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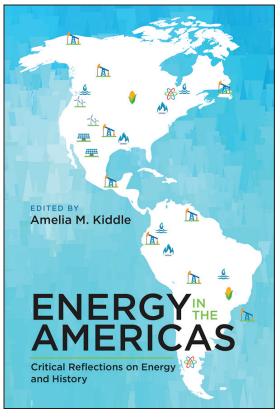

ENERGY IN THE AMERICAS: CRITICAL REFLECTIONS ON ENERGY AND HISTORY

Edited by Amelia M. Kiddle

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Primary Energy Consumption and Economic Growth in Chile, 1844–2010

César Yáñez Gallardo

This chapter presents a reflection on the path of the Chilean economy throughout the nineteenth and twentieth centuries, using the consumption of modern primary energy (coal, oil, hydroelectricity, and natural gas) as the main indicator. This is the result of the collective work of a large team of Chilean and Spanish researchers who systematically gathered series of apparent consumption of modern energy sources for all Latin America countries.[1] The results presented here correspond only to the Chilean case between 1844 and 2000.[2] The main ideas underlying this work is that the primary consumption of fossil energy marks the transition toward economic modernity, and that the history such consumption helps to explain long-term economic trends. These ideas were first championed in 1994 by Vaclav Smil in his pioneering work *Energy in World History*.[3] In that book, Smil asserts that, thanks to the contribution of fossil fuels, and coal specifically, it was possible to overcome centuries of declining economic growth and initiate an era of steady increases in the productivity scale. The English Industrial Revolution of the mid-eighteenth century was based on this distinctive feature (increasing productivity based on the technical potential of machinery driven by steam coal), which laid the foundations for an economic system capable of generating surpluses well

above subsistence levels—which in turn explains the inequality of later periods.[4] In any case, it is important to note the complexity of the relationship between economic growth and energy consumption. Historical evidence indicates that there is a close relationship between the two variables. Throughout the twentieth century, both increased sixteen-fold worldwide. However, the amount of energy per product (energy intensity) and the path of energy efficiency are not similar in all countries, not even among countries with the same level of economic development. Specific features of technological development, economic policies, the endowment of natural energy resources, and energy dependency help explain differences in national paths.

The aim of this chapter, then, is to review how the Chilean economy set off on the path to modernization. The evidence on modern energy consumption suggests that Chile was "blessed" with coal deposits in the areas of Arauco and Concepción, which were exploited from the 1840s on—relatively early in the Latin American and international context.[5] The increasing introduction of coal into the Chilean financial system since the mid-nineteenth century was behind the modernization of the systems of production, as reflected in improvements in productivity. By the late nineteenth century, Chile faced the dilemma of overcoming what I call the "middle income trap." Alejandro Foxley posited in 2012 that Chile and other Latin American countries with incomes between US$9,000 and US$22,000 at PPP (purchasing power parity) were "halfway to becoming advanced economies."[6] The present chapter argues that Chile had faced this situation a century earlier and that the cause was the introduction of coal in production and transportation activities, an important component of which was national fuel. However, in the 1914–90 period, the country's economy was challenged by significant restrictions to the fuel supply, which had a negative impact on economic modernization. The high external dependence on oil led to a difficult transition between fossil fuels, making the transition from steam engines to the use of oil and combustion engines a difficult one. A very rigid energy matrix was also behind delays to the process of electrification in Chile, adversely affecting the process of industrialization, which required modern energy sources.

Energy consumption and economic growth in Chile

The relationship between modern energy consumption and Chile's long-term economic growth broadly concurs with Smil's assertions, which also highlight the particularities of the Chilean case (see table 2.1). In the first place, throughout the twentieth century, the expansion of energy consumption and GDP (at PPP) developed as smoothly as it had in the international context. Energy and GDP grew 29.5 times between 1900 and 2005. In any case, the global average, as Smil suggested, only multiplied by sixteen in both indicators, a figure that Chile reached in the mid-1990s. The strong economic growth of the late-twentieth and early twenty-first centuries explains the difference between Chile and the world average. Beyond any historical specificity, as it was demonstrated, the Chilean economy required proportional amounts of energy to sustain its economic growth. The Chilean economy also followed the international trend regarding energy intensity (units of energy per unit of GDP). In 1900, Chile required 126 units of energy per unit of production, the same number as in 2005. Yet, in contrast to the experiences of countries where Smil observed a steady decline in energy intensity, Chile's stages of contraction and expansion after 1930 were rather erratic.

Empirical evidence suggests that the processes of economic development underwent an initial phase in which more and more energy was consumed per unit of production, and that this later switched to the opposite trend. Technical change was crucial in this regard. More efficient energy converters enabled those countries that accelerated the increase in productivity to do so by means of energy-saving machinery. Yet the specific paths were very different, influenced by specific historical elements.

The specific evolution of energy intensity in the Chilean economy shows steady growth from the mid-1800s until 1917. This is the period when coal and steam engines took centre stage. The entry of oil-based fuels during the First World War, which saw the introduction of combustion engines and turbines, led to an abrupt change in the trend until 1930. Thereafter, the behaviour of energy intensity set a trend toward stability, with relatively few intense, short-term variations.

The comparison with the United Kingdom and Wales, and especially with the United States, highlights the differences in the levels of modern

Table 2.1 Energy Consumption and Economic Growth

	Energy per Ton of Coal					Product and Energy	
Year	Total	Coal	Oil	Natural Gas	Hydroelectricity	GDP	Energy Intensity
1850	25	25				1,313	19
1900	816	800	16			6,492	126
1930	2,047	889	981		117	12,195	168
1950	2,835	1,848	1,169		182	22,352	127
1970	7,290	1,225	4,455	1,130	480	49,011	149
2005	24,151	2,758	11,300	7,831	2,262	191,954	126

energy use between advanced countries and relatively underdeveloped countries like Chile. In the nineteenth century, both the United Kingdom and the United States had abundant coal reserves in the subsoil that were used extensively to support their industrialization. The availability of fossil fuels in their territories allowed them to sustain economic development and incorporate equipment into their production processes. In any case, there is no rule that directly relates energy intensity to the levels of development achieved. The United Kingdom came to consume ten times more energy per product than Chile, while the United States was ten times more intense, energetically speaking, than the United Kingdom. The structural characteristics of the sectors in which economic modernization was based were (and still are) factors determining the level of energy consumed per product. This appears to be confirmed by comparing Chile with two countries within its economic environment, Argentina and Brazil: the levels are much closer and have clear periods of convergence.

It is valuable when comparing the paths of long-term energy intensities to consider the trends. England, which had reached industrial maturity in the mid-nineteenth century, began to reduce energy intensity as soon as it ceased to grow extensively based on fossil resources while seeking greater energy efficiency. The United States, meanwhile, reached industrial maturity before the First World War. From that moment, it turned toward greater energy efficiency, reducing the amount of energy per unit of production. In both cases, the reduction in energy intensity is

a historical trend that is projected to the present. Chile, by contrast, had only five years of sharp decline between 1917 and 1922, followed by a long period of erratic behaviour, with a pronounced tendency to stagnate in energy intensity. This trend contrasts clearly with Argentina and Brazil, which increased the energy per unit of product.[7]

The cause of the stagnation is likely to be found in the nature of the energy transition between fossil fuels (the move from coal to oil) and the scant importance of hydroelectric power within the Chilean energy matrix. In 1970, hydropower accounted for only 6.5 per cent of primary energy consumption in Chile, and in 2005, less than 10 percent. The probable effect has been an economy with increasing energy dependence and increasing restrictions on energy consumption, especially at a time when industry required a fluid and cheap electricity supply.

Coal, the Key to the Prosperity of Nineteenth-Century Chile

One hundred years before Alejandro Foxley drew attention to the trap of middle-income countries, Chile confronted a similar situation. Even from the late nineteenth century, the Chilean economy (as in Argentina and Uruguay) showed a dynamism that resulted in a per capita GDP similar to a middle-income country—slightly ahead of Italy, Spain, and Sweden, though far from the United Kingdom (see table 2.2). Historians have argued that institutional reasons can explain Chilean prosperity in the nineteenth century,[8] forgetting to analyze changes in the production structure that are associated with the introduction of fossil energy sources in the production system. To what extent can we explain Chile's economic prosperity during the nineteenth century and until 1913 by the elite consensus regarding the need to impose the oligarchic social order? Luis Ortega has suggested a different explanation, but he has not yet clarified how important it was that Chile joined other economies with an inorganic energy base in the mid-1840s.[9]

The precedents of the coal era are little known. Chile's energy history is only starting to be written. One estimate of the number of inhabitants and their distribution over the territory allows us to state that in 1843, 15 billion tons of firewood were produced and consumed, an equivalent of

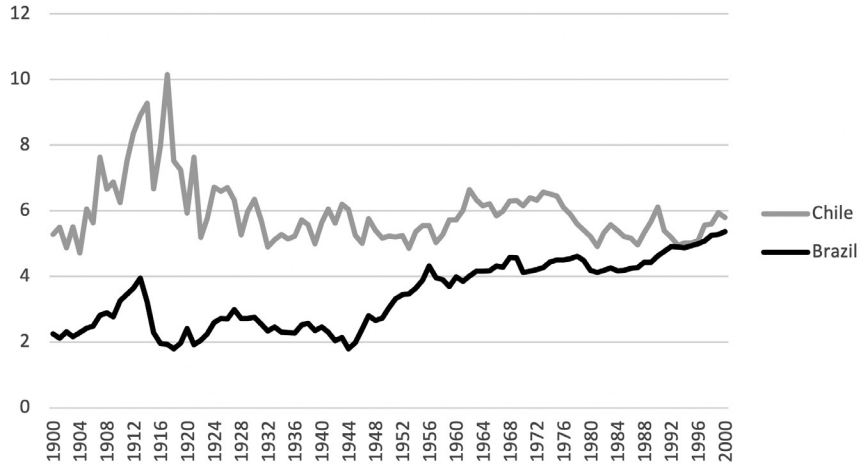

Figure 2.1a Changes in Energy Intensity of Chile Compared to Brazil (TOE per Unit of GDP PPP)

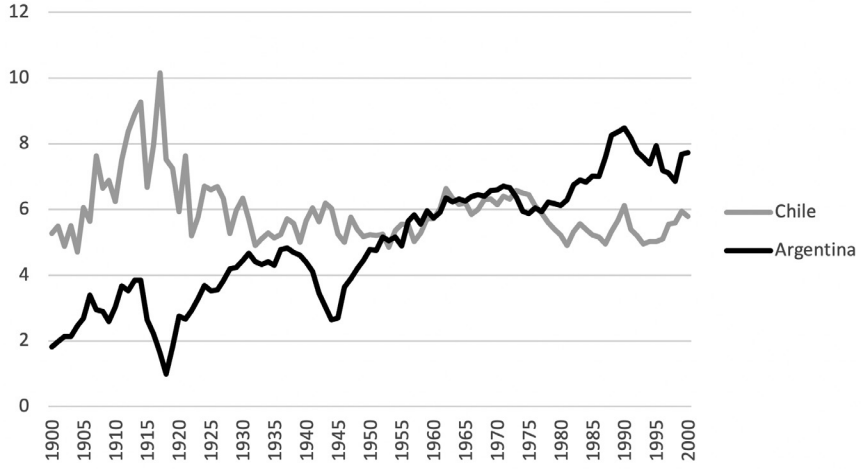

Figure 2.1b Changes in Energy Intensity of Chile Compared to Argentina (TOE per Unit of GDP PPP)

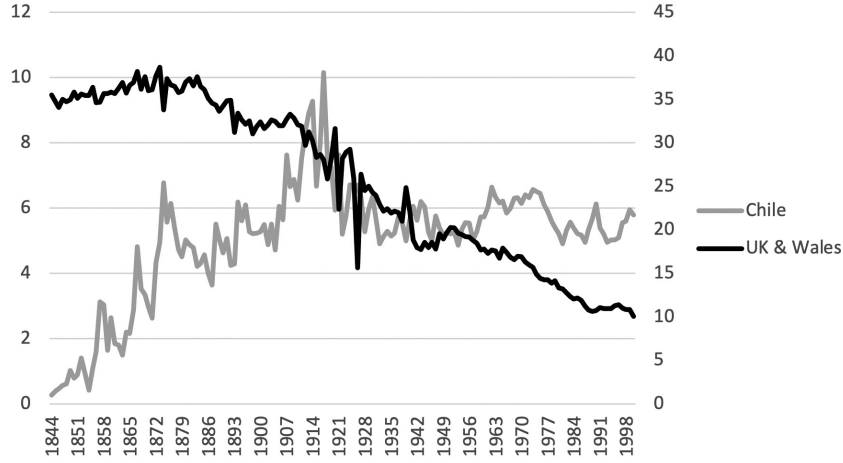

Figure 2.1c Changes in Energy Intensity of Chile Compared to UK and Wales (TOE per Unit of GDP PPP)

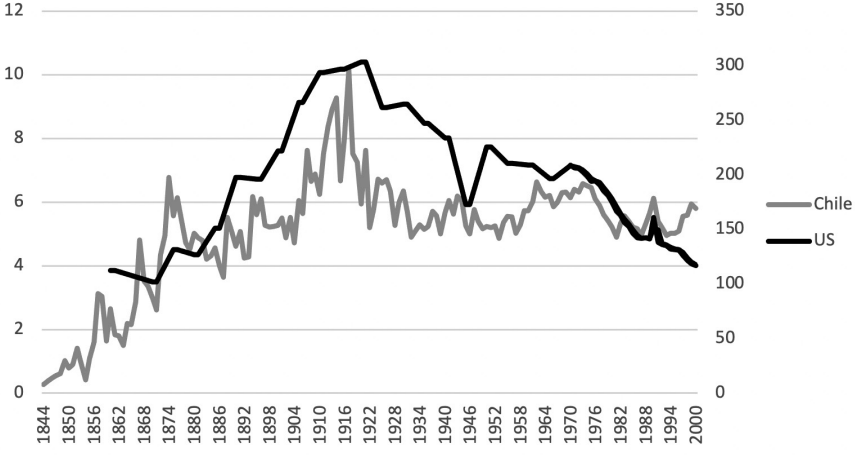

Figure 2.1d Changes in Energy Intensity of Chile Compared to US (TOE per Unit of GDP PPP)

Table 2.2 GDP per Capita at PPP and Annual Growth Rates, 1800–1913

Year	Chile	Argentina	Uruguay	Latin America	Spain	Italy	Sweden	United Kingdom
GDP per Capita at PPP US$ of 1990 (Maddison Project)								
1800	626	931	1,036		916	1,363	857	2,097
1820	605	998	1,165	639		1,511	888	2,074
1850	910	1,251	1,468		1,079	1,481	1,076	2,330
1870	1,290	1,468	2,181	794	1,207	1,542	1,345	3,190
1890	1,966	2,416	2,174	1,052	1,624	1,690	1,635	4,009
1900	2,194	2,875	2,219	1,181	1,786	1,855	2,083	4,492
1913	2,988	3,797	3,310	1,586	2,056	2,305	2,874	4,921
Growth Rate (%) GDP per Capita								
1800–20	-0.17	0.35	0.59			0.52	0.18	-0.06
1820–50	1.37	0.76	0.77			-0.07	0.64	0.39
1850–70	1.76	0.80	2.00		0.56	0.20	1.12	1.58
1870–90	2.13	2.52	-0.02	1.42	1.49	0.46	0.98	1.15
1890–1900	1.10	1.75	0.21	1.16	0.96	0.94	2.45	1.14
1900–13	2.40	2.16	3.12	2.29	1.09	1.68	2.51	0.70

Source: Maddison Project.

542 tons of oil equivalent (TOE). Of these, 70 per cent were in the central zone of the country, between the Aconcagua and Maule Rivers, where most of the population lives. Moreover, the northern region known as the "Norte Chico" had little vegetation suitable for use as fuel, and the southern zone, rich in forests, was scarcely populated.

The main fuel in the country was firewood, a readily available resource used mainly for processing food in the domestic domain and for the heating of homes. A fraction of the firewood (the exact amount remains difficult to identify) was used in metal foundries. Mauricio Folchi

has documented with qualitative sources the deforestation of the Norte Chico as a result of the intensive use of firewood in copper foundries.[10] Prior to this, in the eighteenth century, the gold-mining boom gave rise to the use of a variety of techniques for grinding the mineral—known as the "Chilean mill"—that adapted to hydraulic energy while at the same time employing ancient Inca techniques using human and animal energy.[11]

Until the arrival of coal as a fuel, the growth rate of the economy was sluggish—typical of organic economies. It was only from the 1840s that Chile entered the economic modernity of rapid growth thanks to the arrival of steam engines on the scene (see table 2.2 and figures 2.2 and 2.3).

Chile's economic growth accelerated in the first half of the nineteenth century (see growth rates in table 2.2), which is explained mainly by the introduction of coal to its economic activities. The Chilean "path toward capitalism" is full of coal—to paraphrase Ortega. The only means of escape from the Malthusian trap of decreasing returns and constant 1.73 per cent compound annual growth rates throughout the nineteenth century (note that in the twentieth century, the compound annual growth rate was only 1.6 per cent) was to stop relying solely on organic energy sources. The fact that Chile started exploiting coal deposits in the area of Concepción in the 1840s, and that this was on the route of English steamboats connecting to the Pacific Ocean, explains Chile's advantages—similar only to those of Cuba—compared to other Latin American countries.[12] Between 1844 and 1913, Chile consumed 33,804,440 tons of coal (as measured in TOE), starting with 6,314 TOE up to 1,731,145 TOE. The progression can be seen in figure 2.2. Chile produced coal during this entire period, exporting a small fraction into neighbouring countries (especially Bolivia), and complementing the requirements of its economy with imports coming mainly from the United Kingdom, the United States, Germany, France, Belgium, and occasionally from Australia. However, the period is not homogeneous because there is a major change from 1880. Prior to 1851, when the steepest climb started, almost all coal consumption was domestic, meeting the needs of metal smelting, processing refractory bricks, milling, food manufacturing, and railways.[13] The compound annual growth rate of coal consumption for this period was 12 per cent. After 1880, the period known in Chile as the "Nitrate Cycle" (*Ciclo Salitrero*), the demand for coal continued to expand, increasing more than three times but at a

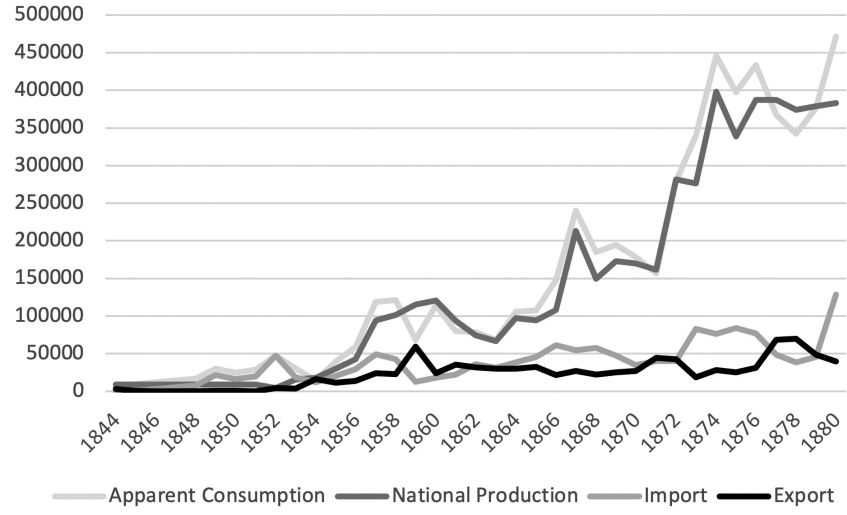

Figure 2.2a Apparent Consumption of Coal, 1844–1880

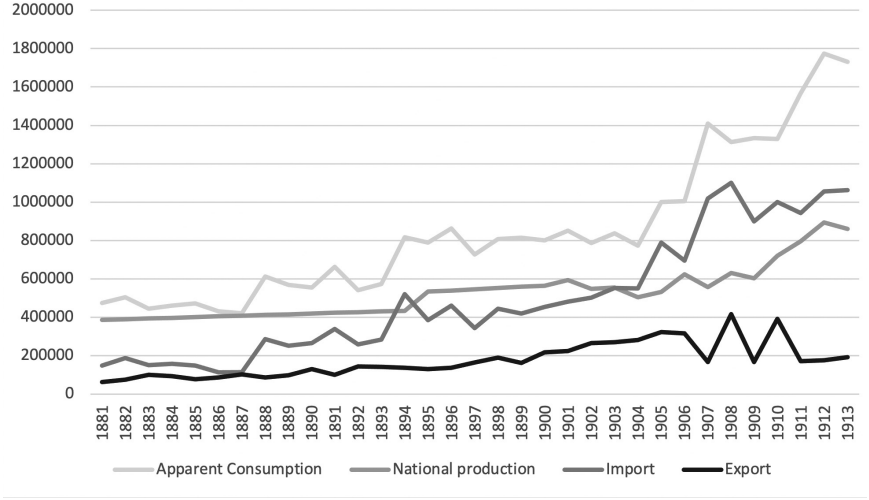

Figure 2.2b Apparent Consumption of Coal, 1881–1913

more moderate cumulative annual growth rate of 4 per cent (7.5 per cent between 1903 and 1913), and with a growing supply of imported coal. At the start of the First World War, Chile was consuming more foreign than domestic coal. The nitrate export economy invigorated the whole economy. Mining, industry, and transport were gradually modernized technologically alongside the use of coal and steam engines.

The introduction of fossil fuels into the Chilean economy allowed a portion of productive activities to avoid the structural risk of recurring cycles of decreasing returns. From the 1850s on, therefore, sustained economic growth relied on those sectors with the capacity to incorporate technology associated with the use of coal as an energy source. By 1860, there were 132 steam engines in Chile, 38 (29 per cent) of which were locomotives for railways, 16 (12 per cent) for coal mining (exploitation and driving), and 44 (33 per cent) for processing industries.[14] Most of these machines, according to the 1860 Statistical Yearbook, still used firewood as an energy source. But in the following decades, coal occupied all the niches of opportunity provided by the Chilean economy. The Statistical Yearbook reports that in 1910–11, 40 per cent of fossil fuels were consumed by mining (34.5 per cent of nitrate), 24 per cent by railways, and the remaining third by industry and other services such as gas and electricity. The Chilean economy not only grew but was also transformed. The US$600 per PPP of the early nineteenth century is an expression of a subsistence economy caught in the Malthusian trap. The US$2,988 PPP in 1913 shows an economy characterized by capitalism and following the modernizing currents of the time. Fossil fuels generated a modern segment in the Chilean economy leading the economic growth.

Economic growth in the sixty years before 1913 correlates perfectly with coal consumption in Chile. However, it would be a mistake to think that this means firewood consumption was not relevant. My own estimates highlight that firewood production in Chile continued for a long time, without experiencing a sudden drop in absolute terms. Figure 2.3, which shows the Chilean energy matrix, is most telling here: although firewood production fell proportionally, it was not until 1907 that it ceded its hegemony to fossil fuels. Despite this, clear signs of firewood's diminishing importance only emerged again in the 1930s.

Table 2.3 GDP per Capita at PPP and Annual Growth Rates, 1913–2010

Year	Chile	Argentina	Uruguay	Latin America	Spain	Italy	Sweden	United States
GDP per Capita at PPP US$ of 1990 (Maddison Project)								
1913	2,988	3,797	3,310	1,586	2,056	2,305	2,874	5,301
1929	3,455	4,367	3,847	2,053	2,739	2,778	4,063	6,899
1950	3,677	4,987	4,659	2,696	2,189	3,172	6,739	9,561
1973	5,034	7,962	4,974	4,878	7,661	10,414	13,494	16,689
1985	5,030	6,835	5,560	5,461	9,722	14,010	16,189	20,717
2010	13,883	10,256	11,526	7,770	16,797	18,520	25,306	30,491
Growth Rate (%) GDP per Capita								
1913–29	0.56	0.54	0.58	1.00	1.11	0.72	1.34	1.02
1929–50	0.30	0.63	0.92	1.31	-1.06	0.63	2.44	1.57
1950–73	1.38	2.05	0.28	2.61	5.60	5.30	3.06	2.45
1973–85	-0.01	-1.26	0.93	0.95	2.01	2.50	1.53	1.82
1990–2010	4.14	1.64	2.96	1.42	2.21	1.12	1.80	1.56

Source: Maddison Project.

In the Chilean economy, firewood has doggedly refused to disappear—in the first place, because it is an abundant resource, and secondly, because modernizing forces have not reached the furthest corners of the country. The excruciating inequality that has characterized Chile's economic history has gradually left behind those economic activities dependent on traditional energies throughout the nineteenth century, and indeed for most of the twentieth century, up to the present.[15]

Society also changed during this period. New business conglomerates of national and foreign origin, new segments of the working class, and new economic relations gave rise to political and labour conflicts.[16] The state acquired new capacities, starting with increased spending on

infrastructure and intervention in social issues.[17] But modernization did not reach all socio-economic strata. Extensive rural and urban areas remained on the periphery of modernity, their inhabitants surviving on incomes that bordered on subsistence levels.[18]

Economic Crises and Energy Transitions in the Last Hundred Years

The last century of Chilean economic history is characterized by two contractionary and two expansive cycles. The interwar period of 1913–50, including the Great Depression, and the period between 1973 and 1985, covering much of the military dictatorship and the foreign debt crisis, saw very low growth. In contrast, the years of strong public intervention in the economy, as in the 1950–73 period (affected by an unprecedented population growth), and the turn of the twenty-first century—both characterized by a strong expansion within an ultra-liberal policy framework—were periods of moderate growth (see table 2.3).

This hundred-year period also saw the complication of the energy matrix (see figure 2.3) and a transition between fossil fuels (from coal to oil and natural gas) coupled with the insufficient expansion of hydro power. These economic crises have affected the country's energy modernization by halting investments that would have allowed the transformation of the energy matrix, which has in turn resulted in continuous energy bottlenecks that eventually weigh on economic growth. Unlike the nineteenth century, during which the country had its own energy resources (coal), in the aftermath of 1913, Chile has become increasingly dependent on fossil fuel energy, delaying its commitment to hydro power and other alternative energy sources that might have satisfied demand with less tension on prices.

The economic crisis that began with the First World War represented a drastic contraction in the consumption of modern energy.[19] In 1913, Chile consumed a total of 2,227,000 TOE (0.60 tons per capita); in 1915, this figure had dropped to 1,386,000 (0.36 tons per capita)—a 40 per cent decrease in energy use in just two years. With ups and downs, the twenties saw a worse decline. But the Great Depression caused a further drop in energy consumption, 1,055,000 TOE (0.22 tons per capita). The recovery of the 1930s and '40s (including the Second World War) was very slow. Only

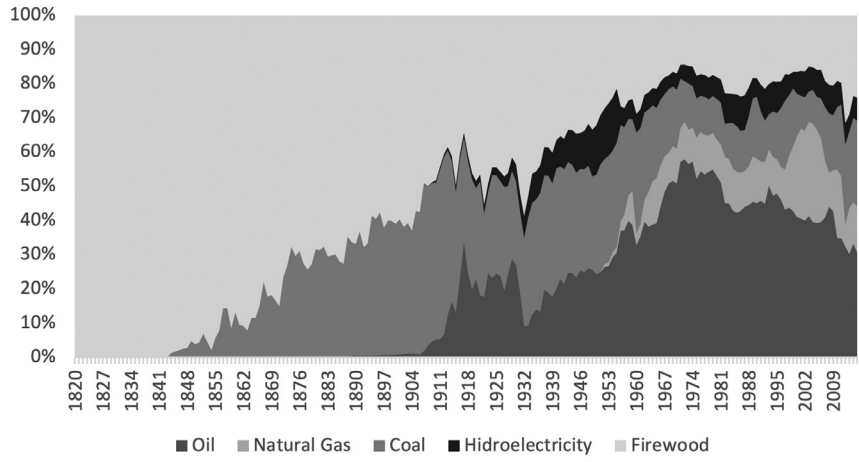

Figure 2.3 Evolution of the Chilean Energy Matrix, 1944–2010

in 1961 were the per-capita consumption levels of the pre–First World War period recovered. Half a century of stagnation in modern energy consumption was induced by the contraction of the economic activity. How to explain what happened?

Everything points to the energy transition depicted in figure 2.4. During the First World War and for the following twenty-five years, the substitution of coal by oil was interrupted. With the collapse of exports of natural resources (mainly salt), activities considered technically archaic—represented in this case by the oldest steam machines, which were also the least energy efficient—were abandoned. Hence, energy intensity dropped sharply until just before the Great Depression, as we saw in figure 2.1. Chile also lost purchasing power abroad during this period, preventing the importation of part of the coal purchased in foreign markets. It also had to contain the expansion of oil consumption, which was entirely imported; this affected the expansion of the most modern and efficient energy activities. Energy intensity stopped declining and tended toward recovery in the 1930s. For the Chilean economy, the effects of this double crisis of export and energy consumption were doubly negative. On the one hand, it

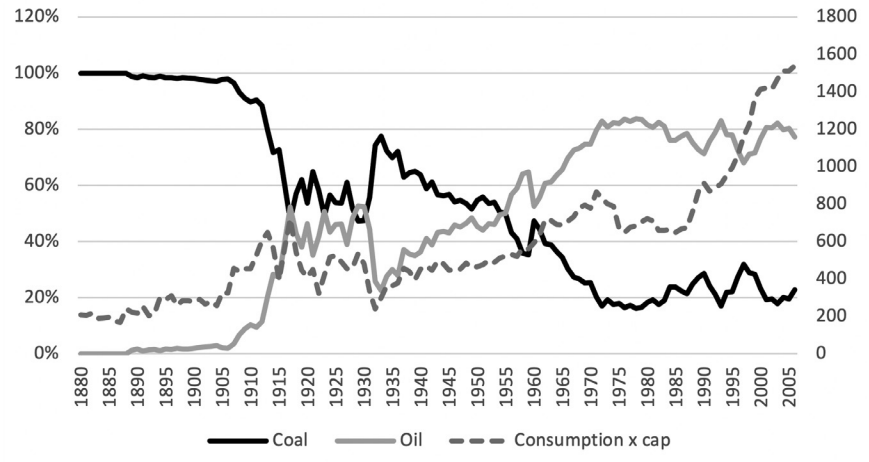

Figure 2.4 Energy Consumption per Capita and Energy Transition

destroyed economic activity, probably of lower productivity, lower energy efficiency, and greater labour intensiveness. On the other hand, the crisis prevented these sectors from being replaced by more modern, productive, and energy-efficient activities because there were no resources to import modern energy (oil), which was indispensable. The concurrence of lower energy consumption with lower oil consumption between 1932 and 1935 confirms this idea.

The economic recovery that started in 1933–4 was gradual and slow. Per capita GDP grew at a rate of 0.30 per cent between 1929 and 1950. External factors related to the shifting international and domestic situation, to which the change in economic policy is relevant, are behind this poor performance.[20] Contributing factors include the recovery of the energy supply, which was slower than the economic recovery, and which in turn slowed down the transition from coal to oil by almost three decades.

During the Great Depression, the country was forced to return to its original sources of coal, boosting mining in all its coal basins. The reluctance to switch from coal to oil was in part a response to the external conditions faced by the Chilean economy, which was unable to import fuel

(on account of its inability to access foreign currency and the dwindling world supply of fuel), and also to the government's decision to promote domestic production to meet local demand.[21] The effort was enormous and the results unsatisfactory. The decline of the Chilean coal industry from the 1930s to the 1970s was unstoppable. In addition, oil was still difficult to import and the supply of energy, mainly for industry, remained an obstacle for decades. Reports from the engineers of the Corporación de Fomento de la Producción (CORFO) are conclusive in this regard.[22] The industrial electricity supply cannot be ensured without a constant supply of fossil fuels for thermoelectric power production. The 1939 Immediate Action Plan emphasised that an additional 100,000 tons of coal were needed. Twenty years later, in 1960, CORFO engineers reported that the electricity industry could not meet domestic demand and that constant power outages prevented an increase in industrial output. If the electricity supply remained dependent on fossil fuels, they said, and the coal industry continued to decline (as actually happened), the external power supply would put the country in position of external dependence, thereby jeopardizing plans for a successful process of industrialization. The alternative was to invest in the production of hydroelectric power.

Again, in a repeat of the drama over coal production, the effort was huge but ineffectual. Figure 2.5 reveals clearly that, although new hydroelectric power plants were opened, their place in the country's energy matrix remained insufficient. Despite the efforts made between 1945 and the late 1960s, electricity produced from water sources failed to overcome the barrier of 7 per cent of the Chilean energy matrix. The problem was not resolved, and domestic industry continued to suffer.

The economic crisis that began in 1973—and which corresponded at the international level with the first oil crisis—left its mark once more on total primary energy consumption. Once again, per capita consumption fell, this time reaching levels lower than those of 1913. At the same time, energy intensity also fell, suggesting that production units (especially factories) that used more antiquated and inefficient energy sources were closing. Chile responded to the increase in oil prices with the two options it had at hand, coal and hydroelectricity. The possibilities represented by the former were limited: the coal basins were unable to offer a solution like they had in the thirties.[23] Nevertheless, there was a new opportunity

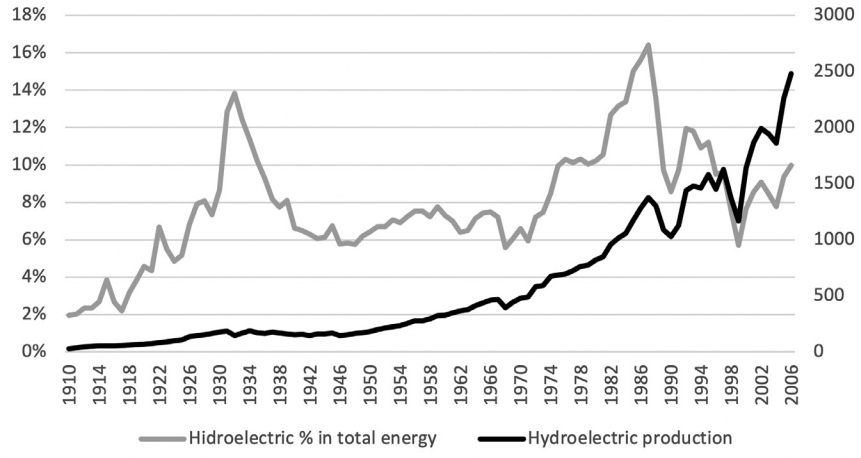

Figure 2.5 Hydroelectric Production and Percentages of Total Modern Energy

for the coal sector, which recovered a small share of the energy matrix (see figure 2.3). But these bad years for the economy were in the end a boon for hydroelectricity, the production of which increased: it henceforth came to represent 16 per cent of total primary energy consumption. The investments of the previous decades bore fruit, highlighting that in this sector of energy, long-term projection is a decisive factor.

Economic prosperity at the turn of the twenty-first century has boosted the consumption of modern energy above 1 ton (TOE) per capita for the first time in Chile's history (see figure 2.4). The barrier of 1 ton per person is significant because the countries that previously followed the path to economic development did so with similar levels of primary energy consumption. This final thought allows us to recall Foxley's analysis about the pitfalls of middle-income economies and the challenges Chile has faced on its way to development. From the point of view of the relationship between energy and the economy, this last phase of expansion continues generating risks. The main risk is that the economy will suffer energy restrictions again, though this time adjusted through prices and

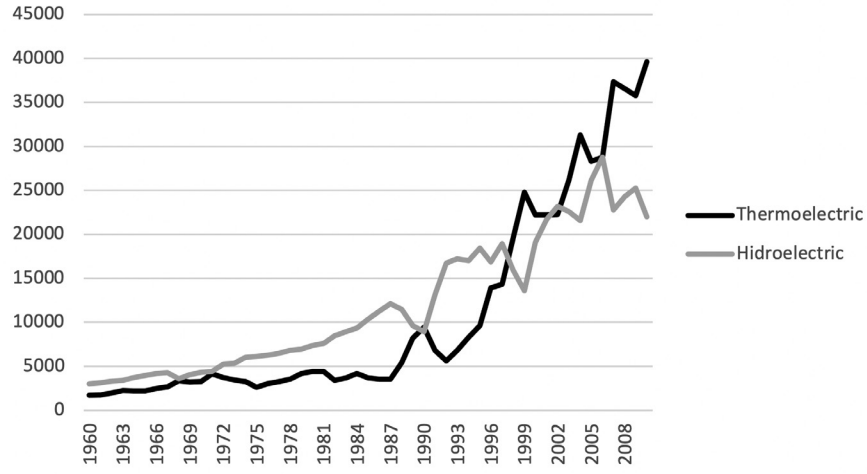

Figure 2.6 Generation of Hydro and Thermoelectricity in Chile, 1960–2010 (GWh)

not via outages, but with similar effects in terms of reducing the future growth potential of the economy.

During these years of prosperity and greater energy consumption, short-term solutions have been implemented to meet local demand—specifically, the importation of natural gas from Argentina (see figure 2.3). Imported natural gas found its opportunity in the face of the collapse of the national coal basins, the oil price pressures caused by the wars in the Middle East, and the hydroelectricity that failed to win a share in the energy matrix (figures 2.3 and 2.5), thus increasing energy dependency. This dependency is aggravated by its link to neighbouring countries with which Chile does not have robust and stable economic relations. In 2004, for example, when the Argentine government decided to limit gas sales to Chile, the consequences were felt immediately with an electricity crisis and rising prices, with the attendant effects on potential economic growth.[24]

The bid for thermal electricity is reflected in figure 2.6. Above all, it is worth noting that since 1992 the generation of thermoelectricity has

increased at ten times the rate of hydroelectricity. Whereas the former expanded at an annual rate of 11.5 per cent, the latter did so at only 1.5 per cent. The most notable economic effect of this energy policy, together with the external dependency mentioned above, was high electricity prices. In 2008, Chilean electricity prices were the highest in Latin America, and in 2010 they were nearly double the average among OECD countries.[25]

Some Lessons from Energy History

We know that there is a close relationship between energy consumption and economic growth, and that this relationship is not simple. We cannot fail to recognize that each national experience has left a record of the unique opportunities and challenges connecting energy to economic growth. In the case of nineteenth-century Chile, an abundant supply of energy (with a high component of domestic coal) contributed to economic growth. The two economic crises of the twentieth century adversely affected the country's energy supply because of the difficulty it had accessing international markets and the delay it faced in securing investments needed to increase domestic energy production. The harmful effect of not acting against energy dependence is also clear, which in the Chilean case over the last hundred years resulted from the country not having made a clear commitment to hydropower. Finally, energy solutions have to be undertaken over the long term, and they require advance planning that cannot be left in the hands of those economic actors who favour the short-term view.

The nineteenth century—which from the perspective of Chile's energy history, with its majority consumption of traditional fuels (especially firewood), extends to 1907—was the period in which coal drove the modernization of the economy. The railways were central to modernization, and they were powered entirely by steam engines. The mining industry in its different sectors (mainly copper and coal) was complemented by the railways, generating a technological critical mass that spilled over into manufacturing. But it was not strong enough to defeat the atavistic tendencies of those sectors that were stuck in the tradition of organic energies. The clearly marked trends of the nineteenth century, characterized by the rise of coal and the relative demotion of firewood, were not repeated

in the following fifty years. The energy transition in Chile was long and complex. Until the 1950s, oil did not clearly dominate coal and firewood. The interwar period, with the Great Depression as its nadir, were marked by economic stagnation (see table 2.3), which in turn made it difficult to translate technological innovation into improved productivity. As a result, the period is associated with an energy intensity that neither improved nor worsened (figure 2.1). Only in the 1960s was the energy transition resolved, at which point a new matrix of primary energies began emerging (figure 2.3). A combination of the old and the new continued until 2010. Firewood stabilized at a magnitude of close to 20 per cent and coal at 10 per cent. Meanwhile, oil and natural gas became consolidated as the country's most important primary energy sources. As both were imported—unlike firewood and coal—this accentuated Chile's energy dependency. Hydroelectricity, which had aroused such high hopes at the beginning of Chilean electrification, occupied a marginal place: an average of 7 per cent between 1960 and 2010.

The electricity sector, which has been so decisive in promoting economic development in past decades, has deepened Chile's energy dependency. The country's bid for thermoelectricity, especially after 1990, meant that electricity generation came to depend heavily on oil and natural gas prices. Furthermore, because generation has been handed almost entirely to private enterprises, which are very sensitive to market signals, the projection of demand has not always coincided with the expansion plans of the electricity sector, which is more sensitive to short-term price fluctuations.

NOTES

This chapter was translated by David Barrios Giraldo with the assistance of Andrew Wiley.

1 These are the results of the Spanish Ministry of Technology research projects *Importaciones y modernización económica en América Latina, 1890–1960* (BEC2003-00412) and *Energía y economía en América Latina y el Caribe, entre mediados del siglo XIX y mediados del siglo XX* (SEJ2007-60445/ECON), led by Albert Carreras at the Universitat Pompeu Fabra from 2003 to 2010. The most recent contributions to this work were made with the support of Fondecyt (Chile) Project 1161425, "Historia de las transiciones energéticas y el cambio estructural en la economía chilena (siglo XIX a XXI)," of which César Yáñez is the principal investigator.

2 The main publications that resulted from the projects mentioned above are María del Mar Rubio, César Yáñez, Mauricio Folchi, and Albert Carreras, "Energy as an Indicator of Modernization in Latin America, 1890–1925" *Economic History Review* 63, no. 3 (2010): 769–804; César Yáñez and Albert Carreras, eds., *The Economies of Latin America: New Cliometric Data* (London: Pickering and Chatto, 2012); César Yáñez, María del Mar Rubio, José Jofré, and Albert Carreras, "El consumo aparente de carbón mineral en América Latina, 1841–2000. Una historia de progreso y frustración," *Revista de Historia Industrial* 53, no. 21 (2013): 25–77. The only publication on the Chilean case is César Yáñez and José Jofré, "Modernización económica y consumo energético en Chile, 1844–1930," *Historia 396* 1, no. 1 (2011): 127–56.

3 Vaclav Smil, *Energy in World History* (Boulder, CO: Westview Press, 1994). See also the following by Vaclav Smil, *Energías. Una guía ilustrada de la biósfera y la civilización*, trans. Ignacio Zúñiga (Barcelona: Crítica, 2001); *Energy at the Crossroads: Global Perspectives and Uncertainties* (Cambridge, MA: MIT Press, 2003); *Creating the Twentieth Century: Technical Innovations of 1876–1914 and their Lasting Impact* (New York: Oxford University Press, 2005); and *Energy in Nature and Society: General Energetics of Complex Systems* (Cambridge, MA: MIT Press, 2008). My co-authors and I have defended this argument in our publications of 2010, 2011, and 2012, cited in the previous note.

4 Two traditions of economic history converge here with the history of energy proposed by Vaclav Smil. The first is that proposed by Edward A. Wrigley in *Energy and the English Industrial Revolution* (Cambridge: Cambridge University Press, 2010) and by Robert Allen in *The British Industrial Revolution in Global Perspective* (Cambridge: Cambridge University Press, 2009), both of which focus on the English Industrial Revolution. The second is the history of the great global economic trends, represented by the seminal work of Kenneth Pomeranz, *The Great Divergence: Europe, China, and the Making of the Modern World Economy* (Princeton, NJ: Princeton University Press, 2000).

5 The reference to Chile being "blessed" refers to the discussion prompted by Sachs and Warner's work about the "curse" or "blessing" of the natural resources to economic growth in developing countries. See Jeffrey D. Sachs and Andrew M. Warner, "Natural Resource Abundance and Economic Growth" (NBER Working Paper No. 5398, National Bureau of Economic Research, Cambridge, MA, December 1995).

6 Alejandro Foxley, *La trampa del ingreso medio. El desafío de esta década para América Latina* (Santiago: Cieplan, 2012).

7 Nicholas Craft, Stephen Leybourn, and Terence Mills, "The Climacteric in Late Victorian Britain and France: A Reappraisal of the Evidence," *Journal of Applied Econometrics* 4, no. 2 (1989): 103–17.

8 A modern version of these interpretations from the perspective of political history can be found in Ana María Stuven, *La seducción de un orden. Las élites y la construcción de Chile en las polémicas culturales y políticas del siglo XIX* (Santiago: Ediciones de la Universidad Católica de Chile, 2000). A nuanced vision of institutional approaches, arising from the economic history, can be seen in César Yáñez, "Economic Modernization in Adverse Institutional Environments: The Cases of Cuba and Chile," in *The Economies of Latin America: New Cliometric Data*, ed. César Yáñez and Albert Carreras (London: Pickering and Chatto, 2012), 105–17. See also Luis Bértola, "Bolivia (Estado Plurinacional de), Chile y Perú desde la Independencia: Una historia de conflictos, transformaciones, inercias y desigualdad," in *Institucionalidad y Desarrollo en América Latina*, ed. Luis Bértola and Pablo Gerchunoff (Santiago: CEPAL, 2011), 227–85.

9 Luis Ortega Martínez, *Chile en ruta al capitalismo. Cambio, euforia y depresión 1850–1880* (Santiago: DIBAM-LOM-Centro de Investigaciones Diego Barros Arana, 2006).

10 Mauricio Folchi Donoso, "La insustentabilidad de la industria del cobre en Chile. Los hornos y los bosques durante el siglo XIX," *Revista Mapocho* no. 49 (2001): 149–75.

11 Inés Herrera Canales, "Trabajadores y técnicas mineras andinas en las fiebres del oro del mundo en el siglo XIX," *Nuevo Mundo/Mundos Nuevos* (online), 10 March 2015, https://doi.org/10.4000/nuevomundo.67746. Herrera says that "it was in the 18th century that gold production in Chile expanded in the same regions as the panning sites of previous centuries with the resulting subterranean seams and veins. Along with this, there was a growth in the use of mining crushers and stamp mills, powered by water. . . . Small owners continued to use *marayes* [small pre-Hispanic mineral mills of Inca origin], artisanal mills powered by draught animals or human power or they took their minerals to big mills" (my translation).

12 Yáñez, "Economic Modernization in Adverse Institutional Environments"; Yáñez and Jofré, "Modernización económica y consumo energético"; and Yáñez et al., "El consumo aparente de carbón mineral."

13 Yáñez and Jofré, "Modernización económica y consumo energético."

14 Yáñez and Jofré, "Modernización económica y consumo energético."

15 Javier Rodríguez Weber, *Desarrollo y desigualdad en Chile (1850–2009). Historia de su economía política* (Santiago: Centro de Investigaciones Barros Arana/DIBAM, 2017).

16 For an excellent example of the changes generated by capitalism in the Chilean economy, see Mario Matus, *Crecimiento sin desarrollo. Precios y salarios reales durante el Ciclo Salitrero en Chile (1880–1930)* (Santiago: Editorial Universitaria, 2012).

17 For more on economic infrastructure spending, see Hernán Cerda Toro, "Inversión Pública, infraestructuras y crecimiento económico chileno, 1853–2010" (PhD diss.,

Universidad de Barcelona, 2013). A summary of this scholar's investigation can be found in the papers presented at the Second Chilean Congress of Economic History; see Hernán Cerda Toro, "Evolución de la inversión pública en infraestructuras productivas, 1853–2010," in *Chile y América en su historia económica*, ed. César Yáñez (Valparaíso: Asociación Chilena de Historia Económica, Universidad de Valparaíso, 2013), 179–94. On the role of the government in the new social and labour conflicts of the early twentieth century, see Juan Carlos Yáñez, *La intervención social en Chile, 1907–1932* (Santiago: RIL Editores, 2008).

18 Income inequality has been studied in detail by Javier Rodríguez Weber, "La economía política de la desigualdad del ingreso en Chile, 1850–2009" (PhD diss., Universidad de la República [Uruguay], 2014). For a summary of the Gini index of income inequality, consult Javier Rodríguez Weber, "De Manuel Montt a Michelle Bachelet. 160 años de distribución del ingreso en Chile," in *Chile y América en su historia económica*, ed. César Yáñez (Valparaíso: Asociación Chilena de Historia Económica, Universidad de Valparaíso, 2013), 455–73.

19 In Chile this period represents an inflection point for exports of saltpetre, ending a growth cycle that began with the War of the Pacific (1879–81), when the country obtained by force natural resources belonging to Peru and Bolivia.

20 Patricio Meller, *Un siglo de economía política chilena (1890–1990)* (Santiago: Editorial Andrés Bello, 1996); Ricardo French-Davis, Óscar Muñoz Gomá, José Miguel Benavente, and Gustavo Crespi, "La industrialización chilena durante el proteccionismo (1940–1982)," in *Industrialización y Estado en la América Latina. La leyenda negra de la posguerra*, ed. Enrique Cárdenas, José Antonio Ocampo, and Rosemary Thorp (Mexico City: El Trimestre Económico/Fondo de Cultura Económica, 2003), 159–209.

21 Martín Garrido Lepe, "El consumo de carbón en Chile, 1933 a 1960," in *Chile y América en su historia económica*, ed. César Yáñez (Valparaíso: Asociación Chilena de Historia Económica, Universidad de Valparaíso, 2013), 329–52; César Yáñez and Martín Garrido Lepe, "El consumo de carbón en Chile entre 1933–1960. Transición energética y cambio estructural," *Revista Uruguaya de Historia Económica* 5, no. 8 (2015): 76–95.

22 Chile. Corporación de Fomento de la Producción, *Fomento de la Producción de Energía Eléctrica* (Santiago: Editorial Nascimento, 1939); Corporación de Fomento de la Producción, *Geografía Económica de Chile*, vol. 3 (Santiago: Talleres Gráficos La Nación, 1962).

23 César Yáñez and Martín Garrido Lepe, "El tercer ciclo del carbón en Chile de 1973 a 2013: del climaterio al rejuvenecimiento," *América Latina en la historia económica* 24, no. 3 (September–December 2017): 224–58.

24 Vittorio Corbo, ed., *Growth Opportunities for Chile* (Santiago: Editorial Universitaria, 2014).

25 Chile. Biblioteca del Congreso Nacional de Chile, "Informe: Comparación de precios de electricidad en Chile y países de la OCDE y América Latina," 6 November 2017, http://bcn.cl/13vae.