The Chilean Nitrate Industry: External Shocks and Policy Responses 1880-1935

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Abstract

This paper examines the decline of the Chilean export boom in nitrates. After the victory against Peru and Bolivia in the War of the Pacific (1879-1883), Chile effectively obtained the only commercial viable deposits of sodium nitrate in the world. The performance of the nitrate industry after WWI contrast sharply with that before. Before the war, nitrate exports grew rapidly, accounting for over two thirds of total exports and about half of total government revenues. After the war, exports and revenues were erratic, and the relative fiscal importance of the industry declined. Although most of the existing literature agrees that the competition of synthetic fertilizers and the Great Depression were responsible for the decline of the industry, no works have estimated their relative importance. In this paper we give econometric estimates of these shocks. We pose various simple counterfactual estimates of Chilean demand in the 1920s and 1930s and show that while the Great Depression shifted demand for Chilean nitrates to the left by 60%, the cumulative effect of the synthetic nitrates was greater, at about 85%. We also survey the record of private and public policy responses to these events in order to fortify our conclusions about the relative importance of international competition and foreign income trends.

Keywords: Nitrates, Natural resources, War of the Pacific, Export-led Growth

JEL Classification: F14, L72, N46, N56, O13

1. Introduction

This paper examines the decline of the Chilean export boom in nitrates, as well as the roles and responses of the Chilean government and private interests. In the early to middle 19th century, Chile's exports consisted mainly of metals and wheat, but the War of the Pacific (1879-1883) was a seismic event that greatly altered the structure of the Chilean economy. After the Chilean victory against Peru and Bolivia, Chile obtained mineral-rich territories from both countries. Although today we focus on the immense deposits of copper found in this region, during the first fifty years after the war, the primary emphasis was placed upon its deposits of sodium nitrate, a natural fertilizer. Indeed, by virtue of its conquest, Chile effectively obtained the only commercially viable deposits of sodium nitrate in the world.

In Chile, the economic period that ensued is called *"el ciclo del salitre,"* or the nitrate cycle. Nitrate exports grew rapidly between 1880 and 1913, accounting for over two thirds of total exports and 15% of GDP over the period. Chile imposed an export tax that remained unchanged until 1930. This policy yielded revenues that accounted for about half of total government revenues, and underwrote a great deal of public investment.

The performance of the nitrate export industry after World War I, contrasts sharply with that before. Exports and revenues were erratic, and the relative fiscal importance of nitrates declined. There was strong government policy intervention, which became even more dramatic after 1930.

We argue that the roots of the decline lay in the development of an immense synthetic nitrogen industry, primarily in Germany. Although the origins of this industry began prior to WWI, the shock of the war provided a great stimulus to its development. After the war Germany, which had been Chile's most important market, switched from being an importer to becoming a nitrogen exporter. In this study, we provide the first econometric estimates of the impact of synthetic nitrogen output growth on the demand for Chilean exports. We pose various simple counterfactual estimates of Chilean demand in the 1920s and 1930s and show that the competition from synthetic nitrates was

significant. While the Great Depression shifted demand for Chilean nitrates to the left by 60%, the cumulative effect of the synthetic nitrates was greater, at about 85%.

The paper proceeds as follows. In the next section we present some basic data on the evolution of the Chilean nitrate industry. We then detail the rise of international competition, and the evolution of import markets. Next, we present our econometric model and estimates of the market for Chilean nitrates. We follow these estimates with a discussion of private and public policy responses to market developments. Section 7 concludes.

2. The Relative Importance of Nitrates for Chilean Export Economy

In this section we describe the importance of nitrate exports to the Chilean economy, and the evolution of nitrate exports, production and prices. After the Chilean conquest of the Peruvian province of Tarapacá, and its formal incorporation into Chile as a result of the Treaty of Ancón (1883), the nitrate industry expanded rapidly. From the early 1890s until the Great Depression, nitrate exports accounted for about half of Chilean exports, and at least ten percent of GDP (see Table 1). Virtually no nitrate was consumed domestically. The export tax on nitrate exports supplied about half of government revenues until shortly after World War I.[1]

The expansion of the industry can be clearly observed in Figures 1 and 2. Figure 1 displays the number of factories and employment in the nitrate industry from 1880-1933. The series follow very similar trends: both increase through 1918, and then begin to suffer rather violent fluctuations, with steep declines in the post war period of about fifty percent from 1919-1921, a collapse in 1926, and another with the Great Depression from 1930.

The pattern of exports in Figure 2 is consistent with the employment and factory trends in Figure 1. The salient feature of the price series, however, is the run-up in prices during and immediately after World War I, and the almost continuous decline beginning in 1922. The decline in prices threatened the profitability of much of the Chilean

[1] The series on export taxes as a percent of government revenues is incomplete –further data collection is in progress.

industry, and, as we discuss below, led to a series of responses by private industry (innovation and government lobbying) and government (public policy). After 1930 the situation became acute, and the industry permanently lost its former significance.

Contemporaries blamed the proliferation of international competition for the decline in prices during the 1920s, and the Great Depression for severely weakening an industry that had become highly vulnerable. We examine each of these phenomena in turn.

3. Rising International Competition in the Nitrogen Industry

From the 1880s, Chilean nitrate faced competition in the nitrogen fertilizer market with other products. The first major competitor was sulfate of ammonia, a by-product of coke production. In the twentieth century, however, significant technological advances occurred that threatened the long-term viability of the Chilean export industry. The initial breakthroughs occurred before World War I, with the design of processes for producing synthetic nitrogenous fertilizers: nitric acid (through the Arc process), calcium cyanamide and synthetic ammonia (U.S. Tariff Commission, 1937; Haber, 1971; Whitbeck, 1931). The Arc Process was the first that was developed commercially, albeit under large power supply needs. At the eve or WWI, the Arc process was in commercial operation in three plants in Norway, and at smaller scale in plants in France, Italy and Austria. The combined production was about 19,000 tons of nitrogen per year. The Cyanamide process produced about three times the output of the Arc process, with smaller plants in Norway, Sweden, Switzerland, Germany, Italy, France, Canada, Japan, and Austria. Both processes together, however, produced only about one sixth of the Chilean nitrate production in 1913 (Jones, 1920).

Synthetic ammonia production, however, became the most important of the three processes and received an important stimulus during World War I when Germany was cut off from Chilean nitrate (Haber, 1971; Hayes, 1987). It was produced via the Haber-Bosch process, which had been put in operation in a single plant in Oppau, Germany, in 1913. Already in 1910, the German chemist Fritz Haber had first shown that nitrogen and hydrogen would react under high pressure using a catalyst to form ammonia (Martin,

1959). In cooperation with the engineer Carl Bosch, he had readied the process for industrial production of nitrogen. At the eve of the war however, production output was small, at about 7,000 tons.

With the beginning of World War I, nitrogen increased in importance due to its military use in the production of explosives. Especially for Germany, which was cut off from Chilean imports, domestic nitrogen production was of critical military importance. Germany secured its nitrogen supplies at the beginning of the war with a relatively large capture of Chilean supplies in the port of Antwerp (estimated at 400,000 tons) but needed to rely on its domestic sources from then on (Jones, 1920). Historians suggest, that Germany would have lost the war by 1916, had it not been for the domestic nitrogen production.

Total German production of nitrogen rose from 129,000 tons in 1914 to 271,000 tons in 1917/1918, with the actual production capacity at the end of the war estimated at 520,000 tons (Szoelloesi-Janze, 1996). This far exceeded the amount of pre-war imports that Germany had received from Chile and readied Germany for its post-war position as nitrogen exporter. Key for this increase in production was the cooperation between BASF (Badische Anilin- und Soda-Fabrik), which operated the Oppau plant, and the Ministry of War. Already in the fall of 1914, negotiations between Bosch and the War Ministry led to a promise by Bosch to produce 5,000 tons of nitrogen monthly by May 1915, increasing this to 7,500 by August, in exchange for a government payment of six million Marks for the construction of a new plant (Johnson, 2003, p. 171). Clever negotiations by Haber tied BASF even closer to the government, and firmly established the dominance of the Haber-Bosch process for nitrogen production over the other processes in Germany (Szoelloesi-Janze, 1996).

Table 2 illustrates the development of synthetic nitrate production, and its size relative to Chilean nitrogen output (see U.S. Tariff Commission, 1937; O'Brien, 1989; and Whitbeck, 1931, for discussion of nitrogen recovery from Chilean nitrate). Chilean output grew very rapidly up to World War I, as did the sulfate of ammonia industry. However, from that point forward the preponderance of growth was in the synthetic ammonia industry, particularly in the 1920s. The output of German nitrogen expanded tremendously, and included a rapid expansion of sulfate of ammonia as well as synthetic

ammonia, and to a lesser degree calcium cyanamide. German producers formed a cartel, the Deutsche Stickstoffsyndikat, that regulated competition between the behemoth I.G. Farben (which included the original producer BASF) and a number of smaller producers (Curtis and Ernst, 1924; Haber, 1971; Hayes, 1987; Stocking and Watkins, 1946). From the mid 1920s, in what Stocking and Watkins call a "nitrogen rush," production of synthetic ammonia increased rapidly in other countries.

4. Import Markets for Chilean Nitrates

The increased international competition in the form of greatly expanded production contributed to a shift in the composition of import markets for Chilean nitrates. Over the period 1880-1935, the principal markets for Chilean nitrates were a handful of countries: the United States, the United Kingdom, France, Germany, the Netherlands, Belgium, Italy and Spain. (They typically accounted for over ninety percent of consumption, the remainder going to Scandinavia, Egypt, South Africa and Japan.) Table 3 shows the shares of these countries' consumption of Chilean nitrates for selected years.

The salient feature of this table is that World War I shifted the market for Chilean nitrates decisively away from Germany toward the United States. This was due to a dramatic decline in German imports, as the country had not just become virtually self-sufficient, but had become a large net exporter of nitrogen fertilizers. The growth of the U.S. market primarily was due to rapidly increasing use of fertilizers, consumption of which had doubled between 1914 and 1924, and increased by another 50% by 1929 (U.S. Tariff Commission, 1937). The U.S. market, however, collapsed during the Great Depression, which explains the dramatic fall in the U.S. share of consumption. Indeed, a consumption-weighted average of Gross Domestic Product in Chile's main markets shows a 20% decline between 1929 and 1932.

We have depicted the important trends in Chilean nitrate exports, and the development of competition and international markets. We now estimate the relative importance of these factors in an econometric model of the market of Chilean nitrates.

5. Econometric Estimation

In this section, we estimate the Chilean export demand and export supply of nitrates in order to better understand the major influences on Chile's nitrate industry. The demand function is given by:

$$\ln XCHILE_t = \beta_{0,t} + \beta_{1,t} \ln PINT_t + \beta_{2,t} \ln FORINC_t + \beta_{3,t} \ln PAMMON_t + \beta_{4,t} \ln INDNITRO_t + \beta_{5,t} WWI_t + \mu_t$$

where XCHILE is the quantity of nitrate exported, PINT is the price of nitrate at the port of import in US dollars per ton, FORINC is the weighted average of foreign income, PAMMON is the price of sulfate of ammonia at export port in the UK measured in pounds per long ton, INDNITRO is the sum of the quantities of synthetic ammonia and cyanamide produced over the period, WWI is a dummy variable indicating the first World War, t ranges from 1880-1934 and μ is a random demand shock.

The inverse supply equation in contrast is:

$$\ln PINT = \alpha_{0,t} + \alpha_{1,t} \ln XCHILE_t + \alpha_{2,t} CARTEL_t + \alpha_{3,t} \ln WAGE_t + \alpha_{4,t} INTEREST_t + \alpha_{5,t} TIME + \varepsilon_t$$

where CARTEL is a dummy for all Chilean cartels, taking the implicit assumption that all cartels had the same effect on exports, WAGE is an index of Chilean wages, INTEREST is the Chilean nominal interest rate, TIME is a time trend, simulating technological advances and ε is a random supply shock.[2]

We expect foreign income, the price of ammonium, as well as the World War I years to increase the demand for Chilean nitrate. Ammonuim sulfate was the principal competitor of nitrate in the early period and continued to be an important competitor after World War I, so a rise in its price should increase the demand for nitrate. During the war, the allied forces almost exclusively relied on Chilean nitrate for the production of

[2] Data sources are Ministerio de Hacienda (1925, 1935), Braun et. al. (2000), U.S. Tariff Commission (1937), International Yearbook of Agricultural Statistics (1919-1930), Partington and Parker (1922), Stocking and Watkins (1946), and Wagner (1992).

explosives and fertilizer, increasing its demand. Moreover, demand for nitrates fluctuated with incomes in consuming countries. Beginning in the early part of the 20th century, however the production of industrial nitrogen, synthetic ammonia and cyanamide, rose and provided increasing competition for Chilean nitrates. Therefore, we expect rising production of synthetic fertilizers to decrease demand for Chilean nitrate (note that complete price series for synthetic ammonia and calcium cyanamide are not available).

On the supply side, Chilean nitrate producers formed cartels of varying duration over the period of our study. We include a dichotomous cartel variable that takes the value of one when a cartel was in operation and zero when it was not. Even though often the cartels were ineffective, we expect in general the price of nitrate to rise when a cartel was in operation. Labor and *caliche* (mineral from which nitrate was extracted) were the major variable inputs in nitrate production, so we include the Chilean wage to control for cost of production. The interest rate effect, in contrast, is uncertain in theory. If interest rates function as an input price, representing the cost of borrowing to finance capital expansion, the coefficient should be positive. If however, the interest rate is interpreted following Hotelling (1931) and functions as an inducement to mine, then the coefficient should be negative. Based on our earlier work (Sicotte et al., 2009) we expect a negative coefficient. Time represents technological change and productivity advances, and is therefore expected to reduce the price. Other supply shifters might have also played a role. Fuel, especially coal, was used to extract nitrate from caliche. We would have liked to include the price of coal in Chile, but these data are not available for the entire period of our analysis.

Following Irwin (2003) and Sicotte et al. (2009) we estimate the model using three stage least squares, which allows for contemporaneous correlation of the error terms and allows for simultaneous estimation of price and quantity. Three different model specifications are presented below (Table 5). For all models, the Chi square values are highly significant. Also, all independent variables show the expected signs.

Looking at the demand specifications in all three models, the price elasticity of demand for nitrates is given by -2.69, -1.38 and -1.58, respectively, indicating that demand was price elastic. Demand was also income elastic with respect to foreign income, with income elasticities of 3.63, 3.19 and 3.27. This implies that a doubling of

foreign income, which took place between 1880 and 1910, should have tripled the demand for Chilean nitrates, ceteris paribus. On the other hand, a reduction in foreign income of 20%, which occurred between 1929-1932 would have reduced the demand for Chilean nitrates by 60%. This shows, that the demand curve for Chilean nitrate shifted substantially in response to income fluctuations in consuming countries.

Insofar as the sensitivity of demand to substitutes, estimates of the cross price elasticity with respect to the sulfate of ammonia price are 2.07, 1.32, and 1.62. All estimates are greater than one, thereby indicating that nitrate exports were quite responsive to the price of this particular substitute. The price trend of sulfate of ammonia mirrors closely that of nitrate. It fell by fifty percent from 1923 to 1929, and forty percent from 1929 to 1932. Our estimates suggest that this had a major effect shifting the demand for Chilean nitrate to the left during this period. The level of significance is greater than ten percent in each case, but never better than one percent.

Rising production of industrial nitrogen reduced Chilean exports. According to our results, a doubling of the quantity of industrial nitrogen reduced Chilean export demand by about 20%. Industrial nitrogen production doubled every year, from 1909 to 1912, then again in 1914, 1916, 1922, 1926, 1929 and 1938, a total of 10 times over this 30 year period. Cumulatively, this implied a reduction of close to 85% in Chilean export demand that can be attributed to the rise in industrial nitrogen.

Exports rose during the WWI years, reflecting the importance of nitrogen for military purposes. Even though exports were re-directed to the allied powers and blocked to Germany, the war had a significant effect, raising export demand by close to 50%.

Within the demand equation, we have the most confidence in the coefficients on foreign income and on synthetic nitrogen production. Both of these coefficients are highly statistically significant, and have large economic implications that seem to go a long way toward explaining the expansion of Chilean nitrate exports before World War I, and the difficulties faced by Chilean nitrates in the post war period. In this sense, our results are consistent with the interpretations of contemporaries (Jorge Vidal, 1933) and the assessments of scholars who have studied the period (Cariola and Sunkel, 1985; Lüders and Wagner, 2003). Our econometric analysis, however, is the first to treat this

issue, and as such not only provides empirical support for this view, but also estimates of the relative magnitudes of the shocks.

For the supply specifications, the reciprocal of the coefficient on export volume indicates the elasticity of export supply. The export supply for Chile is elastic at 15.38, 10.87, and 4.27 however only for model three this coefficient is significant. The cartel variable has the correct sign but is insignificant, indicating the limited effectiveness of the various cartels. The wage is positive and significant in all model specifications. The coefficient is relatively small, however, and given that the percentage changes in wages were smaller than the percentage changes in the demand side variables, it does not appear that wages played a critical role. The interest variable is negative and significant when included, but also with a relatively small coefficient and interest rate changes were usually small in magnitude. The significance of the time trend is consistent with the view that productivity trends were increasing over the period. But the overall results of the supply equation are much less satisfactory than that of the demand equation. In the absence of a good series of fuel prices and other cost data, perhaps at the plant level, we cannot gauge properly how important supply shifts were in compounding or ameliorating the effects of changes in demand on market equilibrium. We return to this issue below in our discussion of innovation and regulation.

6. Private Industry and Public Policy Responses

The increased international competition in fertilizer markets put pressure on Chilean nitrate producers and on the Chilean government to respond. Although aided by economic growth in consuming countries, the pressure was still felt, and when the Depression began it became acute. In this section, we describe some of the responses of private industry and public policy to changing market conditions over the period 1880-1935. Our discussion is limited in some important ways. First, because of the lack of adequate data, we cannot estimate the effectiveness of these policies. Second, we do not present a formal model of the political economy of nitrate policy in Chile. Indeed, for the purposes of this paper, our policy survey is motivated by a desire to fortify our conclusions about the importance of international competition and foreign income trends

by showing how they elicited some rather dramatic developments in Chile. We also wish, by providing this survey, to sketch out possible lines of inquiry for future research.

First, as pointed out by Lüders and Wagner (2003) Chilean government policy was important right from the start in the 1880s. The Chilean government made the momentous decision not to follow through on the Peruvian plan to nationalize the nitrate industry, but rather to tax exports (Greenhill and Miller, 1973; O'Brien, 1979; Cruchaga, 1929). Second, the Chilean government maintained property rights over enormous tracts of land containing rich nitrate deposits, and at various junctures auctioned portions of these lands to private firms for development into oficinas (Cariola and Sunkel, 1985; Cruchaga, 1929). It should also be noted that the government played an important role in the development of transportation infrastructure.

Over our period of study, Chilean policies evolved from an export duty of 2.57 shillings per cwt starting in 1880, and attempts to promote the industry through advertisement campaigns abroad, towards heavy intervention and control.[3] In 1880, after taking over the Peruvian and Bolivian nitrate deposits, the Chilean government formed a commission to assess the alternative policies available for the control of the industry. The government opted for the devolution of the *salitreras* to the holders of the nitrates certificates issued by the Peruvian government in the late 1870s (in payment for their nationalization). This process resulted in a great concentration of the industry in British hands.[4]

The industry expanded quickly, partly due to the liberal policies instituted by the Chilean government. As we discussed earlier, the rapid increase in export volumes provoked a marked fall in nitrate prices in the late 1880s and 1890s, which prompted the formation of *"combinaciones salitreras"* in order to limit production. Several *combinaciones* were arranged between 1884 and 1906 with varied degrees of success (Ministerio de Hacienda, 1935; Brown, 1963). Elements of the government and the public viewed these cartel arrangements very negatively, as they would reduce export tax revenues by contracting output and exports. Others, particularly those closely associated

[3] This specific export duty lasted for nearly fifty years.
[4] The following discussion draws on Memoria de Hacienda (1880-1884, 1918, 1919/1920, 1921, 1927, 1929/1930), Ministerio de Hacienda (1935), McConnell (1935), O'Brien (1989) and Wallace and Edminster (1930).

with the nitrate industry viewed them as a necessary way to stop "destructive competition" among firms with immense fixed costs and comparatively low marginal costs.

In the first decade of the 20th century, firms and the government took notice of the rising tide of competition abroad, and a trend of rising costs at home. Important studies were undertaken, most notably by Alejandro Bertrand (1910), and recommendations were made to reform tax policy away from a specific tax toward a profit-sharing arrangement with the government. This was not adopted (Vidal, 1933). A program of advertising in consuming countries, which had been organized by the Asociación Salitrera de Propaganda in 1894, was intensified (Reyes Navarro, 1986).

With the outbreak of WWI, however, the government issued and emergency law that authorized the provision of cash advances to nitrate producers to help them handle the initial shock of the war (Memoria de Hacienda, 1918, 1919/1920, and 1921). The rising competition from synthetic nitrogen, expanded sulfate of ammonia output and the wild fluctuations in prices from 1919-1922 provoked a more decisive government reaction. The government sponsored the creation of the Chilean Nitrate Producers' Association (CNPA), and offered subsidies on railroad rates and granted exemptions from import duties on bags for the shipment of nitrates to all its members. Some of the key responsibilities of the CNPA was to publicize Chilean nitrates abroad, gather market information, supervise nitrate sales and regulate prices (all producers were incorporated except for two American companies, which claimed that under their anti-trust laws they were forbidden to engage in any combination with other firms in restraint of trade. They represented, however, only 3% of the market).

The CNPA operated from 1919 until 1927. Severe competition from manufactured nitrogen led to the limited success of the agreement, especially with respect to prices. In 1928, the government assumed further leadership in the industry with new laws that included new propaganda measures, as well as the creation of a Nitrate Bank. It also formed a new joint selling agency in September of the same year. The new agreement was more flexible than the one under the CNPA, and was not designed to maintain prices regardless of the market situation, but aimed to limit competition within Chile. The government also announced that any reduction in the price of nitrate

substitutes that might come from the German Nitrogen Syndicate would be matched with a bonus for local producers.

In the 1920s, private nitrate firms increased the intensity of their requests to reduce or abolish the export tax, noting that it was threatening their increased viability due to rising foreign competition. The government was reluctant to do so, but it did recognize the need to diversify its sources of revenues and began to rely on other taxes (Cariola and Sunkel, 1985; Memoria de Hacienda, 1921, 1927, 1929/1930). (Interestingly, the main consuming countries maintained duty free access for Chilean nitrates until 1931 when Germany imposed a duty. Even the onerous Smoot-Hawley Tariff kept nitrate on the free list.)

Private actors, however, did more than simply lobby for changing government policies. The most famous development, with yet unmeasured impact on industry supply, was the introduction of the so-called Guggenheim process for extracting nitrate (Glaser-Schmidt, 1995; O' Brien, 1989). The Guggenheim family had established itself as a major player in Chilean mining, including nitrates, in the early 20th century. They made massive investments in technical development that "promised to cut the costs of nitrate production by 40%."[5] Daniel Guggenheim declared, "The Chilean nitrate industry is at present passing through a severe crisis, but if the Chilean Government will do its share by reducing the high export taxes on nitrate, and the producers will adopt the new process, we believe that the competition with the synthetic nitrogen can be successfully met." (New York Times, Feb. 14, 1927, p. 17) A precise validation of this claim is not possible to obtain with the limited industry-level data at our disposal (the inclusion of a "Guggenheim process" dummy variable in the supply equation was not significant), and will probably require an intensive examination of micro-level data on costs and output to properly estimate the supply functions of plants employing differing techniques.

[5] The productivity of the existing Shanks system was diminishing considerably at the time. This system was labor intensive in extraction and refining, and much less effective for the lower quality caliche that characterized the industry in this period. The Guggenheim process could treat ore with an assay of 8%, which compared quite well to the Shanks minimum requirement of 15%. The Guggenheim process required large-scale production to achieve the envisioned economies. In 1924, the Guggenheims began construction of a large refinery that incorporated the new technology. The next year they added three additional refineries, port facilities, and a railroad to their holdings. In 1929 they acquired the Lautaro Nitrate Co., the most important nitrate producer in Chile at the time. By the time of the formation of Cosach the Guggenheim's already controlled approximately one half of the industry's total output. O'Brien (1989), Glaser-Schmidt (1995).

It is known, however, that the technical advance alone was not sufficient to save the industry when the Depression hit.

The Great Depression marked a major change in the Chilean government management of the industry. Since that point on public policy took an even more activist role. In July 1930 the government engaged in a joint venture with private producers (most importantly the Guggenheims) for the creation of a new company, *Compañía de Salitre de Chile* (COSACH), each side controlling 50% of the company's stock. The corporation would control all production and sales. In exchange for the government's elimination of the export duty Cosach committed to make payments to the government totaling around $80 million through 1933. Afterwards the government would receive 50% of the company's profits.

The precise political economy of this decision remains to be shown. Certainly the financial needs of the Chilean government were pressing. U.S. President-elect Hoover, who visited Chile in December of 1928, strongly lobbied for the Guggenheims' project. According to most accounts, Chilean president Ibañez paid close attention to Hoover given Chile's desperate need for foreign loans with the onset of the Depression.

Cosach, however, was a corporation without working capital. Projected revenues to cover Cosach's obligations were based on very optimistic projection of nitrate prices, which did not materialize. The company was also working under the assumption that the Guggenheims would be raising around $110 million in floating bonds. The depression put an end to this hope –they were able to raise only $34 million. The depression also hurt the International Nitrogen Cartel, which had been formed in 1930 in the hopes of achieving more stable prices. The cartel failed to renew its agreement in 1931. The financial woes of Cosach were only part of its problems, however. There were a number of domestic forces opposed to its consolidation including workers who were outraged about the drastic decline of the industry's labor force (from 36,000 workers to a mere 8,000) and Chilean middlemen, who used to supply tools, food and other products to the industry but were displaced when Cosach consolidated supply services. Facing major financial constraints and political opposition Cosach was dissolved in January 1933.

In 1934 the government instituted the Corporación de Ventas de Salitre y Yodo de Chile (COVENSA -Chilean Nitrate and Iodine Sales Corporation). This new arrangement monopolized the commercialization of the nitrate. The corporation profits were based on the difference between the price paid to the local producers and the final price (after discounting for transportation costs, etc.). The state appropriated 25% of the profits. This new arrangement provided for the state monopoly of nitrate sales for around 35 years.

In addition to domestic private and public policy responses, Chilean producers actively participated in international nitrogen cartels. The first was between the German Syndicate, the British Imperial Chemical Industries Limited and the Chilean producers in 1929. A new international cartel was formed in 1930 to comprise producers in other countries, including Norway, France, Belgium the Netherlands, Italy, Poland, Czechoslovakia and Ireland. U.S. firms were outside the cartel. A price war occurred in 1931, and, as Stocking and Watkins describe, this failure of private cooperation induced a flurry of government action. In Germany and other countries protectionist policies were implemented. Chile adopted a system of foreign exchange controls "which were used to force purchase of Chilean nitrate." (Stocking and Watkins 1946, p. 144) An international cartel was formed again in 1932, and was renewed until World War II.

In sum, the reaction of private firms and the Chilean government were substantial, particularly after World War I. The government and private firms struggled to maintain and later regain the industry's preeminence in world markets through the tools at their disposal. A rigorous examination of the effectiveness of their efforts, however, is not possible in the simple three stage least squares market estimation of annual industry level data that we followed in the previous section, and will require much more extensive research. The issue is complicated by the fact that private and public responses were both endogenous to and affected broader market developments.

7. Conclusions

The acquisition of territories during the War of the Pacific enabled Chile's nitrate export boom, which was a salient feature of its economy up to the Great Depression.

Demand for nitrates rose with rising incomes, leading to increased fertilizer usage in rapidly industrializing Western Europe and North America. The export taxes financed a large portion of Chilean government operations, and quite possibly stimulated the technical developments in synthetic nitrogen production that took place in the first decade of the 20th century.

Still, the dominance of the Chilean industry in world fertilizer markets was not seriously threatened until World War I greatly accelerated German production of synthetic ammonia, and sulfate of ammonia in all consuming countries. The continued increased fertilizer demand in the 1920s made Chile's situation barely manageable during that period, but the onset of the Great Depression signified a crisis the likes of which the industry had never experienced.

We provide econometric evidence that trends in international competition and foreign income had enormous impact on Chilean nitrate demand. Our results suggest that while the collapse of foreign demand reduced the demand for Chilean nitrate by about 60%, the impact of foreign competition was even larger, resulting in a cumulative effect of an 85% reduction of Chilean demand. We also survey the record of private and public policy responses to these developments, sketching the outline of future research on the nitrate boom and Chilean political economy. A promising line of research is to link these policy experiences and market developments with the Chilean transition toward the combination of copper export and import substituting strategies that were employed from 1930 forward. Future work should also develop further the parallels between the Chilean experience and that of other primary product exporters like Cuba that suffered a similar fate after World War I.

References:

Bertrand, Alejandro (1910) *La crisis salitrera*, Louis-Michaud, Paris.

Braun, Juan, Matias Braun, Ignacio Briones and José Diaz (2000) "Economía chilena, 1810-1995: Estadísticas históricas", Documento de trabajo no. 187. Instituto de Economía. Pontificia Universidad Católica de Chile.

Brown, J.R. (1963) "Nitrate Crises, Combinations and the Chilean Government in the Nitrate Age", Hispanic American Historical Review, Vol. 43, No. 2, pp. 230-246.

Cariola, Carmen and Osvaldo Sunkel (1985) "The Growth of the Nitrate Industry and Socioeconomic Change in Chile, 1880-1930", in Cortés Conde, Roberto and Shane Hunt (eds.) *The Latin American Economies: Growth and the Export Sector 1880-1930*, Holmes and Meier, New York.

Chile. Ministerio de Hacienda (1925) *Antecedentes sobre la industria salitrera*, Universo, Santiago de Chile.

Chile. Ministerio de Hacienda (1935) *La Industria del salitre de Chile*, La Nación, Santiago de Chile.

Chile (various years). Ministerio de Hacienda. Memoria.

Cruchaga, Manuel (1929) *Salitre y guano*, Editorial Reus, Madrid.

Curtis, Harry Alfred and Frank Ernst (1924) *The Nitrogen Situation in European Countries*, U.S. Bureau of Foreign and Domestic Commerce, Trade Information Bulletin No. 270, Government Printing Office, Washington, DC.

Glaser-Schmidt, Elisabeth (1995) "The Guggenheims and the Coming of the Great Depression in Chile, 1923-1934," Business and Economic History, Vol. 24, No. 1, pp. 176-185.

Greenhill, Robert and Rory Miller (1973) "The Peruvian Government and the Nitrate Trade, 1873-1879", Journal of Latin American Studies, Vol. 5, No. 1, pp. 107-131.

Haber, Ludwig (1971) *The Chemical Industry, 1900-1930: International Growth and Technological Change,* Clarendon, Oxford.

Hayes, Peter (1987) *Industry and Ideology: IG Farben in the Nazi Era*, Cambridge University Press, New York.

Hotelling, Harold (1931) "The Economics of Exhaustible Resources", The Journal of Political Economy, Vol. 39, No. 2, pp. 137-175.

International Institute of Agriculture (1919-1930) *International Yearbook of Agricultural Statistics*, Rome.
Irwin, Douglas (2003) "Explaining America's Surge in Manufactured Exports", The Review of Economics and Statistics, Vol. 85, No. 2, pp. 364-376.

Johnson, Jeffrey (2003) "Die Macht der Synthese" in Abelshauser, Werner (ed.) *Die BASF, Eine Unternehmensgeschichte*, Beck, Munich, Germany

Jones, Grinnell (1920) "Nitrogen: Its Fixation, Its Uses in Peace ad War", Quarterly Journal of Economics, Vol 34, No. 3, pp. 391-431.

Lamer, Mirko (1957) *The World Fertilizer Economy*, Stanford University Press, Stanford, CA.

Lüders, Rolf and Gert Wagner (2003) "Export Tariff, Welfare and Public Finance: Nitrates from 1880 to 1930", Documento de Trabajo No. 241, Instituto de Economía, Pontificia Universidad Católica de Chile.

Martin, William (1959) "Public Policy and Increased Competition in the Synthetic Ammonia Industry" Quarterly Journal of Economics, Vol. 73, No. 3, pp. 373-392

McConnell, Donald (1935) "The Chilean Nitrate Industry", Journal of Political Economy, Vol. 43, No. 4, pp. 506-529.

McQueen, Charles (1926): *Chilean Public Finance*. Washington, DC: U.S. Department of Commerce Trade Promotion Series.

O'Brien, Thomas (1979) "Chilean Elites and Foreign Investors: Chilean Nitrate Policy, 1880-1882", Journal of Latin American Studies, Vol. 11, No. 1, pp. 101-121.

O'Brien, Thomas (1989) "Rich Beyond the Dreams of Avarice: The Guggenheims in Chile", The Business History Review, Vol. 59, No. 1, pp. 122-159.

Partington, J.R. and L. Parker (1922) *The Nitrogen Industry*, Constable and Co., London.

Reyes Navarro, Enrique (1986) *Salitre chileno, mercado mundial y propaganda, 1889-1916*, Centro de Investigación de la Realidad del Norte, Iquique, Chile.

Sicotte, Richard, Catalina Vizcarra and Kirsten Wandschneider (2009) "The Fiscal Impact of the War of the Pacific", Cliometrica, Vol. 3, pp. 97-121.

Stocking, George and Myron Watkins (1946) Cartels in Action, The Twentieth Century Fund, New York.

Szoelloesi-Janze, Margit (1996) “Berater, Agent, Interessent? Fritz Haber, die BASF und die Staatliche Stickstoffpolitik im ersten Weltkrieg”, Berichte zur WissenschaftsGeschichte 19, pp. 105-117.

United States Tariff Commission (1937) *Chemical Nitrogen*, Government Printing Office, Washington, DC.

Vidal, Jorge (1933) *Veinte años despues: la tragedia del salitre,* Universo, Santiago de Chile.

Wagner, Gert (1992) “Trabajo, producción y crecimiento: la economía chilena 1960-1930”, Documento de trabajo no. 150, Pontificia Universidad Católica de Chile.

Wallace, Benjamin and Lynn Edminster (1930) *International Control of Raw Materials*, Brookings Institution, Washington, DC.

Whitbeck, R.H. (1931) “Chilean Nitrate and the Nitrogen Revolution”, Economic Geography, Vol. 7, No. 3, pp. 273-283.

Table 1: Chilean Nitrate Exports

Year	Nitrate Exports (millions of pesos)	Nitrate Exports as percent of Total Exports	Nitrate Exports as percent of GDP	Nitrate Export Tax Revenues as Percent of Total Tax Revenues
1880	90.8	0.26	0.035	0.047
1885	131.2	0.38	0.066	0.282
1890	221.9	0.57	0.125	0.482
1895	286.5	0.69	0.163	0.561
1900	332.6	0.68	0.152	0.489
1905	544.0	0.78	0.194	0.480
1910	696.8	0.79	0.175	0.513
1915	608.9	0.76	0.177	0.602
1918	1532.6	0.70	0.225	0.448
1919	351.1	0.37	0.051	0.244
1920	1582.5	0.67	0.164	0.410
1921	823.4	0.62	0.111	0.335
1922	514.3	0.51	0.099	0.314
1923	929.5	0.57	0.133	0.406
1924	967.2	0.53	0.133	0.398
1925	1031.6	0.55	0.123	
1926	710.3	0.43	0.100	
1927	860.2	0.51	0.134	
1928	935.3	0.48	0.121	
1929	952.5	0.42	0.105	
1930	666.7			
1931	352.6			
1932	193.8	0.20	0.024	
1933	406.9			

Sources: U.S. Tariff Commission (1937), Braun et al, Cariola and Sunkel, Ministerio de Hacienda (1925), McQueen (1926).

Table 2: World Production of Nitrogen (Thousands of Short Tons)

Year	Chilean Nitrate	Sulfate of Ammonia	Calcium Cyanamide	Synthetic Ammonia	German Total[1]	World Total[1]
1900	220	110	0	0	N / A	330
1905	299	147	0	0	N / A	446
1910	420	227	4	5	N / A	656
1913	473	313	42	24	132	852
1918	488	402	98	172	271	1160
1925	433	369	146	432	560	1380
1929	555	497	251	1102	890	2405
1930	420	477	256	1019	677	2172
1931	193	397	185	991	598	1766
1932	120	346	167	1149	458	1782
1933	76	357	199	1264	429	1896
1934	145	397	235	1348	463	2125
1935	205	434	276	1545	N / A	2460

Source: U.S. Tariff Commission, 1937.

[1] The German total includes output of sulfate of ammonia, calcium cyanamide and synthetic ammonia, whereas the world total includes output of all products from all countries.

Table 3. Consumption of Chilean Nitrates

Year	USA	UK	Germany	France	Netherlands	Belgium	Italy	Spain
1880	0.15	0.28	0.27	0.17	0.09	0.04	-	-
1890	0.09	0.13	0.34	0.28	0.06	0.10	0.01	-
1900	0.11	0.10	0.36	0.21	0.07	0.13	0.02	-
1913	0.19	0.06	0.37	0.14	0.07	0.14	0.02	-
1919	0.78	0.01	0.00	0.07	0.07	0.04	0.01	0.03
1924	0.50	0.04	0.07	0.15	0.07	0.09	0.03	0.05
1929	0.45	0.04	0.05	0.20	0.09	0.07	0.04	0.08
1933[1]	0.26	0.01	0.14	0.23	0.08	0.08	0.05	0.16

[1] The data for 1933 are from imports rather than consumption.

Sources: Min. Hacienda (1925); International Yearbook of Agricultural Statistics (1919-1930), U.S. Tariff Commission (1937).

Table 4: Expected effects of Independent Variables.

	Expected Effect on Demand	Expected Effect on Supply
FORINC	+	
PAMMON	+	
INDNITRO	-	
WWI	+	
CARTEL		+
WAGE		+
INTEREST		-/+
TIME		-

Table 5: Chilean Nitrate Exports: Estimates of Demand and Supply, 1880-1934
(P values in parentheses)

	Model 1		Model 2		Model 3	
	Chilean Export Demand (log export volume)	Chilean Export Supply (log Export Price)	Chilean Export Demand (log export volume	Chilean Export Supply (log Export Price)	Chilean Export Demand (log export volume)	Chilean Export Supply (log Export Price)
Constant	3.0558 (0.064)	2.5145 (0.024)	2.1328 (0.137)	2.8899 (0.009)	1.7644 (0.239)	.21246 (0.882)
Ln PINT	-2.6906 (0.027)		-1.3809 (0.158)		-1.5788 (0.142)	
Ln FORINC	3.6322 (0.000)		3.1941 (0.000)		3.2674 (0.000)	
Ln PAMMON	2.0688 (0.022)		1.3197 (0.071)		1.6214 (0.043)	
Ln INDNITRO	-.19473 (0.000)		-.20022 (0.000)		-.2004 (0.000)	
WW I	.42254 (0.034)		.46311 (0.009)		.44301 (0.016)	
Ln XCHILE		.06549 (0.430)		.09207 (0.254)		.23393 (0.027)
CARTEL		.00756 (0.913)		.01600 (0.813)		.07752 (0.309)
Ln WAGE		.14972 (0.023)		.20745 (0.004)		.60748 (0.003)
INTEREST	-	-		-.09798 (0.069)	-	-
TIME	-	-	-	-		-.02656 (0.017)
CHI 2	107.12 (0.000)	16.62 (0.000)	136.50 (0.000)	20.68 (0.000)	127.61 (0.000)	22.03 (0.000)
„R-SQ“	0.5681	0.2226	0.7154	0.2498	0.7024	0.1793
NOBS	53	53	53	53	53	53

Sources for figures 1 & 2 below:
Memoria de Hacienda (1927, 1929/1930), U.S. Tariff Commission (1937), Min. de Hacienda (1925, 1935).