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Título de la comunicación: Concentration and international markets in big mining industry, 1850-2013¹

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1.- Introduction.

This article aims to provide a detailed analysis of the long-term historical evolution of business concentration in international raw minerals markets. The research is motivated by a basic flaw in international mining sources: the production statistics available have traditionally adhered to national frameworks and none of the traditional mining and overseas investment countries (USA, Germany, France and Great Britain, for instance) afford continuous figures on companies' production. Hence, the literature is short on business concentration studies, with just a few short-term studies limited to copper¹, Aluminium², Mercury³, Chrome⁴ or tin⁵. There are but few detailed studies on the levels of business concentration for certain minerals and metals and next to none on world markets as a whole⁶.

This paper therefore seeks to look more closely at levels of concentration in the international mining industry by drawing on the primary sources available – the corporate reports of the main mining businesses, complemented by records from the archives of some emblematic companies and by the estimations that appear in the literature and in specialist mining journals.

For our database we drew specifically on the corporate reports of mining companies deposited at the Baker Library, of the Harvard Business School, those at the Guildhall Library in London, and those compiled by Association Nationale des Porteurs de Valeurs Mobilières, stored at the Centre des Archives du Monde du Travail (Roubaix). We also use the company production estimates from certain dates that appear in statistical references like the Bureau de Mines Yearbooks and those published by Metallgesellschaft.

The ultimate objective is to ascertain whether the levels of business concentration (including the cartelization episodes of certain markets) led to significant variations in international prices, and whether this concentration may have put up entry barriers or somehow conditioned the composition of world mining markets.

¹ Schmitz (1982) and Herfindal (1959)

² Holloway (1988)

³ MacKie-Mason and Pindyck (1987), López-Morell (2008), Segreto (1991) and López-Morell and Segreto (2013).

⁴ Phimister (1996).

⁵ Hillman (2010).

⁶ There is a previous work to this, for mining companies controlled by the Rothschild family, that analyzes concentration in certain non-ferrous metal markets, López-Morell and O'kean (2014).

2.- A long-term visión of a great mining industry.

The mining sector has its peculiar characteristics that clearly distinguish it from other production sectors. It exploits a non renewable natural resource, which is irreplaceably running out with the passing of time. It has, therefore, something nomadic about it in its constant search for new deposits, its dependence on exploration, the evolution of prices and the arrival of new technologies.

A further fundamental conditioner of the sector is the costs of getting the mineral out of the ground. As a rule of thumb, costs will grow as the minerals are increasingly mined deeper and deeper and, hence, technological advances in mining and the price of energy have been weighty issues when mining less accessible seams without sending the costs soaring.

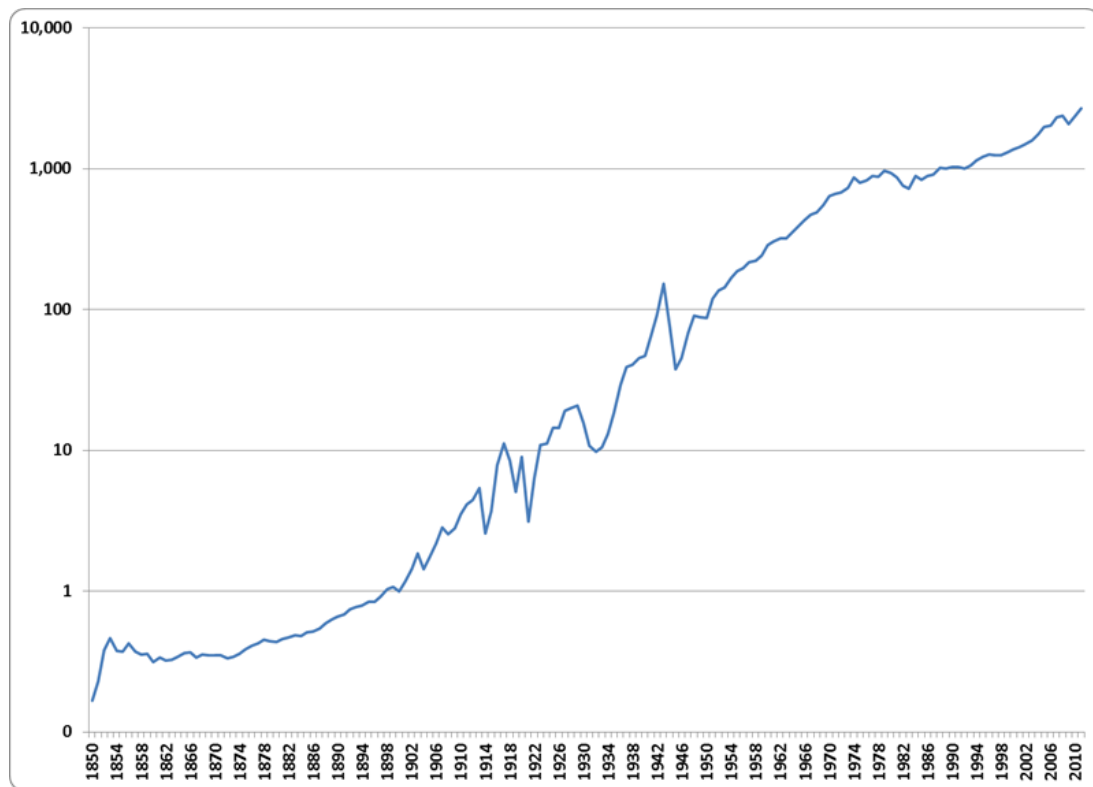
At the same time, there are the issues of social and environmental impact in working the mine and then in using or transforming the minerals, since this all notably affects the surroundings. It is not just a case of valuing the impact of mining in terms of the ensuing depletion of resources, but also that of the environmental effect the activity has. While not a part of this study, these elements are of great importance in understanding the recent development of the sector and the drastic decrease in mining in Europe and North America, which is the consequence of ever greater demands made by labour and environmental law. This has led to a growing pressure on old and new deposits in countries where the law is more permissive or in developing countries.

2.1. General evolution of mining production and international prices.

The mining industry has witnessed to tremendous evolution in its production from 1850, when the rise in industrial demand paved the way for the early big mining companies, to the present day (see Graph 1). There was an upward trend from the 1890s through the whole of the XX century with a huge difference between its dawn and close. A study of this evolution reveals a series of fundamental phases, starting with the rise in production, which was interrupted by the effects of World War I. The 1929 crisis led to a huge decrease followed by a recovery trend through till the outbreak of World War II. After that, production took off before being slowed down by the energy crisis of the 1970s before acceleration kicked in around the turn of the century. This last upward trend came about in the main with the increased industrial demand in emerging countries, seen as driving forces behind these types of products. In short, many circumstances have favoured the development of mining production over the period studied, including increased international consumption of metals, especially in times of war, advances in extraction and smelting processes, developments in business and financing, improved transport, etc⁷.

⁷ Pérez de Perceval Verde (2006), p. 87.

Graph 1: Evolution of world mineral production, 1850-2011 (1900=1)⁸

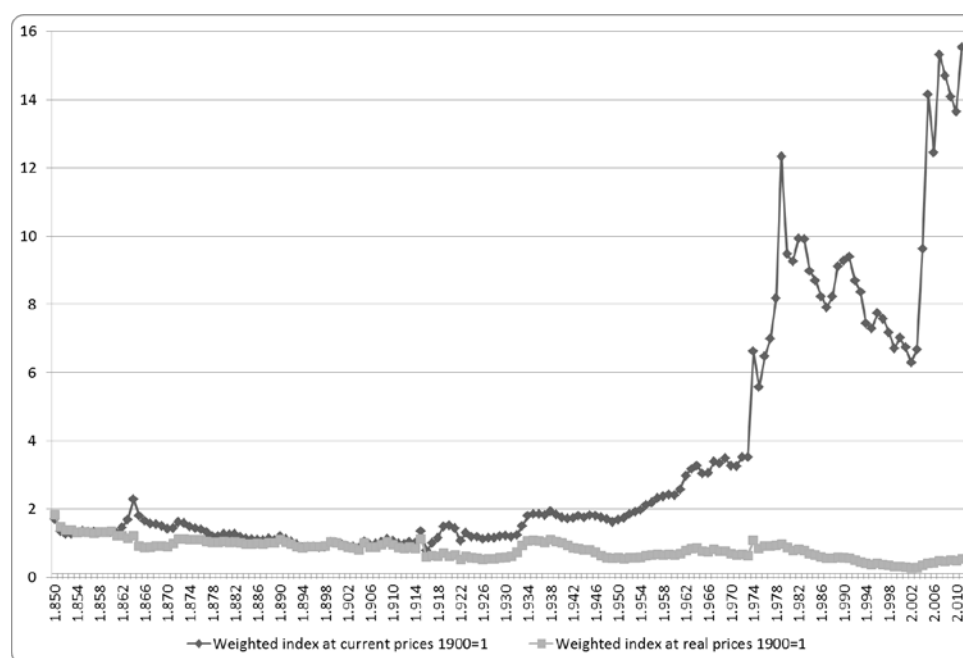


Source: Own, based on data from the Bureau of Mines and Schmitz (1979).

Graph 2 shows a downward trend in real prices over the long term, which is in contrast with the evolution of current prices. We can see the inflationary effect of WWI as well as that produced after 1973 by the oil crisis, which set inflation rocketing because of the industrialized world's energy dependence. Finally, as of 2000 prices started to climb, and even more sharply after 2004, mainly due to demand factors springing, as mentioned above, from emerging countries. Besides, this increase in prices meant increased levels of capitalization for mining companies. As a consequence of this, and of competition, increases in production scale and the arrival of new technology for working and making use of minerals, the industry has been able to reduce its real prices.

⁸ For the preparation of Graphs 1 and 2 the following metals were used: aluminium, antimonium, bauxite, chrome, copper, gold, iron, lead, manganese, mercury, molybdenum, nickel, silver, tin, tungsten/wolframium and zinc. The index in Graph 1 is weighted by the market value of each product. The production value for each metal was calculated and then the weighting for each metal in the total annual production. The indices shown were obtained from the product of each weighting by the production index or respective prices. For the price weighting we used the Lawrence H. Officer and Samuel H. Williamson series, "The Annual Consumer Price Index for the United States, 1774-2013," MeasuringWorth, 2014, URL: <http://www.measuringworth.com/uscp/>

Graph 2: Prices of minerals between 1850-2011 (1900=1)



Source: Own, based on data from the Bureau of Mines and Schmitz (1979).⁹

2.2.- Market organization: LME, intermediaries and large producing companies.

Since the early decades of the XIX century the mining products market has been characterized by its global nature in that the large companies that comprise it come from different countries, including more recently developing and emerging countries. One must remember too that it is a centralized sector since deposits are of fixed location, which often means that exploration, development and processing of the mineral is carried out where the deposits are located. One consequence of this is that there are countries with abundant resources and others with high demands, so many products take on special relevance on the international stage. A further aspect is that the characteristics we have mentioned, which make this sector special and distinguish it from other economic activity, have frequently sparked off social and political conflict.

Businesswise, production and international distribution of mining products have always been closely related to world economy behaviour and world situation influences. Added to this are the intrinsic characteristics of the sector, such as its dispersity and diversity of its products and its location in various geographical areas. Thus, the differences between the nature of the demand for each mineral product and between the determinants of the supply of these give each product its own, unique market structure¹⁰.

A case to mention is that of the non ferrous metals, which take in many of the features of competitive markets, since they are reasonably homogenous and

⁹ To complete the series the molybdenum prices were estimated for 1900-1911.

¹⁰ Crowson (2008)

consumable. Moreover, they lend themselves to a wealth of final uses, they are in high demand and there are many suppliers worldwide, making it very difficult for any one producer to have much influence on price levels, other than fleetingly. These markets have evolved greatly over the years and some are considered to be more competitive than others, although there are some startling exceptions of stable, long lasting oligopolies which we mention below.

Today, the most important reference for metals and minerals is the London Metal Exchange (LME), the main metal exchange in the world where more than 90% of exchanges of aluminium and alloys, copper, lead nickel, tin, zinc and steel are performed¹¹.

The LME was founded in 1877, when the United Kingdom was still at the head of industrialization. The country's dependence on metal imports to complement and replace the products from its own depleted mining activity was already clear by then. The LME's main function is to fix daily the prices of the products to be exchanged, although it also offers risk cover given the volatile nature of the prices. Additionally, it is, in the last resort, a network of warehouses offering the opportunity to invest in metals. Its current structure dates from 2000, when it became an affiliate of the new LME Holdings Ltd. Prior to then it has been a limited company since it was set up in 1987 under the ownership of its partners¹².

Membership of the LME is open, in its seven categories, of which the Ring Dealing and Associate Broker Clearing are by far the most important, to all companies that meet the criteria. Until its reorganization in 1987, only the first category members were allowed to issue contracts, but today both do. The number of Ring Dealing members has fallen with time to its present figure of eleven, while the second category which was created to broaden the base of its membership and to increase market liquidity in the hope that these members would, in due time, join the Ring Dealing. This was not to be, and today its membership has grown considerably and today numbers 31.

In spite of the importance and effectiveness of the LME, a series of individual intermediaries who have always been very influential work alongside and around it.

Historically, the company that has perhaps been most successful in parallel with the LME, and controlling a good share of business dealings, has been the Metallgesellschaft, whose headquarters is in Frankfurt, and which in its time was one of the greatest industrial conglomerates in Germany with more than 250 affiliated businesses specialising in mining, chemical products, basic products and financial and engineering services. It was responsible for a good number of market agreements between big mining companies before and after World War I.

Up to the Second World War a series of investors and large European and North American banks continued to wield influence on the world's metal and mineral markets through their investments and speculations in very specific markets. The Rothschilds¹³,

¹¹ A wealth of information on this body can be found at < <http://www.lme.com/>>

¹² Gibson- Jarvie (1983) and Crowson (2008), p. 217-226.

¹³ Ferguson (1998) and López-Morell (2005 y 2014).

who played an essential role in the non ferrous product markets through Rio Tinto, Peñarroya and Le Nickel, not to mention the world gold market, are a key case in Europe. In the USA it was the Guggenheims actions in founding ASARCO and their first big investments in Chilean mining¹⁴, while J.P. Morgan was a key partner in founding Anglo American. Well known also is the role of Kuhn Loeb & Co. and Lazard Brothers in other investment initiatives and market manipulations of the time. After the Second World War, however, the shareholder weight of these entities in large companies began to wane as the assets of the companies grew and they consolidated their position through important mergers and takeovers. The process was a consequence of the increasing difficulties of getting formal market agreements between firms and the need to cut production costs because of the larger scale economies. Collusive agreements between mining companies had, in short, led to a struggle in the previous decades for greater market shares and better positioning in the capital markets¹⁵, to the point that investment and pension funds held the majority of shares in these companies in what was a very widespread model of managerial capitalism throughout the large mining corporations.

Elsewhere, we must mention Glencore, one of the most important world intermediaries and, moreover, one of the largest natural products businesses in the world, with a turnover in 2012 of 164 743 million euro. As well as commercializing products, its important portfolio of industrial assets has recently grown with its recent merger with Xtrata, making it the number one producer in the world of coal, zinc and ferrochrome, and the third in the copper industry¹⁶.

2.3 Business concentration in mining: the stages and some examples.

The birth of modern mining arrived with the XIX century and spelled the appearance of quite sizeable companies. To explain this, we have to consider various phenomena that coincided. The first was the transformation going on in international economics as the industrial revolution developed, leading, among other things, to the multiplication in the demand for metals and fuel and the search for mineable deposits. So there was an increasing need for metals as the international economy underwent changes. The increase in lead consumption, for example, came with urban development (pipes, paints, guttering, etc.) and in industry, like in the amalgamation in copper and silver smelting. Copper began to be used in abundance for electricity networks from the end of the XIX century, while mercury was used to obtain precious metals as well as playing an increasingly important role in military industries and precision instruments. Private initiative was always going to be the main means of using these resources, which meant that most western countries had to reshape their state monopolies regarding mining and bring in the necessary legal changes¹⁷. High prices were the biggest incentive to encourage mining and bit by bit mining was to become a profitable

¹⁴ O'Brien, T. (1989)

¹⁵ Levenstein (2012) and Shroeter (1996).

¹⁶ For more information on Glencore go to < <http://www.glencorextrata.com/>>

¹⁷ Perceval (2006)

business. This goes some way to explaining the changes occurring in international economy with the arrival of the large mining firms.

In short, the last decades of the XIX century saw mining take off, and this should be seen as one of the most significant signs of the renewed boost in industry that kicked in in the 1890s. Thus it was that coal, iron, copper and sulphur mining, among with that of other raw materials, would become the most expressive indicator of the progress of nations.

This "take-off" we mentioned earlier occurred in two phases: the first can be classified as intensive in terms of land and labour, while the second was intensive in capital.

In first phase the growth of mining was characterized by a complete and systematic use of existing mines and, especially by prospecting and exploitation of new deposits all over the world. This globalization of mining had three great moments: in the mid nineteenth century Europe was still leading the mining of almost all strategic minerals; from 1880 to 1910 the USA overtook European production; and from the 1930s the American dominance was hot by the mining boom in the other continents. An example of this is copper, which we will look at in more detail later.

As for the second phase, which opened in the closing years of the nineteenth century, this was more intensive in capital and this was reflected in the leading role played by the large companies in the sector at the beginning of the XX century. In 1900 the first eight copper producing companies accounted for 45.6% of world production, which by 1935 had risen to 64.7%, while in 1912 twelve mining companies figured in the list of the world's 100 most important companies¹⁸. Furthermore, the irruption of the large mining firm accelerated the mechanization of the mines, which compensated the drop in international prices.

However, the transition from one phase to the other was not immediate, nor can it be precisely dated, although in industrialized countries there is clearly a "before" and an "after" World War I.

In terms of market agreements, these were a feature of the whole period mentioned, although their effects on markets depended on the metal in question. We provide some emblematic examples of these in the next session.

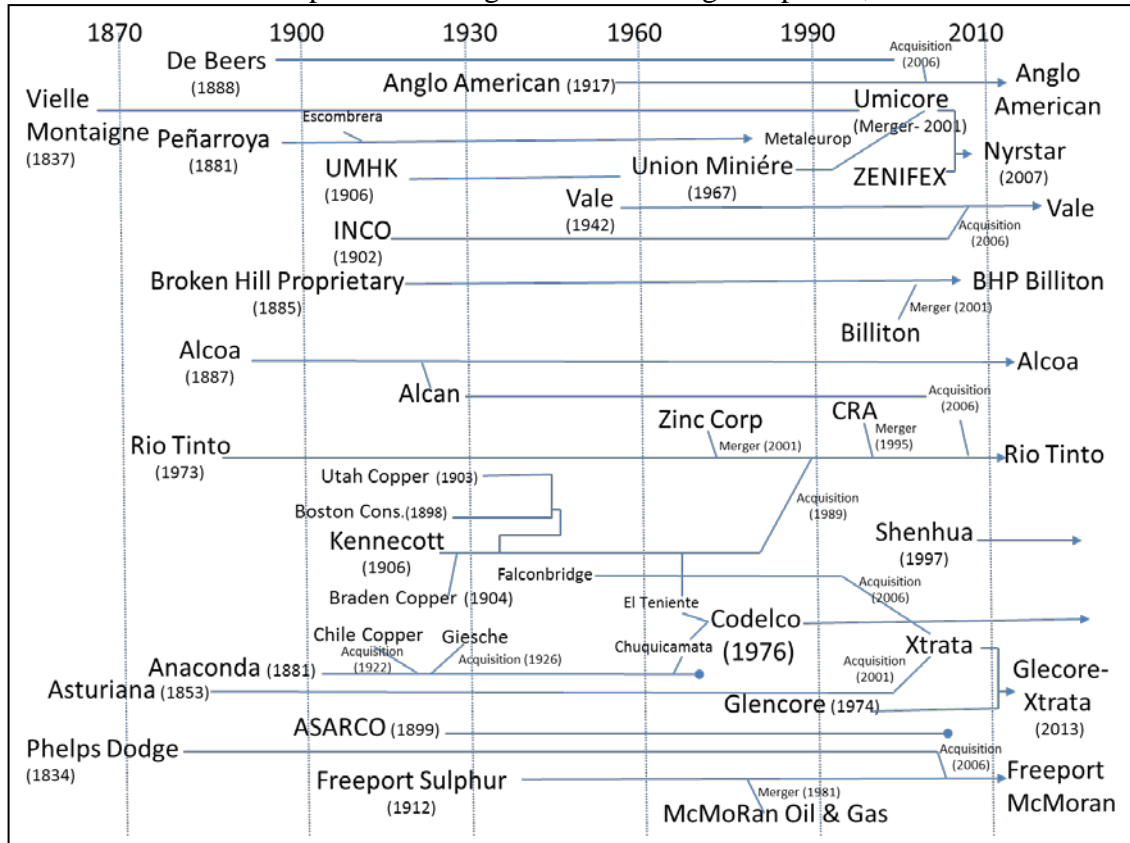
The post-war years the spread of state planning and centralized control of the European satellite states of the former Soviet Union, China and North Korea obviously enhanced the role of the State in the supply of minerals at world level. Until the mid seventies, therefore, there was a contraction of ownership and private control of the mines and a growth in the role of the State. The most emblematic cases were the nationalization of tin in Bolivia (spelling the appearance of the state-run Comibol, in 1952), that of the Congolian mine (Gecamin, 1966) and that of copper in Chile (Codelco, 1976), as well as the Brazilian state company Vale, privatized in the 1990s.

The European and North American mining firms that had previously been part of the mining operations abroad, of internal processing and intermediary activities slowly

¹⁸ Smithz (1989)

lost their control of the raw materials. Indeed, many, like Anaconda and Asarco, pulled out of mining altogether. The arrival of nationalization to a large extent also hampered foreign investment in private mining firms in many countries. The Australian and Canadian Governments both placed restrictions on foreign ownership and control of natural resource projects, as had the Spanish Government earlier.

Chart 1: Concentration process among the main mining companies, 1850-2013



Source: Own.

However, in developed countries like Australia, Canada, Japan, the United States and parts of Western Europe, mining remained essentially a private activity. The main exceptions were coal and iron mineral, which had been strategically important during the Second World War. There were many reasons for nationalization of mining, and these depended on the country in question. Some common features do exist, though. The most important had to do with the widespread belief that mineral resources belonged to the nation and that private interests, especially foreign ones, could not profit from their mining. It was the State that should control mining and its processing since mines, by nature, are real estate and firms would not be able to respond to any government intervention or expropriation by moving elsewhere. In essence, this is the reasoning behind a State's move towards their nationalization.

Against the tide of the current crisis, with the plummeting of financial markets and some other sectors like building and automobiles, raw material businesses have returned extraordinary profits and have climbed into the top places in world rankings by capitalization (among the purely mining concerns Vale SA (1st), BHP Billiton Group (2nd), Rio Tinto Plc (3rd), at September 2011), a trend that has only been broken in the

last year¹⁹. This situation is further proof that modern capitalism and its industry depend on natural resources and that these have been and continue to be strategic markets that offer high probabilities of generating concentrations and market agreements that are hardly desirable for a competitive prices environment.

3. An analysis of long-term business concentration in mining Un análisis de la concentración empresarial en la minería en el Largo Plazo.

3.1 Five examples: mercury, nickel, copper, zinc and lead.

We now analyze the metal markets in greater depth by taking 5 of the most emblematic: mercury, nickel, copper, zinc and lead. These metals, used as the basis for a wider database, are chosen because they reflect two very different realities in terms of both their internal characteristics and their influence in economic development and the industrialization process. Mercury and nickel are part of a group of metals of low supply and easily manipulable prices, while copper, zinc and lead are examples of metals of widespread production and therefore not easy to concentrate because of the global nature of the supply, a feature that will help us to compare extreme cases in our final analysis .

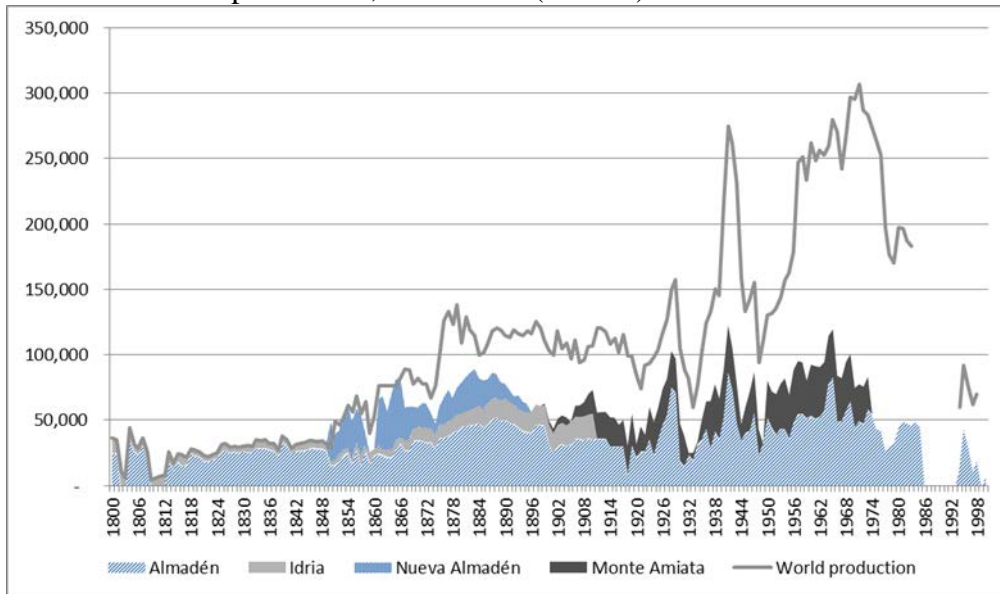
Mercury is one of the most important cases in contemporary history in terms of international market regulations despite being affected by important technological changes and the periodic discoveries of new seams. Until the late XIX century mercury²⁰ was still being used in the Mexican silver mines and the demand would be maintained as more industrial uses for it were discovered. Three decades later it was also being used for metal plating, in physics instruments, paints, mirrors, turbines or explosives, and hardly at all by then as an amalgam.

The biggest and oldest deposits were in Almadén, which had been in the possession of the Spanish crown since 1523, so it found it easy to take advantage of the monopoly it had to mine the metal and to control sales. The only real rival was the Idria mines located in present day Slovenia, but bar a few isolated periods in the XVIII century, the Idria mercury never supposed a competitive threat. All this changed in 1847, during the Rothschilds' control of sales between 1830 and 1921, with the discovery of the new deposits in Nuevo Almadén, in California and in Monte Amiata, Italy in 1897. All the other producers who appeared during this period were subsidiaries, until after the Second World War, when production began to grow in the Soviet Union and China, but through Almadén, Spain was able to hold on to its leading position throughout.

¹⁹ This was due to the decrease in profitability of mining firms brought about in the main by lower demand from emerging countries, the devaluation of the raw materials and the unfavourable economic environment of the markets.

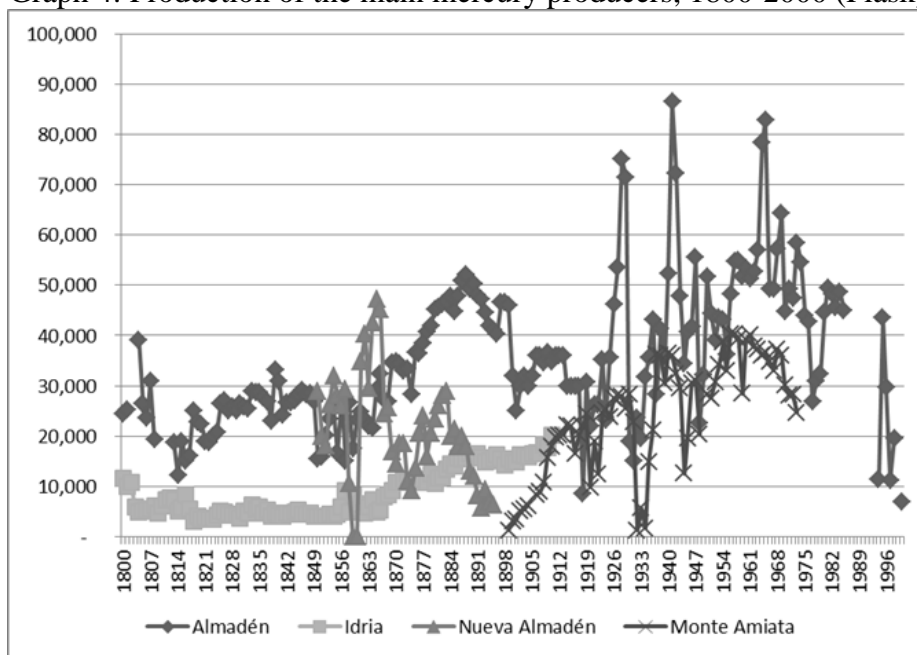
²⁰ López-Morell, M.A., Segreto, L. (2012).

Graph 3: Accumulative production of the main mercury producers versus world production, 1800-2000 (Flask²¹)



Source: Bureau of Mines and U.S. Geological Survey, Lopez-Morell (2008), Segreto (1996) and Quicksilver Mining Co. Corporate reports.

Graph 4: Production of the main mercury producers, 1800-2000 (Flask)



Source: Lopez-Morell (2008), Segreto (1996) and Quicksilver Mining Co. Corporate reports.

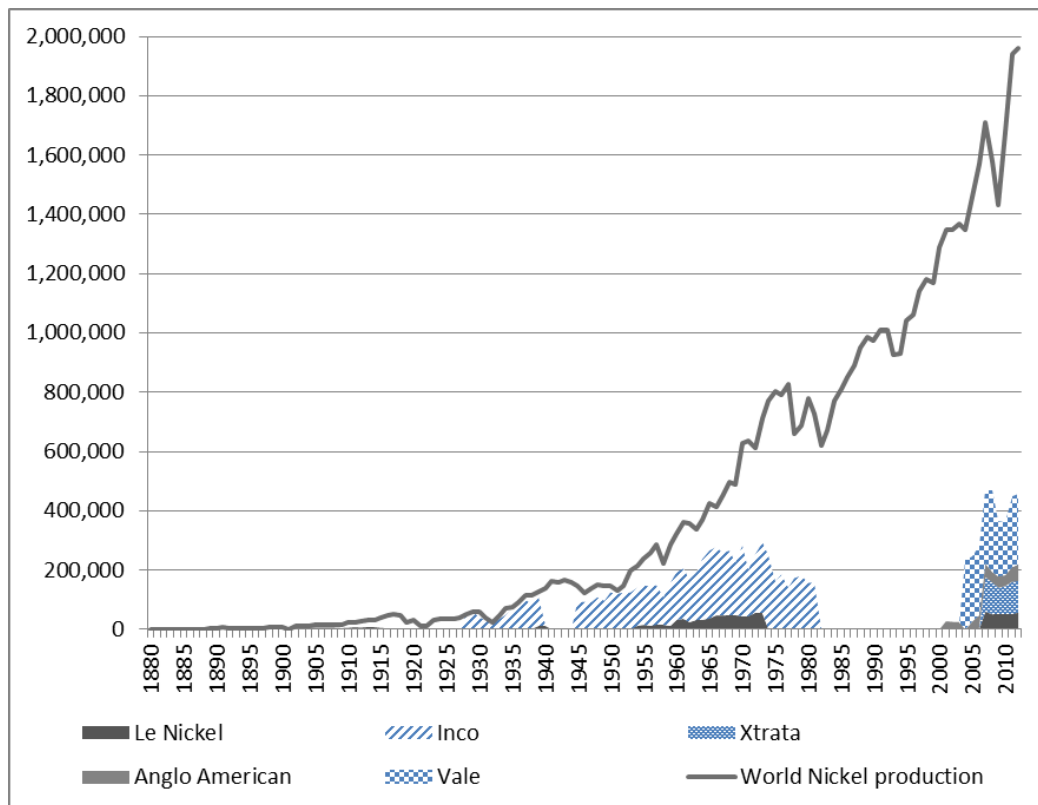
The market was cartelized for almost all of its recent history. After the neo-monopoly of the First World War the Rothschilds reached an agreement with the Spanish and Italian Governments that ensured that sales in London during the conflict would be at highly inflated prices, as is clearly visible in graph x. World production soared in the 1920s until the Spanish and Italian Governments set up a sponsored cartel

²¹ Flask=34.507 kg. of mercury.

of producers known as “Mercury Europe”, which operated almost uninterruptedly until 1973²², when world production of the metal began to fall, mainly on account of technological and environmental aspects which lead to the mercury falling into disuse.

Nickel would only start to have an impact on the markets following the discovery of the deposits in New Caledonia by the Frenchman Jules Garnier in 1864. It was there in 1881 that Le Nickel was born through the merger of the local foundries owned by the Australian John Higginson and those of Garnier and Henry Marbeau in the south of France. Despite the firm's resources its financing and distribution problems meant that the Rothschilds were able to get a foot in, and around 1883 they gained control of the business. From then on, the firm began to buy up the few foundries in Europe; in France (Le Havre), Scotland (Kirkintilloch) and Germany (Iserlohn) as they sought to establish a world monopoly. They even set off a controlled reduction of prices, which dropped by 50% to encourage the use of the metal in industry. This was more than compensated by the huge increase in demand, which grew seven-fold in just one decade, thanks to the increased use of nickel in steel alloys.

Graph 5: Accumulative production of the main nickel producing companies versus world production, 1880-2012 (Tonnes).



Source: Bureau of Mines and U.S. Geological Survey, Schmitz (1976), Lopez-Morell and O’kean (2014), and Le Nickel, Inco, Vale and Xtrata corporate reports.

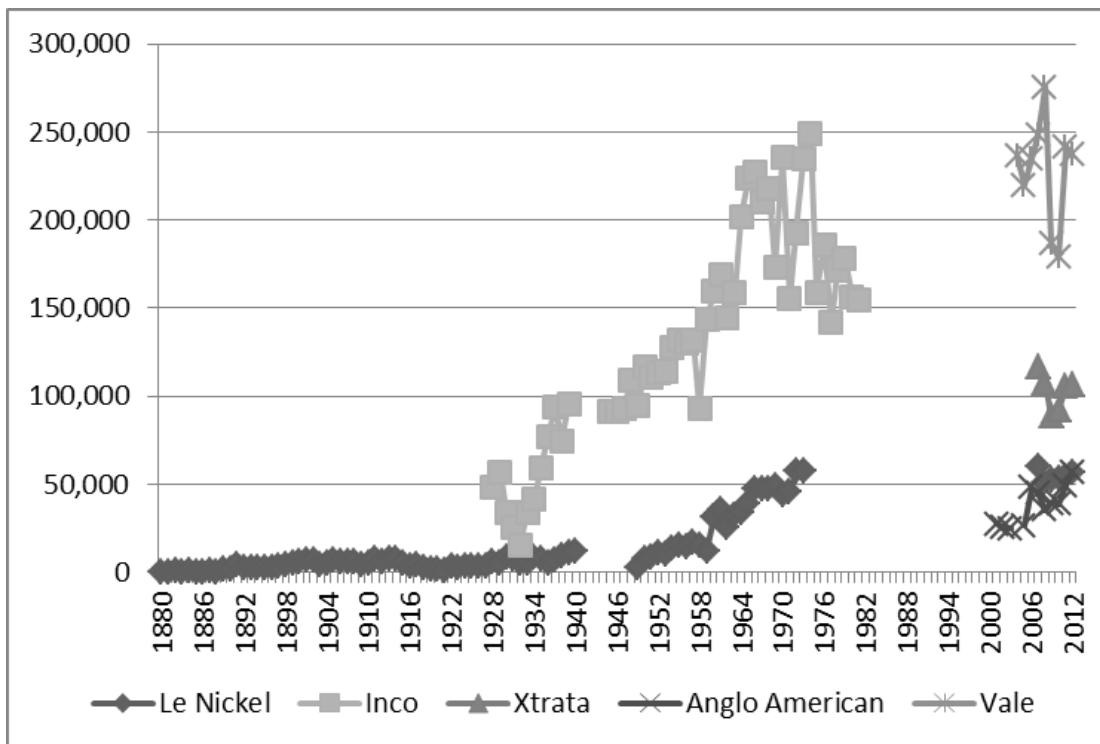
The Le Nickel monopoly did not last long because of the discovery of the Sudbury deposits in Ontario in the 1890s by Canadian Copper Co. This firm later

²² López-Morell and Segreto (2013).

merged with Orford Copper Co. in 1902 and, together with American Nickel Works, set up the International Nickel Co. (INCO), which occupied the top spot among the world producers, so spelling the end of the Le Nickel monopoly. International prices plummeted but were compensated by an important increase in demand, which in the case of industry had a lot to do with the increases in production (Graph 3). Even so, the sales of both companies decreased substantially in the wake of the 1929 crisis.

To avoid a general slump in prices, INCO, Le Nickel and the British Mond Nickel signed market agreements in 1896 and 1904, promoted by the Metallgesellschaft, and further agreements in 1923 and 1940. These supposed a significant recovery in prices, which remained stable until the Second World War (Graph 12), despite the sizeable increase in production. There is no denying the Le Nickel's success; it maintained production levels despite the continuous fall in its market share as the overwhelming INCO grew to represent 90% of the sector²³.

Graph 6: Production of the main nickel producers, 1880-2012 (Tonnes).



Source: Schmitz (1976), Lopez-Morell and O’Kean (2014), and Le Nickel, Inco, Vale and Xtrata corporate reports.

So, like mercury, concentrated localization and scarce supply led to the creation of cartels and market agreements which clearly affected the evolution of international markets influenced by the changing scenarios of each period.

²³ López-Morell and O’Kean (2014).

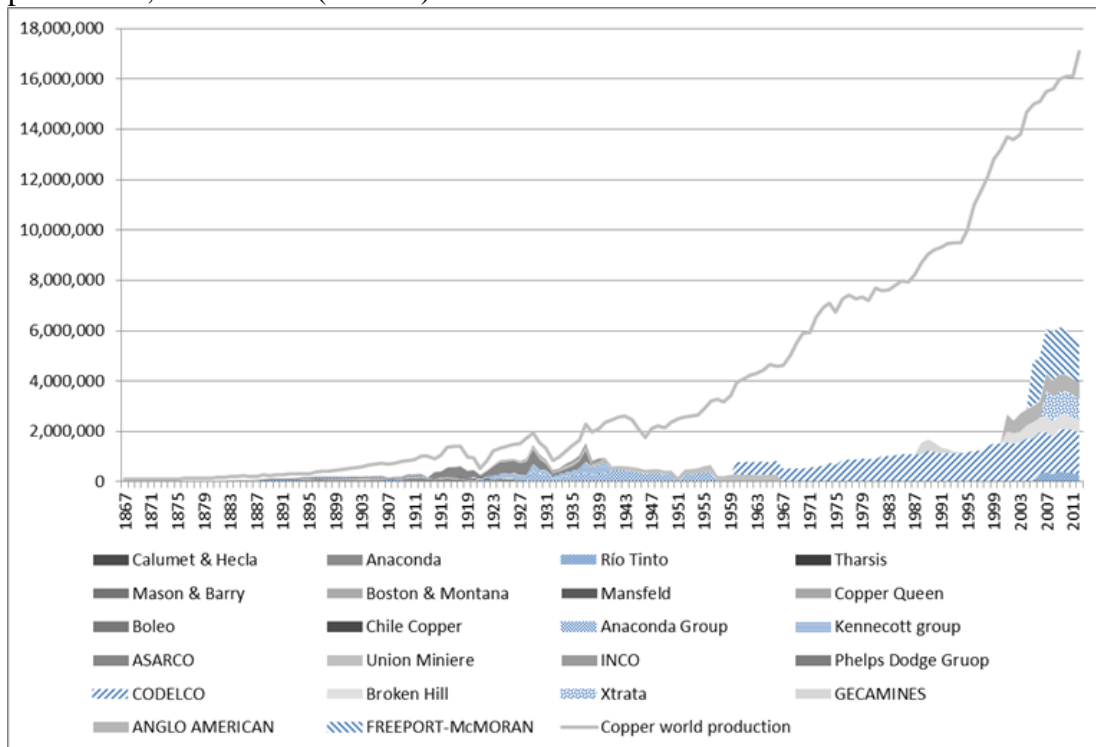
Now, we will look at a different market - that of copper, lead and zinc. Unlike the above, these metals are more common and, therefore, found in more places, which has meant that no single firm has been able to gain any clear control of the market.

Copper is one of the most used metals domestically and in industry. Its most important applications are electricity wiring, roofs, pipes and industrial machinery. It is also needed in alloys like brass and bronze. Further applications would be found in the production of nutritional supplements and fungicides in agriculture.

From 1870 to 1920, the world copper industry was characterized by the rise of the large corporations. Using market share, degree of vertical integration or accumulation of capital as references, we can see the growing domination of the main producers. In 1929 the four leading firms in the sector accounted for more than 50% of world production. Added to this was the growing presence of multinationals like Anaconda, Kennecott and Rio Tinto in Latin America and Africa, which fuelled the fears at the time of the monopoly these companies were exercising. Even with the growth of large scale capital investments in Russia, Chile, Katanga and northern Rhodesia between 1900 and 1939, the level of capitalization of non USA copper firms was well below that of the firms mentioned earlier. Besides the issues of capital, market and institutional factors favoured greater business concentration in the USA, which from 1880 on was the leading world producer and consumer of copper. From 1930, the USA had to face competition from African companies and the market control of the leading firms began to decline. In 1911, the United Metals Selling Co. Group, which included Anaconda-Amalgamated, Lake Mines, Arizona Copper Co, and Greene-Cananea, controlled 31 per cent of refineries' production and 22 per cent of world production. The American Smelting and Refining Co. (ASARCO) Group controlled 24 and 17 per cent, respectively, while Phelps Dodge accounted for 13 and 9 per cent. Elsewhere, the two German groups, the American Metal Co. (Metallgesellschaft) and Aron Hirsch und Sohn, controlled 13 per cent of world production. In 1921, following the rapid expansion of the war years (Graph 3), the three leading US firms controlled 74 per cent of world refining, and American Metal Co. and the Japanese refineries 8 per cent. However, as expected, the end of the war spelled a fall in demand and prices did not take long to fall (Graphs 4 and 5). By 1926, the US total capacity had dropped by around 50 per cent at world level, accompanied by more refinery building in Europe, Africa and Canada, which reached 36 per cent of the world capacity in 1932.

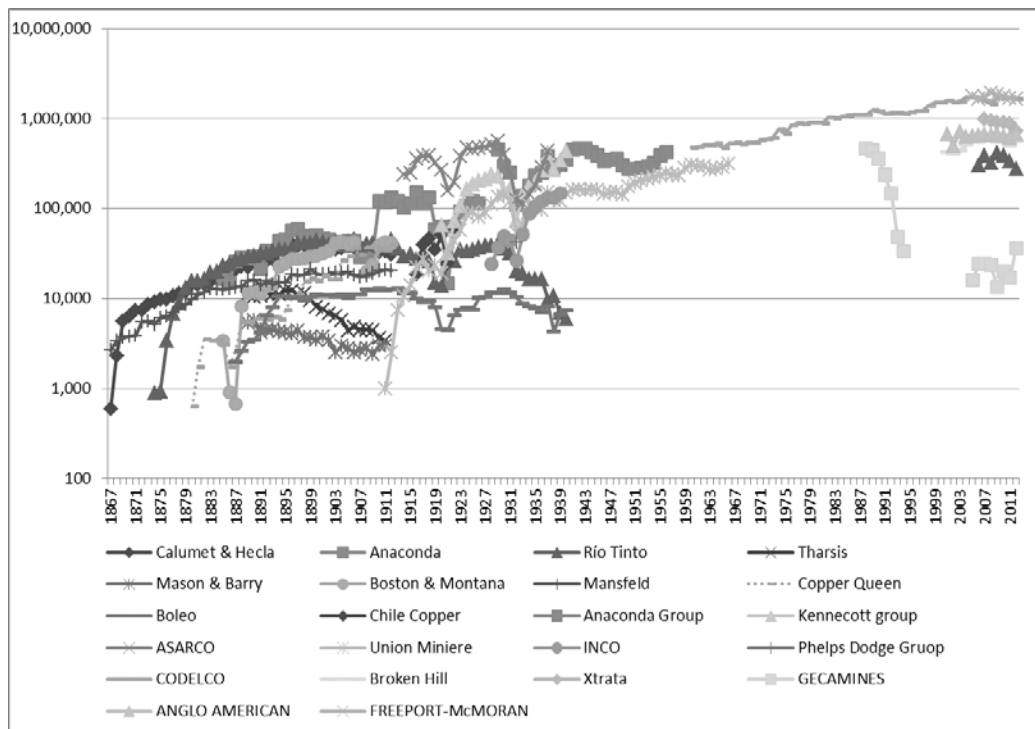
Thus, the increased size and the growing market share of the leading copper firms was due, in part, to internal growth, but also to mergers. In the USA, the four leading companies - Anaconda, ASARCO, Kennecott and Phelps Dodge - grew rapidly from the end of the 1890s thanks to an active process of horizontal and vertical integration. There is no doubt that, particularly during the huge wave of mergers between 1898-1902 accompanied by rapid advances in electrical technology and the ensuing demand for copper, these big companies seemed to have increased their leadership in business concentration.

Graph 7: Accumulative production of the main copper producing firms versus world production, 1867-2012. (Tonnes).



Source: Bureau of Mines and U.S. Geological Survey, Schmitz (1976), The Copper Handbook (1913), and Anaconda, ASARCO, Kennecot, Union Miniere, Chile Copper annual reports.

Graph 8: Production of the main copper producing firms, 1867-2012. (Tonnes)



Source: Bureau of Mines and U.S. Geological Survey, Schmitz (1976), The Copper Handbook (1913), and Anaconda, ASARCO, Kennecot, Union Miniere, Chile Copper annual reports.

The profits for the companies were in the main very high until 1930. However, in spite of the staggering growth and profitability of the large cooper firms, it can be argued that the growth cannot be entirely explained merely by attempts at market control. It is vitally important to establish that, in contrast to the above, that the firms were incapable of fixing prices and controlling supply for more than a short period. We can only talk of a general agreement on prices during the Secretán monopoly (1887-1889) and a fleeting agreement between 1896 and 1898²⁴.

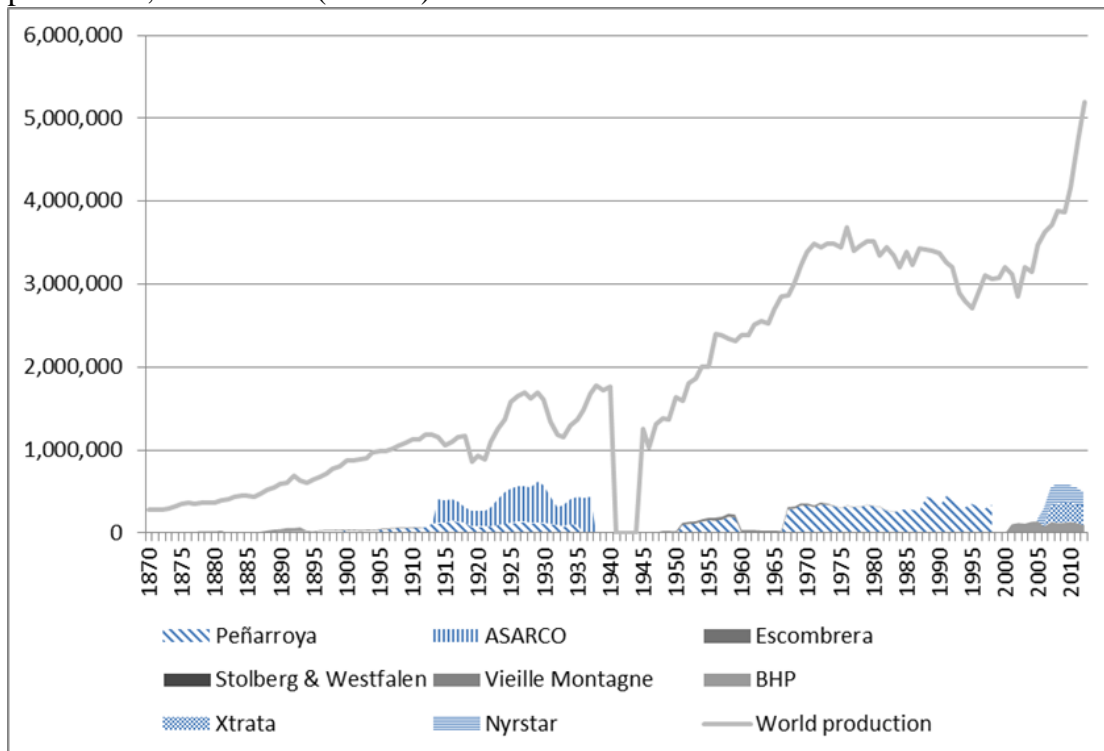
When speaking of lead, mention must be made of the Société Minière et Metallurgique Peñarroya as one of the key reference points in European production, and to ASARCO in the USA before the Second World War. The sector was characterized by a certain dispersion and smallholdings in most of the mines, on account of easy metallurgy and the large number of widely spread deposits,²⁵. From the perspective of geographical extension, Peñarroya was the largest. Born in the south of Spain in 1881, through the Rothschilds, it extended throughout the Mediterranean and to South America. From its origins, it was an example of continued and sustained growth based on the accumulation of assets and productive diversification, a process which led to its hoarding all the profitable assets in its field, taking it to the number one spot of Spanish rooted business in terms of assets and to its becoming a fully fledged multinational company after the Second World War.

Unlike Almadén in mercury and INCO in nickel, neither Peñarroya nor ASARCO ever had a sufficient share to dominate the world market. Their strategy lay therefore in seeking oligopolistic agreements with other producers and, so, directly or indirectly control markets. Specifically, we can refer to the formation of the lead cartel in 1909 which continued to work during the war. After the war, Peñarroya inherited the business structure it had itself generated during that period - the broker *Minerais et Metaux*. But not even the initiatives to set up cartels in the 1920s and 30s could put a brake on the continued price fall that began in 1925, and all the attempts failed. The company's expansion strategy did, however, offset this fall.

²⁴Schmitz, C. (1986), López-Morell, M.A. (2013).

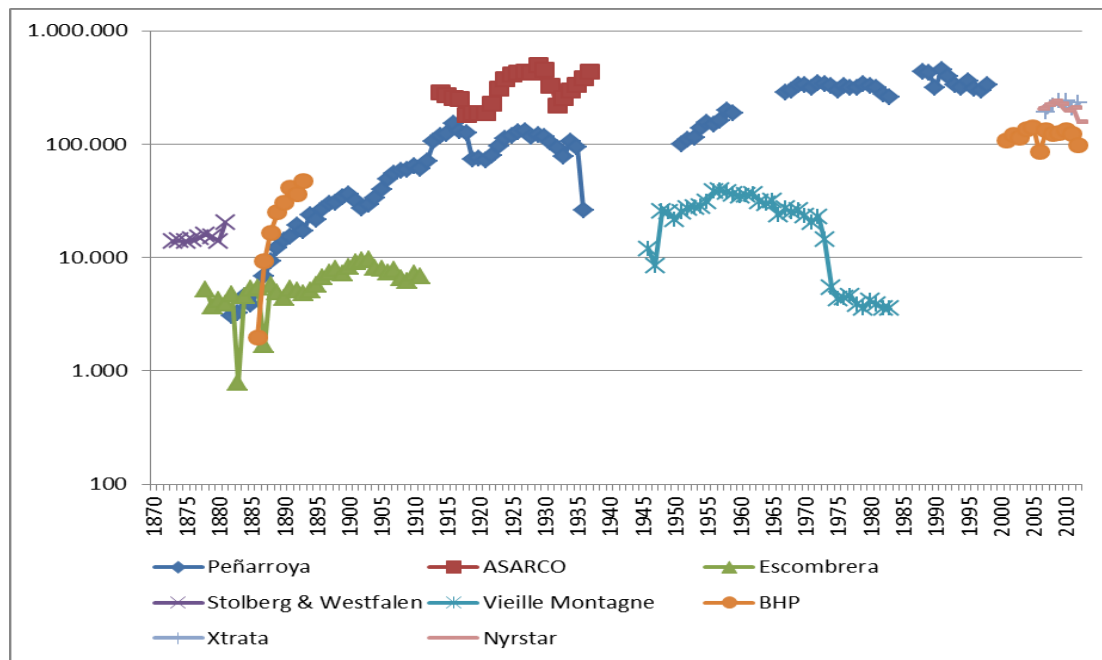
²⁵ In Spain alone there were four large producer areas, and some places, like Cartagena-LaUnión, had as many as 60 foundries. López-Morell & Perceval (2010), López-Morell, M.A. (2003 and 2013,).

Graph 9: Accumulative production of the main lead producing firms versus world production, 1879-2012. (Tonnes)



Source: Bureau of Mines and U.S. Geological Survey, Schmitz (1976), ARP 132 AQ 103 and Peñarroya, ASARCO, Vieille Montagne, Escombrera-Bleyberg, Stolberg and Wesgafalen corporate reports.

Graph 9: Production of the main lead producers, 1879-2012. (Tonnes)



Source: Bureau of Mines and U.S. Geological Survey, Schmitz (1976), ARP 132 AQ 103 and Peñarroya, ASARCO, Vieille Montagne, Escombrera-Bleyberg, Stolberg and Wesgafalen corporate reports.

In the zinc sector the distribution of mining and metal production was also very important, although not on the scale of lead. The predominant firm in Europe from the mid XIX onwards was VM (today, Nyrstar), along with the Polish producers (Silesia), the Spanish (Asturiana) and Germans. We do not have important information on Australian and North American producers so our results will not be very conclusive, especially after WWII, when production took off.

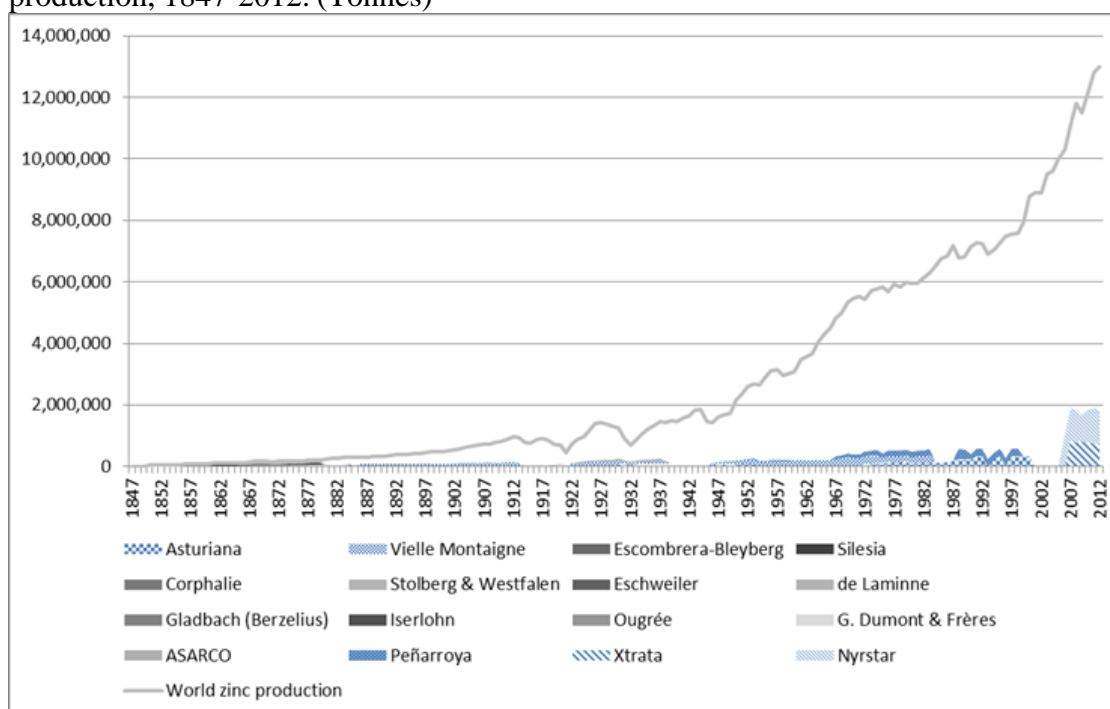
The zinc market was fairly oligopolized from the XIX century, although we have no records of agreements in the zinc market, except that of 1909-1910 when the European zinc foundries reached an agreement to limit production and stabilize prices in Europe, initiated by the German producers. Production was limited to the following quotas, which were respected:

	1909	1910
Group A, comprising 18 German, Belgian, Austrian and Dutch factories	252,700 tonnes	264,200
Group B, comprising 10 Belgian and French factories	174.500	175,900

Source: Metallgessechaft (1910): Recueils Statistiques, plomb, Cuivre..., p. XXIII

In the interwar period a International cartel functioned between 1928 and 1929, was barely able to halt the fall in prices, since it could not stop the new producers in Australia, Canada and Mexico, who had carried out a massive introduction of the new electrolytic systems²⁶.

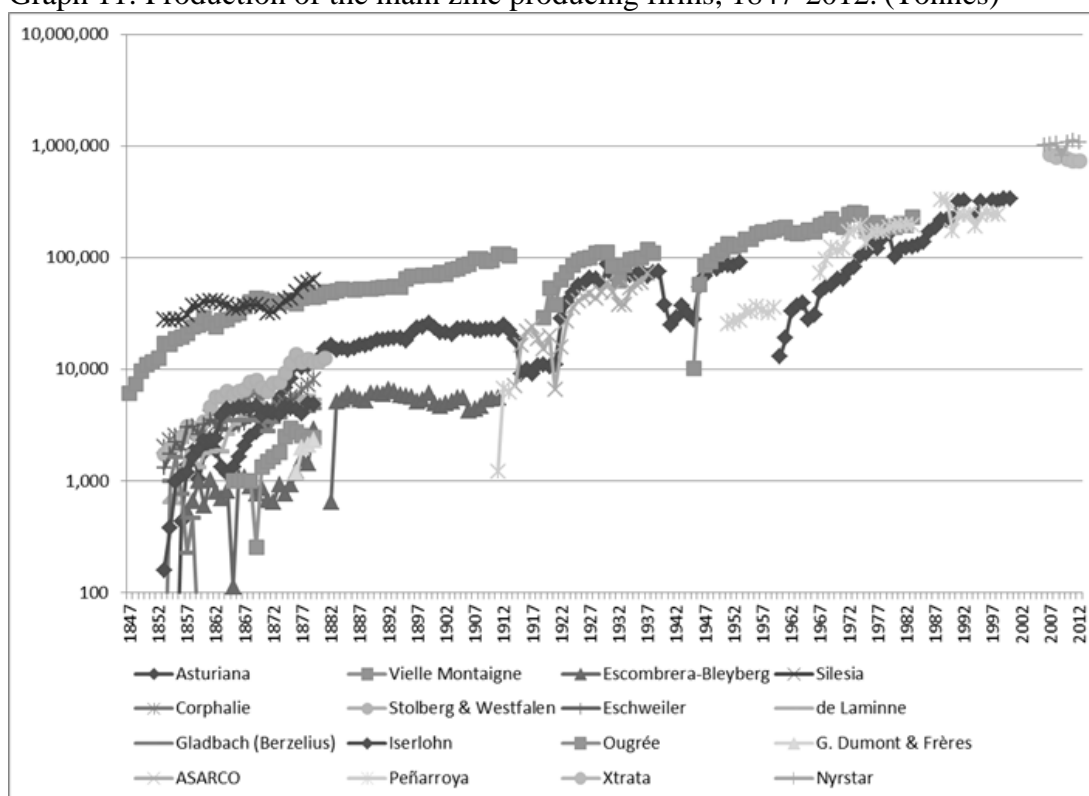
Graph 10: Accumulative production of the main zinc producing firms versus world production, 1847-2012. (Tonnes)



Source: Bureau of Mines and U.S. Geological Survey, Schmitz (1976), ARP 132 AQ 103 and Peñarroya, ASARCO, Vielle Montagne, Escombrera-Bleyberg, Stolberg and Wesgafalen corporate reports.

²⁶ Gibson-Jarvie, R., *The London Metal Exchange*. (Cambridge, 1989), 177-179.

Graph 11: Production of the main zinc producing firms, 1847-2012. (Tonnes)



Source: Bureau of Mines and U.S. Geological Survey, Schmitz (1976), ARP 132 AQ 103 and Peñarroya, ASARCO, Vielle Montagne, Escombrera-Bleyberg, Stolberg and Westfalen corporate reports.

3.2 Analysis of the effect on prices of the concentration of mining firms

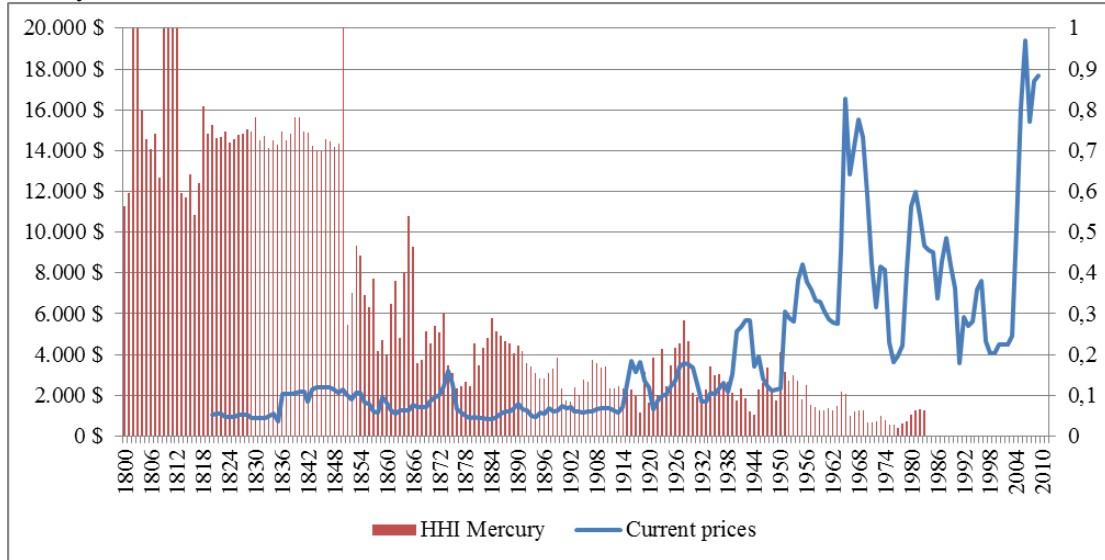
After our analysis of the evolution of the markets in terms of production and prices, we now turn our attention to the processes of business concentration. We will use the Herfindahl Hirsman Index²⁷, one of the most commonly used in these types of analysis²⁸. It is generally assumed that a HHI above 0.2 represents a large market concentration, 1 is an absolute monopoly and negligible values point to a very widely spread production. In the price agreements we have considered the cartels as a concentration, like a single firm, representing the sum of the participants' world market quotas. Graphs 12 to 15 reflect the evolution of current prices for each metal along with the market concentrations. Thus, we find that for mercury and nickel, the HHI are generally higher than for copper and lead, since we are dealing with two very

²⁷ The Herfindahl Index (HHI) is a measure of economic concentration in a market. The higher the index, the more concentration and less competitive is the market. It is calculated by totalling the squares of the market shares of each firm in the market. Proportionally, the index gives greater weight to the market shares of larger firms.

²⁸ For example, the European Union Commission-Competition uses it in legislation to this effect. See [http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52004XC0205\(02\):ES:HTML](http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52004XC0205(02):ES:HTML)

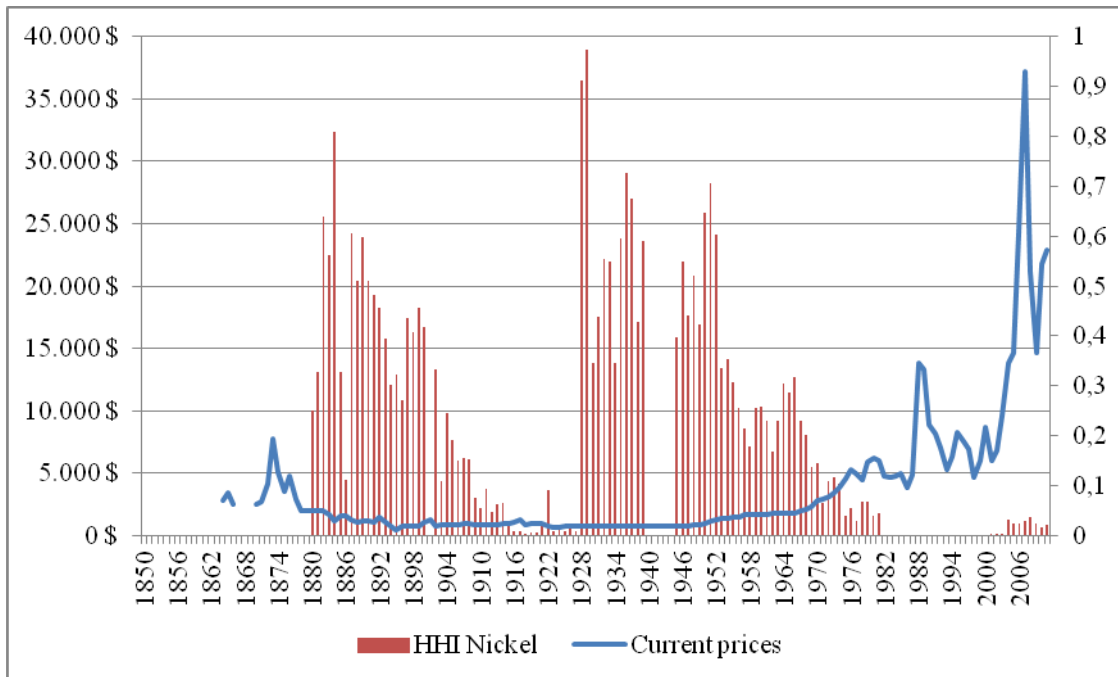
different scenarios. The first is conditioned by a scarce, concentrated supply, while the second enjoys more international competition. From Graph 7 we can note that in the case of nickel INCO, the leading company par excellence along with its partners (Le Nickel and Mond) did not establish high prices even though its levels of concentration were very high. This factor in itself was a barrier to entry on the market for both the mines, with their high production costs, and for metals of other alloys.

Graph 12: Evolution of current prices and concentration index (Herfindahl) in the world mercury market (1800-2011).



Source: author's own elaboration based on Lopez-Morell, *La comercialización*, Segreto Monte Amiata and Quicksilver Mining Co. Corporate reports

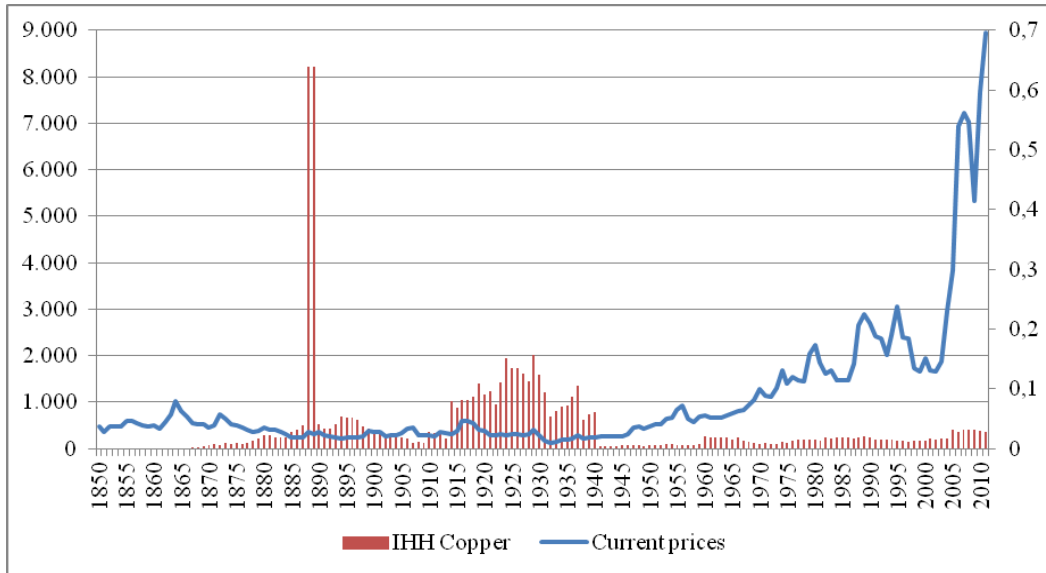
GRAPH 13: Evolution of current prices and concentration index (Herfindahl) in the world nickel market (1850-2011).



Source: author's own elaboration based on Le Nickel and Inco Corporate reports and Schmitz, *World non-ferrous metal*.

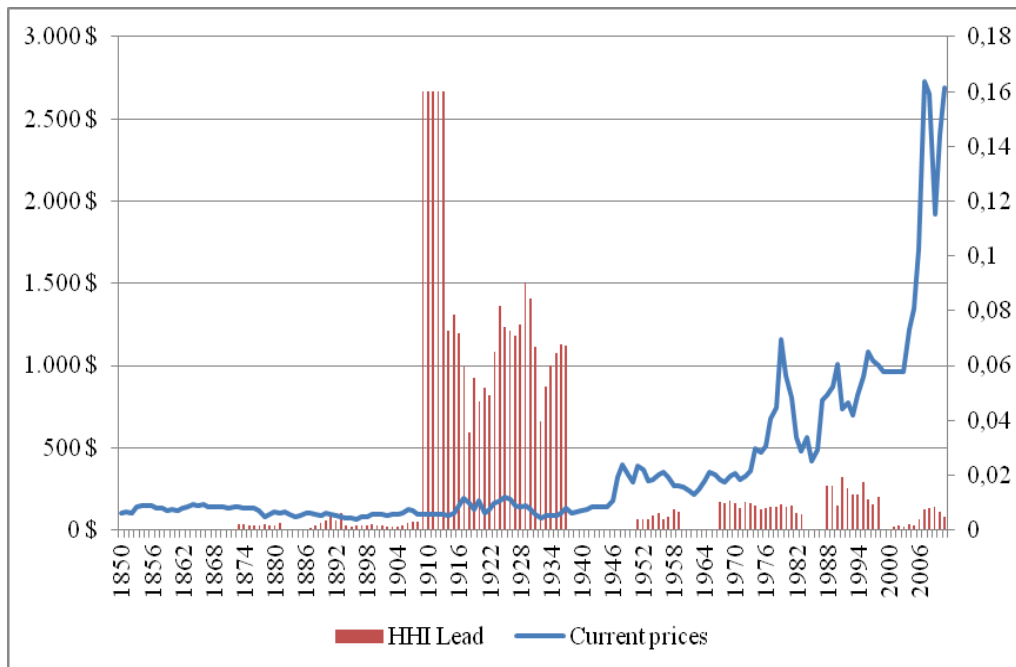
The copper market graph shows the problems in generating large concentrations. Only the special case of the Secretán cartel (1888-1889) and the creation of the three big North American copper conglomerates as of 1910 provide significant concentration indices. No equivalent growth of prices is observed, however. Indeed, it seems as if the market agreements served more as shock absorbers of falls in prices than as a stimulus.

GRAPH 14: Evolution of current prices and concentration index (Herfindahl) in the world copper market (1850-2011).



Source: author's own elaboration based on Anaconda, ASARCO, Kennecot, Union Miniere, Chile Copper annual reports and The Copper Handbook (1913).

GRAPH 15: Evolution of current prices and concentration index (Herfindahl) in the world lead market (1850-2011).

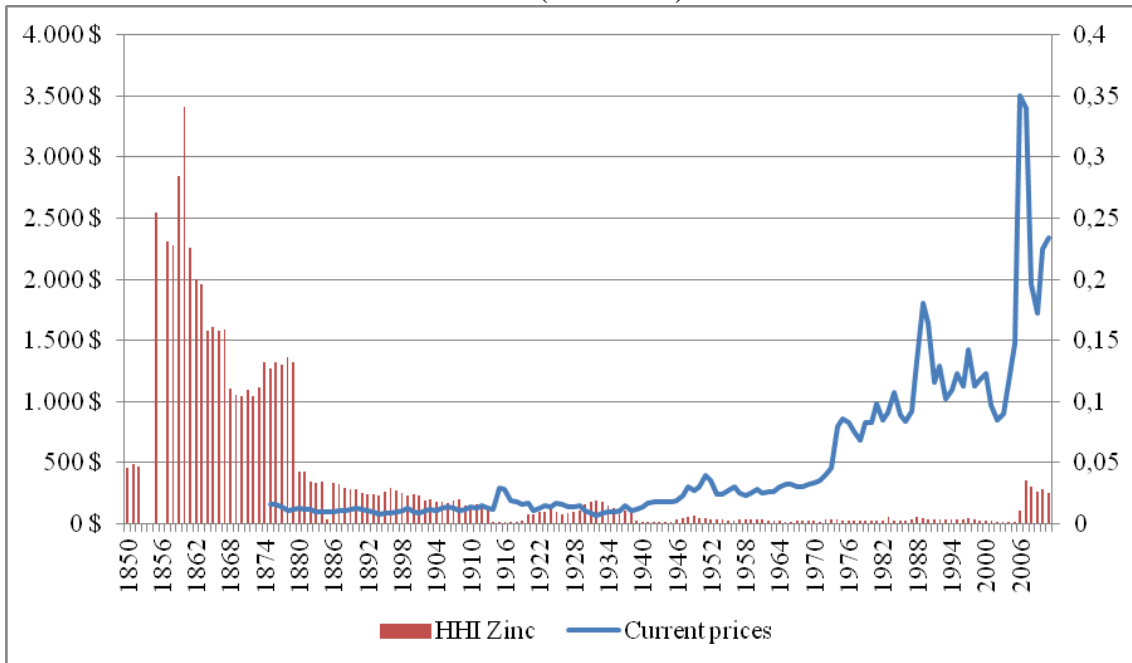


Source: author's own elaboration based on ASARCO and Peñarroya reports: Schmitz, World non-ferrous metals, and ARP 132 AQ 103.

In the case of Lead, Graph 15 only shows high levels of concentration in the years following the launch of the 1909 cartel. Yet it also shows stable prices. We have detected that this is due to a problem of sources, since although no price increases are reflected for America, they are for Europe. So there was a market segmentation, with a difference of 20% between the two areas. In other words, the concentration effect was more regional (Europe) than global, even if the indices are relatively low.

Finally, the lack of data since the First World War means we cannot as yet draw conclusions on the great market trends for zinc, except to report the greater market concentration existing in Europe until the 1880s, although again not entirely due to missing global prices.

GRAPH 16: Evolution of current prices and concentration index (Herfindahl) in the world zinc market (1850-2011).



Source: author's own elaboration based on Bureau of Mines and U.S. Geological Survey, Schmitz (1976), ARP 132 AQ 103 and Peñarroya, ASARCO, Vielle Montagne, Escombrera-Bleyberg, Stolberg and Wesgafalen corporate reports.

As a complement to the above, we have made an econometric analysis to see if there is any relation between the evolution of these concentrations and prices for the period 1800-2012 and for all the series. We analyze the dynamic correlation for a window period of 30 years for each series so that the result could be significant. Unfortunately, this approach means we lose the data from the first three decades. The formula for this approach would be:

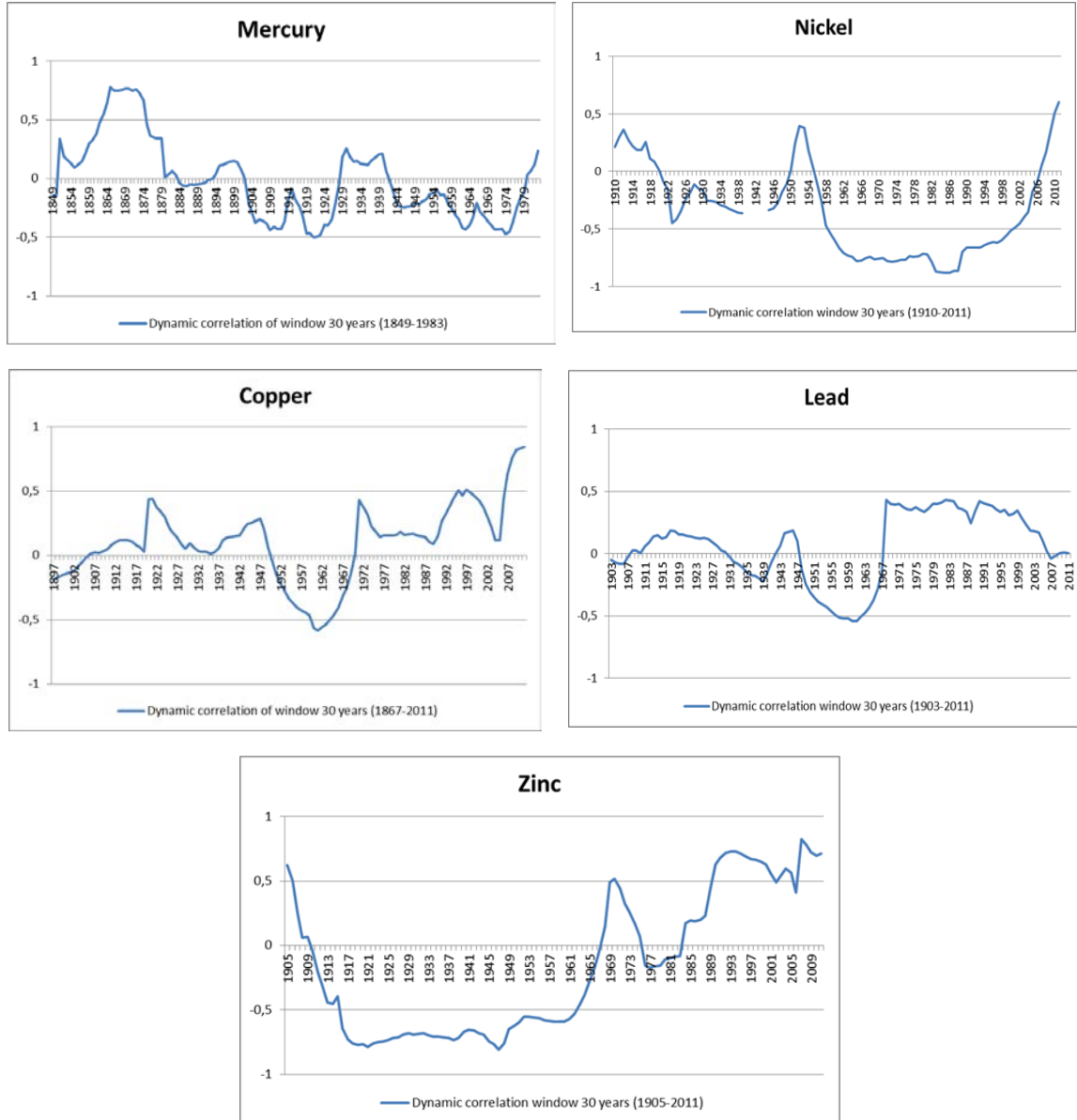
$$r = \frac{Cov(P_t, HHI_t)}{(s_P s_{HHI})} \Big|_{t-30}^t$$

r= correlation coefficient

s= standard deviation

And the results of the correlations between the series are shown in the graphs below.

GRAPHS 17 to 21: Correlation between current prices and the hhi for the metals studied (Dynamic correlation for a 30-year window *)



In general, it is important to note that that our database is still incomplete for long periods, leading to incomplete and, to a certain extent, contradictory results, that future drafts for this study will have to amend. Clear correlations are only observed between business concentrations and prices for mercury, between 1849 and 1875, and copper in the interim war period. The lack of data means that conclusions cannot be reliable, in the main, for the period after the Second World War, and the series available is too short to give any conclusive response for XXI century markets. The remaining data confirm, on the one hand, that the dominant firms have not systematically imposed

price rises, either through not having the necessary market capacity to do so or, probably, to discourage production in less productive mines. On the other hand, the evolution of the markets has followed different steps, both in terms of situation and structure, which rather than being effective seems to be the reason for the process of business concentration. In short, it appears that the market has functioned better than expected given the preponderance of some firms. This has been noted more forcefully in some markets, like the nickel market, which also depends heavily on the steel market. So the evolution of both series has been conditioned by periods of expansion, coinciding with times of war, especially World War I, and by successive industrial crises, in particular that in the 1930s.

4. Conclusions.

Throughout this paper we have seen how mining production has, historically, grown almost exponentially over the long term. The evolution of prices has also been upward although their real evolution is indicative of the growing importance of the market, which translated into higher competition among firms in prices and production costs alike. The analysis of the fundamental metals for the non ferrous sector reveals two very different scenarios - those with a greater level of business concentration, like mercury and nickel, due to a scarce and concentrated supply, and the great metals, like lead and zinc, and fundamentally copper, with its widespread abundance, which set off higher levels of competition. Finally, the specific analysis of business concentration and the evolution of prices for the period 1850-2012 has not proved as significant as might have been expected, although a more complete database would probably offer a different vision and enable us to put forward some general norm or theory to explain the behaviour of the markets in certain situations. It has been shown that the higher concentration levels are not always reflected in the evolution of prices, so the door remains open to longer term analyses, and to the use of more complex variables which are not always accessible, like the real production costs for each metal and, of course the analysis of specific situations

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