

Sunk costs and cartel formation: Theory and application to the dyestuff industry

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Abstract

We first develop a simple model of entry showing that cartels are more likely to emerge during periods of downturns and in industries with significant sunk costs. Cartel formation is also accompanied by a decline in profits. We then use the framework to investigate the emergence of the Swiss dyestuff export cartel during the inter-war period and find empirical evidence that supports the main predictions of the model. The analysis indicates that sunk costs and entry may be important determinants of cartel formation and are complementary to the traditional cartel stability conditions. © 1998 Elsevier Science B.V. All rights reserved

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1. Introduction

The purpose of this article is to investigate the role of entry and sunk costs for cartel formation. We build a simple model to analyze the timing of cartel formation and apply it to the dyestuff export cartel which was established in Switzerland during the inter-war period. Without relying on arguments about firms' cheating, the model predicts that cartels are more likely to emerge during downturns and in industries with high irreversible set-up costs. Moreover, profits should decline with cartel formation. We use the model to explain the timing of the emergence of the dyestuff cartel.

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There is extensive literature on cartel stability which investigates how structural parameters (like the price elasticity of demand) or shocks (like changes in demand) affect a cartel member's incentive to cheat (see Stigler, 1964).² Interesting results have also been found in the literature on the stability of tacit collusion in infinitely repeated games. In particular, Green and Porter (1984) show that, with secret price cuts, tacit collusion is more likely to hold during periods of booms. Rotemberg and Saloner (1986), however, argue that tacit collusion is more likely to be stable during periods of downturns if prices are observable and if downturns are expected to be temporary. Haltiwanger and Harrington (1991) reverse this last result when shocks are permanent, and, generalizing some of these models, Bagwell and Staiger (1995) are consistent with both results.

Although models of tacit collusion do not require explicit agreements among firms, they are still useful to analyze cartel behavior as they provide an incentive compatibility constraint that cartel members should satisfy. They can thus be used to predict when cartels emerge. For instance, Rotemberg and Saloner's model could be used to claim that cartels are more likely to emerge during downturns, whereas, with Haltiwanger and Harrington (1991) or Green and Porter (1984), the opposite is true.

Whether framed in a static (as in the traditional models of cartels) or in a dynamic approach (as in the tacit collusion approach), all these models rely on collusion instability due to the possibility that firms deviate from some target. All ignore sunk costs as well as entry which may arise from collusion (or cartelization) itself. In this paper, we argue that sunk costs and entry may be as important determinants of cartel formation as stability conditions. For this reason, we develop a simple cartel model where entry plays a key role but where all considerations of instability are ignored.

Over the last 15 years, entry and sunk costs have played an increasing role in the theory of market structure. Today, we have theories predicting when entry matters for competition (contestability theory), and when entry can be prevented by incumbent firms (market preemption theory).³ Sunk costs have also become an important element for investment decisions (Dixit and Pindyck, 1994) and in the choice of corporate governance structure (Williamson, 1985; Whyte, 1994). However, thus far, entry and sunk costs have not played a major role in our understanding of cartel formation.

The few articles where sunk costs and entry are used to explain cartels rely on the theory of the empty core (Sjostrom, 1989; Pirrong, 1992; Telser, 1994). In this approach, unrestricted entry implies that cartel members earn no pure profits. When demand fluctuates and production has indivisibilities (due to sunk cost), efficient production with a stable number of firms can only be achieved with a change in firms' behavior. Cartels, earning competitive returns in periods of downturns, are then possible. Sjostrom (1989) and Pirrong (1992) argue that this approach fits well with the case of the ocean shipping industry. Our approach is different as it does not rely on the theory of the core, and free-entry equilibria are not characterized by competitive rates of return. Our aim is to understand cartel formation in oligopolistic industries. Hence, pure profits become

² Although there exist conditions for a cartel to be stable (see, e.g. d'Aspremont et al., 1983), the broadly accepted wisdom is that cartels are inherently unstable. Studies investigating the internal organization of specific cartels include Porter (1983) and an empirical survey of cartel instability can be found in Suslow (1988) and Marquez (1992).

³ See Gilbert (1989) and Shapiro (1989) for surveys of this literature.

possible and indeed it is the willingness to protect the firms' quasi-rents in periods of downturns which explains why cartels might emerge. As a result, we expect cartels to earn a lower rate of return than before their formation; a prediction which is different from other models.

In Section 2, we show that if potential firms face significant setup costs of entry, cartelization without attracting entry becomes possible whenever the industry faces a decline in profits due to structural changes. Simply, the incumbents exploit the fact that an entrant's expected profit is reduced. In Section 3, we apply the model to the Swiss dyestuff cartel. We argue that the empirical evidence is in line with the main assumptions and predictions of the model. In particular, the industry was characterized by high sunk costs and a cartel was formed when the industry anticipated considerable structural change due to rising import protection in the main export markets. Section 4 concludes the discussion.

2. A model of scope for cartel

We first build a model establishing a relationship between the emergence of cartel and structural changes. To focus on the role of entry and sunk costs, we ignore the traditional forces which influence collusion. In particular, we ignore cheating among members as well as the incentive that some existing firms might want to remain outside a cartel. In this sense, the model establishes the scope for cartelization.

2.1. Free-entry equilibrium

Since the empirical analysis deals with an export cartel, consider a model where production takes place in one market and consumption in another one. Suppose there are n identical firms which export their entire production to a market in which there is no local production. The (inverse) market demand function in the market of consumption and the cost function of a representative firm are assumed to be linear given respectively by

$$p = a + \alpha - bny, \quad (1)$$

and

$$C = (c + \beta)y + K. \quad (2)$$

In Eqs. (1) and (2), y is the quantity sold by the representative firm; c , the marginal cost, and α and β are shift parameters. In the sequel and without loss of generality, we normalize $(a-c)$ to one, and we use a single shift parameter γ defined as $\gamma = \beta - \alpha$. An increase in γ can thus be interpreted as an exogenous decrease in demand or as an exogenous increase in costs such as an increase in transport costs or (specific) tariff between the two markets, or else an increase in input prices.

In Eq. (2), K is a fixed (flow) cost associated with an exogenous setup cost S such that $K = iS$, where i is the relevant interest rate.⁴ The setup cost S is interpreted as total costs associated with some specific investment, like R&D, advertising, or investment in

⁴ See Dixit and Pindyck, 1994, p.8 for a characterization of sunk costs, and Sutton (1991) for a discussion of exogenous and endogenous sunk cost.

specific machinery. Since S is sunk, the profit-maximizing decisions of the existing firms are not affected by S . However, this investment is avoidable by new firms. As such it creates an asymmetry between new and existing firms. As argued by Gilbert (1989), the main feature of sunk cost is to be a barrier to entry creating a rent that is derived from incumbency.

Suppose n firms determine output as their strategic variable.⁵ To simplify the analysis, assume also that entry can only occur in the market of production. We first determine the free-entry equilibrium or the number of firms which operates in this market without attracting entry.

To do so, we first calculate the expected profit of a potential firm. In the presence of setup costs, potential firms should not be allowed to make mistakes by entering when they cannot cover costs. Accordingly, we require that entry decisions be made on the basis of the post-entry equilibrium. The entry decision also depends on firms' behavior. We consider two types of firms' rivalry: Cournot competition and perfect cartel (i.e. the cartel members act as a single monopoly). In both cases, we assume that a new firm always plays the same game as the established firms.⁶ We thus maximize the entrant's profit function with respect to output, taking as given other firms' behavior and the fact that n existing competitors are already in the market (and thus the industry would have $n+1$ firms). Using Eqs. (1) and (2), the entrant's problem is to find y_e which maximizes

$$\pi_e^i(n+1, \gamma) = [1 - \gamma - bny - by_e]y_e - K, \quad (3)$$

where γ is the shift parameter defined earlier, $i=c$ if firms play a Cournot game and $i=m$ if they act as a monopoly (perfect cartel).

Since all the firms are identical, $y_e = y = \hat{y}^i$ in equilibrium. The equilibrium production of a new firm conditional on the shift parameter γ , firm's behavior, and an industry with $n+1$ firms is therefore

$$\hat{y}^i(n+1, \gamma) = \frac{1 - \gamma}{b(2 + n + \lambda)}, \quad i = c, m \quad (4)$$

where λ is the parameter which captures the degree of rivalry among firms. In Cournot competition, $\lambda=0$ and, in a perfect cartel, $\lambda=n$.⁷ Clearly, we require that $\gamma < 1$. Substituting Eq. (4) in Eq. (3), the post-entry profit of a new firm is

$$\hat{\pi}_e^i(n+1, \gamma) = \left(\frac{1 + \lambda}{b}\right) \left[\frac{1 - \gamma}{2 + n + \lambda}\right]^2 - K, \quad i = c, m. \quad (5)$$

⁵ The analysis also holds with competition in prices provided that products are imperfect substitutes.

⁶ This is a reasonable assumption even when firms collude. To see this, suppose an entrant plays non-cooperatively (Cournot) with the cartel. It is well known that an entrant may have no incentive to join a cartel when her output is greater than that of a cartel member. Suppose then that the entrant cannot produce more than a cartel member. In this case, the entrant always prefers to be a cartel member and it is in the cartel's best interest to accept her as a member. Hence, entry occurs provided that the newcomer covers costs as a cartel member.

⁷ See Brander and Spencer (1985) for a similar formulation. The model can easily be generalized to any degree of collusion between Cournot and full collusion (see Mercenier and Schmitt, 1996). The parameter λ is, of course, also known as the conjectural variation parameter. From a game-theoretic point of view, this concept is questionable (Shapiro, 1989). We note, however, that recent advances in game theory have established a direct link between this parameter and equilibria in dynamic games among firms (Dockner, 1992).

The potential firm decides to stay out of the market whenever $\hat{\pi}_e^i(n + 1, \gamma) \leq 0$. This condition determines the minimum number of existing firms (\hat{n}) which, given the shift parameter and the firms' behavior, is consistent with the free-entry equilibrium. Thus, entry is not profitable whenever

$$n \geq \hat{n}_i(\gamma) = (1 - \gamma) \left(\frac{1 + \lambda}{bK} \right)^{\frac{1}{2}} - (2 + \lambda), \quad i = c, m. \tag{6}$$

Not surprisingly, there is an inverse relationship between K and \hat{n}_i . The maximum number of firms consistent with a free-entry equilibrium is given by the zero-profit condition of an existing firm. In this simple model, it is easy to find that $n_{\max} = \hat{n}_i + 1$. To generate pure profit in equilibrium, we assume in the sequel that the free-entry equilibrium is exactly binding ($n = \hat{n}_i$).

2.2. The incentive to form a cartel

We now show two results. First, given an initial environment, firms have no incentive to form a cartel when there is free entry. Hence, if firms can either act as Cournot competitors or as cartel members, they prefer the Cournot behavior when entry is endogenous. Second, established firms consistent with the Cournot free-entry equilibrium may have an incentive to form a cartel when a significant downturn arises.

The first result is shown as follows. Consider an initial environment defined as $\gamma=0$. Using Eq. (6), the equilibrium number of firms \hat{n}_c and \hat{n}_m , corresponding, respectively, to a Cournot equilibrium ($\lambda=0$) and to a cartel equilibrium ($\lambda=n$), is then

$$\hat{n}_c = \frac{1}{(bK)^{\frac{1}{2}}} - 2; \quad \hat{n}_m = \frac{1}{4bK} - 1. \tag{7}$$

We require these market structures to have at least one firm and thus that $K \leq \frac{1}{9b}$. Adapting Eq. (5) to an industry with n firms and using Eq. (7), each of the Cournot competitors earns

$$\hat{\pi}^c(\hat{n}_c, \gamma = 0) = \frac{1}{b(1 + \hat{n}_c)^2} - K = K \left(\frac{1}{(1 - (bK)^{\frac{1}{2}})^2} - 1 \right), \tag{8}$$

whereas, in a cartel, each member earns $1/n$ of the monopoly profit (equal to $\frac{1}{4b} - K$ in this model) or,

$$\hat{\pi}^m(\hat{n}_m, \gamma = 0) = \frac{1}{4b\hat{n}_m} - K = K \left(\frac{1}{1 - 4bK} - 1 \right). \tag{9}$$

It is easy to verify that $\hat{\pi}^c(\hat{n}_c, \gamma = 0) \geq \hat{\pi}^m(\hat{n}_m, \gamma = 0)$ if and only if $K \leq \frac{4}{25b}$ or $\hat{n}_c \geq \frac{1}{2}$ which, given our assumptions, is always the case. Thus, given $\gamma=0$, an established firm always prefers the Cournot free-entry equilibrium to the free-entry equilibrium with cartel. This is the case because the number of firms in the latter equilibrium is larger than in the former one, more than compensating the gains from a lower degree of competition. Entry thus matters to the firms as they face a trade-off between the degree of rivalry and the equilibrium number of firms.

We now show that, following a downturn, a perfect cartel may become sustainable. To see this, suppose that the shift parameter γ rises to some positive level $\tilde{\gamma}$ where $\tilde{\gamma} < 1$. In the context of this model, think, for instance, of an increase in the tariff rate levied by the country of consumption. Since $\frac{\partial \hat{\pi}_e}{\partial \gamma} < 0$ (see Eq. (5)), an increase in γ reduces an entrant's expected profit. This implies that the free-entry condition, which was exactly binding in the initial equilibrium, must become slack at $\tilde{\gamma}$. Thus, a firm which was just deterred from entering the market at $\gamma=0$ must a fortiori be deterred from entering at $\gamma = \tilde{\gamma}$. However, since variable costs are still covered (i.e. $\tilde{\gamma} < 1$), existing firms have no incentive to exit the industry. We determine now how strong $\tilde{\gamma}$ should be to sustain a free-entry perfect cartel among the \hat{n}_c established firms.

If the firms established in the initial equilibrium (\hat{n}_c) collude perfectly ($\lambda = \hat{n}_c$), the expected profit of a potential firm is, using Eq. (5),

$$\hat{\pi}_e^m(\hat{n}_c + 1, \tilde{\gamma}) = \frac{(1 - \tilde{\gamma})^2}{4b(1 + \hat{n}_c)} - K. \tag{10}$$

A perfect cartel constitutes a free-entry equilibrium provided that $\hat{\pi}_e^m(\hat{n}_c + 1, \tilde{\gamma}) \leq 0$. Given the initial number of firms (\hat{n}_c), the free-entry condition defines the minimum value of the shift parameter γ_{\min} above which a perfect cartel is consistent with no entry. Substituting $\hat{n}_c = [(bK)^{-\frac{1}{2}} - 2]$ into Eq. (10), entry does not occur as long as

$$\tilde{\gamma} \geq \gamma_{\min} = 1 - 2 \left[(bK)^{\frac{1}{2}} - bK \right]^{\frac{1}{2}}. \tag{11}$$

Fig. 1 illustrates γ_{\min} . For any K in the feasible range $0 \leq K \leq \frac{1}{9b}$, $0.057 < \gamma_{\min} \leq 1$, and for $1 \geq \tilde{\gamma} \geq \gamma_{\min}$, there is no entry associated with a perfect cartel among the \hat{n}_c firms. If, for given K , the shift parameter does not increase sufficiently ($\tilde{\gamma} \leq \gamma_{\min}$), perfect collusion among the \hat{n}_c firms will attract entry. As expected, Fig. 1 shows that an industry

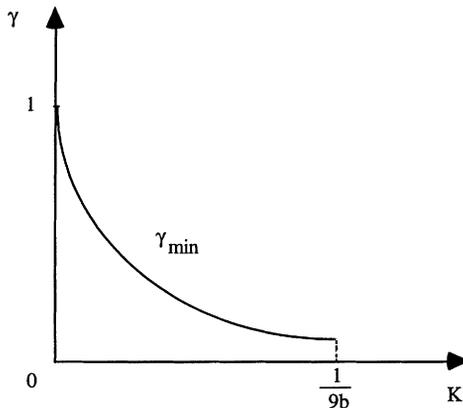


Fig. 1. Sunk costs, structural change and scope for cartelization

facing higher sunk costs has greater scope for collusion (i.e. it requires a smaller γ_{\min} to sustain collusion) than an industry with low sunk costs.⁸

Recall now the interpretation of a change in γ : it represents a change in an exogenous variable of the demand or of the cost function such that existing firms' profits decrease permanently. In this static model, permanently simply means that firms do not expect the shift parameter to return to its initial level. We summarize the discussion by:

Proposition 1: If firms face setup costs of entry, scope for a perfect cartel exists whenever existing firm profits fall due to structural changes $\gamma \geq \gamma_{\min}$. The larger the setup cost, the greater the scope for perfect cartelization.

When γ is interpreted as a foreign tariff on imports, this result establishes a link between increased protection and scope for cartelization. Clearly, any other structural changes than tariffs affecting supply or demand and leading to lower profit have exactly the same effects. Hence, a negative shock may create scope for cartelization which did not exist in the initial free-entry equilibrium. Sunk costs are key for this result; without them, existing firms would not earn any quasi-rent. These rents are, of course, returns on firm-specific assets. By lowering these returns, structural change does not induce any exit as long as returns are still positive since these assets have no alternative use. This creates a strong incentive to form a cartel as it is a sure way to recoup some of these lower returns, at least as long as it does not induce entry.

2.3. Implications and extensions

Consider now an important implication of the model:

Proposition 2: Given a structural change which triggers the formation of a cartel, an existing firm earns lower profits as a cartel member than as a Cournot competitor before the change.

To see this, we first find a cartel member's equilibrium profit given \hat{n}_c firms and the shift parameter γ ; it is a simple transformation of Eq. (9) or Eq. (5):

$$\hat{\pi}^m(\hat{n}_c, \gamma) = \frac{(1 - \gamma)^2}{4b\hat{n}_c} - K. \tag{12}$$

We then compute the difference in equilibrium profits for an established firm as a Cournot competitor (without shock) and as a cartel member given the minimal shock keeping out entry. That is, we calculate the difference between $\hat{\pi}^c(\hat{n}_c, \gamma = 0)$ as given by Eq. (8), and $\hat{\pi}^m(\hat{n}_c, \gamma_{\min})$ as given by Eq. (12). With Eq. (11), it becomes

$$\text{sign}[\hat{\pi}^c(\hat{n}_c, \gamma = 0) - \hat{\pi}^m(\hat{n}_c, \gamma_{\min})] = \text{sign} \left[\frac{bK + 1 - 3(bK)^{1/2}}{1 - 2(bK)^{1/2}} \right]. \tag{13}$$

⁸ γ_{\min} decreases in K because higher values of K imply fewer firms and thus lower competition among existing firms in the initial Cournot equilibrium. Hence, as K rises, the difference in the level of competition between full collusion and the initial Cournot equilibrium diminishes.

The right hand side of Eq. (13) is unambiguously positive for $K \leq \frac{1}{\theta b}$ and thus for $\hat{n}_c \geq 1$ (see Eq. (7)). Since $\hat{\pi}^m(\hat{n}_c, \gamma)$ decreases with γ , Eq. (13) is positive for all $\hat{\gamma} \geq \gamma_{\min}$. Thus, firms can recoup some, but not all, of their lower returns following a shock.

Proposition 2 predicts a different outcome than the traditional approaches described in Section 1. In equilibrium, profits are always zero in the theory of the empty core. Since collusion arises during booms and the number of firms is held constant, profits rise with collusion in Green and Porter (1984) and in Haltiwanger and Harrington (1991). The case is more ambiguous with Rotemberg and Saloner (1986) since their model predicts that firms cut prices in periods of booms. There is, however, no force in their model which ensures that collusion and downturns lead to lower profit with respect to periods of booms without collusion as entry does not play a role.

The model just developed is static; γ is thus considered as both an unexpected and a permanent shock. Before proceeding with the dyestuff case, it is useful to discuss briefly how the timing of cartel formation changes if, instead of a static model, we had adopted a dynamic one. This introduces two additional considerations: anticipation and persistence of a shock.

Suppose $S > 0$ is the specific investment to be incurred by firms upon entry, and that, at any point in time, there are many potential entrants. In a dynamic setting, a free-entry equilibrium exists if the present value of a newcomer's expected profit is non-positive. Since the present value can be non-positive whether the shock is permanent or not (for an appropriate discount rate), the persistence of the shock does not qualitatively affect our analysis. Suppose now that demand is expected to shift down at some future date and the shift in demand is just sufficient for existing firms to form a cartel without attracting entry (i.e. there is a dynamic equivalent to γ_{\min}). This implies that the scope for cartelization can only arise at the exact date of the shift in demand. Any attempt to cartelize before this date would attract entry as the newcomer would benefit from the cartel and high demand. Thus, when firms anticipate a shock, the scope for cartelization arises before the date of the structural change only if this change is greater than the dynamic equivalent of γ_{\min} .

Even though the model is quite specific, the results hold in a more general setting (see Mercenier and Schmitt, 1996). In particular, the argument does not require that all fixed costs be sunk. The present formulation makes clear that an empirical investigation of cartel formation must look for the following evidence: evidence regarding the structure of the industry, the timing of events and industry profits. Considerations about sunk costs are, of course, a key element in industry description. With respect to the timing of events, evidence should be found of a non-cooperative, free-entry equilibrium before cartelization takes place. We must also show that at the time of cartel formation, structural changes have increased substantially, affecting negatively firms' profits. If cartel formation preceded structural change, we should find unambiguous signals about strong impending shocks observable by firms at the time of cartel formation. As the model makes a distinct prediction about profits, we finally have to show that cartel formation is not sufficient to maintain profit at its pre-cartel level.

3. The Swiss dyestuff cartel

The dyestuff cartel agreement was signed in September 1918 among the three major Swiss producers, Ciba, Geigy and Sandoz which accounted for approximately 95 percent of Swiss dyestuff production. The agreement eliminated competition among these firms with regard to sales and the purchase of inputs. Profits of the three firms were aggregated and redistributed to each member according to a fixed formula. Patents and technical know-how became common property of the cartel and increases in equity capital, as well as building new plants or mergers were subject to approval by all members (see Ciba, 1918b and Haber, 1971, p.307). All these elements of the cartel contract indicate that the three firms intended to maximize joint profit. Such a contract was legal in Switzerland.

We now want to examine whether the timing of the cartel formation is in line with the prediction of the model. First, we describe dyestuff manufacturing and provide evidence that sunk costs were relatively high in this industry. Second, we characterize products, markets and competition before WWI showing that the Swiss firms had some monopoly power in their product segments which could be exploited in case of cartelization. Third, we show that cartel formation is closely associated with a strong structural break, namely, a significant increase in foreign protection and subsidies. Finally, we provide arguments for the exact timing of the cartel agreement of 1918 and show that the rates of return were lower during the years following the cartel formation as compared to the pre-cartel period.

3.1. *Production, R&D and asset specificity*

The production of a textile dyestuff required a sequence of complex chemical reactions (e.g. nitration, reduction, oxidation) in various vessels. Many intermediate products were used and the dyestuff mixture had to be stirred, heated and cooled down according to an exact plan. The dyestuff was then either precipitated or salted out, filtered, washed and dried.⁹ Dangerous gases generated by the production process had to be collected or redirected into production. Each step of the production was performed and supervised by experienced workers and chemists. Minor deviations from the production plan could cause serious injuries, damages or make production worthless.

Product development was already a key activity in this industry. Beer (1964, p.138) argues that, by WWI, the dyestuff industry had already put in place a ‘modern industrial research laboratory.’ The production of dyestuffs required a long-term commitment to research in the firms’ own facilities without any guarantee of positive return (Haber, 1971, p.352; Hohenberg, 1967, p.91). For example, the German BASF’s effort to develop the synthetic Indigo took 18 years of research (Hohenberg, 1967, p.77) and Ciba’s development costs of an improved Indigo around 1908 were Sfr. 0.46 million, corresponding to about 10 percent of Ciba’s total equity value at the time (Jaquet, 1923, p.69).

⁹ Descriptions of this industry can be found in Haber (1958, 1971), Hohenberg (1967) or Weder (1995). Description of the technology can be found in Martin, 1915, p.27 and Haber, 1958, p.82.

The Swiss dyestuff industry focused on the top segment of vertically differentiated dyestuffs (see also Section 3.2). This implied that firms, more than others, were forced to upgrade existing products and abandon less sophisticated ones; each firm produced a few specialties in which it was technically a world leader (Haber, 1971, p.163; Hohenberg, 1967, pp. 7, 91). To achieve this, the firms even built small dyeing and printing facilities in order to tailor and test the dyestuffs before they were delivered to particular customers (Jaquet, 1923, p.9). In many cases, the production of each of these specialties required specific equipments (e.g. vessels made of a particular material and size) and supervision by chemists and workers with experience in the production of one particular dyestuff or class of dyestuffs (Jaquet, 1923, p.103). The introduction of new or technically improved dyes often called for significant changes in plants and equipments. In fact, firms employed technical designers and engineers just for this purpose (Wilhelm, 1934, p.34; Svenilson, 1954, p.162).

One consequence of the above description of the dyestuff industry is that production was subject to increasing returns to scale. Given the cylinder-shaped vessels and the necessary supervision of each batch of dyes by highly qualified people, input costs (material, human capital) were likely to increase less than proportionally with output. Moreover, firms had to carry considerable R&D activities in order to remain competitive. Thus, it is not surprising that the average dyestuff producer was relatively large.¹⁰

The critical question is, however, whether a significant share of investments was specific to the firms or to the industry. Several elements in the above description indicate that this was the case. Dyestuff production required specially designed equipments which could not be used for producing other chemical products, and sometimes for other types of dyestuffs. For some of the more sophisticated dyestuffs, vessels had to be plated with copper. Others required particularly solid vessels because of the pressure arising from certain chemical reactions. With the continuous invention of new processes and improved dyes, parts of the equipments had to be replaced. This, in turn, required significant installation costs as vessels were heavy, had to be bolted or even integrated to the floor and be connected to various pipes transporting steam, water, chemical products and gases (note that permanent staff was employed only for this purpose). These productive assets were clearly industry- and often firm-specific. This means that their value was greater than their opportunity cost. In addition, their value was enhanced by complementary capital (Gilbert, 1989) such as R&D, reputation for top of the line products (the dyeing and printing facilities to test products may be viewed as maintaining this reputation), and specific human capital essential to production.¹¹ In particular, R&D activities – which, according to Sutton (1991, p.7) can “be thought of as sunk costs” – avoided that capital wore out since, through the invention of new processes, they helped maintain the specificity of the productive assets through time.

The overall importance of specific assets in this industry is probably best appreciated by considering the capital structure of the Swiss dyestuff firms. The idea is based on

¹⁰ The Swiss chemical industry had three and four times as many employees per production plant as the average Swiss industrial plant in 1905 and 1929, respectively (see BFS, 1930, p.36).

¹¹ Dyestuff production has, for a long time, been described as ‘alchemy’ because its success depended heavily on the experience and knowledge of chemists and lab technicians trained by the firms who monitored the processes and who could not be replaced by even detailed recipes.

Table 1
Capital structure of the Swiss dyestuff producers relative to other industries

| Firms, industry | Debt/equity (1923, 1928, 1929) | Debt/equity (1911–1916) | Debt/total capital (1911–1916) | 'Redefined' debt/equity (1911–1916) |
|--------------------------------|-----------------------------------|----------------------------|-----------------------------------|--|
| Swiss chemical industry | 0.40 | na | na | na |
| Ciba | na | 0.55 | 0.18 | 0.42 |
| Swiss industrial sector | 0.58 | na | na | na |
| 130 firms of industrial sector | na | 0.67 | 0.30 | 0.48 |
| All Swiss industries | 0.85 | na | na | na |

na = figure not available.

Williamson (1988) who makes a convincing analogy between the determinants of vertical integration in production and those of the financial structure of the firm. Debt financing becomes increasingly costly the more specific assets are, just as vertical market arrangements become more costly with rising input specificity. As the liquidation value of specific assets is small, the debt holders' right to redeploy assets in case of mismanagement is less valuable. Debt holders, knowing this, require compensation. This makes debt to finance specific assets relatively more expensive than equity financing. Shleifer and Vishny (1992) extend this analysis to a general equilibrium setting by including the liquidity of potential buyers of industry-specific assets. Both articles predict that debt financing is relatively low and equity financing relatively high in those firms or industries characterized by highly specific assets and, thus, by high sunk costs.

Table 1 provides some indications about this hypothesis. The first column shows the average debt–equity ratio (i.e. bonds held by third parties divided by share capital) over 3 years (1923, 1928, 1929). We find that the ratio is 0.40 for the Swiss chemical industry which is below the average of the Swiss industrial sector (0.58) and more than half as low as the average for all Swiss industries (0.85). The second column shows the average of the same ratio over 7 years (1911–1916) for Ciba, one of the four dyestuff producers, and the average ratio for 130 firms in the Swiss manufacturing sector. With 0.55, Ciba's ratio is also below the average ratio of the 130 firms (0.67). Both findings support the view that debt financing was relatively small compared to equity financing in the Swiss dyestuff industry. They are, thus, compatible with the claim that the industry is characterized by relatively high sunk costs.

Note, however, that there is some limitation with this reasoning. For instance, the debt–equity ratio may be distorted by the fact that firms may not be financially constrained. In such a case, firms may use internal financing like retained earnings rather than equity to finance their specific investments. As it is difficult to determine whether an industry is financially constrained or not (see Fazzari et al., 1988), we have calculated the ratio of debt-to-total capital to take into account this possibility. The third column of Table 1 shows the result. Ciba's ratio (0.18) remains largely below the average ratio for the 130 firms in the Swiss industrial sector (0.30). Finally, we redefined debt by including items such as the firm's contribution to pension funds and, most importantly, credits implicitly provided by the suppliers of intermediates and raw materials. The latter arises from unpaid delivered material and is likely to be high in the dyestuff industry as the firms carry large inventories of these inputs. Nevertheless, the fourth column of Table 1 shows

that Ciba's ratio of redefined debt to total capital (0.42) remains below the corresponding average ratio of the 130 firms of the Swiss manufacturing sector (0.48).

Taken together, the above elements depict an industry characterized by high sunk costs: entry in this highly specialized industry required industry- and firm-specific capital which, in case of exit, would be unrecoverable to a large extent.¹²

3.2. *Products, markets and competition before WWI*

In 1913, Germany produced approximately 80 percent of the world consumption of textile dyestuff. Switzerland was the second most important producer and exporting country with a share of about 10 percent in dyestuff production. Despite this relatively low market share, Swiss firms had a dominant position in specialized, high-quality dyestuffs and faced a relatively inelastic demand. To make such an argument, the products should be differentiated.

One important dimension of differentiation between Swiss and rivals' products was vertical or quality differentiation. This is reflected by several indicators. First, experts agree that Swiss dyestuffs were more complex and better products. In particular, they were characterized by a much higher degree of fastness than that of their competitors.¹³ Second, this differentiation is reflected in the value of output per employee which was 3.3 times as high in the Swiss firms as in the German firms.¹⁴ Third, the differentiation is also supported by the higher average price of Swiss products as compared to rivals' products: the unit price of Swiss dyestuff exports was, depending on the time period, as much as 25–35 percent higher than that of German exports.¹⁵ This can only be possible if Swiss products occupied niche markets for which foreign products, particularly German dyes, were poor substitutes. In turn, this implies that Swiss firms faced a downward sloping demand curve and thus had some monopoly power in their particular product segments.

Also note that the Swiss firms were extremely dependent on foreign markets exporting at least 90 percent of their production and also importing a large part of intermediate products. Before WWI, Germany was the most important export market for finished Swiss dyes (see Table 2) and an important source country for intermediate and raw materials. Exports to the major six markets – Germany, US, UK, Italy, Japan, and France

¹² We also investigated – as suggested by Kessides (1990) and Worthington (1995) – whether there existed a rental market or a second-hand market for machines or equipment since the existence of such a market would go against the asset specificity hypothesis. We could not find any evidence of its existence and interviews with representatives of dyestuff producers implied that firms typically have not been renting or buying used equipment. We also attempted to determine the asset value of a liquidated firm which may provide some indication of the existence of sunk costs. Consider the case of the Basel dyestuff company Petersen & Cie, established in 1862, and sold to the 'Chemische Fabrik Schweizerhall' in 1911. A contemporary business report by the buyer indicates that the "main advantage of this purchase was the extremely good geographic location of Petersen & Cie which would provide interesting possibilities to enlarge the production plant of Chemische Fabrik Schweizerhall" (Chemische Fabrik Schweizerhall, 1915). The land had value, but not the plant. This case is compatible with a high degree of sunkness in Petersen's assets. Unfortunately, we cannot exclude the possibility that the physical assets of the firm may simply have depreciated because they were old.

¹³ That is, the colour did not become mate, pale or dull with time or when exposed to light. See Haber (1971, p.251), Hohenberg (1967, pp.42, 72), Jaquet (1923, p.103) and Svenilsson (1954, p.162).

¹⁴ This ratio is calculated from Hohenberg (1967, p.42).

¹⁵ The lower bound is an average of 4 years (1895, 1900, 1905, 1910) reported by Jaquet (1923, p.106); the upper bound refers to 1913 and is based on Haber (1971, p.163).

Table 2
Swiss dyestuff exports to major markets

| Year | Exports to (in 1000 Sfr., 1914 prices) | | | | | | | | | | Profit of Ciba (in 1000 Sfr., 1914 prices) | |
|------|--|---------|---------|-------------|--------------------|------------|------------------|-------------|------------|------------|---|--|
| | Germany 1 | UK 2 | US 3 | France 4 | Japan 5 | Italy 6 | Six markets 7 | Others 8 | Total 9 | Total 9 | | |
| 1910 | 6.334 | 3.663 | 4.417 | 1.139 | 1.770 | 1.922 | 19.244 | 7.629 | 26.873 | 1.763 | 1.763 | |
| 1911 | 6.177 | 3.344 | 4.517 | 1.165 | 975 ^a | 2.215 | 18.302 | 9.213 | 27.515 | 2.154 | 2.154 | |
| 1912 | 6.239 | 3.375 | 4.541 | 1.111 | 965 ^a | 2.231 | 18.462 | 9.444 | 27.906 | 2.252 | 2.252 | |
| 1913 | 5.943 | 3.379 | 4.598 | 923 | 1.723 | 2.180 | 18.746 | 10.526 | 29.273 | 2.433 | 2.433 | |
| 1914 | 4.620 | 6.764 | 6.314 | 1.168 | 1.357 | 2.303 | 22.526 | 9.095 | 31.621 | 2.889 | 2.889 | |
| 1915 | 356 | 13.349 | 4.396 | 2.020 | 270 | 3.457 | 23.847 | 3.277 | 27.124 | 5.950 | 5.950 | |
| 1916 | 0 | 19.400 | 7.584 | 5.200 | 712 | 4.184 | 37.080 | 6.058 | 43.138 | 5.710 | 5.710 | |
| 1917 | 0 | 22.219 | 9.723 | 11.892 | 1.364 | 4.740 | 49.937 | 7.143 | 57.081 | 9.001 | 9.001 | |
| 1918 | 0 | 16.652 | 5.655 | 12.662 | 1.933 | 4.983 | 41.886 | 6.169 | 48.055 | 6.884 | 6.884 | |
| 1919 | 0 | 16.625 | 6.741 | 13.404 | 2.344 | 6.565 | 45.678 | 15.512 | 61.191 | 4.752 | 4.752 | |
| 1920 | 0 | 28.135 | 7.359 | 21.997 | 2.042 | 4.844 | 64.378 | 29.776 | 94.154 | 1.855 | 1.855 | |
| 1921 | 54 | 5.483 | 5.655 | 6.683 | 1.516 ^a | 1.761 | 21.151 | 13.157 | 34.308 | 1.045 | 1.045 | |
| 1922 | 82 | 8.097 | 7.759 | 8.619 | 1.790 ^a | 1.308 | 27.654 | 14.631 | 42.285 | 2.802 | 2.802 | |
| 1923 | 140 | 5.903 | 3.610 | 6.735 | 2.310 ^a | 2.185 | 20.884 | 21.215 | 42.099 | 2.959 | 2.959 | |
| 1924 | 426 | 4.152 | 2.247 | 9.122 | 2.164 ^a | 2.108 | 20.220 | 20.108 | 40.328 | 2.159 | 2.159 | |
| 1925 | 1.992 | 3.653 | 4.846 | 6.715 | 1.582 ^a | 1.883 | 20.671 | 17.126 | 37.797 | 2.832 | 2.832 | |

^aEstimations.

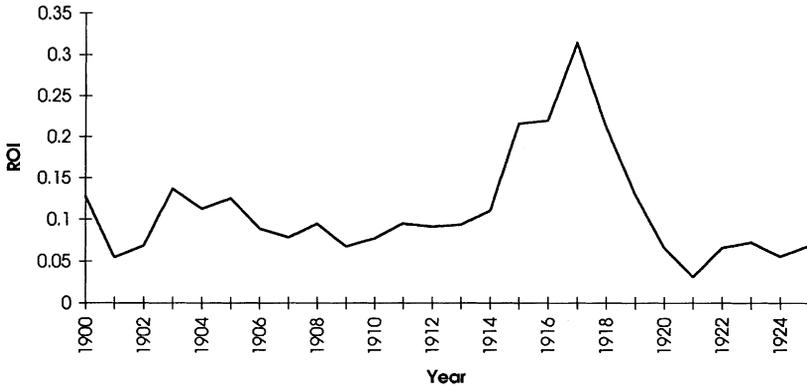


Fig. 2. Ciba's return on investment (1900–1925).

– represented 64 percent of total Swiss exports of dyes in 1913 (col. 7). Clearly, any major structural changes affecting exports to these countries must have had strong effects on the profit of Swiss producers.

Was there competition among the Swiss firms before the cartel formation? Three elements suggest that the industry can be characterized by a free-entry oligopoly before WWI. First, there were four firms in the industry in 1908 and this number remained constant before WWI. Second, Jaquet (1923) argues that profits were becoming very low around 1910 due to prices pushed down 'close to average costs' (p. 62). Third, Ciba's return on investment (ROI), measured as the ratio of profits after interest and taxes divided by total assets, sharply decreased from 1896 to 1905, becoming quite stable from 1906 onwards oscillating between 8 and 9 percent from 1906 to 1913 at an inflation rate of 2 percent (see Fig. 2).¹⁶ Thus, a stable period of 7 years, both in terms of the number of firms and real returns as well as relatively low real rates of return, suggests that the period from 1908 to 1913 can be regarded as a free-entry equilibrium consistent with non-cooperative behavior among firms and the oligopolistic structure of the industry.

3.3. Structural changes around the cartel formation

The outbreak of WWI marks the beginning of a major restructuring of the world dyestuff industry which, in many countries, resulted in replacing international trade by local production. The negative effect of this structural change on the Swiss dyestuff exporters was, however, postponed until the end of the war. Increasing foreign protection overlapped with an increase in foreign demand for Swiss dyestuffs during the war, mainly caused by the ban imposed by the Allies on imports from Germany. The overall result of these events was a scarcity of dyestuffs and a much higher profit for Swiss producers of dyes during the war followed by a sharp drop after WWI.

¹⁶ Ciba is the only company for which yearly business reports were available during the war and for which an ROI can be calculated.

As can be seen from Table 2, the period until 1917 is characterized by a large increase in Swiss exports despite the loss of the German market until 1921. The real value of exports of dyestuff almost doubled during the war from Sfr. 29.3 million in 1913 to Sfr. 57.1 million in 1917. The value of exports to the six traditional markets increased by 166 percent (col. 7). Even though the war also had negative effects on the Swiss exporters,¹⁷ the net result was a rise in profits for the Swiss dyestuff producers. The profits of Ciba, for example, increased by 270 percent from 1913 to 1917 in real terms (see Table 2, col. 10). A similar increase can be observed with respect to the company's ROI which rose from 9 percent in 1913 to 25 percent in 1917 (see Fig. 2). A revealing fact indicating that profits rose is the entry of two, albeit small firms during the war.¹⁸

There is no evidence that the Swiss firms colluded during WWI. The rise in the value of exports from 1914 to 1917 is, in part, due to an increase in the quantity of exports.¹⁹ Presumably, dyestuff prices also rose with costs of production and with foreign demand for Swiss dyestuffs. The absence of collusion is also supported by Jaquet who argues that during the war Swiss firms were overbidding each other for raw materials as well as undercutting each other's price of finished products. Moreover, the *Abteilung für Industrielle Kriegswirtschaft* (1925, p.175) states that the Swiss dyestuff firms remained independent even though the Swiss government 'repeatedly recommended some cooperation' during the war.

The post-war period brought drastic structural changes to the world dyestuff industry. Foreign demand for Swiss dyestuffs decreased sharply in 1921 stabilizing close to its pre-war level (Table 2).²⁰ This sharp fall in exports in 1921 was due to a dramatic increase in foreign protection following expansion of production in the former major six dyestuff importing countries (Table 3). A huge decline in dyestuff imports can be observed in the UK where total imports fell from 18,900 tons (1913) to 3,600 tons (1924), and in the US with a drop from 20,000 (1913) to 1,600 tons (1924). Table 3 shows that in five of the six export markets, import protection through tariffs and quantitative restraints rose considerably after the war.

Import substitution policies spread quickly among the major consumption markets. In the UK, the Dyestuff Import Regulation Act became law in 1921, prohibiting imports of dyes and intermediate products for 10 years except under licence (Haber, 1971, p.243). In the US, the government introduced the Dye and Chemical Act (1921) which prohibited imports of dyes except for varieties which were not produced domestically. These provisions were repealed by the Act of 1922 and replaced by a 60 percent ad valorem duty (plus 7 cents per pound) on dyestuffs (USTC, 1946, p.38). Tariffs protecting local dyestuff producers also increased in France, Italy and Japan.

¹⁷ Transport costs, prices of raw materials and intermediates as well as production costs rose sharply because Swiss firms had to build new facilities to process intermediate products that could no longer be imported from Germany after 1914; see Jaquet (1923, p.86 and Table 5) and *Abteilung für Industrielle Kriegswirtschaft* (1925, p.176).

¹⁸ Rohner & Cie. in 1915, and Stickelberger & Cie. in 1916; see Jaquet (1923, p.72) and Haber (1971).

¹⁹ This can be inferred from the considerable increase in the quantity of Swiss imports of raw materials and intermediate products for dyestuff production. The quantity of exports is not an accurate measure as dyestuffs were shipped in a much higher degree of concentration during WWI; see Jaquet (1923).

²⁰ Note that the value of exports in 1921 is influenced by the cartel behavior.

Table 3

Import and protection of major dyestuff consuming countries: before and after WWI

| Country | Import in 1000 tons | | | Tariffs (% = Ad valorem) | |
|---------|---------------------|------|------|--------------------------|--|
| | 1913 | 1924 | 1925 | Before WWI | After WWI |
| US | 20.0 | 1.6 | 2.6 | 20 | Import licensing system (1921) 60 plus 7 cents per lb. (1922) |
| UK | 18.9 | 3.6 | 2.0 | 0 | Very restrictive import licensing system (1921) |
| France | 2.1 | 2.4 | 1.5 | 65 | 103 (1926) ^a |
| Japan | 5.5 | 8.0 | 3.1 | 14 | 137 (1926) ^a |
| Italy | 7.1 | 2.7 | 2.2 | 0 | 65 (1926) ^a |
| Germany | na | na | na | 0 | Market reopened slowly in 1921 |

^a These years mark end points of a period of increasing tariffs (e.g. a major increase in protection took place in France in 1919). na=figure not available.

In addition, all major dyestuff importing countries began to subsidize their local infant industry (see Haber, 1971). For instance, the British government created the British Dyestuff Company in 1918, and, in 1916, the Italian government created the ‘*Industria Nazionale Colori di Anilina*.’ In France, the government set up an inter-ministerial council for dyes in 1916 and a group of industrial enterprises established the ‘*Syndicat National des Matières Colorantes*’ in 1916, followed by the creation of the ‘*Cie Nationale de Matières Colorantes*’ in 1917. In Japan, a law was passed granting subsidies to firms producing dyestuffs and owned or controlled by nationals. In 1915, the Tokyo Gas Co. supplied the first domestically produced aniline dyestuff.

These import substitution policies had strong adverse effects on the profit of Swiss producers of dyes after WWI. Table 2 (col. 10) tells the story for Ciba. In 1920, Ciba’s profits were 24 percent below their 1913 level, and, in 1921, they decreased even further since they were, in real terms, only 43 percent of their 1913 level. Observe also that the average profit for the period 1920–25 was below its level of 1913, even though Ciba was a member of the Swiss cartel since 1918. The same interpretation is supported by the evolution of Ciba’s ROI which remained below its pre-war level during the first half of the 1920s (see Fig. 2).²¹ We conclude that there is no evidence that Swiss firms colluded during the war, but there are clear indications that import substitution policies adopted in the traditional export markets created considerable scope for cartelization among Swiss firms in the post-war period.²²

²¹ It is also in line with the development of Ciba’s and Sandoz’ real share values which, on average, remained below their pre-war level during 1920–1925; see Fig. 3.

²² These policies led to large overcapacity in the world dyestuff industry (see Svennilson, 1954, p.162 and Haber, 1971, p.252). Based on the prediction of our model, it is not surprising that, by the mid-1920s, further cartelization of the dyestuff industry took place, ultimately leading to a cartel arrangement in 1930 controlling world trade of dyestuffs (Haber, 1971, p.276). Also note that, in 1916, the German firms had formed a cartel, the so-called ‘*Community of Interests*’ (see Haber, 1971, p.280). This may have helped the Swiss firms to create a cartel later on.

3.4. *Timing of the cartel*

If there was a clear scope for cartelization in the post-war period, especially from 1920, as compared to the pre-war period, why was the cartel agreement signed in late 1918? We want to argue that, by 1918, the dyestuff producers had signals telling them that the good times were over and that important structural changes were about to take place.

The immediate indications were a fall in exports to key markets and, more importantly, a decrease in profits. Foreign demand decreased for the first time since the outbreak of the war by 16 percent in real terms. Exports to the US – the second largest export market before the war – plunged by 25 percent. Exports to the UK – the third largest market before the war and the largest during the war – decreased by 6 percent in 1918. As for profits, Ciba's profits declined by 23 percent in real terms in 1918 (see Table 2, col. 10). These changes would mean little if they were simply cyclical. But they were not. Dyestuff producers could expect changes to be structural and more bad news would soon hit the industry.

The first of these signs was, of course, the end of WWI. The immediate implication for the Swiss producers would have been that German dyestuff producers would soon re-enter the world market. As the pre-war production capacity of Germany was large and apparently had not been reduced by the war, Swiss firms must have expected a considerable redistribution of market shares (see Haber, 1971, pp.253, 329).

Second, by 1918, signs of import-substitution policies and increasing protection abroad were clear. In the UK, a committee of the government recommended, in 1917, the creation of a British Dyestuff company and the introduction of a restrictive import licensing system.²³ The report was published at the beginning of 1918, and during the same year, the government established the British Dyestuff Corporation. In the United States, domestic pressures to increase protection grew considerably during the last years of the war. The Longworth Bill (1915), which would have increased the ad valorem tariff rate to 45 percent, failed to pass in 1916, but remained in discussion (Haber, 1971, p.187). Moreover, preparation took place between 1916–1918 to create the Dye Licensing Commission allowing imports of dyestuffs only if domestic supply did not meet the demand. This licensing system came into effect in 1921.²⁴

The minutes of the first meeting of the negotiations to establish the cartel indicate that negotiators had no doubt about these structural changes. The Ciba representative “pointed to the necessity to establish some close form of cooperation among the Basel dye factories, in order to successfully meet the competition from the established German firms as well as from the new producers in all countries (...) which would arise once normal circumstances return.”²⁵

²³ The first advice in the report was to “(...) coordinate the operations of the principal manufacturers (...).” The second one that “(...) the importation of foreign dyes should be prohibited except under licences to be issued by an independent authority, whose duty it would be, while fostering the growth and maintenance of the colour producing industry, to safeguard the interests of colour users (...).” (see Haber, 1971, p.241).

²⁴ See Jaquet, 1923, p.79. Note also that, in 1918, France formally denounced all treaties containing the most-favored-nation clause (see Pollard and Holmes, 1972, p.395) and increased tariffs on dyestuffs in 1919.

²⁵ Authors' translation of Ciba (1918a, p.1).

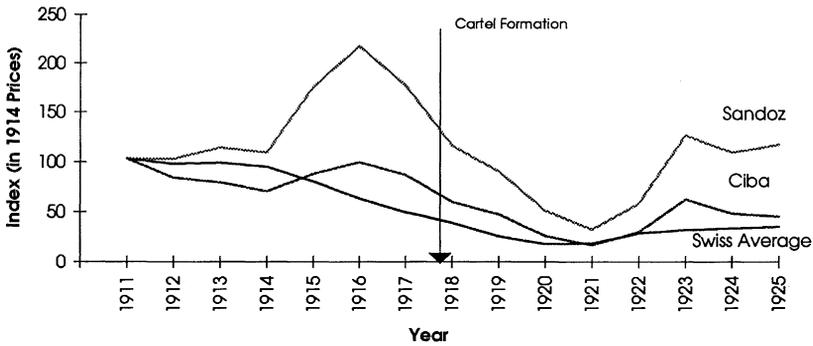


Fig. 3. Index of real share values (Sandoz, Ciba, Swiss average).

The market also seems to have anticipated negative structural changes as early as 1917. Fig. 3 shows yearly indices of real share values for Sandoz, Ciba and a Swiss index – consisting of 21 companies (including Ciba and Sandoz) – from 1911 to 1925. It indicates that the real share values of the two Swiss dyestuff producers began to drop in 1917, after a big hike at the beginning of the war, and declined both absolutely and relatively to the Swiss index until 1921. Thus, a fall in the real value of assets and profit of the Swiss dyestuff producers were already expected in 1917, several months before the cartel agreement was finalized.

Note that colluding firms must expect a shock strong enough not to attract entry. The evidence reviewed above suggests that rising protectionism in the six key export markets (representing 87 percent of Swiss exports in 1917), the expected re-entry of the German competitors, and the decline in exports to some of the main markets were strong signals that fed expectations of a major structural shift. The timing of the cartel formation is thus not inconsistent with information available in 1918. Ex post, this conclusion is supported by the fact that no entry or attempt of entry took place in 1919 and 1920 despite a temporary booming world demand for dyestuffs and that profits decreased significantly for four consecutive years from 1918 (see Table 2). We have also shown that, after the cartel formation, profits, asset returns and real share values were, on average, below their pre-war level (see Figs. 2 and 3). This is consistent with the prediction of the model.

4. Conclusions

In this paper, we have shown that entry and sunk costs can be important determinants of cartel formation. The basic argument is that structural changes leading to a reduction in expected profits provide scope for cartelization in industries characterized by sunk costs as they create a barrier to entry. Decrease in demand, rise in foreign protection or increase in costs are all examples of shocks which may trigger cooperative behavior among existing firms. Cartel formation is less likely when setup costs are small because established firms have little scope to change their behavior without attracting entry.

The predictions of the model are consistent with the dyestuff case. The formation of the Swiss dyestuff export cartel can be interpreted as a reaction to increased foreign protection and import substitution policies. As the industry is characterized by a high degree of asset specificity, scope for cartelization arose when firms expected a considerable decline in their profits at the end of WWI. Note that we would expect industries with low sunk costs to be unsuccessful in establishing a cartel even if they were faced with a similar structural change. This may have been the reason why the attempt by the Swiss watch industry to cartelize 10 years later was not successful until the government intervened and banned entry in 1934.

There are some interesting extensions of the analysis concerning the dyestuff cartel. In this paper, we have implicitly assumed that existing firms care more about entry in their market of production than in export markets. This may not be the case as foreign protection itself can induce entry abroad. An interesting issue is to analyze the role of the cartel in controlling entry abroad especially as Swiss producers established foreign subsidiaries after the cartel agreement of 1918.

How does this paper fit in the literature? Existing literature insists either on stability conditions or, like in the core theory, on entry. In the first literature, the number of firms is generally fixed and, in the second one, cheating is irrelevant since firms usually earn competitive returns even when they belong to a cartel. In our approach, firms earn pure profit despite free entry so that cheating cannot be excluded. Thus, our model explains the scope for collusion and, as such, it is complementary to other explanations about cartel stability and cartel formation.

How then to distinguish this explanation from competing ones? We have argued that the response of firms' profit to cartel formation can do just this. The core theory applied to the cartel predicts that firms earn a normal rate of return, after as well as before, cartel formation. If the tacit collusion literature is the relevant one (at least when applied to the case of the cartel) then models such as Rotemberg and Saloner (1986) predict that profit may rise or fall with cartel formation. Green and Porter (1984), and Haltiwanger and Harrington (1991) predict, however, that profit increases with cartel formation. Given that some empirical studies support Green and Porter's predictions (Slade, 1990) and, in addition, that Haltiwanger and Harrington's model can be interpreted as a generalization of Rotemberg and Saloner's model with a persistent phenomenon, there is a presumption that, in this literature, cartel formation is accompanied by an increase in firms' profit. Our model can then be distinguished from them as it predicts the converse: if entry and sunk costs matter, cartel formation is accompanied by a fall in firms' profit.

The picture which then emerges from the analysis is one where cartel formation can be explained by both cheating and entry/sunk cost arguments, and where change in profit following cartel formation may give us indications as to which force plays the key role. Our analysis is suggestive and requires additional research. The findings, however, might provide an explanation for Asch and Seneca's (1976) empirical results. Investigating U.S. manufacturing firms over the period 1958–1967, they found that collusive behavior is negatively associated with profitability and some evidence that unsatisfactory profit performance by firms provides an incentive to collude.

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Appendix

This appendix describes the data used in Tables 1, 2, 3 and Figs. 2 and 3.

Table 1

1. Columns 1 and 2 are defined as bonds ('capital des obligations') divided by share capital ('capital versé'). Column 3 is defined as bonds divided by total capital which is equal to the value of all assets. Debt in column 4 includes bonds, contributions to pension funds and mainly credits implicitly granted by suppliers of intermediate products ('créditeurs').
2. Data of rows 1, 3 and 5 are calculated from BFS (1930, p.118). Data of row 2 are calculated from Ciba's yearly company reports (Ciba, 1911–1917). Data of row 4 are calculated from BFS (1917, p.112).

Table 2

1. Columns 1 to 9 are adapted from BFS for the years 1911, 1912, and 1922–1925, and from Jaquet (1923, Tables II and III) for other years. Swiss inflation rates are adapted from Maddison (1982). The values for Japan – for years 1911, 1912, and 1921–1925 – are estimated based on Japan's share in Swiss exports to Asian countries in 1913 and 1920, respectively.
2. Column 10 is based on yearly company reports of Ciba (1912–1922), deflated by the inflation rates adapted from Maddison (1982). The values from 1912–1916 are company profits from July 1 of the preceding year to June 31 of the current year. In order to make the years 1917–1918 comparable, profits of 1917 have been calculated by (1) adding profits from July 1 (1916) to June 31 (1917) and from July 1 (1917) to December 31 (1917) and (2) by multiplying this amount by a factor of 0.66.

Table 3

1. Columns 1–3 are based on Svennilson (1954, p.164).
2. Columns 4 and 5 are collected from Haber (1971, p.238), Jaquet (1923), USTC (1917–1922), and from Pollard and Holmes (1972, p.395).

Fig. 2

1. The ROI (return on investment) is calculated and plotted based on company reports of Ciba (1900–1925). ROI is defined as net earnings (after taxes and interest) divided by total assets, taken from the balance sheet. Profits of 1917 have been calculated based on two company reports as the reporting period has been changed in 1917. See the description above with respect to Table 2, col. 10.

Fig. 3

1. The real share values of Ciba and Sandoz are calculated from nominal share values at the end of each year – except in 1914 where the stock exchange was closed from July to December – from ‘Kursblatt der Basler Boerse’ (found in the archive of the Basel Stock Exchange), deflated by the inflation rates adapted from Maddison (1982).
2. The Swiss index of real share values is composed of 21 Swiss companies and is adapted from BFS (1911–1925), deflated by inflation rates from Maddison (1982).

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