COOPERATION AS A PRICE STABILIZING MECHANISM IN MINERAL MARKETS

by

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Abstract

Typically, mineral markets are governed by boom and recession periods characterized by high price volatility. The extreme variability of prices, which causes a multiplicity of problems, for both producers and consumers, has encouraged a wide variety of studies of price stabilizing mechanisms. However, most of them have aimed at creating commodity buffer stocks between producers and consumers, with the UNCTAD's Integrated Program for Commodities during the decade of the seventies as the clearest example. The problem with this type of approaches is that they are more focused on setting prices on their mean values rather than on controlling their instability, which is precisely the target of price stabilization. The alternative view that I present explains how while allowing cooperation (explicitly or tacitly) among few large producers which pursue profit maximization in the presence of a sufficiently large competitive fringe, a price stabilization mechanism results as an outcome of this cooperative behavior. This can be illustrated by considering that during recession periods, each member's strategy should consist of either production cutbacks or stock holdbacks while in boom periods, the best strategy of firms should be an output expansion with the objective of restraining the entry of the competitive fringe. Consequently, a theoretical *trigger price* mechanism is derived, which is more likely to be successful than other previous stabilization mechanisms, as the preceding schemes do not consider profit maximization in order to keep low price volatility. As a matter of fact, many commodity buffer stocks have failed because this condition was not taken into account. Furthermore, I posit that the International Copper Cartel, which acted in the 1935-1939 period, used this type of mechanism in a successful way. Through an econometric model I show that this cartel engaged in cooperative behavior not only while facing recessions but also during booms. This behavior apparently did not damage social welfare but yet considerably reduced price volatility.

Introduction

In general, mineral prices present high volatility. The problems that arise in an industry in which prices are continuously experimenting booms and recessions affect both producers and consumers. In the case of producers, an extreme volatility makes mining planning more difficult from exploration to production (Lane, 1988). On the other hand, in

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the case of consumers this instability causes a high risk referred to input prices and therefore to future costs.

The structure of many mineral industries is oligopolistic, which means that a finite number of firms (two or more) compete in the market of a particular mineral. As Montero and Guzmán (2005) have described, there are many examples of industries which market is composed by few large firms (or *strategic firms*), and a large amount of small and non-influential firms (at least in what concerns to price formation), which are commonly denominated in economics as the *competitive fringe*. Even when this type of market structure and the competition that takes place among strategic firms has been studied in economic literature since early days (Arant, 1956), it is surprising that only recent studies have considered the effect of the competitive fringe as an important determinant rather than just modeling it through residual demand.

Interaction among strategic firms has been modeled through the Nash-Cournot equilibrium, in which each one of the firms chooses its level of production simultaneously to the others in every period, assuming that each one of the other firms is solving a similar problem. This obviously requires, besides rational behavior, complete knowledge (in the strictest sense) among the firms about their own cost structures and those of the other firms in the industry, as well as the way in which prices are formed. This may not always be a very realistic assumption, but it seems to be a good approach in cases such as copper and oil. As a matter of fact, Salant (1976) estimates production levels of the major world oil producers finding the equilibrium through this technique. When firms in a market choose production levels according to the Nash-Cournot equilibrium we say that they are competing in a strict or unilateral way.[2]

The problem with competition *à la* Nash-Cournot is that it originates what is known in game theory as the *prisoner's dilemma*, which affects producers. To understand in a better way how this occurs in mineral markets, copper is a good example. Until the year 2001 firms were reluctant to lowering prices in this market and acted by individually increasing their production levels due to the economies of scale that were achieved this way. Apparently, there seemed nothing wrong with this competitive strategy (in spite of the biggest investment that was needed to create a larger capacity); but if each firm in the market or a considerable portion of them had behaved in this *rational* way, the market would be nowadays saturated with copper. Regarding price, this behavior would have made them fall even more, which would have made firms respond again with increments in their capacities and this way *ad infinitum*.[3] Finally, the most efficient firms would have been the only ones achieving a *pyrrhic victory* with this type of strategic behavior. Hence, the natural question is whether there exists any possibility for firm to achieve equilibrium in a different way. In a world in which firms can only choose their levels of production initially, it may be demonstrated by using a game theory approach that the only possible production

[2] Although one should not confuse this type of competition with *perfect competition*, in which none of the firms has enough market share in order to influence price.
[3] Strictly speaking, there exists a limit to this policy. Firms could invest in higher capacity only if its net present value is at least the minimum required for the company.

levels are, in fact, those of the Nash-Cournot equilibrium. However, when firms have the possibility of choosing their production levels every period (i.e. every quarter or year), which is more appropriate for mineral markets, they can reach cooperative agreements that report them greater profits.

Cooperation has been widely studied in the economic theory. Cooperation models in mineral commodities industries had their highest peak during the seventies, partly due to the 1973 oil embargo driven by some of the OPEC members, and mainly due to the cartelization impulse that arose in later periods to this punctual event (which lasted six months). In this way, the CIPEC (in the case of copper) and the IBA (in the case of bauxite) made intents (most of which ended up failing), to exercise a market power that they supposedly had. Classic examples of cartels in mineral markets have been pointed out by Van Duyne (1975), Pindyck (1979) and Labys (1980a), among others.

In this paper the word cooperation is used instead of *collusion* as they do not have the same meaning. Collusion, according to the Oxford Dictionary means "*Secret agreement especially in order to do sth dishonest or to deceive people*". For anti-trust agencies watching for consumer' interests, all acts of market cartelization (explicit or tacit) are considered collusion because the popular belief (also supported by the economic theory) is that, without ambiguity, it harms consumers due to the increase in prices (Kinghorn and Nielsen, 2004). This grants collusion, the qualification of illicit behavior according to these institutions, even though it is allowed among countries in some cases (with the eleven countries that conform the OPEC as the clearest example). Nevertheless, Montero and Guzmán (2005) have recently shown that in markets in which producers compete in quantities and under the presence of a sufficiently large competitive fringe (both of these being common characteristics of many mineral markets), it is possible that cooperation within a group of strategic firms bears a higher surplus for consumers than in the case where cooperation does not take place (although it diminishes the surplus obtained by producers in the competitive fringe). Under these circumstances the word collusion should not be applied as this action does not necessarily constitute illegitimacy for anti-trust commissions.

It seems then that any coordinated intent of production in mineral industries is more of the cooperative than of the collusive type. However, this rests in two strong assumptions that not all of these industries satisfy. On the one hand, the key issue is that this result is a characteristic of competition in quantities. For some minerals, such as iron or lithium, the strategic variable of producers is price rather than production. Just as Montero and Guzmán (2005) have show in markets where producers compete in prices, cooperation is also collusion; this is, it damages consumer surplus because it necessarily bears (as much in recessions as in booms) a higher price. On the other hand, it requires the competitive fringe to be sufficiently *large*. For example, Montero and Guzmán (2005) find for a series of simple assumptions that 50% is enough for cooperation to lead to periods of expansions of supply. In the case of silver for instance, in which the four largest firms hardly accounted for a 24.1% of the market in 2003 (considering controlled output) there is no doubt that the competitive fringe was sufficiently large for the latter to occur; the increase in output would not have only redounded in an increase in the firm's profits but in a larger consumer's surplus as well. However, in the case of platinum, where the four largest firms accounted for an 89.7% of the market in 2003, the competitive fringe seemed to be not large enough in order to avoid damaging consumers.

Furthermore, Montero and Guzmán (2005) showed that cooperation in periods of booms is not determined by production cutbacks of large firms. On the contrary, it is determined by an increase in production with respect to the case in absence of cooperation, this is, in the Nash-Cournot equilibrium. The reason of this surprising result is that in periods of booms large companies' profits may increase if they are able to coordinate (explicitly or tacitly) in order to increase their production so as to limit competitive fringe's expansion. Although this additional production makes the price fall even below what would be observed under other circumstances, the increase in output and consequent limit in the expansion of the competitive fringe (and therefore of higher production costs firms), largely compensates for the fall in prices.

Therefore, it seems that cooperation could be used as a price stabilizing mechanism. Commodity price stabilization through stocks is not new in literature and in reality[4], but this proposal is new because all the previous price stabilization mechanisms are referred to common stocks, whose objective function is precisely fixing mean prices or floor-ceiling ranges for them. In this paper, a price stabilization mechanism is derived as an outcome of a profit maximization strategy. Particularly I obtain a *trigger price* mechanism, which may be used by cooperative firms to regulate their productions in order to maximize their profits, and leading price stabilization as a secondary effect.

It is necessary to mention that the main difference between the purpose of this stabilization mechanism and the previous ones is that would be more successful as it rests in the individual *rational* behavior of each firm. Precisely, the failure of many of these mechanisms was related to the existing conflict of interests between an independent agency trying to stabilize prices and the profit maximization objective of each firm. A classical example of failure in mineral agreements is the collapse of the International Tin Agreement (Anderson and Gilbert, 1988), in which consumers' interests were clearly opposite to those of producers. On the other hand, the *trigger price mechanism* here derived does not present the problem of conflict of interests because only a single group (the cooperating firms), manages their outputs having maximization of profits as their mere objective.

Surprisingly, this *trigger price* structure has been used a couple of times before. Specifically in the International Copper Cartel, ICC, formed in the four previous years to World War II. This cartel operated by production cutbacks during recessions, by means of individual stocks holdbacks and physical cutbacks, and expanding the output in booms, either through their own stocks or through the exploitation of their richer grade ores. To implement this mechanism, the cartel established a *pivotal* or *trigger price*. For prices lower than the latter, cutbacks were assumed to have taken place while the opposite occurred for higher prices.

However, Herfindahl (1959) argues that the ICC was only cooperating during recessions, except that all export restrictions were eliminated when the price was higher

[4] See Labys (1980a) for a survey.

than the trigger price. This *trigger price* strategy led to higher prices during recessions, but not to lower prices during booms, thus negatively affecting social welfare. With the use of an econometric model I posit that cooperation of the ICC members would have equally worked in recessions as in booms, making Montero and Guzmán's (2005), that cooperation occurred as an all-period strategy, hypothesis more likely than Herfindahl's (1959). Moreover, the econometric model indicates that the supply elasticity of the cartel would have been even higher in booms than in recessions, which would be an indication of a welfare-enhancing policy.

In the next section, I derive a theoretical *trigger price* mechanism of price stabilization, using the results by Montero and Guzmán (2005). Using the econometric model as a back up, I subsequently reveal the ICC behavior. In the last section of this article I present some important conclusions and delineate areas for future research.

2 Cooperation as a price stabilizing mechanism

By reviewing all the existing studies in the economic literature, one will find that the answer to the question of whether collusion among a group of strategic actors can lead to lower prices is unequivocally one: No. Cooperation has always been associated to production cutbacks and rises in prices that are translated in welfare losses, an effect that is completely absorbed by consumers. However, Montero and Guzmán (2005) have shown that the latter is not necessarily true, particularly in many mineral industries. They consider a reduced number[5] of companies of relatively large size and many small sized companies producing a certain mineral. As in Montero and Guzmán (2005), large companies will be referred to as large actors or *strategic firms* and the group of small companies, as the *competitive fringe*. In every period (i.e. quarter or year), companies decide on their quantities or production volumes. These quantities are *added* in a metal exchange market or other similar clearing price mechanism, and its interaction with the demand of that particular period clears up the equilibrium price.

The resultant market equilibrium is known in the economic literature as the Nash-Cournot (or simply Cournot) equilibrium. It is a static non-cooperative equilibrium in the sense that in each period, each company decides on its production volume in a unilateral way, but taking into account the actions of the others firms. Companies are under a Nash-Cournot equilibrium when none of the companies wish to change their production levels if the others keep their outputs unchanged. Thus, the Nash-Cournot equilibrium is built on the premise that strategic firms compete in today's market without taking into account the fact that they will be competing again in the future and this, taking place in a recurrent fashion. This repeated interaction in the market among a group of companies is known as dynamic competition in industrial organization. Although the Nash-Cournot equilibrium continues to be valid as feasible market equilibrium, the repeated interaction allows the existence of other less competitive outcomes (Friedman, 1971). I will refer to these other equilibriums as cooperative (and not collusive) equilibriums, since they do not necessarily imply, as it was mentioned in the introduction, an undermining of the consumers' welfare.

[5]A reduced number means a quantity not greater than ten.

It is important to understand that these cooperative agreements are not necessarily explicit under the shape of a cartel, but rather in many cases tacit, which means that they occur exclusively under the interaction between firms in the market. One should notice that this is not solely derived from informal conversations among strategic firms but it may also arise from market conditions such as those present in the copper market during the 1999-2003 period, in which the announcements of production cutbacks by a certain firm triggered others to perform similar statements.[6] On the other hand, the largest copper companies publicly requested other efficient producers to increase their investment in new capacity in order to lower current prices of copper. These prices do not only threaten the most efficient firms with the entrance of inefficient mines, but they also diminish the competitiveness of copper in comparison to other metals, such as aluminum, therefore increasing the risk of substitution.

The latter results are consistent with those of Montero and Guzmán (2005) which indicate that during booming years the best cooperative strategy for agents is to expand their production levels beyond those that would be observed in a competitive environment (Nash-Cournot). This can be explained by considering that the actors belonging to the competitive fringe are less efficient when its size is sufficiently large.[7] When this happens, the increase in production levels (with respect to the Nash-Cournot level) largely compensates the fall in prices. In other words, it is favorable for the strategic group to implement a coordinated expansion of production in order to interrupt the growth of the competitive fringe during a boom. It is important to point out that this expansion is a combined effort and not the optimal response (in the Nash-Cournot sense) of each firm to a growth in demand.

In contrast to Montero and Guzmán (2005), this research considers that a perfect and fluid monitoring of the market exists, which means that all possible cheating carried out by a firm is immediately detected.[8] Thus, there is no possibility for a firm to deviate from its behavior and the cartel's stability will therefore not be considered a major concern. Consequently, the arising question is in which way may a cooperative agreement among large firms be implemented? One possible strategy derived from Montero and Guzmán (2005) is to congregate the members about a cooperation mechanism with trigger or pivotal prices. In this way, when the market price is under a certain minimum price P^L, the cartel could assume that a recession of demand is taking place and reduce its output interrupting the decline in prices and thus exercising its classical principle in the cartel theory. On the other hand, while prices do not exceed a certain level P^H (with $P^H \geq P^L$), after which a boom in demand is considered to take place, it is possible to suppose an expansion strategy with the objective of restraining the entry of the competitive fringe; the latter, now facing higher prices and ready to invest in new capacity and begin operating new mines. In

[6] Some of these firms performed production cutbacks while others announced stock holdbacks until certain inventory levels were achieved in worldwide exchange.
[7] This condition is generally satisfied in many mineral industries as a corollary of a small market share, due to the existence of economies of scale (Crowson, 2003).
[8] This assumption is particularly true in the case of the ICC, which regulated trade practices of its members by means of a daily price-reporting system.

Montero and Guzmán (2005) it is assumed that $P^H = P^L$, however two different levels of prices seem to be a more general scenario.[9]

Let us consider *N* strategic firms that are cooperating in a mineral market of a good which may be perfectly substitutive, with the same discount factor given by δ for each one of them. At the beginning of each period, firms (either the strategic ones or those belonging to the competitive fringe) must decide on their output levels and prices are cleared in the market. Let us also assume that this quantity setting is repeated infinitely.[10] The mineral commodity's price is given by the inverse demand function $P(\theta, Q, \chi) = \theta P(Q, \chi)$, where $D_Q P(Q, \chi) \leq 0$ and $\theta \in \left[\underline{\theta}, \overline{\theta}\right]$ represent a random shock with an accumulated probability function given by $F(\theta)$ (with $\underline{\theta} < \overline{\theta}$). χ represents other relevant variables such as dummy or income variables which are assumed to be deterministic in order to simplify the analysis.[11] It is also assumed that the past prices are known by all the actors, previous to each *i*th- firm's decision to produce a quantity equal to q_i at the beginning of every period. Consequently, a Markov strategy is constructed by using the trigger prices (P^L and P^H). The net present value of the cartel cooperating in output cutbacks during recessions is given by V and the net present value during booms is given by W. On the other hand, π^C and π^E are the cartel's profits during recessions (when the members diminish theirs sales physically or through inventory) and during booming periods respectively.[12] Due to the mentioned cooperation structure, these variables solve the following system:

$$\begin{aligned} V &= \pi^C + \delta \Pr\left\{\theta P^C(Q,\chi) \leq P^H\right\} V + \delta \Pr\left\{\theta P^C(Q,\chi) > P^H\right\} W \\ W &= \pi^E + \delta \Pr\left\{\theta P^E(Q,\chi) \leq P^L\right\} V + \delta \Pr\left\{\theta P^E(Q,\chi) > P^L\right\} W \end{aligned} \qquad (1)$$

Solving (1) with respect to V and W and using the accumulated probability function of θ, we thus find the following expressions for these variables:

$$\begin{aligned} V &= \frac{\left(1-\delta\left[1-F\left(P^L/P^E\right)\right]\right)\pi^C + \delta\left[1-F\left(P^H/P^C\right)\right]\pi^E}{(1-\delta)\left[1+\delta\left(F\left(P^L/P^E\right)-F\left(P^H/P^C\right)\right)\right]} \\ W &= \frac{\delta F\left(P^L/P^E\right)\pi^C + \left(1-\delta F\left(P^H/P^C\right)\right)\pi^E}{(1-\delta)\left[1+\delta\left(F\left(P^L/P^E\right)-F\left(P^H/P^C\right)\right)\right]} \end{aligned} \qquad (2)$$

[9] As shown in the next section, there also exists evidence of one cartel operating with this two-trigger prices mechanism.

[10] In a strict sense, we only need that every cooperating firm expects to remain in the market during a finite time horizon.

[11] As a matter of fact, this could be extended into a more general model that takes χ as a vector of random variables.

[12] To see how these profits are derived, the reader should consult Montero and Guzmán (2005). Basically, they include the competitive fringe reaction in the cartel maximization problem.

Thus, the Markovian Perfect Equilibrium[13] (MPE) is a strategy that guarantees that both stages are credible (i.e., a Sub-game Perfect Equilibrium). The minimum and maximum trigger prices ($P^{L,*}$ and $P^{H,*}$ respectively) could be obtained by calculating the first derivatives of the net present values with respect to these prices and setting them equal to zero:

$$\frac{\partial V}{\partial P^H} = 0 \qquad \frac{\partial W}{\partial P^L} = 0 \tag{3}$$

Figure 1 shows the trigger prices strategy described earlier. The continuous, narrow line shows the non-cartel (Nash-Cournot) equilibrium price whereas the classical cartel scenario (in which a large portion of the producers are colluded) is shown by the dotted line. As it may be seen, prices are always higher than those in the non-cartel scenario. As a result of collusion, price is stabilized in higher levels (Pindyck, 1979). Nevertheless, under the presence of a sufficiently large competitive fringe, the trigger price strategy derived in (3) does not only result in a less volatile price (which is shown with a continuous and thicker line) but also in an average price which is in the neighborhood of the non-cartel one. On the other hand, it is important to notice that a one trigger price strategy may be defined, where $P^L = P^H$ as a particular case of the trigger price mechanism here derived.

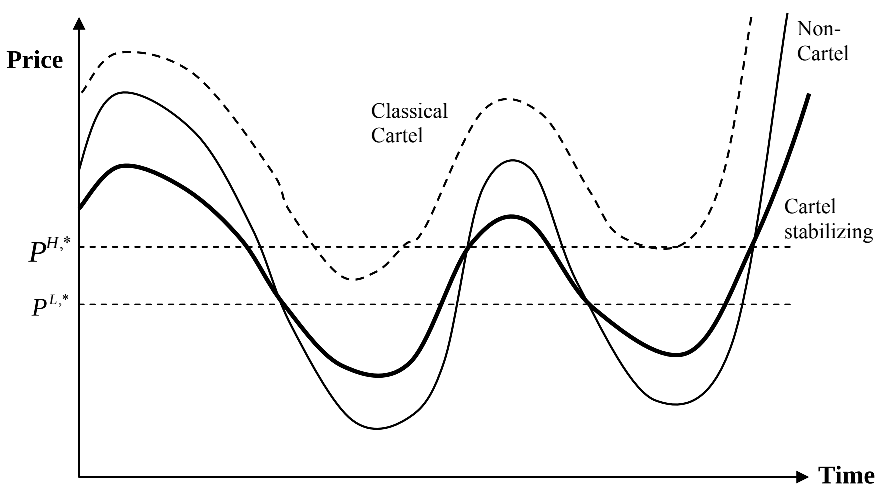

Figure 1. Trigger prices as a price stabilizing mechanism

In summary, during recessions firms belonging to the cartel will collude through production cutbacks until a certain maximum or boom trigger price is reached, while during booms, they will collude through expansions of their production levels until a minimum or recession trigger price is achieved. Indeed, when firms are able to sustain this cooperative profile the result will necessarily drive to a decrease of price volatility and could even lead

[13] The Markov Perfect Equilibrium is a profile of Markov strategies that yields Nash equilibrium in every proper subgame. For a detailed description of the MPE, see chapter 13 in Fudenberg and Tirole (1991).

to an increase of social welfare (with the condition that the decrease in prices during booms exceeds the increments in prices during recessions). This is a theoretical possibility that requires an empirical contrast for each mineral industry despite seeming feasible given the current structure of many mineral markets.

3 Evidence of the theory: International Copper Cartel, 1935-1939

The varied difficulties experienced by the copper industry after the depths of the Great Depression were followed by the idea of getting relief through some form of collective action in order to reduce the intensity of competition. In this way on March, 28th, 1935, the International Copper Cartel was formed. There were five members in the cartel and two *friendly* foreign subsidiaries. The voting members were: Anaconda, Kennecott, Roan Antilope (Mufulira), Rhokana (Rhodesia) and Katanga, while the non voting members were Bor (Yugoslavia) and Rio Tinto (Spain).[14] All these account for more than half of the refining copper market. The main difference between this and the previous copper cartels[15] is that the ICC members did not want to set uniform prices. Rather, they merely wanted to influence prices indirectly and *smooth out* wide price fluctuations (Walter, 1944). It is interesting to note that the ICC was never reproached for charging exorbitant prices, as opposite as what had happened with the previous cartels. Indeed, in Herfindahl's opinion the cartel did not have any significant effect on price.

Herfindahl (1959) posit that the operation of the ICC was similar to that described in the previous section but in this case the cartel members returned to the Nash-Cournot competition once the pivotal or trigger price was exceeded. There is enough information to think that this was not true on this occasion. Conversely, the cooperative behavior continued in booms, as Montero and Guzmán (2005) have postulated, based on partial information obtained from newspapers and on a numerical model. Moreover, Montero and Guzmán (2005) suggested as a future topics of research to determine whether the International Copper Cartel's behavior would have been cooperative during booms as much as it would have been during recessions by means of an econometric model. The following is a first and initial approach to the problem, although the lack of relevant data cannot make it a totally satisfactory analysis. However, the results indicate that Montero and Guzmán's hypothesis (2005) is better sustained than that of Herfindahl (1959).

As Montero and Guzmán (2005) have shown, it seems that the ICC behaved as a price stabilizer in the search of own profits, reducing its exports during recessions and increasing them during booms. To implement this stabilizing mechanism, the cartel used a flexible production criteria and a storage policy, besides a single-trigger price of 10 cents a

[14] A thorough study of this cartel may be found in Walters (1944), Hexner (1946) and Herfindahl (1959).

[15] The first copper cartel to set prices is recognized to have done so in 1548 (Walters, 1944). In Herfindahl (1959) at least two previous cartels were identified: The Copper Export Association (1918-1923) and the Copper Exports Inc. (1926-1932). The latter controlled nearly an 85% of the world primary refined copper, and it was accused many times of price fixing policies. In this case, however, the competitive fringe appears too small to allow output expansions or even the use of some trigger price strategy. Simply, whichever business cycle the industry was at, the CEI acted as expected, causing a rise in prices.

pound.[16] Under recessions, the cartel members stocked copper and exploited lower grade ores to reduce their exports, while during booms the cartel members sold their stocks and exploited richer grades ores. This kind of policy during booms was possible due to the excess of smelter and refining capacity after the Great Depression. On the other hand, there is no evidence of an agreement between members to limit increases in their own capacity, although it was expected at the outset that such settlement could be attained (Herfindahl, 1959). This is relevant to understand the large expansions that occurred during booms, which could not have been possible if capacity constraints had existed.

Tilton (1992) shows that in perfect competition the supply elasticity of the mineral industries is a decreasing function of price. It is not difficult to show that under an oligopolistic market structure this continues to be true. However, in the case of a cartel this is not necessarily correct and the inverse may be true according to Montero and Guzmán (2005)'s hypothesis. In the upcoming part an econometric model is used with the objective of testing whether the ICC elasticity of supply was lower or higher when the price was above the trigger price used by the cartel.

The data was extracted from Table 4 of Herfindahl (1959, page 118) and consists of monthly information, between July 1935 to July 1939; it corresponds to the cartel's market share of the world's copper production MS_t and the average monthly London Metal Exchange spot prices P_t.[17] Information about quota states which were defined under trigger prices is included in this table as well. A total of 49 observations were used.

It would be ideal to test Herfindahl's (1959) or Montero and Guzmán's hypothesis (2005) using outputs rather than participations in the scenarios where the cartel was present and where it was not. Unfortunately this information was not available. However, Walters (1944) observed that the competitive fringe's elasticities were very low and did not vary significantly during the period.[18] Therefore the ratio of the cartel's production levels to that of the competitive fringe, $\lambda_t = MS_t / \left(1 - MS_t\right)$, seems to be a good proxy for the variation in the cartel's production level. Consequently, and assuming that the competitive fringe was in fact competitive (which seems reasonable), this ratio would depend mainly on the cartel's elasticity rather than on the difference between the cartel's and the competitive fringe's elasticties. Similarly, $Q_{ICC} = P^{\varepsilon_{ICC}} f_{ICC}\left(\Theta\right)$ and $Q_F = P^{\varepsilon_F} f_F\left(\Theta\right)$ are the ICC's and the competitive fringe's production levels respectively, ε_{ICC} and ε_F are the ICC's and the competitive fringe's elasticities in that order, and Θ is the vector of other relevant variables. Hence, $\lambda = Q_{ICC} / Q_F = P^{\varepsilon_\lambda} g\left(\Theta\right)$, where $\varepsilon_\lambda = \varepsilon_{ICC} - \varepsilon_F \approx \varepsilon_{ICC}$ (due to footnote 18). We are interested in testing whether the ICC's behavior was different in recessions than in booms, and if this case is true, whether the cartel's elasticity during booms was lower than during recessions as Herfindahl suggests. With this in mind, two econometric

[16] Estimated as 138 cents per pound (in 2004 dollars) using the CPI deflator (US Department of Labor, 2006).
[17] The price was not deflated for two reasons. In first place, the monthly deflators are not reliable for the analyzed period, and in second place, the cartel's policy regarding trigger price was nominal.
[18] Although Herfindahl (1959) questions this affirmation, he shows that the elasticity of the competitive fringe with respect to the ICC was very low during the mentioned period.

models are developed. The first one, assuming that λ_t depends on price but allowing the existence of different elasticities during recessions and booms. Due to the nature of this assumption this model is referred to as unrestricted. The second one is modeled assuming that the elasticity is the same in both stages of demand, which is referenced as the restricted model.

Among the other relevant variables to be included in the econometric models, D_t represents a dummy variable that captures the quota status of the cartel, which is equal to 1 if the price is higher than 10 cents a pound in month *t* and 0 if it is not. On the other hand, a lagged accumulated contraction period ACP_t (equal to the amount of periods in which the cartel is under a quota status) is included in order to test for the natural pressure against maintaining a production cutback scenario through a number of periods. A lag in the dependent variable λ_t is also included due to the property of inertia of the ratio.[19] Finally, an unrestricted log-linear model which assumes elasticities to remain constant is defined by:

$$Ln(\lambda_t) = \alpha_0 + \alpha_1 Ln(P_t)(1 - D_t) + \alpha_2 Ln(P_t) D_t + \alpha_3 ACP_{t-1} + \alpha_4 Ln(\lambda_{t-1}) + \varepsilon_t \qquad (4)$$

, while the restricted model is given by:

$$Ln(\lambda_t) = \beta_0 + \beta_1 Ln(P_t) + \beta_2 ACP_{t-1} + \beta_3 Ln(\lambda_{t-1}) + \varepsilon_t \qquad (5)$$

The results of the parameters estimation are shown in Table 1. It was estimated by OLS because the independent variables in both equations are not clearly dependent of the ratio λ_t. Nevertheless, if this were not the case, a 2SLS estimation would not be very useful as both methods would be biased and consistency (in the case of 2SLS) would not make sense with only 49 observations.

Many implications arise from Table 1. In first place, whether model (4) or model (5) is being used, there exists a pressure to expand output when the accumulated contraction period increases. A test to prove that $\alpha_1 > \alpha_2$ may be rejected at an 85% confidence level [20] (using a one-tail t-Student test), and while being Herfindahl's hypothesis rather weak, the unrestricted model is statistically different to the restricted one and the relevant statistics (Adjusted R-squared, Durbin-Watson statistic or Schwarz criterion) are all unambiguously favorable to the unrestricted model, even though multicolinearity is present. As a matter of fact, at a 95% confidence level we may reject the null hypothesis $\alpha_1 = \alpha_2$.[21] This is important as it further sustains the hypothesis of a cooperative behaviour under strong demand.

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[19] A partial adjustment model could justify the incorporation of this variable.

[20] The calculated t-value was 1.033.

[21] The F-value for the hypothesis $\alpha_1 = \alpha_2$ is equal to 5.88, while the $F(1, 43)$ table value at 5% significance level is 4.07. Strictly speaking, it can be rejected at the 98% confidence level.

On the other hand, whichever model is used (restricted or unrestricted) the elasticity of price with respect to λ_t is high enough, especially if we compare it with the standard supply elasticity of the copper industry (approximately 0.1). This reinforces the hypothesis that the members of the cartel acted in a cooperative way when prices were above 10 cents a pound, as Montero and Guzmán (2005) have already posited.

Table 1. OLS estimation of the ratio between the cartel's and the competitive fringe's output

	Unrestricted Model	**Restricted Model**
α_0, β_0		
Coefficient	-0.3750	-1.0041
Std. Error	0.3815	0.2947
β_1		
Coefficient	-	0.5363
Std. Error	-	0.1447
α_1		
Coefficient	0.2493	-
Std. Error	0.1813	-
α_2		
Coefficient	0.3061	-
Std. Error	0.1670	-
α_3, β_2		
Coefficient	0.0077	0.0056
Std. Error	0.0031	0.0031
α_4, β_3		
Coefficient	0.4286	0.4532
Std. Error	0.1257	0.1321
Adjusted R-squared	0.70	0.67
Durbin-Watson statistic	2.03	2.06
Schwarz criterion	-1.44	-1.40

As a matter of fact, Montero and Guzmán (2005) have shown by using a numerical simulation that the cartel managed to sustain a mean price of 10.4 cents a pound. Had the agreement not taken place (this is, if all firms had been competing among them *à la* Nash-Cournot), a price of barely 10.3 cents a pound would have been achieved; this means that only a 1% increase in prices would have occurred. However, a simple calculation based upon the data presented in Table 2 of Montero and Guzmán (2005) shows that in the scenario in which the cartel was operating, the reduction in the standard deviation of the price (which may be considered as a possible measure of volatility) was almost 34% below than in the case where cartels did not act. Taking into account that consumers that use copper as an input face increasing marginal costs, a one percent decrease in the price of copper during booms is more beneficial to them than a one percent increase during recessions. With this latter argument having been said, it may well be that the copper cartel of 1935-1939 did not have a negative impact on welfare but that the opposite was true.

Finally, one might say that the ICC is an example of a single-trigger price mechanism to stabilize prices which is not exceptional in mineral markets. There is evidence of a two-trigger price mechanism, as the one derived here even though there is no data to test this statement. This case corresponds to the International Zinc Syndicate, which controlled zinc and lead world output before World War II and which created a lead cartel based upon this type of two-trigger prices strategy. If prices in the London Metal Exchange were below £15 during 20 consecutives days, members would reduce their exports by 5 %. Only when prices went over £16 or £17 the cartel members would sell their surpluses, acting so as price stabilizers (Hexner, 1946).

4 Implications and future research

Typically, mineral markets are governed by boom and recession periods that are at the same time characterized by high price volatility. The problems of this irregular behavior in prices are varied and not easy to solve for both producers and consumers. This has encouraged a wide variety of studies of price stabilizing mechanisms. However, most of them have been aimed at creating a commodity buffer stock between producers and consumers, which have failed in most of the cases mainly due to the misalignment of interests between stabilizing prices and maximizing profits.

Montero and Guzmán (2005) have shown that when competition occurs upon quantities and under the presence of a sufficiently large competitive fringe, welfare is not necessarily damaged in a cooperative setting (as compared to the Nash-Cournot or non-cooperative equilibrium). The authors also demonstrate that while during recessions affecting demand, cooperation of strategic firms necessarily implies a reduction of supply and an increment of prices (in comparison to that of the Nash-Cournot equilibrium), during booms cooperation among them leads to an increase in their production levels beyond of what they would have been if they had acted individually. In this way firms achieve a market participation that would otherwise be taken by the competitive fringe's production (either due to the expansion of existing projects or to the creation of new capacity). Consequently, strategic firms increase their profits by compensating the lower prices that these policies bring about with a higher production level and finally increasing consumers' surplus. Following this, an anti-trust agency would only be willing to allow cooperation during booms but not aware of the fact that cooperation in these circumstances is exercised at even a higher level when firms cooperate during recessions. Consumers can therefore be better off (in average) in a cooperative environment at every moment rather than exclusively under booms. In addition, substitution may become an important hazard in minerals industries, making cooperation more attractive to strategic firms of which at the same times contributes to achieving *reasonable* prices. This cooperative strategy bears a higher price stability which finally redounds in benefits not only for producers and consumers, but also for countries which economies strongly depend on these minerals.

In consequence, this cooperation strategy does not necessarily imply damage to the consumers, which is a reason why it should be analyzed by anti-trust commissions in order to avoid claims of collusion in these types of industries. These cooperation policies only affect the actors belonging to the inefficient competitive fringe in a direct way, so cooperation among strategic firms also seems to act as a self-regulating structure that delimits the entrance of inefficient mines into the industry during periods of prosperity. As an outcome of this cooperative policy I have derived in this paper a *trigger price* mechanism for price stabilization as a secondary effect of a *rational* maximizing strategy, first introduced by Montero and Guzmán (2005). Due to the fact that this is only a result of profit maximization policy carried out by some strategic firms, this mechanism appears to be much more stable than the previous ones. In fact, many of these failed precisely because the individual firm's objective of profit maximization was not necessarily related to an independent buffer stock, which objective is to stabilize price around a fixed value that is even higher than the price obtained in the Nash-Cournot equilibrium.

One disadvantage of this type of partial cooperation in mineral markets is that during recessions it is technically simpler to cut output (either through physical production or through holder stocks) than to increase it during booms. This is because the expansion of output during booms requires either investment in new capacity or deep modification in the mining planning (Lane, 1988). The first one is slow to implement while the second one is possible, even though mining planning could be affected in subsequent periods. A solution to this problem is stockpiling output; this is, to reserve own stocks during recessions for selling them during booms. However, this solution is not necessarily sustainable in time. It seems then that better investment timing (in such way that investment in new capacity is carried out during periods of depression and operations are initiated during booms), as well as a greater integration among mining planning and marketing departments within mining companies, are a more effective solution. Both constitute in their selves relevant future research topics for the minerals industry.

To test the theoretical output expansion during booms, other interesting examples for future research are the Coal, the Iron and Steel Cartels that operated in Germany between 1893 and 1914, which maintained prices apparently always below those that have been observed in a more *competitive* scenario with the objective of limiting the competitive fringe's expansion, which accounted for approximately a 60% of market share (Kinghorn and Nielsen, 2004).

Regarding the econometric model here developed, the availability of a best resource of disaggregated information is critical to elaborate a more powerful econometric test so as to strongly reject Herfindahl's hypothesis (1959) in favor of Montero and Guzmán's (2005).

Finally, it is necessary to take into consideration that even when market conditions allow companies to sustain a cooperative equilibrium, it is not always possible to assure that these will finally become coordinated. In other words, the economic theory only enables us to argue about the necessary conditions for the existence of a cooperative equilibrium. The existence of these conditions does not actually guarantee that companies will be able to coordinate their behavior through a cooperative agreement.

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