

Fertilizer, Fiscal Crises and the War of the Pacific

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In the War of the Pacific (1879-1884), Chile defeated the combined armies of Peru and Bolivia and acquired territories on the Pacific coast of South America from both countries. Peru lost its two southernmost provinces, Tarapacá and Arica, and recovered the province of Tacna after a final treaty was signed in 1929. Perhaps the war is best remembered today because Bolivia lost its entire seacoast to Chile. The issue continues to be a flashpoint in relations between the countries and resonates strongly in their respective domestic politics. Most recently, the proposal to build a gas pipeline to export natural gas from Bolivia to the United States and Mexico through a Chilean rather than Peruvian port – a potential savings of \$600 million, led to rioting and the resignation of Bolivia’s president in October 2003.¹

But from the perspective of the time, the war was a major turning point as much in the economic history of Chile and Peru as of Bolivia. The territories that Chile absorbed contained vast deposits – the world’s only commercially viable deposits – of sodium nitrate, a natural source of nitrogen that was the world’s leading fertilizer in the decades before World War I. Nitrate so dominated the economic life of Chile during those years that the period is now referred to as “*el ciclo de salitre*” – the nitrate cycle. The export tax on nitrates routinely accounted for at least one half of all government revenue. With those revenues, the Chilean government invested heavily in transportation, infrastructure, and public education. For Peru, the loss of immense nitrate wealth came at the most inauspicious time imaginable. The country had defaulted in 1875 on its enormous foreign debt and was counting on public revenues from the nitrate

¹ “Lingering Feud with Chile Threatens Bolivia’s Pipeline Plan,” *New York Times*, July 8, 2002; “Bolivian Leader Resigns and His Vice President Steps In,” *New York Times*, October 18, 2003; “Political Problems in South America,” *Power Economics*, October 18, 2004. Two maps at the end of the paper that illustrate the geography of the conflict.

industry to return the government to solvency. Economic depression, financial chaos and civil war followed Peru's defeat. The country's economic orientation shifted toward agriculture, especially sugar and cotton. Peru came to an agreement with its creditors in 1890 by placing the country's railroads and some other major assets under the control of a company owned by the bondholders but under the direction of Michael Grace, an American entrepreneur. Grace interests held substantial influence over Peruvian economics and politics into the 1950s. The differences between Chile and Peru, already substantial in 1879, grew considerably after the war.²

Thus, the war had major implications for the economy in general and public finance in particular in the three countries. But how much? This paper is the first attempt to provide quantitative estimates of the gains and losses to the respective countries as a result of the changing jurisdiction over the nitrate deposits. In 1878 nitrate was found in all three countries, but the largest industry was in Peru, followed by Bolivia and then Chile. What were the gains that Chile would have obtained in the absence of conquest? What were the gains that Bolivia and Peru could have obtained from their nitrate deposits had they not lost the war? We provide estimates of the revenue that each respective government could have earned from nitrates if the borders had not changed. The conclusion confirms that Bolivia, at least in proportion to its obligations, suffered severely. Chile, however, would have gained comparatively little in the short run if it had not taken the war to Peruvian territory. It is very likely that its financial problems would

² Indicators of economic development are very difficult to come by for these countries in the nineteenth century. Nonetheless, some estimates are available that suggest that while in 1800 the two countries had basically the same level of per capita income, by 1900 Chilean GDP per capita was almost twice as large as the Peruvian one. Scholars point to widening differences in literacy and education, as well as in political rights. In terms of infrastructure, Chile and Peru had similar railway systems in the 1870s, as measured in kilometers open. By 1913, however, the Chilean system had more than quadrupled and was more than twice the size of Peru's. For data on GDP levels and political rights see Engerman and Sokoloff (2001), Table 3, and Engerman and Sokoloff (2003), Table 3; also see Mitchell (2003), pp. 546-47.

have continued, and that its investments in public works and education would have been diminished and delayed. Peru's debts were so large that even holding onto the territory probably would not have enabled Peru to resume servicing the debt. However, at a minimum, it would have given Peru's government the opportunity to come to better terms with its bondholders than what actually occurred.

The paper proceeds as follows. We first describe the market for nitrate and the industry's situation before the war. Next we examine the financial crises facing the three countries. We then present our counterfactual analysis of the revenue estimates.

The Fertilizer Market, 1870-1913

Plants require large amounts of three elements that are usually provided by fertilizers in commercial agriculture: phosphorus, potassium and nitrogen. Sodium nitrate was one of several nitrogen fertilizers in the late nineteenth and early twentieth centuries. Others included ammonium sulfate, manure, guano, cotton-seed meal, dried blood, fish waste, and meat tankage. Synthetic ammonia and calcium cyanamid became major sources of nitrogen fertilizer during and after World War I. The most important commercial nitrogen products during the period of study were ammonium sulfate and sodium nitrate.³

The two main competing products differed significantly. First, sodium nitrate is a base whereas ammonium sulfate is a powerful acid. Thus, some soil types required liming prior to applying ammonium sulfate. Both products were used especially for sugar beets, potatoes, cereals, onions, and vegetables. Germany was consistently the largest importer of Chilean nitrate before World War I, with most of the product consumed by

³ Partington and Parker (1922); Soto Cárdenas (1998), p. 75; Yunge (1909), pp. 308-324; Chile, Memoria de la Delegación Fiscal de Salitreras (1893, 1897, 1902). See also annual reviews of the chemicals trade in the *Economist*.

the beet sugar industry (see Table 1). The use of nitrogen products in the manufacture of munitions and explosives was a secondary source of demand, although this changed during World War I.⁴

Insofar as production, while sodium nitrate is produced through intensive mining and treatment operations (described in the next section), ammonium sulfate is produced as a by-product in the manufacture of coke from coal, and illuminating and fuel gas. The by-product nature of ammonium sulfate meant that its supply was mostly determined by the output of coke and gas products.⁵ Ammonium sulfate was produced and consumed in Europe and North America.

The entire production of sodium nitrate took place in the Atacama Desert of South America. Because it dissolves easily in water, large deposits could only build up in extremely arid climates. The Atacama Desert is one of the driest places on Earth. From there it was exported to Europe and North America. Miniscule amounts of nitrates were consumed in South American markets. As a source of nitrogen, nitrate was more important (see Table 2), but the prices of both sodium nitrate and ammonium sulfate followed one another closely (see Figure 1). Thus, as the only source of a valuable fertilizer, the Atacama Desert was a strategic asset for the three countries that shared it.

The Nitrate Industry in the Atacama Desert before the War

Before the War of the Pacific, nitrate deposits existed in all three countries. A layer of rock, usually several feet below the surface called *caliche* contained sodium nitrate. The

⁴ Brown (1963), p. 231; Bermúdez (1984), p. 198; Greenhill (1977), p. 247; Partington and Parker (1922); Wheeler (1918); Chile, Memoria de la Hacienda (1889); Chile, Memoria de la Delegación Fiscal de Salitreras, various years.

⁵ Partington and Parker (1922), pp. 85-146.

nitrate content of *caliche* varied substantially. *Caliche* was mined by setting off charges of dynamite below the surface and blowing apart the rock of a large area. Workmen would then gather the chunks of *caliche* and transport them to a processing facility, called an *oficina*. At the *oficina*, the sodium nitrate was extracted from the *caliche* in a process called the Shanks system after its inventor. The process included grinding down the *caliche*, leaching it out with hot water and then crystallizing the nitrate. The Shanks system thus used large amounts of fuel (coal) and water. Most coal was imported from England. Then the nitrate was bagged and transported to the port for shipment. The Shanks system was widely employed from the 1870s until the 1920s, when it was replaced by the Guggenheim system.⁶

Thus, the cost differential between different regions depended on the geologic situation of the *caliche* (extension, depth and thickness), and its nitrate content. Costs also differed depending on transport costs between the respective *oficinas* and their port, mainly due to distance and whether there existed a railroad connection, and access to water. The Peruvian province of Tarapacá was the low cost producer at the time of the War of the Pacific, with costs about 25% lower than in Antofagasta and about 33% lower than in Taltal.⁷ The deposits in Tarapacá were known of in colonial times, and had been exported to Europe, albeit in small quantities, from 1830. Deposits were of high quality, generally close to the main ports of Iquique and Pisagua, and by the 1870s there were good rail links to many *oficinas*. More than fifty *oficinas* were constructed in Tarapacá in the 1870s, quintupling the province's productive capacity.⁸

⁶ Bain and Mulliken (1923), Bermúdez (1963), Crozier (1997), Whitbeck (1931).

⁷ Bermúdez (1984), pp. 153-154.

⁸ Billinghamurst (1889), pp. 15-20.

The first discovery of nitrate deposits in Bolivia was in the 1860s. A large company, the Antofagasta Nitrate and Railway Company, owned by Chilean and British investors, exported nearly all the nitrate from Bolivia in the years before the war. Bolivia had granted the firm a concession to produce and export nitrate duty free for fifteen years.⁹ In the 1870s discoveries of nitrates were made in two areas of the Chilean province of Atacama – Aguas Blancas and Taltal. These deposits were far from the ocean, had no established rail link, and were of uneven quality. Exploitation of these deposits began in the 1880s and accelerated rapidly after about 1905.¹⁰

Figure 2 shows the exports of nitrates from the different regions during the period 1876-1913. The export dominance of Tarapacá was due to superior deposits and to the fact that its railroad system was established early on – both factors contributed to its cost advantage. With the depletion of high quality deposits that were close to the coast and rail lines, firms began to exploit higher cost deposits. Because of this, and of growing demand in Europe and North America, railroads were expanded in competing regions, lowering their costs and cutting into Tarapacá's market share. This relationship is discussed in more detail below.

Table 3 shows the export taxes that were in force in the respective countries from 1876-1913. Peru charged an export tax, which it increased, on exports by private producers. Beginning in 1876, the Government of Peru began to purchase nitrate

⁹ The original concession was in 1866 to two Chilean entrepreneurs, José Santos Ossa and Francisco Puelma, who explored the area in the 1860s. They founded the Sociedad Exploradora del Desierto de Atacama, which joined later with important English and Chilean partners to form the Antofagasta Company. The concession was expanded to include the terms noted above in 1868, and the exemption from export duties was extended a further twenty years in a treaty between Chile and Bolivia in 1874. Bermúdez (1963), pp. 197-199, 203; Dennis (1967), p. 69; Mayo (1979), pp. 74-75. The concession was intimately related with the border dispute between Bolivia and Chile, which dated to independence. The countries signed treaties about the border area in 1866 and 1874. See Dennis (1967) and Querejazu (1995).

¹⁰ Bermúdez (1963), Crozier (1997), Mayo (1979), Whitbeck (1931).

companies. The industry was virtually nationalized by 1879. The Peruvian government paid 3.6 million pounds for the expropriation, through the issue of nitrate certificates bearing 8% interest and a 4% sinking fund.¹¹ Because the nationalization was gradual, private exports accounted for about fifty percent of total exports during the three years prior to the war.¹²

Bolivian exports were duty free. Indeed, it was Bolivia's enactment of a 10-cent per quintal export tax in 1878 that was the direct cause of the war.¹³ The Antofagasta Company refused to pay the tax. Chile claimed that this contravened the border treaties between Chile and Bolivia, which included economic considerations. When Bolivia refused to rescind the tax, Chile occupied Antofagasta. Chile later declared war on Peru, which was a signatory to a mutual defense treaty with Bolivia.¹⁴

Prior to the war, Chile had no export tax on nitrates. With occupation and the extraordinary expenses of war, the Chilean government created a commission to study how best to take advantage of the resources now under its control. The commission's recommendations, which were by and large adopted, were to privatize the *oficinas* that had been in possession of the Peruvian government, and to enact an export tax. Beginning in 1880, Chile charged an export tax of 2.57 shillings per cwt, which it maintained until the 1920s.¹⁵

¹¹ Basadre (1983), vol. 5, p. 301, 303.

¹² Bermúdez (1963), p. 343; Cruchaga (1929), pp. 257-260; Greenhill and Miller (1973), p. 125.

¹³ In 1878 10 Bolivian cents were equal to roughly 3.7 pence, so the tax amounted to 7 shillings per ton. As the price of nitrate was 10.6 pounds sterling per ton, the tax was equivalent to about 3% ad valorem. For Bolivian – British exchange, see Peñaloza Cordero (1984), p. 49.

¹⁴ Bermúdez (1963), Dennis (1967), Kiernan (1955), Mayo (1979), Querejazu (1995).

¹⁵ Bermúdez (1984), pp. 148-194; Billingham (1889), pp. 38-46; Sater (1986), pp. 135-140. The report of the commission, known as the *Comisión Consultiva de Salitres*, is reproduced in the *Memoria de la Hacienda* (1880). The tax rate was that proposed by the commission, and it was approved by the Chilean Congress after considerable debate. The belief was that the rate struck a balance between extracting

The nitrate export tax revenues earned by Peru and Chile during the years 1876-1913 are displayed in Figure 3.¹⁶ By the late 1870s, nitrate revenues constituted at least 20% of all Peruvian government revenues, although much of it was earmarked for payments related to the expropriation scheme and the administration of the company. In Chile's case, nitrate revenues rose steadily in importance throughout the 1880s until they reached 48% of revenues in 1890. This percentage remained more or less constant until World War I.¹⁷

Nitrates, Government Revenues and Fiscal Crises

On the eve of war, the nitrate deposits took on a special significance for all three countries involved. Their economies were by all accounts in very poor conditions. In this section, we describe the predicaments of each national government. In the absence of national income accounts, we must rely on alternative measures of economic activity. We first focus on Chile and Peru, where better data are available.

A number of authors have described Chile's difficulties. Sater (1979) notes that the recession was international in scope. He points to declining prices of copper and silver, which were then Chile's most significant mineral exports and particularly poor harvests of wheat in the late 1870s. As shown by Table 4, Chile's exports declined

revenues for the nation at war, while at the same time not prejudicing the industry because the foreign consumers would bear most of the tax burden.

¹⁶ The figures for revenues include nitrate of soda and iodine. Some *oficinas* also produced iodine from the nitrate deposits. The vast majority of these iodine-producing *oficinas* were in Tarapacá. See Crozier (1993), and *Memorias de la Delegación de Salitreras*, various years, for iodine exports by port. Iodine export tax revenues were about 15% of the total for most of the period. Government revenues include both export tax revenues and revenues from government sales (the Peruvian Government company for 1876-1879 and the Chilean government during 1880-1882). Figures for Chile do not include proceeds from the privatization of nitrate deposits, which could amount to 200,000 pounds sterling per year (see *Resumen de la Hacienda Pública de Chile desde 1833 hasta 1914*).

¹⁷ Tantalean (1983), Madueño (1919), Greenhill and Miller (1973), Mamalakis (1971), p. 184. Nitrates were about 70 percent of total Chilean exports.

considerably from their peak in 1872. The declining export earnings rippled throughout the economy, leading to a large increase in non-performing loans and an outflow of specie. The recession ultimately threatened the stability of the banking system, with prominent bank failures in 1877 and 1878.¹⁸

The government's fiscal condition deteriorated, as indicated by Table 5. Government revenues declined, and the government faced increasing budget deficits. In the 1870s, the government sought to pay for these deficits by taking out loans. Chile placed three bond issues in Europe in 1870, 1873 and 1875, totaling 4.4 million pounds sterling. The interest rate of 5% and amortization of 1-2% amounted to annual service on these loans of roughly 300,000 pounds, to be added to the service of another 300,000 pounds from four other foreign loans dating to 1843, 1858, 1866 and 1867. Chile relied on high interest bond issues in the domestic market in the late 1870s. The debt service was increasingly onerous, rising to about 20% of the value of total exports, and over 40% of ordinary government revenues.

In January 1878, the U.S. Minister in Santiago wrote to the State Department, "The condition of this country, in the financial view, [is] quite the reverse of flattering...The determination to preserve the credit of the government is everywhere manifest, but just how to do it does not clearly appear to those who have the interest of the public in charge." Chile's President, Aníbal Pinto, put it starkly: "If a new mining discovery or other news in the same line does not come to improve our position, the crisis which has been affecting us for years will get even worse." In July 1878, the government suspended convertibility. The reaction of financial markets was swift. Chilean bonds lost one quarter of their value on London markets between July 1878 and January 1879

¹⁸ Sater (1979), pp. 79-82, Fetter (1931), pp. 16-26.

(see Figure 4). Expenditures were cut, customs duties were increased, but proposed income and inheritance taxes were stalled in Congress. The government attempted, and was unable, to obtain a further foreign loan of one million pounds.¹⁹

As unenviable Chile's situation was, that of Peru was much worse. Peru had the largest external debt, in per capita terms, in Latin America at the time. In 1870 and 1872 Peru issued bonds in Europe, incurring an external debt in excess of thirty million pounds sterling. Much was earmarked for the ill-conceived construction of railroads to the mountainous interior of the country. The total debt service amounted to around 2.7 million pounds per year, an amount equivalent to about fifty percent of the Peruvian budget. Peruvian government revenues depended mainly on customs (about one to one and one-half million pounds per year) and sales of guano. Guano revenues, which had been several million pounds per year until the early 1870s, fell off dramatically with the exhaustion of the best deposits. By 1878 they amounted to only 418,000 pounds.²⁰ The declining revenues from guano and the enormous debt service put the Peruvian government in an increasingly difficult situation. It needed to find additional sources of revenues if it wished to maintain its external credit and complete the expensive railroad development projects.

In 1875 the government suspended the convertibility of bank notes, took out a 3.6 million pound loan from the banks of Lima, and expanded the banks authority to issue paper money. In December 1875, the government announced that it was suspending service of the foreign debt. The government's decision to nationalize the booming nitrate

¹⁹ Letter from Mr. Thomas Osborn, U.S. Minister in Santiago to Mr. William Evarts, U.S. Secretary of State, January 31, 1878. *Foreign Relations of the United States, 1878*, pp. 83-85. Pinto quoted by Luis Ortega (1984), p. 345. The quote dates to November 1877. For an extensive discussion of Chilean public finance during this period, see Sater (1979).

²⁰ Data on guano revenues from Hunt (1985), p.299.

industry must be seen in this context.²¹ Of course, as explained above, the plan for financing expropriation involved the accumulation of yet more government debt. In 1878 the Economist estimated that Peru's total indebtedness had now reached between 50 and 55 million pounds sterling (including interest in arrears), for a country of about three million people. The price of Peruvian bonds in London had plummeted after the default and would not recover (Figure 4). The Minister of Finance was called before Congress in late 1878, and excoriated for the government's borrowing for the nitrate monopoly, and for yet another issue of bank notes. The Minister resigned in October 1878. Congress debated ways to cut expenditures, and in particular openly discussed cutting the size of the officer corps and reducing military pay. The financial chaos was mirrored in the political realm, with assassinations, rebellions and rumors of coup plots.²²

Our discussion of Bolivia's finances is limited by the scarcity of information. Bolivia was involved in litigation in England over its default on a curious bond issue of 1.7 million pounds sterling, engineered by a foreign entrepreneur who proposed to build a railway and steamship service through the Amazon to connect Bolivia to the Atlantic Ocean. As security, much of the proceeds were deposited in a bank in London and could only be used for the construction project. Shortly after the bonds were issued, it became evident that the true cost of construction far exceeded the funds raised. The process of actually releasing these funds took a number of years, however. The additional debt was denominated in local currency. The two major loans were at 8% from a Chilean bank owned by Melchor Concha y Toro, and a dubious loan at 12% carried out by the

²¹ Greenhill and Miller (1973), pp. 117-118.

²² Letter no. 286 from Richard Gibbs, U.S. Legation in Lima, to Secretary of State William Evarts, November 20, 1878, Foreign Relations of the United States (1879), pp. 855-859; the Economist, March 23, 1872, October 23, 1875, December 25, 1875, and November 2, 1878;

American entrepreneur Henry Meiggs. The total outstanding debt on these loans amounted to about 300,000 pounds sterling in 1877. Additional internal debt was less than 100,000 pounds. Although substantially lower than the debts incurred by Chile and Peru, the weight on the Bolivian treasury was profound. Much of Bolivian revenue came from customs, and these were relatively small sums as the foreign commerce of the country was not developed. When Peru joined the war on the side of Bolivia, a protocol was signed in which Bolivia committed to pay back Peru for any military expenditures incurred. When the news of this reached La Paz, the chief of the council of ministers (left in charge of the government while the president was away with the army), stated, “[All the burden] on the poor one. In La Paz there is great alarm. It is believed that Bolivia has been sold. The little enthusiasm that existed for war with Chile is diminishing at an accelerated pace.”²³

From this discussion, it is clear that for all three governments, revenue maximization was of paramount concern. The nitrate deposits were a large potential source of revenue. Whoever should control them would want to maximize revenue over the short term to alleviate the budget pressures.

Did Chile start the war with the object of invading Tarapacá and seizing the nitrate deposits for her own? Although some have noted the influence of the Antofagasta Nitrate and Railway Company in Bolivia, and the indignation of the dispossessed Chilean salitreras of Tarapacá, there is no evidence that this was the case.²⁴ Still, once the conflict had begun it became clear that the financial burden would be large. Chile initially financed the war through further loans and tax increases, but mostly through the

²³ Peñalozo Cordero (1984), vol. 5, p. 36, Querejazu (1995), pp. 144-146, Bolivia (1877), pp. 10-12, Investors' Monthly Manual (Jan. 30, 1875), Economist (Nov. 25, 1876).

²⁴ See Mayo (1979), Ortega (1984), and Sater (1986).

issue of inconvertible paper money. Peru found it even more difficult to raise money through other means, and had to rely almost entirely on the issue of currency. Imports of ships and arms were critical to the war efforts of both countries, and those imports required hard currency or specie.

Peru initially could obtain substantial funds through nitrate exports. Control of those deposits was the most important strategic objective of the war. Shortly after the declaration of war in April 1879, the Chilean navy blocked Peruvian nitrate exports, contributing to already disastrous Peruvian finances. Still the Chilean government's financial situation was also grave. The U.S. Minister there noted in July 1879, "Business in all its branches is at a standstill, and I can see nothing but universal bankruptcy in a long continuance of the war...There is here a strong party urging upon the government greater energy in the prosecution of the war, and one of the movements demanded is the capture of Iquique [the main port of Tarapacá]." In late 1879, Chile captured Tarapacá, and in 1880 received in excess of 700,000 pounds sterling from nitrate exports. To give some idea of the importance of nitrate revenues for the war effort, Chile's Treasury reported that expenses for the Army and Navy Departments were a bit less than 2,000,000 pounds in 1880. The nitrate revenues more than doubled by the end of the war in 1884. The decisive fiscal impact of the conquest of Tarapacá is indicated by the dramatic coincident increase in the quotations of Chilean bonds in London (Figure 4).

Figures for Peru's military expenditures are harder to obtain, but records of their primary arms merchants indicate weapons expenditures of 680,000 pounds sterling between May 1879 and August 1880. The government was able to obtain some internal loans in 1879 and raised some taxes, most notably an export tax on sugar, but Peru's

attempts to take on more external debt were unsuccessful. It was forced to rely increasingly on the issue of paper money. One estimate is that paper money issues accounted 25-30% of revenues in 1879-1880. The result was inflation of 1000% over the two years.²⁵

Counterfactual Analysis

The financial condition of the countries prior to the war suggests that there was a great deal at stake. The actual historical record of the three countries from 1880-1913 also indicates that Chile was a major beneficiary of the war – this position has been forcefully argued by the scholarship cited above. The war is also supposed to have been devastating for Peru and Bolivia, but no attempt has yet been made to measure the costs of the conflict with respect to the geographic reallocations. The major prize of the war was the nitrate deposits in Antofagasta, and especially Tarapacá. In this section, we provide some counterfactual analysis that permits us to get a better idea of the dimensions of the loss.

The basic premise that we will follow is to suppose that the borders did not change, and that each country was free to pursue sovereign commercial policies.²⁶ Another assumption that we make is that all parties, at least initially, viewed the deposits as effectively limitless. This eliminates some of the thorny issues regarding the optimal depletion of a non-renewable resource. Estimates put the life of the deposits as at least

²⁵ Letter from Isaac Christiancy (new US Ambassador to Peru) to Evarts, May 12, 1879; Letter from Osborn to Evarts, July 24, 1879. *Foreign Relations of the United States, 1879*, pp. 178-180, 874-877. *Resumen de la Hacienda de la República de Chile desde 1833 hasta 1914*. On arms purchases by Peru, see G. de Secada (1985), pp. 614-15. On Peru's finances, Armas Asín (2001).

²⁶The counterfactuals suppose that no differences in mining law would have developed that would have had significant impact on the development of the nitrate industry in each country. On the similarity between mining law in Bolivia, Peru and Chile before the war, see Bermúdez (1963), Billingham (1903), and Chile, *Memoria de la Delegación Fiscal de Salitreras* (1900), pp. 113-168.

one hundred years.²⁷ Given the acute short-term financial problems facing all countries, it is reasonable to suppose that the governments would have discounted the future sufficiently so that the problem reduces to short-term tax revenue maximization.

The simplest counterfactual is that all three countries would have adopted the same 2.57 pounds per ton tariff (Chile's export tariff from 1883-1913), so that nitrate exports are supposed to have followed a pattern similar to what actually occurred. Under this assumption, Peru would have garnered revenues proportional to the production of Tarapacá. These revenues would have exceeded two million pounds sterling per year by 1889 (compare Figure 2).²⁸ Chile and Bolivia would have earned less than 100,000 pounds per year in the late 1880s and would have only broken the one million pound figure about 1910. This suggests that seizing Antofagasta alone would not have been sufficient to aid Chile in the midst of its financial crisis. Recall that Chile's budget deficits were running around 500,000 pounds sterling per year in the late 1870s, with debt service requiring a bit under one million pounds sterling annually. One hundred thousand pounds sterling, however, for Bolivia, was one quarter of their outstanding debt in 1877 (excluding the unusual loan being litigated in Europe). As for Peru, its foreign debt service (before it defaulted) was about 2.7 million pounds sterling per year –see Table 5. The nitrate proceeds could have helped, but were not sufficient to pay for debt service alone. In combination with cuts in expenditures, and increased customs revenues, however, they may have been decisive. At the very least, they may have opened the way to a settlement with the bondholders. A pessimistic view is that Peru would have

²⁷ See, for example, Yunge (1909), pp. 307-308, Partington and Parker (1922), p. 18.

²⁸ This figure actually underestimates Peruvian revenues by about ten percent relative and overestimates revenues elsewhere because the tax figures include revenues from iodine, most of which was produced in Tarapacá.

mortgaged the revenues so heavily to pay off the mountain of internal debt, finance expropriation and build railways to the Andes, that its foreign credit would have not been substantially affected by such an amount.

A second counterfactual is that the Peruvian government nitrate company continued operation, and that private production was either outlawed or dissuaded through a prohibitive export tax. This seems to have been the intention of Peru in 1878. In the best case scenario for Peruvian finance, the nitrate company would have maximized profits, setting marginal cost equal to marginal revenue. Marginal revenue in this case is a function of the elasticity of residual demand for nitrate, which in turn depends on the elasticity of world demand, the elasticity of Chilean and Bolivian supply, and Chilean and Bolivian policies. Chilean and Bolivian exports would increase as Peru restricted its quantity, but because of cost differentials, the nitrate price would still rise. The governments of Chile and Bolivia, if assumed to be revenue-maximizing, may have chosen to raise (or enact) export taxes. This would have assisted the aims of Peru, because it would have restricted somewhat the growth in rival exports.

Given the difficulties that Peru was encountering paying off the nitrate certificates, however, it was a serious possibility that it would have dissolved its monopoly, and enacted an export tax policy.²⁹ The potential revenues from an export tax depend on the elasticity of residual demand, just as with a government monopoly. If the three countries followed export tax policies based upon revenue-maximization, the choice of an export tax becomes a strategic matter in which the optimal tax for each

²⁹ Basadre (1983), p. 304, discusses such proposals.

country is a function of the tax chosen by the others. It can be shown that the low-cost exporting country will charge the highest tax and earn the highest tax revenues.³⁰

A potentially fruitful empirical strategy is to estimate structural supply and demand relations for the three regions, thus deriving estimates for revenue-maximizing taxes for each region, as well as the maximum potential revenues for a hypothetical Peruvian government monopoly. These estimations are in progress. In lieu of the full structural estimates, we present preliminary estimations of the residual demand for nitrate exports from Tarapacá for the years 1874-1909. Simply put, the more inelastic is residual demand, the greater the potential revenues from either an export tax or a government monopoly. The residual demand elasticity is equal to

$$\varepsilon_{TARA} = \frac{\varepsilon_{WORLD}}{S_{TARA}} + \frac{(1 - S_{TARA})\varepsilon_{FRSUPPLY}}{S_{TARA}} \quad (1)$$

where ε_{WORLD} is the elasticity of world demand for nitrate, S_{TARA} is Tarapacá's market share, and $\varepsilon_{FRSUPPLY}$ is the elasticity of supply from other regions (Taltal and Antofagasta).³¹ Demand elasticities are expressed as absolute values.

Thus, it is necessary to estimate both world demand elasticity and the elasticity of supply from other regions. The world demand equation takes the form

³⁰ In contrast to a monopoly, a revenue-maximizing export tax is not calculated by equating industry marginal cost to marginal revenue. Rather, it is calculated by equating the marginal cost of raising tax revenue to marginal revenue. The marginal cost of raising revenue is to the industry supply curve what the marginal revenue curve is to the demand curve. In a multi-country context, the relevant demand curve for each country is its residual demand curve, which is dependent on industry costs and taxes in other countries. See Panagariya and Schiff (1995).

³¹ See Irwin (2003), pp. 280-281.

$$Q_{Wt} = \beta_0 + \beta_1 P_{Nt} + \beta_2 P_{At} + \beta_3 Beet_t + \beta_4 t + v \quad (2)$$

where P_N is the price of nitrate, Q_W is the quantity of nitrate exports from all ports, P_A is the price of sulfate of ammonia, $Beet$ is the quantity of beet sugar processed in Germany, and t is a time trend. Sulfate of ammonia was the principle competitor of nitrate, and German beet sugar farmers were the principle consumers in this period. The time trend is intended to capture the increase in demand for nitrate as knowledge of its effectiveness as a fertilizer became more widely disseminated. The supply equation for exports from Taltal and Antofagasta is

$$P_{Nt} = \alpha_0 + \alpha_1 Q_{Ft} + \alpha_2 Coal_t + \alpha_3 Cartel_t + \alpha_4 t + \mu \quad (3)$$

The exports from Taltal and Antofagasta are denoted by Q_{Ft} . The price of coal is included because coal was a major variable input in production. Labor and *caliche* were the other major variable inputs. Unfortunately neither time series of wages nor the nitrate content of *caliche* are available. Nitrate producers formed cartels of varying duration over the period of our study. These cartels principally included producers from Tarapacá until the 20th century. We include a dichotomous cartel variable that takes the value one when a cartel was in operation and zero when it was not. Alternative specifications including additional cartel variables were conducted, but as expected the coefficients were small in an economic sense and statistically insignificant. Finally, we include a time trend intended to capture changes in supply due to technological improvements, improvements in transportation, and ongoing geological surveys. In both the demand and

supply equations prices and quantities are expressed in logarithms. The data and sources are described in an appendix.

We estimate the demand and supply equations using three-stage least squares. Results from the regression are presented in Table 6. The resulting elasticities are 3.92 for supply from Taltal and Antofagasta and -0.85 for world demand. Both estimates are significant at the five percent level. The residual demand elasticity calculated for 1878 is -1.77. Saving (1970) has shown the inverse relationship between the residual demand elasticity and the Lerner index of market power in a competitive fringe model. The Lerner index is defined as the difference between price and marginal cost divided by the price. The corresponding Lerner index value for Tarapacá in 1878, during the Peruvian government monopoly is 0.57.³²

This estimate can be compared against some contemporary cost data. In 1880 Chile's *Comisión Consultiva de Salitres* provided a figure of 52.8 pence per English quintal (4.4 pounds sterling per ton) in "normal times," which serves as a very rough estimate of the marginal cost of an average *oficina* in Tarapacá that can be judged as an upper bound.³³ The price in 1878 was 10.6 pounds sterling per ton, giving a Lerner index of 0.58, remarkably close to the estimate.

The Peruvian government's attempt to exercise this potential market power in the late 1870s through the creation of the government monopoly was mitigated by increased output from Antofagasta and the loss of market share (see Figure 5). We estimate that residual demand elasticity fell from -1 to -1.77 from 1875 to 1878. Yet from 1884, when

³² The mean for 22 industries for which Lerner indices were calculated in the 1980s was 0.62. This suggests that, at least in comparison with relatively recent industries, Tarapacá's nitrate industry possessed market power slightly below average.

Kahai, Kaserman and Mayo (1996), p. 511, Hall (1988).

³³ Chile. Informe de la Comisión Consultiva de Salitres, p. 22. In Memoria de la Hacienda, 1880.

the treaty that ended the war was signed, until about 1900, Tarapacá's market share remained between 75-90%, a period in which prices varied from 3.46 pounds per ton to 7.67 pounds per ton. This suggests that Tarapacá producers had a persistent sizeable cost advantage throughout the 19th century, a factor that would have enabled the government with authority over the area to extract substantial additional revenue beyond what Chile actually did with its uniform export tax. This means that the naive counterfactual estimate of about two million pounds sterling per year is a lower bound for Peru, at least in the 1880s.

Over the long run, Peru would have found it increasingly difficult to earn revenues from Tarapacá over and above what Chile actually did, as the province's *oficinas* depleted their best deposits and costs fell elsewhere. Tarapacá had a significant advantage from being the first area developed that persisted for some time. Railroad expansion came later to the southern provinces, and geological surveys initially were less complete.³⁴ The estimate of residual demand elasticity for Tarapacá in 1909 is -5.87, clearly indicating that the revenue-maximizing export tax for Tarapacá (or the profit-maximizing monopoly price) would have fallen substantially over time.

In addition, the fact that the estimated world demand elasticity was -0.85 means that Chile's export tax of 2.57 pounds per ton was, on average, yielding an equilibrium elasticity of demand of -0.85. If Chile was truly maximizing tax revenue over the period, the observed elasticity of world demand would have been positive. Indeed, this suggests that Chile was "under-taxing" nitrate exports from both welfare-maximizing and revenue-maximizing objectives, and this also suggests that the two-million pound estimate for

³⁴ Greenhill (1977), p. 233, Hernández (1930), Long (1930).

Peruvian potential revenues is on the low end.³⁵ One of Chile's most prominent scholars of the nitrate cycle wrote, "There exists no evidence that the Chilean government had a clear policy, or was interested in establishing a policy, that would be best of Chile's acquisition of nitrate revenues, nitrate income, or a nitrate-generated resource surplus." It is conceivable that the size of Chile's nitrate windfall was so large that the government did not set the tax as analytically as it might have, but perhaps had a threshold of minimum revenue that it wanted, and that it easily maintained. Similarly, it might have set the tax low in order to avoid international political repercussions with its major foreign investor, Britain. British capital has heavily invested in the nitrate industry, and European agriculture was a large consumer of nitrate. Because Peru was in default to a multitude of (primarily British) bondholders, it would likely have taken more care in extracting revenue and would have had a powerful lobby in England favoring the tax that might have been able to counteract to some extent the foreign interests opposed to it.³⁶

Conclusions

The War of the Pacific redrew the map of South America and had profound effects on the countries involved. In order to better grasp the magnitude of the economic impact of the war, we have focused on the changing jurisdiction over the nitrate deposits of the Atacama Desert. The conquest of Tarapacá was a boom for Chile, and a grievous loss for Peru. The conquest of Antofagasta, in contrast, would have only been a minor

³⁵ This follows from the optimal export tax equilibrium condition that the post-tax price received by exporting firms be equal to marginal revenue. Because that price must be positive, marginal revenue must be positive, and the elasticity of demand greater than one. See Helpman and Krugman (1989), pp. 17-19.

³⁶ The quote on Chilean policy is from Mamalakis (1971), p. 203. See Blakemore (1974) and Soto Cárdenas (1998) on British influence in Chilean politics and nitrate policy. On the conflicting interests of British holders of Peruvian bonds and British investors in the nitrate industry, see the *Economist*, January 17, 1880, p. 62.

asset to Chile (until the massive copper deposits were discovered and exploited in the mid to late 20th century). However, the lost nitrate revenues represented a significant sum for the poorest nation of the three, Bolivia.

Scholars of Chile such as Palma (2000), Cariola and Sunkel (1985) and Mamalakis (1971), have argued that the nitrate boom was beneficial to Chile's economic development, although their opinion is not shared by all, for example Gunder Frank (1976). We suggest here that Chilean public finance could very well have melted down entirely without the war, perhaps leading to an arrangement with European creditors as odious as the Grace contract was in Peru. Instead, Chile's credit was maintained. With the steady stream of nitrate revenues behind it, Chile's government borrowed frequently in international capital markets. Between 1885 and 1900, she accumulated 19 million pounds of external debt.

There are clearly limits focusing exclusively on nitrates – other resources also came into play, such as guano and copper. We have also skirted the important question of the resource curse in order to focus on the public finance consequences of the war. Further, we have not attempted to estimate the economic consequence of losing access to the sea for Bolivia, even though the vast majority of Bolivian commerce went through Peruvian ports before the war. The psychological impact of the war and its effect on the sense of national identity in the three countries was and continues to be profound.

Table 1: World Consumption of Chilean Nitrate, metric tons

Country	Year		
	1885	1900	1913
Germany	147,800	482,100	833,112
USA	44,000	164,900	589,187
France	75,700	284,400	327,192
Belgium	49,700	171,200	318,515
Holland	23,500	95,300	164,502
UK	98,400	139,600	128,561
Other	2,700	52,200	195,904
TOTAL	441,800	1,389,700	2,556,973

Source: 1885, 1900: Cariola and Sunkel (1985), pp. 197-198; 1913: Partington and Parker (1922), p. 67.

Table 2: Sources of Nitrogen in 1912

	Output in Metric Tons	Metric Tons of Nitrogen	Percent of Total Output
Chile Nitrate	2,628,367	411,329	57.5
Ammonium Sulfate	1,249,449	272,007	38.0
Cyanamide	128,563	22,435	3.1
Arc	76,200	9,907	1.4

Source: Partington and Parker (1922), p. 25.

Table 3: Export Duties, 1876-1913, shillings per cwt

Year	Peru ¹	Bolivia	Chile ²
1876	1.93 (January – June); 3.23 (July – December)	None	None
1877	2.42	None	None
1878	3.45	0.35 (not enforced)	None
1879	-	-	None
1880 – 1913	-	-	2.57

¹The Peruvian export tax only applied to exports by private producers, not the government company. Duties from 1876 until occupation were specified in Peruvian currency. The duty was initially 60 centavos of a *sol* per quintal (45.9 kilograms), but was changed to 1.25 *soles* per quintal. See Madueño (1919), pp. 7-8, Bermúdez (1963), p. 342-344. Peruvian – British exchange rates from O’Brien (1982), p. 161, were used to calculate shillings per cwt. These values fluctuated substantially during the period, so the Peruvian duty is a rough estimate.

²Chile first imposed export duties on the occupied territories in 1879 (from September for Antofagasta and from December for Tarapacá). These duties were 40 centavos of one *peso* per 100 kilograms for Antofagasta, and 1.5 *pesos* per quintal for Tarapacá. Bermúdez (1984), pp. 98-99, 144-147. Again using exchange rates from O’Brien (1982), p. 161, these correspond to 0.52 shillings per cwt, and 4.29 shillings per cwt, respectively. In October, 1880, Chile enacted an export duty 2.57 shillings per cwt, which remained in place until the 1920s. Exports from Taltal and Aguas Blancas paid fifty percent of the duty until June 30, 1882, and June 30, 1883, respectively (Hernández (1930), pp. 112-118).

Table 4: Foreign Trade of Peru and Chile, 1870-1878

Year	Exports		Imports	
	Chile	Peru	Chile	Peru*
1870	5,128,216	6,559,542	5,365,526	2,113,074
1871	6,121,429	5,172,504	5,097,453	2,595,054
1872	7,173,142	4,564,664	6,696,923	3,711,887
1873	7,145,422	7,698,772	7,081,869	3,039,900
1874	6,946,532	7,342,160	7,303,370	1,945,259
1875	6,558,732	9,205,722	7,150,781	2,036,734
1876	6,396,713	10,109,892	6,617,070	1,182,581
1877	5,207,867	7,507,809	5,477,393	1,521,404
1878	5,233,118	8,148,513	4,728,104	

Source: Resumen de la Hacienda Pública de Chile desde 1833 hasta 1914, Bonilla (1980), pp. 39 and 43. *Imports from U.S. and Great Britain only.

Table 5: Public Finance in Peru and Chile, 1870-1878 thousands of pounds sterling

Year	Government Revenues (excluding loans)		Budget Balance		Debt in Circulation		Debt Service		Debt Service / Exports	
	Chile	Peru	Chile	Peru	Chile	Peru	Chile	Peru	Chile	Peru
1870	2914	7763	276	98	8783	16096	636	2495	0.12	0.38
1871	2605	10236	-97	1145	8650	19080	651	6416	0.11	1.24
1872	2675	8626	-288	-1423	8605	19665	649	2865	0.09	0.63
1873	2874	9649	-313	440	10944	27426	817	2735	0.11	0.36
1874	2872	7864	-1314	1548	10674	27597	858	2709	0.12	0.37
1875	2985	4675	-1041	988	11416	33047	892	2644	0.14	0.29
1876	2727	4401	-769	60	11468	22111	905	n.d.	0.14	n.d.
1877	2426	1919	-1160	-254	11584	20109	1504	411	0.29	0.05
1878	2334	2336	-416	1062	11711	33763	991	456	0.19	0.05

Sources: Resumen de la Hacienda Pública de Chile desde 1833 hasta 1914. Chile repaid 600,000 pounds of Treasury bills in 1877. The high figure for Peru in 1871 results from a debt rollover. Tantalean (1983).

Table 6: Nitrate Exports: Estimates of World Demand and Fringe Supply

Dependent Variable	World Export Demand (log total export volume)	Fringe Export Supply (log export price)
Constant	3.72 (2.22)	1.41* (0.22)
Log export price	-0.85* (0.43)	-
Log ammonia price	0.05 (0.30)	
Log beet sugar quantity	0.40 (0.22)	
Log fringe export quantity	-	0.26* (0.06)
Log coal price	-	0.26 (0.14)
Cartel	-	0.25* (0.07)
Time trend	0.04* (0.01)	-0.04* (0.01)
Adjusted R ²	0.90	0.63

Standard errors are in parentheses.

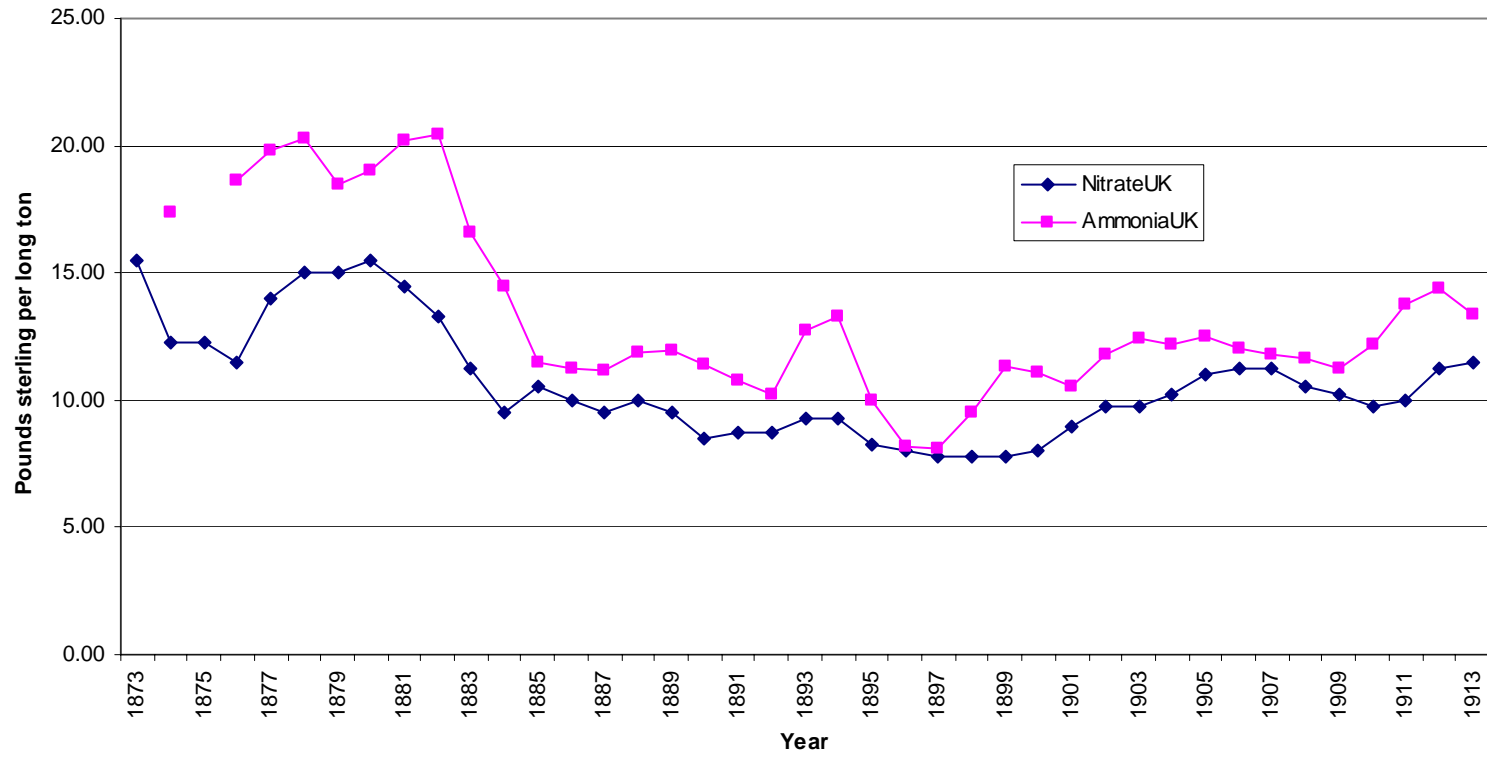
*Significant at the five-percent level.

Appendix

Nitrate prices are from Partington and Parker (1922), p. 77. Nitrate quantities by port of embarkation are from Bermúdez (1963), pp. 372-374, various years of Chile, Memoria del Ministerio de Hacienda, and Memoria de la Delegación Fiscal de Salitreras for 1880-1909, and Estadística Comercial for 1910-1913. Sulfate of ammonia prices are from Chile, Memoria de la Delegación Fiscal de Salitreras (1902), Memoria del Ministerio de la Hacienda (1886, 1893), Yunge (1910), p. 271, and Partington and Parker (1922), p. 123. Beet sugar processed in Germany is NBER series 01024. The coal price was calculated by obtaining the United Kingdom export price of coal from Sauerbeck (1886, 1891, 1899) and Paish (1914), and adding freight rates for coal from the United Kingdom to the west coast of South America, from Oribe (1989) and Angiers (1920). The specification of the cartel variable was derived from Chile, Ministerio de la Hacienda (1935) and Brown (1963).

Figure 1

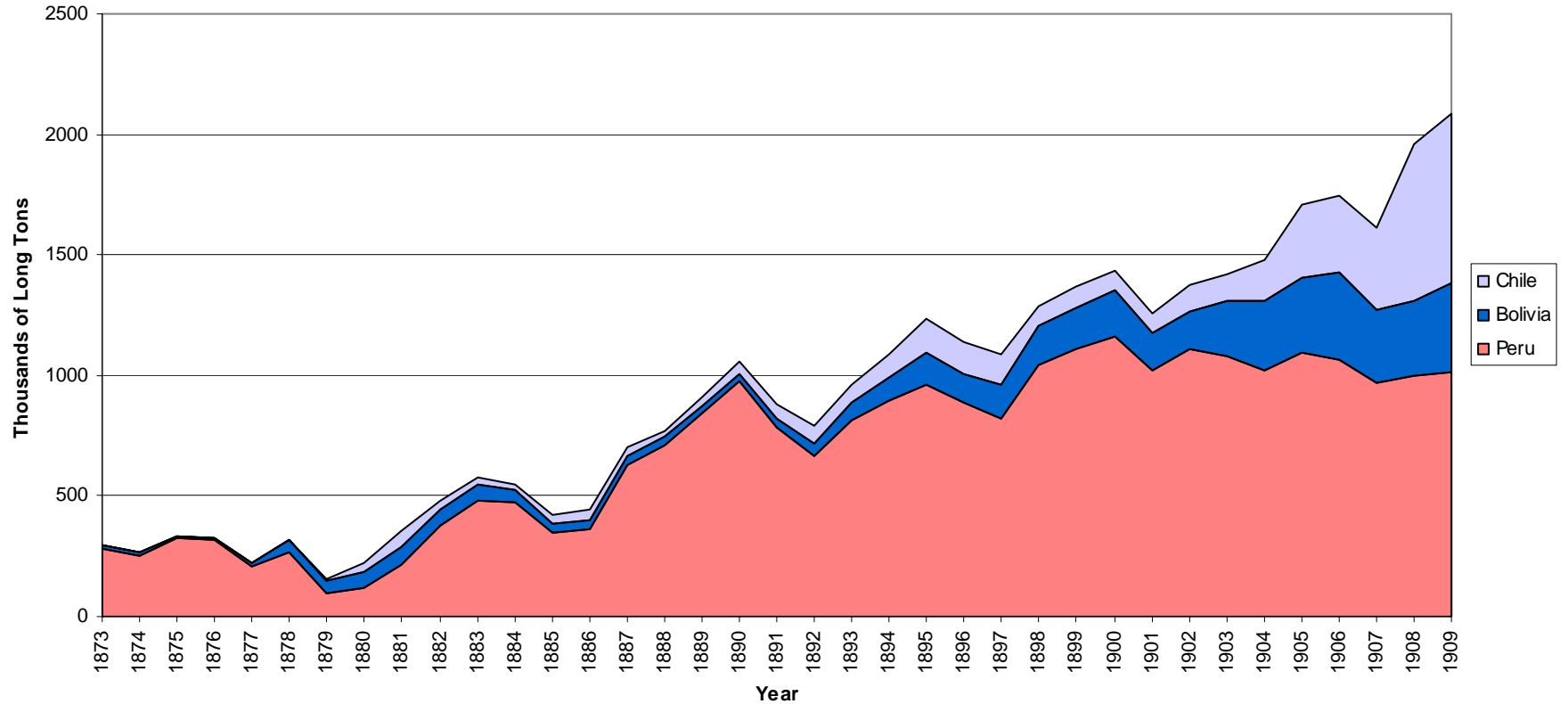
Fertilizer Prices



Sources: See data appendix.

Figure 2

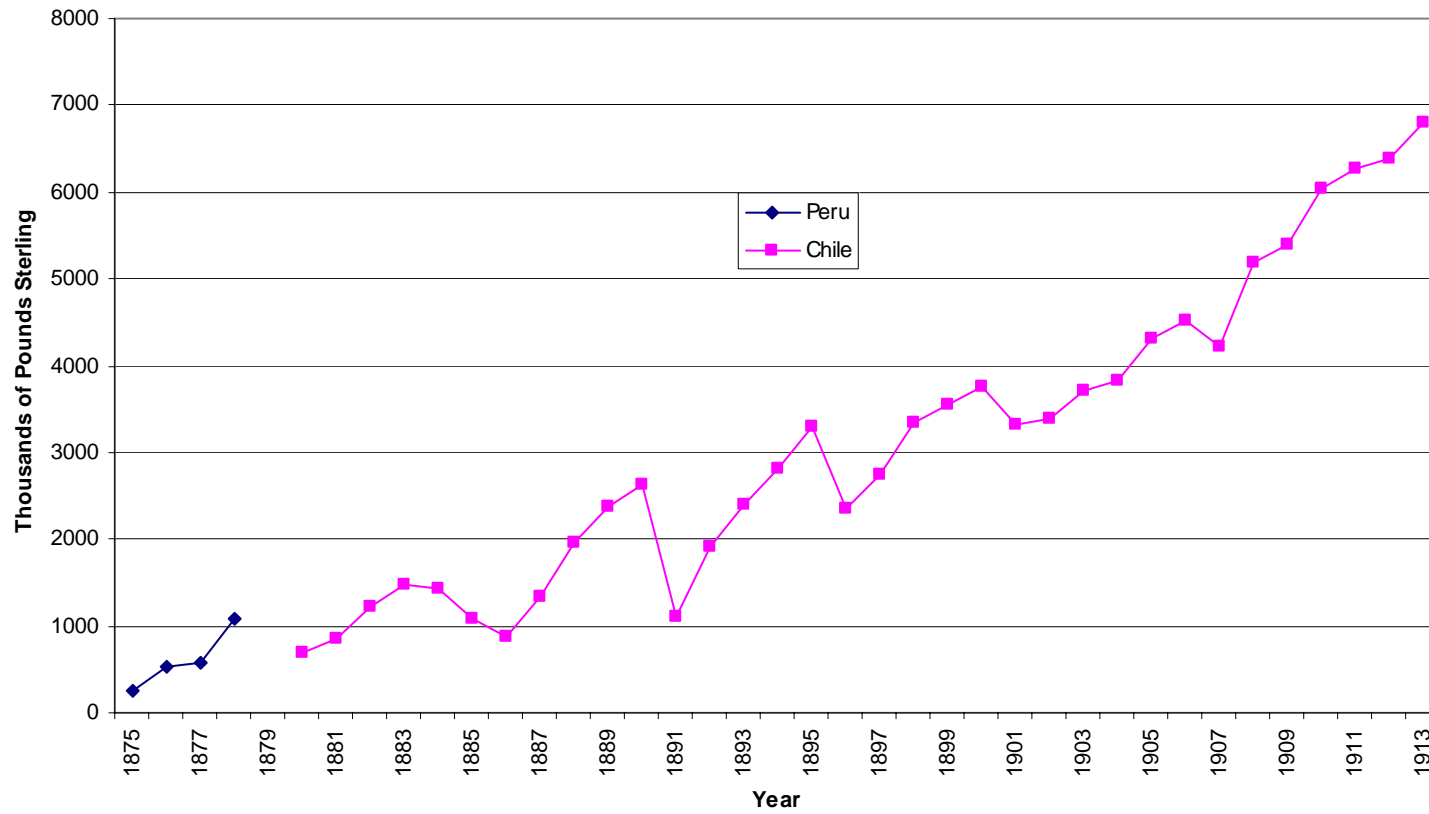
Nitrate Exports by Region



Note: The legend shows countries, which is correct prior to 1879. From 1879 forward, “Chile” corresponds to exports from the port of Taltal and Caleta Colosa, “Bolivia” from the ports of Antofagasta and Tocopilla, and “Peru” for exports from the various ports of Tarapacá.
Sources: See data appendix.

Figure 3

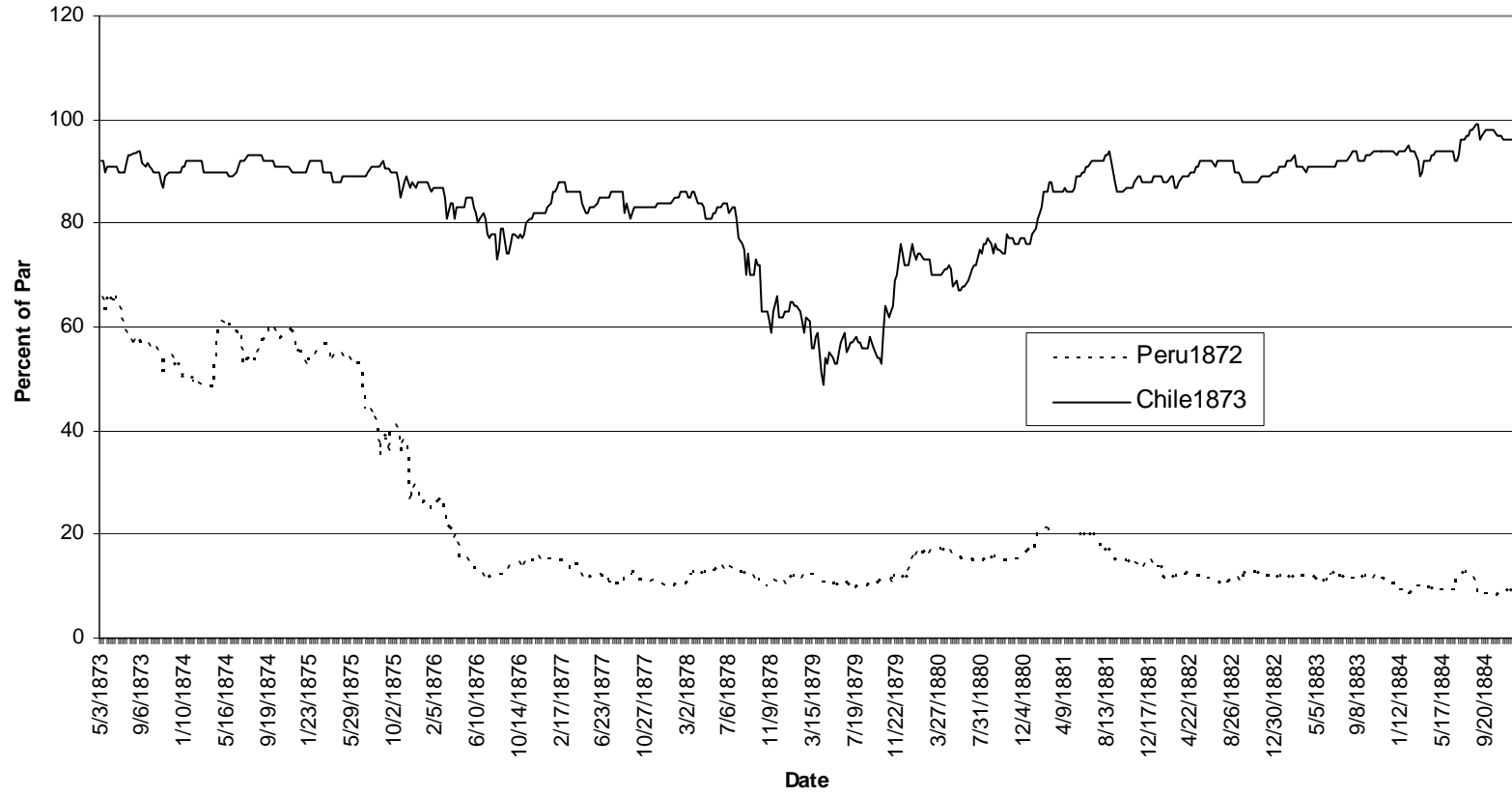
Government Revenues from Nitrate



Sources: Chile: Resumen de la Hacienda Pública de Chile desde 1833 hasta 1914, Mamalakis (1971), p. 184. Peru: Hunt (1985).

Figure 4

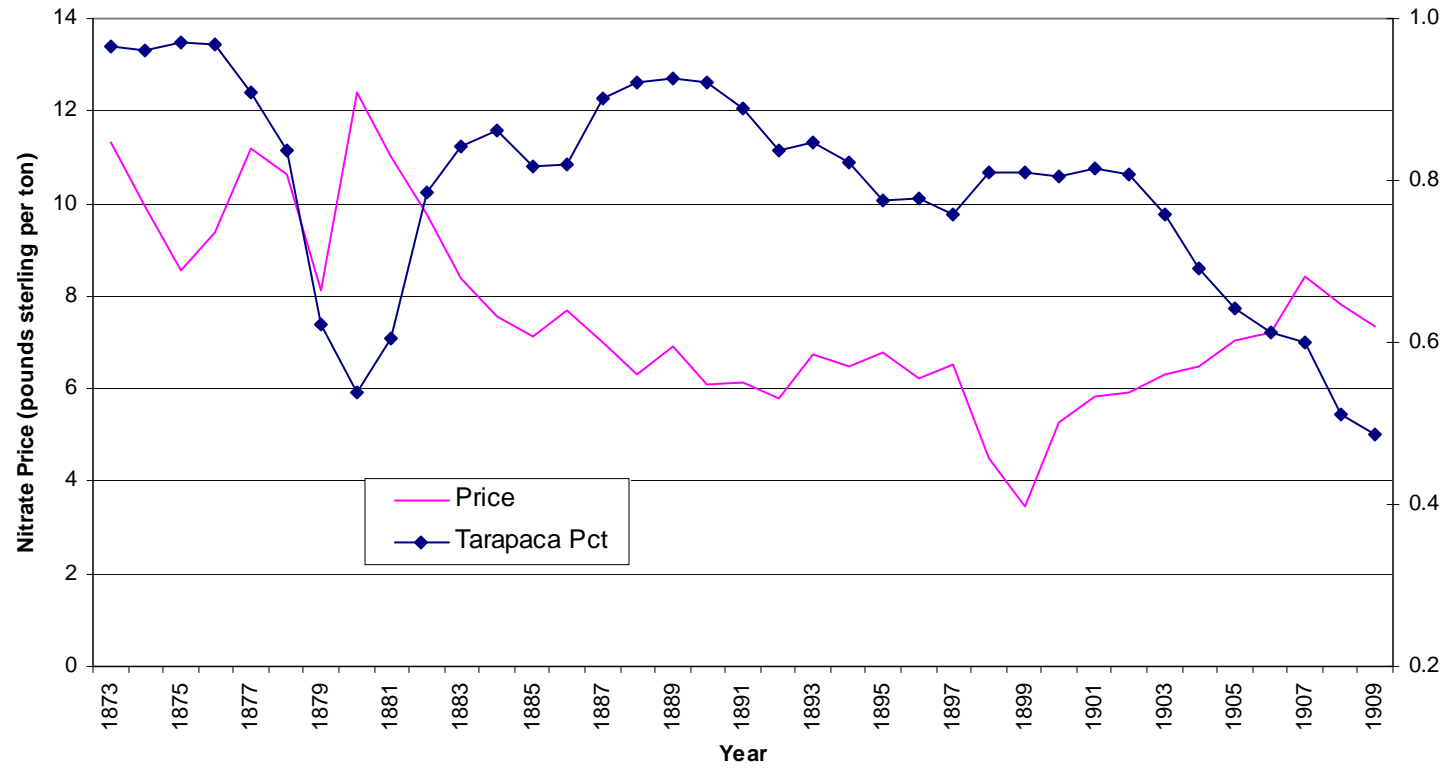
Bond Prices



Source: The Economist.

Figure 5

Tarapaca Market Share versus Nitrate Price



Sources: See data appendix.

Map 1: Disputed area before the war



Source: International Atlas (1873).

Map 2: Contemporary South America



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