industry more dependent on the Spanish ore. After 1890, Lancashire and Cumberland (Britain's own hematite mining districts) also began importing the Spanish ore [Allen (1979); Pearl (1978, §12)]. Only after 1920 did the importance of the Spanish provinces decline. English capital was invested in the Basque iron ore industry in order to provide the English iron and steel industry with this necessary input. Companies such as *Orconera Iron Ore Co., Somorrostro Iron Ore Co.*, and sixty two others invested more than five million pounds in the Basque Country before the Great War. The importance of this investment was due not only to the high quality of the iron, but also to the "endowment complementarity" which allowed Spanish based firms to avoid backhaul problems. Trade took place in both directions: the Basque Country exported iron ore and ships carried coal at very low cost when they

[9] By 1900, 90% of the open–heart and 71% of the English Bessemer steel was produced using acid methods. See Carr and Taplin (1962), p.237.

returned from Wales and Northeastern England. The economic integration between the Basque Country and England was stronger than it was with the rest of Spain. This process generated very important capital accumulation that resulted in rapid growth of the Spanish iron and steel industry, and in the development of important financial institutions in the last third of the century which further enhanced the industrialization process.[10] The Basque Country arose as one of two regions that sustained the economic industrialization of Spain. The Spanish iron and steel industry grew significantly from the beginning of the 20th century but not as much as in other European regions which were also integrated with the English trade in coal and iron. The First World War temporarily increased the demand for these products. Indeed, the old furnaces in the south of Spain restarted production. And, in 1917, construction of another big firm began, but *Altos Hornos del Mediterráneo* (AHM) did not operate until 1923, and then with high excess capacity.

The oligopolistic market structure evident in Spain is a common feature of the iron and steel industry elsewhere as well. However, the Spanish industry was the most concentrated of all European countries. Only in Spain did one firm produce over 60% of the nation's output. As a consequence, price agreements among producers were prevalent, beginning as early as 1886. And, partial agreements persisted until the foundation of the *Central Siderúrgica* in 1907, a producers union which controlled 100% of the Spanish production. Table 2 presents measures of the degree of market concentration for years for which production information by firms is available. Larger inverse Herfindahl indexes represent less concentrated markets.[11]

INSERT TABLE 2

The development of the Spanish Iron and Steel industry took place after the construction of the rail network (at least of its peak phase) which generated a huge demand for steel products. At that time, they were mainly supplied by French firms. Before the Liberal Revolution of 1868, steel producers had begun asking for protection. They succeeded only after over twenty years, when their interest coincided with those of other producers. Producers from several industries as well as landowners' interests influenced the Tariff Act of 1891. Given the low stage of industrialization in Spain at that time, and the loss of landowner income due to massive grain imports after 1870 (which was due to large reductions in transportation costs after the Crimean War), the idea of protecting the domestic market to facilitate industrialization became very popular. The initial protective tariff was so high that most imports dried up. But unfortunately, industrialization did not happen as fast as was expected. Industrial profits and landowners' rents increased

[10] The owners or tenants of the iron ore mines were also the owners or major shareholders of the iron and steel firms. For more information on the relationship between iron ore exports and the industrialization of the Basque Country, see González (1981) and Shaw (1977).

[11] The concentration ratios of Fraile (1991), p.132 are inadecuate because they are based on firms' capital instead of production. Even when the argument of the high concentration around one firm remains correct, Fraile's indexes overestate the degree of concentration of the industry.

significantly, but this did not result in substantial growth in demand for iron and steel products. New tariffs were imposed in 1906 and 1922 in order to avoid competition from highly productive foreign firms. Figure 1 shows the Spanish tariff as a percentage of the British price over the first thirty years of the century. The effects of the 1906 and 1922 Tariff Acts are clearly shown in this figure.

INSERT FIGURE 1

Since the end of the 19th century, the demand for iron and steel goods exceeded supply. After the establishment of the protective tariff, iron and steel firms followed a less agressive production strategy and benefited from their monopolistic power. Increasing protectionism was a dominant market feature beginning in the last decade of the 19th century. The effective tariff level in 1913 was as high as in the rest of Europe in 1930. The iron and steel tariff was 30% higher than the mean of European tariffs in 1913 and 250% higher in 1927.[12]

As a result, steel producers became one of the most economically important and politically influential groups in Spain. According to the traditional explanation, this interest group constituted a solid organization with financial power, which turned into the leading industry asking for protection as a method of rent seeking instead of competing for foreign markets to increase the scale of production and profits as they had done before. Given the industry concentration (economic and geographic) it is reasonable to assume a high homogeneity of preferences among members although firm characteristics were quite different. The group was lead by *Altos Hornos de Vizcaya* (AHV). It is commonly accepted that *Altos Hornos de Vizcaya* behaved as price leader in the producers union *Central Siderúrgica*, and the remaining firms comprised a competitive fringe, taking prices as given. The development of the sector generated so much liquidity that it was the origin of today's most important financial institution in Spain. Political influence reached the point that some of the firm managers had simultaneous responsibilities at the government, as General Directors of Tariffs and Customs, or even as Ministers of the Government.[13]

3.2 Key Assumptions of the Model

Now, I will point out the links of the main features of the Spanish iron and steel industry that the theoretical model developed in the previous section captures. Though this is not a completely homogeneous period, some of the model's parameters can be estimated using information from these years that show stable patterns. Parameterization of the model will be focused on 1913, a year that represents the end of a long homogeneous

[12] Most of the data provided in this overview on the Spanish iron and steel industry can be found in Fraile (1991) and Nadal (1975).

[13] Pablo de Alzola, president of AHV, was also appointed president of the commission of enquiry set up in 1904 to report on the revision of the 1891 tariff. See Harrison (1978), pp.84–85.

period of industrial development and tariff protection. Following approximately the order of appearance of the model's assumptions, I have:

a) No entry–exit. This hypothesis is completely satisfied before WWI. Most firms started producing in the last quarter of the 19th century. During the war, a few firms entered the industry to benefit from the strong demand in that period. And firms also took advantage of the restrictive tariff policy and the subsequent expansive economic policy of Primo de Rivera's Dictatorship. Some of these firms had their origin in previously small related business or, as in the case of *Altos Hornos del Mediterráneo*, in other Basque entrepreneurial groups (mining and ship building). However, as Table 2 shows, with this exception, none of the entrants achieved a market share above 2.5%. Hence, an analysis of the tariff policy in 1913 is consistent with the model but the implications for later periods should be interpreted more carefully.

b) Infant–Industry. The Spanish firms had not exhausted the learning process, so that production decisions must also be considered investment decisions. The low mean size of the Spanish firms as compared with the world standard suggests that large cost reductions would be possible. While the international average firms' capacity increased from 50,000 tons/year to 500,000 tons/year between 1900 and 1930, Spanish iron and steel average firm's capacity increased only from 24,000 tons/year at the beginning of the century to 66,000 tons/year in 1930.[14] By the turn of the century, Spanish accumulated production since 1860 reached 4,786 thousand tons of iron and 2,787 thousand tons of steel compared to the British accumulated production of 281,201 thousand tons of iron and 72,449 thousand tons of steel for the same period.[15] While this indicates the existence of unexploited static economies of scale, it also allows for the possibility of potential important learning by doing efficiency gains unless the learning curve is very steep in the first stages of industry development.

c) Learning only reduces fixed cost. Dynamic economies of scale reduce costs in general. Economic analysis is traditionally focused on the effect of learning on marginal costs. This is the appropriate approach in a long run framework, but fixed cost reductions up to the optimal long run level should not be neglected. The iron and steel industry is highly capital intensive. Furthermore, most productivity increases for variable factors over the first half of the century are explained by capital embodied technical improvements in furnaces and equipment.[16] And, one common and important feature of the iron and steel industry is the high share of fixed to total costs. Most improvements involve the employment of more fixed factors such as increasing the size and height of blast–furnaces, mechanization of handling and stocking, or addition of mixers, gas cleaners, electric steel-making, etc. Pratten (1971) has shown that scale expansion of the British industry in

[14] Moreover, as stated before, around 60% of this capacity was concentrated in *Altos Hornos de Vizcaya*. See Fraile (1991), pp.146–149.

[15] See Carreras (1989), pp.200–201 for the Spanish case and Mitchell (1992), pp.448–456 for the British case.

[16] See Pearl (1978) for a detailed survey of major technical advances in steelmaking between 1900 and 1950.

1960's reduced fixed cost more than variable cost. It seems reasonable then to assume that this effect is even larger in the initial stages of industrial development. However increasing productivity, which took place during the first third of the century should also be accounted for. For instance, the wage/ton ratio of cast iron ration at AHV reduced 33% between 1902 and 1921. And labor productivity in the Spanish steel industry increased 60% between 1916 and 1930 although it decreased 14% in the iron industry [Fernández de Pinedo (1992), p.136; Fraile (1991), p.155]. Therefore, the optimal tariff policy derived herein should at least to be considered an upper bound since variable costs do decrease over this period. Using the same reasoning, calibration of the model will provide a lower bound for welfare losses due to departure from the optimal policy.

d) Constant instantaneous returns to scale. The assumption of constant marginal costs is justified by the important excess capacity that characterized the Spanish iron and steel industry during this period. Even during the peak demand war period and despite the dictatorship induced expansion of the 20s, the average production/capacity usage ratio was only 72% for iron and 67% for steel [Fraile (1991), pp.120–123]. This is a key assumption in order to solve the model in closed form, not because more general cost functions are excluded, but because if marginal cost is dependent on accumulated output, the model could only be solved numerically, and I would not have any criteria to select the time–consistent tariff protection policy if the model allows for multiple solutions.

e) Quantity competition. Economic historians commonly agree that the *Central Siderúrgica* allowed for the cartelization of the industry through price agreements. However, signed agreements involved both price agreements and market quotas according to chapter 7 of González (1985). I adopt the conjectural variation approach which should capture, at least in some limited sense, the strategic elements of firms' decisions indicating whether price or quantity competition was more likely to be the main control variable.[17]

f) Tariff policy vs. other trade restrictive policies. Spain's iron and steel exports constituted only 5% of domestic production between 1908 and 1930. In the peak war demand period, it rose to 15%. However, imports amounted to 18% of domestic production for the same period reaching a maximum of 49% in 1921. These facts definitively characterized Spain as an importing country. Until the end of the Spanish Civil War, the government did not participate directly in the production of iron and steel. Nor was there a generalized subsidy policy. Instead, there existed important government contracts during this period: the replacement of the Spanish fleet after the Spanish–American war awarded by the Maura Government and Primo de Rivera's Public Works Policy are good examples of this [Harrison (1978, §4–5)]. However, tariff policy was by far the most extensive trade restricting policy employed.

g) Competitive foreign firms. International cartelization in the iron and steel industry was widespread by the mid–twenties, but prior to World War I, there were only minor

[17] Fraile (1991, §5) applies the standard static Stackelberg price–leader oligopoly model to explain the welfare implications of the leadership of AHV into this producers union. The major problem with his approch is that it does not account for dynamic issues that necessarily arise in a period of over fifty years.

differences between national and international prices for the European major producers: United Kingdom, Germany, France, and Belgium–Luxembourg [Svennilson (1954, §7)]. Moreover to make the model simple, it is assumed that strategic effects are ignored by foreign firms. This may be justified by the small size of the Spanish iron and steel industry as compared to the European market and in particular relative to the British market which was the major foreign supplier.[18] The mean of the relative size of all the Spanish imports over the British production is slightly above 1% for this period.[19]

h) Foreign firms do not reduce cost. The world steel industry expanded during the last quarter of the 19th century as a result of radical technical innovations: the Bessemer process (1869) that required high grade hematite ores, the Martin–Siemens process (1869) that allowed for the use of scrap iron, and the Thomas process (1879) that made possible the use of phosphorous ores. Altogether, these represented 90% of European production at the beginning of the war. The increase in iron and steel production between 1900–1950 was due to no such striking inventions but rather to increases in the scale of operation; improvements of larger furnaces and associated equipment, a much higher driving rate, developments in the manufacture of coke, the utilization of waste gas and greater fuel economy, and the discovery, exploitation, and transportation of more plentiful, richer, and cheaper ores. The American industry was by far the innovative leader. However, most of these technological advances can be ignored for the present study case. The technological gap was particularly important between the American and the British iron and steel industry. As a matter of fact, by 1900 the American/British ratio of labor productivity was 2.5:1 for open–heart and 6:1 for Bessemer steel. The British industry (Spain's major foreign supplier) was characterized by a low degree of concentration and a slow technological diffusion speed which made it clearly obsolete as compared to its Continental competitors by the outbreak of the war [Carr and Taplin (1962, §22); Pearl (1978); Svennilson (1954, §7)]. In addition to the increase in production of steel products, there was a major process of substitution of steel for wrought iron. This important factor of modernization in the steel industry had already been exhausted by the British industry in 1913. This substitution process was particularly early and sharp for the British industry. Between 1883 and 1895 the percentage of pig iron converted into wrought iron shrunk from 70% to 5%. [Schubert (1978)]. Finally, most innovations took place after the war. In the U.S. coke consumption per ton of pig iron fell from 21.5 cwt (hundredweight = 112 pounds in U.K.) to 13 cwt between 1900 and 1950 but the mean British consumption exceeded 30 cwt between 1900 and 1930. By–products methods of coke production (tar, benzole, ammonia, and naphta) were not generally in use until the end of World War I. Technical

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[18] This is a common opinion although difficult to illustrate with appropiate data. The *Memorandum on the Iron & Steel Industry* of the League of Nations (1927) provides a joint measure for Spain and Portugal imports. Between 1913 and 1925, British iron and steel products increased its share of these two countries imports from 45.3% to 61.5%. See also Fraile (1991), p.176.

[19] This measure has to be considered an upper bound since I am accumulating all Spanish imports on the British market. With the data provided by the Department of Overseas Trade (1928), Spanish imports from the United Kingdom represented only 0.23% of British production in 1913 and 0.36% in 1928. According to the League of Nations (1927), the share of Spanish purchases of British exports increased from 0.86% in 1913 to 1.37% in 1925.

difficulties in increasing the size and driving rate of blast–furnaces were not overcome until that date either. Agglomeration of iron ore by heat treatment began before 1900 but pelletizing of fine ores was developed by 1936, and only 14% of the burden charged to British blast–furnaces by 1950 was sintered. Lastly, automatic charging did not start until mid–1920s. Therefore this assumption may be reasonably applied for the analysis of 1913.

i) Product differentiation. This is a difficult point to justify because of the lack of accurate and detailed information. Spain can be considered a small importing country with a low development level during the relevant period. Figure 2 shows the importance of Spanish exports relative to domestic production. As can be seen, the percentage of exports over domestic production declines. It is realistic to assume that import products were those technically more difficult to produce. As tariffs increased, imports of elaborated products (e.g., from Germany and Belgium) fell sharply according to the League of Nations (1927).

INSERT FIGURE 2

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j) No spillovers. According to Fraile (1991), p.145, Spanish producers knew about innovations in the industry and international transfer of technology was allowed most of the time. However, location, product specialization and differences in scale among firms justify the assumption that learning economies did not spread through the industry.[20] The efect of this assumption is alleviated because cost function parameters will be estimated with data for AHV only (due to availability of information). Since the symmetric oligopoly solution is characterized by the same accumulated output and (implicitly) the same accumulated cost reduction due to learning spillovers, small firms of the Spanish iron and steel industry are (also implicitly) assumed to benefit more from learning spillovers.

3.3 The Symmetry Assumption

The assumption of symmetry is essential for the model to be calibrated. It would not be legitimate to use this approach if data are not consistent with the dynamic implications of the symmetric model. In this subsection I analyze static and dynamic strategic equivalence of both solutions, and I show under which circumstances it is justified to calibrate a symmetric equivalent solution of the model to study the strategic interaction of Spanish iron and steel firms.

Firms in the Spanish iron and steel industry were not homogeneous. This was discussed earlier and data is detailed in Table 2. The largest firm was by far *Altos Hornos de Vizcaya*, established in 1902 as a merger between *Altos Hornos de Bilbao*, *La Vizcaya*, and *La Iberia*. This merger established the main feature distinguishing the Spanish industry from the rest of the European industries: It was highly concentrated

[20] González (1985, §4) provides a complete descriptive analysis on differences in production, labor productivity, prices, and product specialization of Spanish iron and steel industry between 1870–1913.

around one single firm. However, the symmetric specification of the model allows me to identify how these firms interacted throught the market conjectural variation parameter (or alternatively the Cournot–equivalent number of firms). The procedure is to construct a symmetric oligopoly solution that, given some level of sustainable collusion, povides the same market outcome at one given period of time, *i.e.,* the same domestic market price, the same domestic industry total output, and the same degree of market concentration for a particular moment in time. Regarding this last equilibrium feature, for every real world N^t–firm asymmetric equilibrium at time t, it is possible to construct a hypothetical n^t–firm symmetric equilibrium that leads to the same Herfindahl index of concentration [Tirole (1989), §5.5; Waterson (1984), §9.1]. The number of firms n^t is not necessarily an integer. Let s_i^t be the firm i's actual share of market sales at time t. Then the hypothetical n^t is defined by:

$$H^t = \sum_{i=1}^{N^t} (s_i^t)^2 = \sum_{i=1}^{n^t} \frac{1}{(n^t)^2} = \frac{1}{n^t}$$

Table 2 reports inverse Herfindahl indexes for different years and markets. They will be used later in the parameterization of the model. The advantage of the hypothetical symmetric equilibrium approach is that it suffices to capture the actual strategic behavior of firms by measuring the level of sustainable collusion allowed by the actual industry equilibrium at a single point in time. This approach enables me to study how firms perceive that their marginal revenue is related to their own price or output decisions. The formal strategic equivalence between the asymmetric equilibrium and the symmetric Herfindahl–based equilibrium is shown in the following proposition:

Proposition 1: *If firms' cost functions are convex and the demand function is concave, for every N^t–firm domestic market outcome $\{N^t, \tilde{X}^t, \tilde{P}^t\}$ at time t, and any given tariff level τ^t on the foreign substitutive product, there exists a unique level of sustainable collusion $\theta \in [0,1]$ at time t such that the Herfindalh–based symmetric Nash equilibrium $\{n^t, X^t, P^t\}$ with market conjectural variation parameter θ at time t is such that $X^t = \tilde{X}^t$ and $P^t = \tilde{P}^t$.*

Proof: Assumptions on demand and cost functions ensure that each firm's profit function is concave in its own production. Through equations (1)−(2), the inverse domestic demand function is $P^t = P^t(X^t, M^t, \tau^t)$. The optimal firm's output level under static Cournot competition is given by:

$$P^t(X^t, M^t, \tau^t) - C_i'(x_i^t) + x_i^t \frac{\partial P^t(X^t, M^t, \tau^t)}{\partial X^t} = 0$$

The marginal revenue depends on the actual tariff and the amount of imported good at time t. Aggregate imports also depends on the tariff level and the vector of prices, but are given for each domestic firm since foreign producers behave competitively. Aggregating for n^t symmetric firms, the Cournot market solution is given by:

$$P^t(X^t, M^t, \tau^t) - C_i'(X^t/n^t) + X^t \frac{\partial P^t(X^t, M^t, \tau^t)}{\partial X^t} \frac{1}{n^t} = 0$$

Similarly, the n^t–firm symmetric Nash equilibria with conjectural variations solves:

$$P^t(X^t, M^t, \tau^t) - C_i'(X^t/n^t) + X^t \frac{\partial P^t(X^t, M^t, \tau^t)}{\partial X^t}\theta = 0$$

which includes the monopoly ($\theta = 1$), Cournot ($\theta = 1/n^t$), and competitive ($\theta = 0$) solutions as particular cases depending on firms' perceived effect of their output decisions on their respective marginal revenue. This equation defines a continuous industry output function $X^t = X^t(\theta, P^t, M^t, \tau^t)$ such that:

$$\frac{\partial X^t}{\partial \theta} = \frac{-XP'(\cdot)}{(1+\theta)P'(\cdot) + XP''(\cdot)\theta - C''(X/n)/n} < 0$$

Finally, let $\tilde{X}^t$ be the industry aggregated production, and consequently $\tilde{P}^t = P^t(\tilde{X}^t, M^t, \tau^t)$ be the market equilibrium price. Since $\tilde{P}^t$ is between the domestic monopoly and the competitive equilibrium price, the industry output $\tilde{X}^t$ is also bounded between the monopoly and competitive solution. Since $X^t(\theta, P^t, M^t, \tau^t)$ is a continuous and monotone function of θ, the equality $\tilde{X}^t = X^t(\theta, P^t, M^t, \tau^t)$ holds for a unique value of θ between 0 and 1 given M^t, τ^t, and the domestic market price, $P^t = \tilde{P}^t$ at time t. ∎

COROLLARY 1: *It is equivalent to find a hypothetical number of firms $n^\star = 1/\theta$ so that the Cournot market solution is such that $X^t = \tilde{X}^t$. The inverse Herfindahl index, n^t, provides with a reference to evaluate the competitiveness of the market solution.*

This approach compares the actual strategic behavior with that consistent with different levels of collusion while the market outcome, which is the result of firms' joint strategic decisions, remains constant.[21] The estimated parameter, θ is an average of individual conjectural variations, and it provides a simple summary of the market conduct which allows me to compare alternative market equilibria.

Proposition 1 has formally established the strategic static equivalence between the hypothetically symmetric equilibrium outcome and the real world asymmetric market outcome. This static equivalence will allow me to focus on the empirical analysis at one particular value of t (the representative year 1913) for which imports and tariffs will be considered as given at the calibration stage. This means that I will calibrate the market conjectural variation neglecting, because of lack of data, the dynamics of this parameter.

Although many theoretical and empirical studies assume a constant conjectural variation parameter [Bresnahan (1989, §2.2.3)], I should however delimit the structural implications of the model on the industry configuration dynamics in order to evaluate whether this is a reasonable approach. This issue is particularly important because the present model is essentially dynamic, and if the data available are not consistent with the implications of the structural model, then the validity of the results of the single year calibration could be questioned.

[21] This method is also used by Dixit (1985) to analyze the US automobile industry.

The problem is that the calibrated conjectural variation parameter is compared with the Herfindalh–based Cournot solution. However, it could be argued that this approach is not appropriate because the degree of market concentration evolves over time depending on the protection policy that is actually applied. This is not the case with the linear–quadratic structure of the differential game. The following proposition shows that the dynamics of firms' market shares is exclusively driven by the asymmetry of firm sizes but it is independent of the optimal tariff.

PROPOSITION 2: *Firms' market shares remain constant over time only if the industry configuration is symmetric. If firms sizes differ at any period, the industry will eventually collapse in a monopoly. Finally, the dynamics of market shares is independent of the applied tariff along the equilibrium path.*

PROOF: Equation (10) characterizes the market equilibrium strategies of a symmetric linear–quadratic differential game. Firm equilibrium strategies are linear in the state, *i.e.*, their accumulated level of output y_i^t. According to equation (10a), the optimal equilibrium strategy for each firm is of the form $\hat{x}(y_i^t) = a_i + b_i y_i^t$, where a_i and b_i are determined by common costs and demand parameters, and particular parameters of the corresponding co–state variables $(\phi_{0i}, \tilde{\phi}_0, \phi_{1i}, \tilde{\phi}_1)$. Using this differential equation, it is straightforward to show that the change in firm i market share is:

$$\frac{\partial r_i^t}{\partial t} = \frac{x_i \sum_{j \neq i}^{n} (b_i - b_j) x_j}{\left[\sum_{j=1}^{n} x_j \right]^2}$$

If $b_i \neq b_j$, firm i market share will evolve according to the difference in magnitude of ϕ_{1i} and each of the other ϕ_{1j}, weighted by the production of the competitor. This is the asymmetric case, and in general, r_i^t will not remain constant over time. Only if $\phi_{1i} = \phi_{1j}$, *i.e.*, $b_i = b_j$ for each firm (symmetric case), then all r_i^t will remain constant. Second, let consider an asymmetric market configuration, and label b_i such that $b_1 < b_2 \leq b_3 \leq \ \ldots \ \leq b_n$. Solving the linear nonhomogeneous equation of optimal production decision, the market share of firm i can be written as:

$$r_i^t = \frac{(b_i y_i^0 + a_i) e^{b_i t}}{\sum_{j=1}^{n} (b_j y_j^0 + a_j) e^{b_j t}}$$

It is then obvious that $\lim_{t \to \infty} r_i^t = 1$ for $i = 1$, and zero for $i = 2, 3, \ldots, n$. Finally, equation (10b) describes the government's optimal tariff strategy. It does not depend on individual accumulated production, y_i^t, but rather on the aggregated accumulated output, Y^t, both in the symmetric and asymmetric case. Parameters $\tilde{\phi}_0$ and $\tilde{\phi}_1$ always enter symmetrically into firm strategies through a_i and b_i. Therefore, the dynamics of r_i^t is independent of the applied tariff. ■

Corollary 2: *The hypothetically symmetric equilibrium outcome is dynamically equivalent to the real world asymmetric market outcome if firms' market shares remain constant over time.*

The effects of the tariff are common to all firms in the industry, as opposed for instance to firm specific subsidies due to particular individual circumstances. In this later case, government intervention would directly affect the dynamics of market concentration. In the present model however, the tariff protection is neutral in terms of the dynamics of market concentration. On the contrary, an asymmetric industry with the characteristics of the model of Section 2 will end up concentrating its production in one single firm. But, that process may take quite long to occur, and it is not what can be observed for the case of the Spanish iron and steel industry during the first third of the century. For instance, between 1913 and 1930, the AHV's yearly cumulative growth rate of production was only 0.67% for iron, and 3.30% for steel. Under these circumstances, the equivalent symmetric model captures the market dynamics of a real world asymmetric (but stable) industry configuration.

Therefore, the model imposes a very strong structural restriction that reduces the applicability of the dynamic, symmetric–equivalent approach to cases where firms' market shares do not vary significantly over time. For those cases, solving an asymmetric model explicitly does not add any further qualitative results. Calibrating the symmetric model of Section 2 in this case for one particular year, can therefore be considered equivalent to any other period, because although the domestic industry is growing over time, the firms' market shares remain mostly unchanged and the industry structure stays unaltered. If there is no change in the tariff policy (as in the present study case), and the distribution of market shares of firms remains the same, there is no reason for the firms strategic behavior to change either.

As I explained before, dealing with the entry–exit assumption, the industry remains quite stable with the exception of the entry of AHM at the end of WWI. However, it did not started operating its first blast–furnace until 1923 and later, it kept working with approximately 50% excess capacity for sevaral years [Fraile (1991), p.124] during which AHV retained its leading role in the cartel *Central Siderúrgica* [Fraile (1991), p.139].

Ignoring the participation of AHM in this industry, for years were detailed data are available (1900, 1913, 1925, 1929), the market share of each firm remains quite stable over this 30 year period. The mean of each firm's deviation from their average market share is just 1.29% including all four years, and only 0.94% from 1913 onwards.[22] Firms' market shares variation are not only very small, but they tend to decrease over time, which is in accordance with the dynamic features of the theoretical model of Section 2, as pointed out in Proposition 2 above.

These statistics are quite descriptive but they do not provide any confidence interval to evaluate the significance of the changes in the distribution of market shares. Using the

[22] Considering AHM these statistics only change to 1.74% and 1.29% respectively.

information of Table 2, I computed simple t–statistics to study whether each firms' market shares differences accross years are statistically significant from zero. I use the differences of market share among years in which this firm level information is available. The largest value of this test is 0.98, which leads to the conclusion that firms' market shares of the Spanish iron and steel industry do not vary significantly over the first third of the century.

It could still be argued that although firms' market shares can be considered constant over this period, the effect of the protection policy is to modify the dispersion of these market shares at the industry level so that few periods after the application of the tariff policy, the domestic iron and steel industry may end up being much more or less concentrated, and therefore the dynamic symmetric equivalence would no longer hold. However, the empirical evidence is also against this argument. Using the same data than before, it is straightforward to compute F–statistics to test whether the ratio of yearly variances of market shares is statistically different from one. All six possible tests clearly fall within the corresponding 95% confidence interval limits, so that it is not possible to affirm that the variance of the market shares has changed over this 30 year period.[23]

Therefore I conclude that there is enough supporting evidence that market structure of the Spanish iron and steel industry remained quite stable during the first third of the century. The empirical market structure dynamics is consistent with the structural implications of the linear–quadratic differential game of Section 2, and therefore the calibration of a symmetric equivalent industry configuration is well justified because, as Proposition 1 and 2 prove, under these circumstances the symmetric equivalence cannot only be considered static, but also dynamic.[24]

4 Model Calibration

Since there are not data available on tariff revenues by products the production of iron and steel is derived by adding up the Spanish production of iron and steel. Imports of iron and steel products are obtained in the same way. Domestic and foreign prices for these aggregated goods are computed as weighted averages of the reported prices for each good. A representative measure of the applied tariff is added to the weighted average of foreign iron and steel products in order to obtain their value in Spain's domestic market. Over the first third of the century, the 1891, 1906, and 1922 Tariff Acts apply. I choose the 2nd tariff on the item: "Wrought Iron and Steel Products which exceeds 100 Kg." as the repesentative tariff for each subperiod. It has values of 50, 100, and 200 pesetas

[23] For example, the largest value for this test, 2.47, is obtained comparing the variances of years 1900 and 1925. This value falls between 0.22 and 6.68, the limits of an 95% confidence interval of an $F_{(9,5)}$. Similarly, the smallest value for this test, 0.94, is obtained comparing the variances of years 1925 and 1929. This value falls between 0.25 and 4.03, the limits of an 95% confidence interval of an $F_{(9,9)}$.

[24] As I have already emphasized before, the conclusions of the calibration of the model should not be automatically extended to later periods. The entry of AHM, major events as the WWI, and later technical innovations in this industry, are important aspects of the problem that cannot be addressed with the present model, but that will necessarily affect the results.

per ton (Pts./ton). I chose the 2nd tariff instead of the 1st because it applied to most European countries for which trade agreements were established. Also, the ratio between tariff revenues from imports of iron and steel products and quantity imported is 92.83 Pts./ton for 1913 according to the *"Estadísticas de Comercio Exterior de España."* The chosen tariff shows the closest approximation to this ratio. Table 3 shows the estimates of the model structural parameters.

INSERT TABLE 3

Demand equations (1) – (2) have been estimated for 1907–1928 by Iterative Three Stage Least Squares constrained to satisfy symmetric cross–effects. The price of iron and steel products shows two clearly different patterns over this sample; they steadily grow up until the end of the 1910s but sharply decline since the beginning of 1920. A dummy variable has been introduced in order to capture this effect so that each demand intercept is a_i^0 up to 1919 and $a_i^0 + a_i^1$ from 1920 on. As can be seen, all parameters are positive and the concavity condition of the utility function is fulfilled, $(b_x b_m - k^2)/4 = 0.389 > 0$. Cost parameters are obtained by estimating (6) using OLS for 1902–1916. The estimation is referred to AHV. Data on cost are not available; it has been inferred from the data on profits and estimated sales.[25]. Cost parameters are not significant but they will be taken here as given in order to illustrate the model. Sign restrictions are fulfilled resulting in a convex decreasing fixed cost function. In addition to these estimates, it is necessary to specify the following model parameteres: $r = 0.04$ is the average return of the Spanish Public Debt between 1900 and 1923, $n = 124$ is the inverse Herfindahl Index for year 1913 as shown in Table 2, finally, $X^t(P^t, 0)$ and $M^t(P^t, 0)$ are computed in each case by solving (1) – (2) for $\tau^t = 0$. Furthermore, α and β, the weights of the planner's social welfare function, are constrained to be equal to one for most of the cases.

Table 4 shows the solutions of the model under different assumptions. Parameters ϕ_0, ϕ_1, $\tilde{\phi}_0$, and $\tilde{\phi}_1$ are the unknowns of the Riccati equations; $\hat{x}_0$, $\hat{x}_1$, $\hat{\tau}_0$, and $\hat{\tau}_1$ are respectively, the intercepts and slopes of the optimal aggregate production and tariff strategy as implicitly defined by equation (10). Welfare components are shown in 1913 millions of Pts.; $\hat{\tau}(Y)$ is Pts./ton of iron and steel imports. Optimal domestic production and imports are measured in thousand of tons. Finally, I_W is an index of the relative (static) welfare for each situation. The reference value corresponds to $\theta = 0.463/124$. The bottom of Table 4 presents the best response strategies and induced welfare components for the actual accumulated output in 1913 which is 16,712.1 thousand tons.

The conjectural variations approach followed here allows me to determine for which value of θ firms' perceived marginal revenue equals their marginal cost. By repeatedly

[25] AHV's production of iron and steel, x_i^t, is computed as a share of the Spanish total production. This share evolves linearly according to the domestic market shares provided in Table 2 for few years. Accumulated output, y_i^t adds each year production on an initial value of 5,534.4515 thousand tons, *i.e.*, 79.61% of the iron and 61.87% of the steel produced in Spain between 1860 and 1900.

solving the Riccati equations for values of θ between 0 and 1, it is found that for the present parameterization of the model, $\theta = 0.463/124$ is the value for which optimal domestic production equals actual domestic production for 1913. It is worth noting that the chosen value of θ corresponds to a fairly competitive regime according to Table 1 (268 *vs.* 124 Cournot–equivalent firms). This is the first empirical result of this paper: it contradicts the general belief about competitiveness of the Spanish iron and steel industry in the first third of the century.

INSERT TABLE 4

It may be useful at this point to discuss the nature of the solutions that results from this model. The Nash equilibrium of any differential game will generally depend on the structure of the players' information sets. In the *open–loop* equilibria, players' information sets are limited to the initial state of the game. In this case, players simultaneously commit themselves to the entire path of actions over the game's horizon. By contrast, in the *closed–loop* equilibria players have perfect recall, so that their actions depend on the complete history of the game [Fudenberg and Tirole (1991, §13.4.1); Hanig (1986, §2)], and more importantly, strategies are time consistent. In a stochastic game like this one, the state follows a Markov process in the sense that the probability distribution over next period's state is a function of the current state and actions, and hence, the history at t can be summarized by y^t. Markov strategies depend only on the state of the system and player's information sets includes only the payoff–relevant history [Maskin and Tirole (1994)]. A Markov Perfect Equilibrium (MPE) is a profile of Markov Strategies that yields a Nash equilibrium in every proper subgame.

In terms of the present problem, for the *open–loop* case, each of the Hamilton–Jacobi conditions do not differ from those of the one agent dynamic programming problem because each co–state variable does not depend on the remaining players' strategies since these are simultaneously chosen at the beginning of the game. By contrast, the MPE is a Subgame Perfect Equilibria in Markov strategies, that is, strategies that only depend on the state, and which capture the interaction among players over the game horizon. In this case, co–state variables depend on opponents' actions [Başar and Olsder (1995, §6.5); Fudenberg and Tirole (1991, §13.3.2)]. The solution to equations (7) and (8) provide the MPE directly. I only need to impose $\partial \hat{x}_j^t / \partial y_i^t = \partial \tau^t / \partial y_i^t = 0$, $\forall\, i, j, t$, to avoid any effect of each player on others' co–state variables, and therefore for these equations to solve the *open–loop* equilibria.

There are two *open–loop* equilibria for each value of θ. None of these solutions fulfill the requirements of time consistency since ϕ_1 is always positive. *Open–loop* solutions require an additional institutional or technological source of commitment to be considered credible equilibria. The present model does not provide any source of commitment to either firms or the government, so that it is possible for players to deviate in later periods. *Open–loop* equilibria should therefore be disregarded. Since, in addition, they always lead to time inconsistent policies under the actual parameterization of the model, I do not need to search for any source of commitment to justify this strategy. Therefore, I will focus on *closed–loop* equilibria for the remainder of the paper.

There exist four possible values of ϕ_0, ϕ_1, $\tilde{\phi}_0$, and $\tilde{\phi}_1$ for the MPE since the Riccati equations that solve (10) generates a fourth degree polynomial in $\tilde{\phi}_1$. Table 4 shows these four solutions for $\theta = 0.463/124$. Only one of them is such that $\phi_1 < 0$ and $\tilde{\phi}_1 < 0$. Therefore, there is a unique time consistent tariff policy for the infinite horizon game within the space of continuous strategies.[26] The behavior of the time consistent solution as a function of θ is depicted in Figure 3. Several iterative computations show that for the present parameterization of the model, there is no time consistent solution for the Riccati equations in a very narrow neighborhood of the symmetric Cournot oligopoly solution defined by $\theta = 1/124$. In particular, the solution is not time consistent between $\min_\theta\{\theta \mid \phi_1 = 0\} = 0.49395/124$ and $\max_\theta\{\theta \mid \tilde{\phi}_1 = 0\} = 1.51215/124$. Since the value of θ that equals the perceived marginal revenue and marginal cost falls outside this interval, we can rule this interval of conjectural variations parameter out of consideration.

INSERT FIGURE 3

Table 3 shows that the optimal level of tariff protection for the time consistent policy is much higher than that actuallly representative of 1913. This second empirical result also contradicts the traditional view of this problem. However, this result should be expected from the argument about the small average size of the Spanish firms compared to the European standards at that time. Using (4) and the model parameterization, it follows that any tariff level above 99.161 Pts./ton is prohibitive. Similarly, from (6) and the symmetry assumption, the aggregate level that for which learning is exhausted is Y^* $= -nc_1/c_2 = 1,099,220$ th.tons. Therefore, since learning is far from being exhausted (the aggregate accumulated production for year 1913 is 16712.1 th.tons), there still existed huge economies to exploit.

This model also allows me to measure distributional effects through the computation of α and β. Fraile (1991) justifies the traditional explanation of a "captured government" by iron and steel producers. His argument relies on arbitrary measures of pressure group's power. He also argues that tariff policy was used primarily as an instrument to raise revenues for the government as opposed to being used to maximize welfare. None of these hypothesis are supported by the present calibration of the model. The advantage of the present method is that it obtains α and β as the result of intertemporal optimization by consumers, producers, and the government.

[26] The equilibrium strategies of a linear–quadratic game are linear for $y_i^t \in [0, y^*]$. It may be shown that the optimal tariff is constant for $y_i^t > y^*$ at the static, optimal tariff level. Therefore the equilibrium strategy is unique and continuous for the infinite horizon game but kinked at y^*. See Miravete (1994).

To compute α and β, in addition to the four Riccati equations, (10a) and (10b) must be included and equated to actual production and tariff levels. Then a system of six nonlinear equations must be solved for ϕ_0, ϕ_1, $\tilde{\phi}_0$, $\tilde{\phi}_1$, α, and β. These results are shown in the last two lines of Table 4. In the first of these two lines, production is fixed at 837.7 thousand tons and tariffs are fixed at 100 Pts./ton, the actual levels for 1913. In addition to the effects on the rest of variables, it should be noted that both α and β are lower than 1. This result leads to the astonishing conclusion that the government is relatively captured by consumers instead of by producers, and that it underweights tariff revenues into its objective welfare function.

However, in this case, the optimal tariff level is slightly above the prohibitive level. While this result is quite accurate for iron products, it does not match well for imports of steel products, which reached up to 26.48% of domestic production in that year. The model is then calibrated on the last line for a different scenario where (10a) is equated to the level of production for 1913, and (10b) is equated to a tariff level that generates the actual imports of iron and steel products for that year. Since a subsidy is required to generate 1913 levels of imports under the present parameterization of the model, consumer surplus rises while profits decline. This is due to the reduction in prices of iron and steel products forced by foreign competition.

Observe that the distributional parameters α and β remain quite stable even under such different scenarios. Nevertheless, these results must be interpreted carefully. Between these two scenarios τ goes from above the prohibitive level to negative values. The structure of the demand system may be driving this result because the actual estimation of demand parameters allows a relatively low prohibitive tariff level. In the first scenario β could be very low because τ is so high that imports are restricted, and tariff revenues are zero. By contrast, in the second scenario, β could be very low because τ has to be negative in order to allow for imports to reach their actual 1913 levels. However, this caveat does not apply to α. Under both scenarios, the applied tariffs are very low as compared to the surplus maximizing tariff level, so that it is difficult to argue that the government was captured by producers. On the contrary, since imports were in fact allowed while there still existed huge learning (and also possibly scale) economies to exploit, I must conclude that the government was more significantly captured by consumers or alternatively by foreign interests. This is correctly reflected in the estimates that imply an 18% higher valuation of consumer surplus over producer's profits in the social welfare function.

INSERT TABLE 5

To complete the analysis, I must address how changes in the model's parameters affect the optimal production decision and tariff policy (except c_0 which does not enter into the Riccati equations). Table 5 summarizes these effects. This table shows the arc–elasticity of each item with respect to several parameters evaluated in a neighborhood of $\pm5\%$ about their estimated values.

A shift in demand for domestic goods, a_x, increases the domestic market profitability so that optimal production is also higher. It also raises the optimal tariff by the same proportion as the increase in demand in order to mantain this increase in demand served by domestic firms and to extend the learning effect. All of the components of welfare increase but most of the gain accrues to consumers.[27]

Since $b_x > 0$, the steeper is the demand for domestic goods, the lower is consumer willingness to pay. The argument is the opposite of the previous discussion for a_x, as is the effect on the optimal prouction and tariff levels. Welfare decreases, but while a decrease in the slope of domestic demand sharply reduces the consumer surplus, profits increase. This is easily explained by the elasticity of demand for domestic goods with respect to its own price which is less than 1. The reduction in domestic production without allowing imports raises producers revenues by a larger percentage, and therefore, profits increase.

Exactly the same argument applies to k, the degree of substitution between the domestic and foreign produced goods. The difference relies only on the magnitude of the effect of changes of parameters. An increase in the degree of substitution reduces consumer willingness to pay for domestic goods less than a decrease in the slope of domestic demand given the estimates of Table 3. This increase in the degree of substitution slightly reduces optimal domestic production, which allows for an important reduction in tariffs, even though consumers are now more willing to buy foreign goods. Profits increase by the same proportion as consumer surplus falls due to the inelastic domestic demand. Overall, welfare decreases.

Changes in demand parameters for foreign goods have just the opposite effects of the correspondig parameters on demand for domestic goods. An increase in a_m and a decrease in b_m raise the willingness to pay for foreign goods. Since the demand system has only two goods, this implies that they lower the willingness to pay for domestic goods. The absolute values of the effect of changes in a_m and b_m on welfare components are significatively lower than the corresponding changes in a_x and b_x.

The following set of parameters refer to the cost function. All of them are inversely related to the optimal production decision, and therefore also to the optimal tariff and consumer surplus. Compared to the magnitude of demand parameters, cost parameters' effects are of second order. When the speed of learning increases ($c_1 < 0$ becomes smaller) production increases. Consumers benefit from a lower cost supply of domestic goods even when the tariff has increased. The reduction in the price of the domestic good also reduces producers profits because of the inelasticity of demand. This reduction offsets the increase in consumer surplus. An increase in the convexity of the fixed cost function c_2 causes cost to decline sharply, hence producers benefit more while learning lasts. However, the increase in profits does not compensate for the reduction in consumer surplus. Finally, any reduction in the marginal cost, c_3, increases optimal production levels, consumer surplus and even

[27] Parameters ϕ_1 and $\tilde{\phi}_1$ are invariant to a_x because it does not enter two of the four Riccati equations. Consequently, the slopes of the optimal linear strategies for both, production and tariff, are also unaffected. The same applies to a_m, c_1, and c_3. See the appendix of Miravete (1994).

producers' profits. Changes in the interest rate generate the most dramatic changes in all of the items reported in Table 5. Production is strongly and negatively related to r. An increase in r reduces production levels and consumer surplus, while profits increase sharply. As has been shown to be typical, the effect on consumer surplus dominates. The same happens to α but on a smaller scale, and the opposite holds for changes in β.

5 Concluding Remarks

This paper has provided and exploited an analytical framework to evaluate the effects of tariff protection in the Spanish Iron and Steel industry by the outbreak of WWI. Assuming that learning is limited to fixed cost reduction and that demand follows a simple linear structure, the optimal equilibrium strategies have been derived in closed form so that the time consistency of the policy may be evaluated.

To calibrate the model, its theoretical assumptions have been linked to features of the iron and steel industry and the protectionist policy employed over the first third of the century. The calibration of the model yields surprising results as compared to the established interpretation of this issue. First, firms seems to behave more competitively than expected. Second, the learning effect is far enough from being exhausted that even a higher tariff than the one actually applied is required to maximize total surplus. Third, the hypothesis that the government is captured by producers and that tariff revenues are used by the government as a way of rent seeking is rejected.

Appendix: Data

In addition to data explicitly mentioned in the text, all estimates, figures, and percentages used to illustrate the arguments of the paper may be found in the following sources. Data on Spanish production of iron, steel, and production capacity of iron and steel are available in Fraile (1991), p.121. The value of Spanish imports and exports of iron and steel products, as well as tariffs revenues from imports of iron and steel products may be found in the "*Estadísticas de Comercio Exterior de España.*" Fraile (1985), p.99 gives detailed information of Spanish imports and exports of iron and steel separately. Mitchell (1992), pp.450–51 and pp.456–59, provides information on British production of iron and steel. Mitchell and Deane (1962) and Mitchell and Jones (1971) report British iron and steel prices. Fraile (1985), p.88 shows the exchange rate at which these prices were converted into Pts. Spanish prices can be found in Fraile (1991), pp.172-173. Finally, data on the rate of return of the Spanish Public Debt are reported by Martín (1985), while AHV's gross profit may be found in Fernández de Pinedo (1992), p.151. The whole data set used in this paper is available in Miravete (1994).

References

Allen, R.C. (1979): "International Competition in Iron and Steel, 1850–1913." *The Journal of Economic History*, 39, 911–937.

Bairoch, P. (1993): *Economics and World History.* Harvester.

Baldwin, R.E. (1984): "Trade Policies in Developed Countries", in R.W. Jones and P.B. Kenen (eds.): *Handbook of International Economics*, Vol. I. North–Holland.

Baldwin, R.E. (1985): *The Political Economy of U.S. Import Policy.* MIT Press.

Başar, T. and G.J. Olsder (1995): *Dynamic Noncooperative Game Theory*, 2nd Ed. Academic Press.

Brander, J.A. and P.R. Krugman (1983): "A Reciprocal Dumping Model of International Trade." *Journal of International Economics*, 15, 313–321.

Brander, J.A. and B.J. Spencer (1983): "International R&D Rivalry and Industrial Strategy." *Review of Economic Studies*, 50, 707–722.

Bresnahan, T.F. (1989): "Empirical Studies of Industries with Market Power," in R. Schmalensee and R.D. Willig (eds.): *Handbook of Industrial Organization*, Vol. II. North–Holland.

Carr, J.C. and W. Taplin (1962): *History of the British Steel Industry.* Blackwell Publishers.

Carreras, A. (ed.) (1989): *Estadísticas históricas de España. Siglos XIX–XX.* Fundación Banco Exterior.

Department of Overseas Trade (1928): *Report on Economic Conditions in Spain.*

Dixit, A.K. (1985): "Optimal Trade and Industrial Policies for the U.S. Automobile Industry", in R.C. Feenstra (ed.): *Empirical Methods for International Trade.* MIT Press.

Estadísticas de Comercio Exterior de España. Years 1913–1929.

España, J.M. (1927): "La producción de lingote de fundición y de acero en España." *Boletín Industrial*, September, 187–188.

Fernández de Pinedo, E. (1992): "Beneficios, salarios y nivel de vida obrero en una gran empresa siderúrgica vasca. Altos Hornos de Vizcaya (1902–1927). Una primera aproximación." *Historia Industrial*, 1, 125–153.

Fraile, P. (1985): "Crecimiento económico y demanda de acero", in L. Prados and P. Martín (eds.): *La nueva historia económica de España.* Editorial Tecnos.

Fraile, P. (1991): *Industrialización y grupos de presión. La economía política de la protección en España, 1900–1950.* Alianza Editorial.

Fudenberg, D. and J. Tirole (1991): *Game Theory.* MIT Press.

González, M. (1981): *La formación de la sociedad capitalista en el País Vasco.* Haranburu.

González, M. (1985): *La siderúrgia vasca (1880–1901). Nuevas tecnologías, empresarios y política económica.* Servicio editorial de la Universidad del País Vasco.

Hanig, M. (1986): "Differential Gaming Models of Oligopoly." Ph.D. Thesis. MIT.

Harrison, R.J. (1978): *An Economic History of Modern Spain.* Manchester University Press.

Hillman, A.L. (1989): *The Political Economy of Protection*, in J. Lesourne and H. Sonnenschein (eds.): *Fundamentals of Pure and Applied Economics.* Harwood Academic Publishers.

Krugman, P.R. (1984): "Import Protection as Export Promotion: International Competition in the Presence of Oligopolies and Economies of Scale", in H. Kierzkowski (ed.): *Monopolistic Competition and International Trade*. Oxford University Press.

League of Nations (1927): *Memorandum on the Iron and Steel Industry.*

Martín, P. (1985): "Déficit público y política monetaria en la Restauración, 1874–1923", in P. Martín and L. Prados (eds.): *La nueva historia económica en España.* Tecnos

Maskin, E. and J. Tirole (1994): "Markov Perfect Equilibrium." Mimeo, Harvard University.

Matsuyama, K. (1990): "Perfect Equilibria in a Trade Liberalization Game." *American Economic Review*, 80, 480–492.

Mayer, W. (1984): "Endogenous Tariff Formation." *American Economic Review*, 74, 970–985.

Merello, E. (1939): "La industria siderúrgica y la minería del hierro y el carbón." *Dyna*, November–December, 381–387.

Miravete, E.J. (1994): "Learning by Doing and Protection of an Infant–Industry." The Center for Mathematical Studies in Economics and Management Science, Discussion Paper 1097. Northwestern University.

Mitchell, B.R. (1992): *International Historical Statistics: Europe 1750–1988.* Stockton Press.

Mitchell, B.R. and P. Deane (1962): *Abstract of British Historical Statistics.* Cambridge University Press.

Mitchell, B.R. and H.G. Jones (1971): *Second Abstract of British Historical Statistics.* Cambridge University Press.

Nadal, J. (1975): *El fracaso de la revolución industrial en España, 1814–1913.* Editorial Ariel.

Noll, R.G. (1989): "Economic Perspectives on the Politics of Regulation", in R. Schmalensee and R.D. Willig (eds.): *Handbook of Industrial Organization*, Volume II. North-Holland.

Olson, M. (1968): *The Logic of Collective Action: Public Goods and the Theory of Groups.* Schocken Books.

Pearl, M.L. (1978): "Iron and Steel", in T.I. Williams (ed.): *A History of Technology*, Volume VI, Part I. Clarendon Press.

Pincus, J.J. (1977): *Pressure Groups and Politics in Antebellum Tariffs.* Columbia University Press.

Pratten, C.A. (1971): *Economies of Scale in Manufacturing Industry.* Cambridge University Press.

Schubert, H.R. (1978): "The Steel Industry", in C. Singer, E.J. Holmyard, A.R. Hall, and T.I. Williams (eds.): *A History of Technology*, Volume V. Clarendon Press.

Shaw, V. (1977): "Exportaciones y despegue económico; el mineral de hierro de Vizcaya, la región de la ría de Bilbao y alguna de sus implicaciones para España." *Moneda y Crédito*, 142, 87–114.

Svennilson, I. (1954): *Growth and Stagnation in the European Economy.* United Nations.

Tirole, J. (1989): *The Theory of Industrial Organization.* MIT Press.

Waterson, M. (1984): *Economic Theory of the Industry.* Cambridge University Press.

Figure 1. Spanish tariff relative to British prices

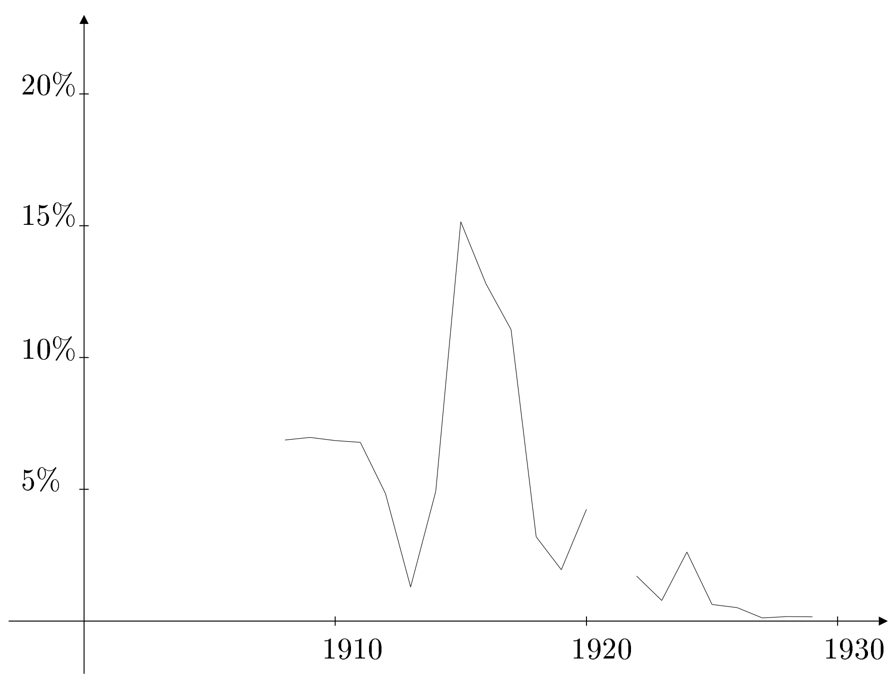

Figure 2. Spanish exports over domestic production

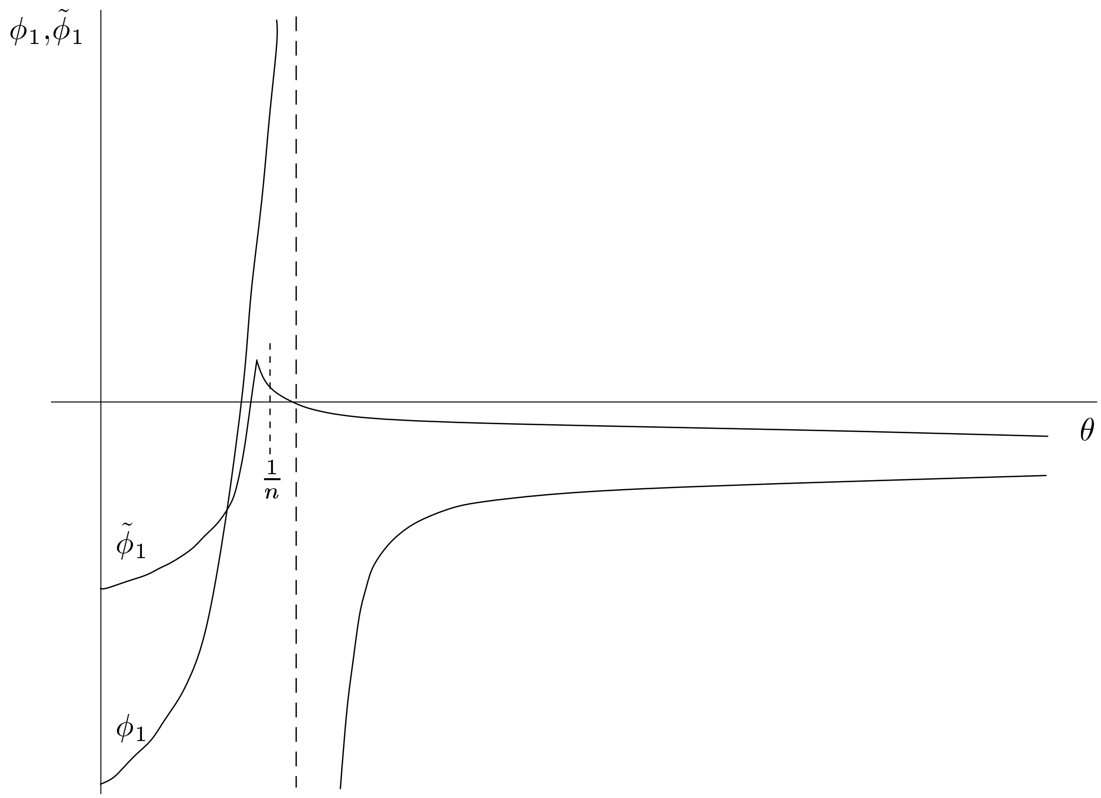

Figure 3. Solutions of Riccati Equations

Table 2. Market Shares

FIRM		1900	1913	1925	1929
A.H. Vizcaya	Total	71.33	69.63	53.29	52.22
(1902)	Iron	79.61	71.91	58.32	57.47
	Steel	61.87	67.33	49.24	48.18
A.H. Mediterráneo	Total			15.40	19.33
(1917)	Iron			15.62	19.33
	Steel			15.23	19.32
Duro–Felguera	Total	7.77	5.09	5.99	6.36
(1900)	Iron	4.78	4.77	4.31	6.89
	Steel	11.19	5.41	7.34	5.96
Fab. de Mieres	Total	14.07	4.40	3.18	3.42
(1879)	Iron	5.30	5.83	3.70	3.55
	Steel	24.09	2.96	2.77	3.31
Ind. Asturiana	Total	4.93	4.88	3.84	2.91
(1895)	Iron	9.24	4.97	4.52	3.09
	Steel		4.79	3.30	2.77
Comp. Basconia	Total		4.04	5.32	4.32
(1892)	Iron				
	Steel		8.12	9.59	7.65
S.A. Echevarría	Total			2.33	2.63
(1920)	Iron			2.39	2.14
	Steel			2.29	3.01
Material F.C. & C.	Total		1.27	1.61	1.38
(1881)	Iron				
	Steel		2.55	2.90	2.45
J.M. Quijano	Total	1.33	1.06	1.37	1.19
(1914)	Iron				
	Steel	2.85	2.14	2.47	2.11
Nueva Montaña	Total		5.73	3.95	3.27
(1899)	Iron		11.41	8.86	7.51
	Steel				
Others	Total	0.57	3.89	3.72	2.96
	Iron	1.06	1.10	2.28	
	Steel		6.70	4.87	5.24
Inverse	Total	284.59	124.06	354.57	475.54
Herfindahl	Iron	136.61	211.97	382.01	504.54
Indexes	Steel	713.67	146.97	420.77	510.91

Year of legal establishment is shown between parenthesis. Percentages of market share for each product and the Herfindahl indexes computed from the information provided by Merello (1939), for 1900, 1913, and 1929; and España (1927), for 1925. "Others" includes five (assumed) symmetric, small firms to compute the Herfindahl index.

Table 1. Conjectural Variations

Regime	γ	θ
Cournot	0	$\frac{1}{n}$
Bertrand	$\left[\frac{-1}{n-1}, 0\right]$	$\left[0, \frac{1}{n}\right]$
Competition	$\frac{-1}{n-1}$	0
Collusion	1	1

Table 3. Estimates

Parameter	Estimate	t–statistic
a_x^0	615.714501	4.23
a_x^1	274.016070	3.04
b_x	0.990809	2.66
k	0.450731	1.69
a_m^0	500.114550	2.87
a_m^1	345.732890	1.98
b_m	1.775377	0.57
c_0	658.429820	0.75
c_1	-0.185449	-0.91
c_2	2.092E-5	1.19
c_3	1.409824	0.64

Table 4. Solutions

	θ	α	ϕ_0	ϕ_1	$\tilde{\phi}_0$	$\tilde{\phi}_1$	$\hat{x}_0$	$\hat{x}_1$	$\hat{\tau}_0$	$\hat{\tau}_1$
Open Loop	0	1	-567.45	0.000523	4.58	-0.000004	490.578	0.000003	60.368	-0.000002
	0	1	5.14E+08	4.346312	-4.14E+06	-0.035051	2.95E+06	0.024975	-1.89E+06	-0.015945
	0.5	1	-568.94	0.000523	4.59	-0.000004	490.569	0.000003	60.373	-0.000002
	0.5	1	6.42E+08	5.433021	-5.18E+06	-0.043815	3.69E+06	0.031220	-2.36E+06	-0.019932
	1	1	-569.93	0.000523	4.60	-0.000004	490.564	0.000003	60.377	-0.000002
	1	1	7.71E+08	6.519729	-6.22E+06	-0.052578	4.43E+06	0.037464	-2.83E+06	-0.023919
	0.463/n	1	-567.46	0.000523	4.58	-0.000004	490.578	0.000003	60.368	-0.000002
	0.463/n	1	5.15E+08	4.354427	-4.15E+06	-0.035116	2.96E+06	0.025022	-1.89E+06	-0.015975
Closed Loop	0.463/n	1	35130.80	-4.043018	14473.05	-0.553800	2274.800	-0.085984	6642.245	-0.251930
	0.463/n	1	9.54E+08	4.737284	-21808.27	-0.000113	6.30E+06	0.031298	-9862.550	-0.000051
	0.463/n	1	67883.31	0.000523	4.52	-0.000004	942.982	0.000003	60.342	-0.000002
	0.463/n	1	71266.36	11.434891	4990.25	0.402153	1498.868	0.118611	2328.409	0.182944
	0.463/n	0.843037	139408.35	-6.731636	3.44	-0.000146	3317.869	-0.324110	5516.557	-0.324110
	0.463/n	0.843475	148434.78	-6.965996	3.18	-0.000138	8 3380.493	-0.152153	5479.524	-0.330485
	θ	β	$\hat{X}(Y)$	$\hat{\tau}(Y)$	$\hat{M}(Y)$	$CS(Y)$	$\Pi(Y)$	$R(Y)$	$W(Y)$	I_W
Open Loop	0	1	490.63	60.34	49.45	66.18	98.11	2.98	167.27	63.79
	0	1	2.95E+06	-1.89E+06	2.40E+06	6.32E+09	-5.92E+09	-4.53E+09	-4.13E+09	-1.57E+09
	0.5	1	490.62	60.34	49.44	66.18	98.11	2.98	167.26	63.78
	0.5	1	3.69E+06	-2.36E+06	3.00E+06	9.88E+09	-9.25E+09	-7.08E+09	-6.45E+09	-2.46E+09
	1	1	490.61	60.34	49.44	66.17	98.11	2.98	167.26	63.78
	1	1	4.43E+06	-2.83E+06	3.60E+06	1.42E+10	-1.33E+10	-1.02E+10	-9.29E+09	-3.54E+09
	0.463/n	1	490.63	60.34	49.45	66.18	98.11	2.98	167.27	63.79
	0.463/n	1	2.96E+06	-1.89E+06	2.41E+06	6.34E+09	-5.94E+09	-4.54E+09	-4.14E+09	-1.58E+09
Closed Loop	0.463/n	1	837.83	2431.96	0.00	173.88	88.36	0.00	262.24	100.00
	0.463/n	1	6.30E+06	-9863.41	12688.47	9.85E+09	-1.97E+10	-1.25E+05	-9.83E+09	-3.75E+09
	0.463/n	1	943.03	60.31	49.48	231.89	49.66	2.98	284.53	108.50
	0.463/n	1	3481.11	5385.79	0.00	3001.68	-3943.48	0.00	-941.79	-359.14
	0.463/n	0.500102	837.70	100.00	0.00	173.82	88.39	0.00	262.21	99.99
	0.463/n	0.500095	837.70	-43.57	181.78	222.81	54.07	-7.92	268.96	102.56

Table 5. Comparative Statics

	ϕ_0	ϕ_1	$\tilde{\phi}_0$	$\tilde{\phi}_1$	$\hat{X}(Y)$	$\hat{\tau}(Y)$	$CS(Y)$	$\Pi(Y)$	$W(Y)$
a_x	9.995		85.025		228.077	230.220	450.298	119.575	341.062
b_x	5.882	99.715	110.412	212.330	-280.868	-169.758	-457.167	195.667	-245.744
k	-12.596	0.032	-230.751	-225.317	-7.266	-135.465	-14.532	14.898	-4.623
a_m	-2.054		-17.530		-47.016	-47.457	-93.979	96.416	-29.940
b_m	6.978	-0.016	121.418	113.050	18.766	132.994	37.530	-38.276	11.958
c_1	-0.481		-0.199		-0.501	-0.539	-1.003	4.533	0.863
c_2	-0.229	0.269	-0.223	0.121	-0.762	-0.813	-1.524	1.533	-0.494
c_3	0.042		-0.130		-0.384	-0.378	-0.768	-0.551	-0.695
r	-147.567	99.461	-48.889	99.758	-301.257	-303.955	-589.147	698.502	-193.274
α	-5.743	0.014	-3.919	0.006	-7.215	-8.224	-14.429	14.765	-4.593
β	1.844	-0.029	201.286	199.988	2.449	2.815	4.897	-5.007	1.559