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PRODUCTIVITY AND GROWTH IN PERSPECTIVE: CHILE, 1833–2010

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This paper presents a long-period growth accounting for Chile, an emerging economy, from the early nineteenth century through to 2010. The methodology, data, and sources used are thoroughly discussed, and the results are compared with a benchmark based on a sample of countries. Some of the findings are: Chile's average productivity growth over the whole period is explained mainly by capital deepening, but long period averages hide huge and variable differences when various time subdivisions are explored. Gross TFP growth increases throughout phases until 1973 when an international reduction sets in. The research also put the role of employment-population ratio into perspective.

JEL Codes: N16, O47, O54

Keywords: Chile, productivity, sources of growth

1. Introduction

Economic growth used to be seen as a recent phenomenon, dating back to the Industrial Revolution. However, thanks to the spread of systematic per capita income measurements, we can now trace it back to the early fourteenth century.[1]

In overall systematic growth evidence, three aspects of this phenomenon stand out. First, early growth rates were rather low, particularly when compared to the twentieth century. Second, GDP growth decomposition analysis shows that the relative importance of capital, labor and the corresponding residual changes over time and the latter appears to gain in importance in the twentieth century. Third, the overall sample on which these general impressions are based is not necessarily representative of the world's economic growth because, at least until now, it has tended not to include estimates for relatively poorer economies.

The main contribution of this paper is its estimation of long-period growth accounting for Chile from the early nineteenth century through to 2010. It, therefore, also helps to fill the gap in earlier samples by increasing knowledge about the growth of an economy with a relatively low income in the nineteenth century.

Our growth accounting estimations are based on year-to-year data and permit any time subdivision. However, this paper emphasizes the long-period view and

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[1]Broadberry *et al.* (2015) and Crafts and O'Rourke (2014). See also Astorga *et al.* (2011); Bergeaud *et al.* (2016); for point estimates of TFP growth before 1800, see Zanden (2009).

focuses on: (i) overall average growth rates for the complete 1833–2010 period, and (ii) average growth rates for selected sub-periods, in particular the Maddison (1995, 2007) phases.

Growth rates and other expressions referring to income or growth breakdowns acquire much of their meaning once compared with relevant reference indicators. Long-period descriptions for a given economy are, therefore, informative because the outcomes can be used for comparisons across periods or even years. The possibility of comparison with third economies constitutes another step towards comparability and additional meaning and, in the last section of the paper, we compare our estimates for Chile with results obtained for other economies by third parties (for whose use we are indebted to the corresponding authors).

Growth accounting measurements for Chile already exist and a short review can be found in our Online Appendix. However, research in this field has tended to focus on the second half of the twentieth century and data sources and procedures have varied widely. The measurements cover different periods and are not necessarily comparable without further work. Only one of these measurements covers the first decades of the twentieth century.

We include the nineteenth century, which has not previously been considered at all, and our annual estimates use a precise methodology, with the definitions of the pertinent variables included in a coherent data set specially prepared by the authors. A few conceptual and data treatment issues are discussed in Section 2, including the treatment of natural resources in the overall production function, the evolution of hours worked, eventual differences between stocks and services of physical capital, and estimates of human capital.

Our results refer to factors' contribution to growth over the whole period from 1833 to 2010 and to participation shares. Additionally, we have estimated the volatility of contributions, a dimension of growth decomposition that can help to better describe Chile's economic growth.

An institutional process that began in 1810 transformed Chile into an independent Republic, replacing a colonial regime that had lasted more than two centuries. By 1833, the year our growth decomposition begins, this process was more or less complete: there was a functioning state and international trade was gaining in importance. Figure 1 shows Chile's economic performance over time using two variables: GDP per capita as a percentage of the corresponding level in the United States and Chile's total trade as a percentage of its GDP.

Domestic reactions to changes in the global economy are a matter of choice for the local state. In this sense, the economy's openness to world trade is an outcome determined by the interaction of two forces: on the one hand, opportunities and incentives and, on the other, the domestic choice made as regards trade policy.

Income estimates by Díaz *et al.* (2016) show that Chile's per capita income increased over 15-fold between the early nineteenth century and 2010. In this context, Chile's growth relative to that of the USA has been far from constant (Lüders, 1998). Although precise magnitudes for such a long-period comparison depend on the exact deflator used for international comparisons, Figure 1 indicates that, by 2010, Chile still lagged behind the level it had reached two hundred years earlier. Using this relative measure, it can be seen that, after converging slightly in

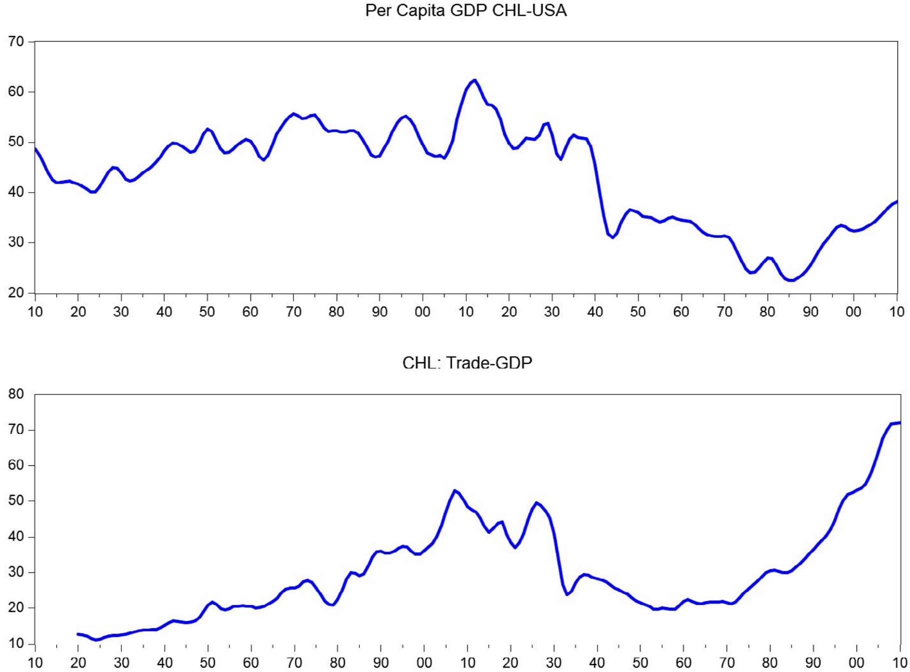

Figure 1. Chile, 1810–2010: relative per capita GDP (percentage of USA, 2015 PPP) and trade over GDP (%). 3x3-year moving average
[Colour figure can be viewed at wileyonlinelibrary.com]

the nineteenth century, the trend diverges and it is only in the last decades of the twentieth century that a vigorous reversal is observed.

In the case of foreign trade, the state had already declared its importance for the country by 1811 and, throughout the nineteenth century and until World War I, this sector constituted the main tax base (López, 2014; Díaz *et al.*, 2016). When discussing growth and formation of the state in the first half of the nineteenth century, Bulmer-Thomas (1994) identifies the Chilean case as an exception in Latin America. In this period, Chile can be seen as benefiting from the "commodity lottery," a combination of natural resource endowment, transport facilities and location, the structure and growth of world demand, and the state's willingness to obtain revenues through trade taxes. Subsequently, the state embarked on a project of territorial consolidation and expansion that allowed it to increase the trade base over the following decades.

World Wars and depressions, with their trade-inhibiting procedures such as beggar-thy-neighbor policies, led the Chilean state to adopt a very complex policy, a construction it could not dismantle when world trade started to grow more rapidly in around 1950. Like other Latin American countries, Chile persisted in this restrictive policy for a quarter of a century, partly as a consequence of protectionism but also because the policy's complexity itself favored inertia. Interest in accessing a broader trade base did not disappear, however, and mutated into active participation in trade and production agreements within the subcontinent, although their practical importance for the economy proved to be minor (Hachette, 2011). It was not until around 1975 that the state imposed a drastic change of policy, re-establishing easier access to the world economy. This resulted in rapid growth of trade, which reached an unprecedented level with respect to GDP.

This paper is organized as follows. Section 2 below describes the methodology, data, and sources used as well as discussing some particular issues that are especially relevant in long-period analysis. Section 3 sets out general results on sources of growth in Chile, taking the period between 1833 and 2010 as a whole, while Section 4 examines Chilean data broken down into Maddison's phases. Section 5 puts the results in an international context and is followed by a short summary and the conclusions. Finally, an Online Appendix provides additional information.

2. General Framework

2.1. *Methodology*

This growth decomposition starts with a standard aggregate production function $Y_t = F\left(K_t, L_t, A_t\right)$, where Y is the total product and K and L are capital and labor, respectively, while A captures the impact of changes in other elements that also affect production.

Rates of growth can be expressed as:

$$g_Y(t) = \alpha(t) g_K(t) + \beta(t) g_L(t) + g_A(t) \quad (1)$$

where g_x is the growth rate of x and α and β are the corresponding distributional factor shares.

Both factors, K and L, are seen as separable components, the first being understood as capital stock (C) and the element transforming C into potential services (q) so that $K = C\,q$. Labor is employment (E) weighted by an index capturing the evolution of human capital (h), hence $L = E\,h$. No independent variable with the capacity to represent A is available and, therefore, g_A is generated as the residual of the empirical estimation, commonly identified as total factor productivity growth (TFP).

This residual indicates possible product changes not captured by C or E growth and stands for a wide variety of situations such as movements in the technological frontier or changes in the Hicksian shift parameter. It also acts as a recipient for product changes that may be attributed to the development process such as possible quality variations in essential inputs not captured by quality indices, a reallocation of resources that enhances or reduces productivity, product variations due to increasing utilization of non-rival goods, and scale effects (Griliches, 1996; Lipsey and Karlaw, 2000; Fuentes *et al.*, 2006). TFP can also incorporate product variations due to cyclical movements, depressions, and booms or other short-period fluctuations that the analyst may prefer to keep apart.[2] Accordingly, the

[2]A standard procedure for separating the effects of short-period fluctuations, keeping them apart from product changes due to more fundamental changes, is to calculate TFP growth and contributions in general over an extended period. The distinction between structural product variations and short-period fluctuations will depend on the underlying theoretical growth outlook. The procedure opens up the question of the optimum length of such a period, an issue that, as seen in our discussion, is not easily resolved.

residual of the estimation depends on the precise nature or definition of the factors as indicated above. In this paper, we refer to A as net TFP or, in other words, productivity growth obtained after considering the increase in q and h.

Assuming as a general growth equation a traditional Cobb-Douglas function:

$$Y = K_t^{\alpha} L_t^{1-\alpha} A_t = (C_t q_t)^{\alpha} (E_t h_t)^{1-\alpha} A_t \tag{2}$$

product per employee can be formulated as:

$$\frac{Y_t}{E_t} = \left(\frac{C_t}{E_t}\right)^{\alpha} q^{\alpha} h^{1-\alpha} A = \left(\frac{C_t}{E_t}\right)^{\alpha} \tilde{A} \tag{3}$$

The last term $\tilde{A}$ includes contributions arising from h and q plus A so $\tilde{A} = q^{\alpha} h^{1-\alpha} A$. In other words, product per employee is composed here of weighted capital per employee (C/E) and a gross TFP measure.[3] In what follows, we refer to gross TFP growth when the estimation does not specify the evolution of q and h explicitly, and to net TFP growth when the role played by these elements is identified.

In this framework, per capita output (Y/N) is obtained as $\frac{Y}{N} = \frac{E}{N} \times \frac{Y}{E}$, where N stands for population and E/N is the employment-population ratio (Cole *et al.*, 2005). Therefore, per capita income growth decomposes into:

$$g_{Y/N} = g_{E/N} + g_{Y/E} = g_{E/N} + \alpha g_{C/E} + g_{\tilde{A}} \tag{4}$$

In this way, per capita GDP growth is an outcome of changes in the employment-population coefficient plus capital deepening and the variations derived from gross TFP (i.e. income changes attributed to human capital, the service-stock ratio, and net TFP growth).

Growth decomposition results are presented as contributions to growth, that is, weighted rates of change. For instance, $\alpha g_{C/E}$ is the contribution of C/E growth to Y/E growth. Contributions to growth are also shown as shares of total growth so, for example, $\alpha g_{C/E}/g_{Y/E}$ is the share of capital deepening in explaining growth of per employee output. These are two different but related measures and complement each other in the description of growth.

2.2. *Data*

The GDP figures used in our estimations are taken from Díaz *et al.* (2016), who include a lengthy discussion on sources, procedures, and other issues. The stock of physical capital, C, is taken from Díaz and Wagner (2016) and the series is generated using the perpetual inventory method and yearly fixed capital

[3]In a richer data context, Caselli (2005) decomposes Y/E into a Factor Only Component (FOM), given by a capital-deepening element multiplied by weighted human capital, where C already refers to capital services. The second element of Caselli's decomposition is, therefore, "pure" TFP, and not $\tilde{A}$ as in our version.

investments. It considers two types of investment goods: infrastructure, and machinery and equipment.[4] This C measure implies a rising capital-output ratio for the economy in the second part of the nineteenth century[5], an expansion that explicitly incorporates the stock of fixed capital in the area of northern Chile that was formally annexed around 1880, although this accounts for a minor fraction of the total capital increase in those years.[6]

The q index transforms the capital stock into capital services and, therefore, $K = Cq$. Jorgenson and Griliches (1967) note that the role of capital in production takes the form of the services it provides and the cost of these services can be seen as a reasonable proxy. Equilibrium of the capital composition mix implies, among other things, that one dollar of capital in the form of machinery and equipment relative to one dollar of capital in the form of infrastructure delivers services per unit of time in a ratio that is inversely proportional to the corresponding unit costs. Hence, capital characterized by high depreciation implies higher service per dollar of C compared with an asset with low depreciation.

As in Gordon (2000), the capital composition index (q) reflects the differential lifespan of the service capacity of infrastructure, on the one hand, and, on the other, machinery and equipment. In other words, the index captures a critical component of the differential costs, although not the complete capital cost. Formally,

$$q = \left[\left(\frac{\delta_M}{\delta_I} \right) C_M + C_I \right] \frac{1}{C} \tag{5}$$

where C_M and C_I stand for machinery and infrastructure capital stocks, respectively, and δ represents the corresponding depreciation rate of each type of capital. Due to its substantially higher implicit depreciation rate, one dollar of capital stock in the form of machinery and equipment constitutes a higher cost and, therefore, signals a higher contribution to growth than one dollar in infrastructure capital.[7] A rising share of machinery and equipment in total capital (C), which was a subtle but growing phenomenon in the Chilean case, expands the composition index, q and, in this way, the role of capital (C) in explaining product growth.[8]

[4]Production of infrastructure is mainly a domestic activity while, to a significant albeit varying extent, machinery and equipment are imported. This raises two issues: the construction of an international price index for Chilean capital imports and the determination of the relevant exchange rate (see Díaz and Wagner, 2016).

[5]Díaz and Wagner (2016) also provide a discussion about the initial 1833 level of stock of capital.

[6]Chile is not the only country where a substantial increase in the corresponding capital-output ratio can be observed; for the nineteenth century, see the United States, the United Kingdom, and Spain (estimates based on Maddison, 1995; Prados de la Escosura and Roses, 2009).

[7]The average implicit depreciation rates in the perpetual inventory method for the full 1833–2010 period are 8 percent for machinery and equipment and 3 percent for infrastructure, with dispersion ranging from 0.5 percent to 16 percent in the former case and from 2 percent to 6 percent in the latter. In explaining US growth since 1870, Gordon (2000) employs a constant ratio of three to one for the whole period.

[8]This composition index is used to obtain an empirical expression for the quantity of service implicit in different types of capital, something that should not be confused with changes in capital's quality. Insofar as quality improvements, beyond equalizing price expansions, occur, as in the case of IT equipment, they are not identified by the indicator used here. Therefore, developments of this type are captured in the residual. See Corbo and González (2014) for an estimate of the role of ICT goods in Chile in recent years.

Employment, E (number of workers), is taken from the annualized labor force generated by census data. A correction term for unemployment is incorporated. From 1985 onwards, the unemployment rate calculated by the National Statistics Office (INE) is used while, between 1960 and 1985, this term is based on unemployment rates from the INE and the University of Chile. For earlier years, it is generated using an Okun-type estimation based on the 1960–2005 period, plus an index of changes in the agricultural labor force as a percentage of the total labor force (Díaz *et al.*, 2016).

The best representation of labor's contribution to growth calls for estimates of the total number of hours worked, a figure that is not readily available in Chile for the long period. Figures for yearly hours worked by the labor force in Santiago are available back to 1956.[9] Between 1956 and 2000, average working hours remained more or less stable and it is only in the first decade of the twenty-first century where we find some decline (Universidad de Chile, 1963; Hofman, 1998; Ministerio de Hacienda, 2016; The Conference Board, 2016).

Systematic information on hours worked before 1950 has not been found. However, De Shazo (1983), based on a few small firms in the early twentieth century, and Bauer (1975), based on the aggregate accounting sheets of a large central farm, provide some indications: vacations are not mentioned and the working day easily exceeded 10 or 12 hours. Based on these admittedly very scattered impressions, we can conclude that, in the nineteenth century and even the early twentieth century, the working day was long compared to the second half of the twentieth century when it shortened, a phenomenon also seen in many other countries (Huberman, 2004).

Yearly hours of work are, however, not the same as the length of the working day. There is direct and indirect evidence suggesting that an increase in the number of days worked began in the nineteenth century and persisted at least until 1950. One aspect of this trend involves the so-called "short" week under which workers took days off beyond established conditions, an old practice that appears to have lost much of its appeal in the second half of the twentieth century.[10]

A second aspect refers to the evolution of the occupational structure of employment. In the 1860s, two-thirds of the total labor force was employed in agriculture, a figure that, by the beginning of the twenty-first century, had dropped to 14 percent. Due to climatic and other specific sectorial restrictions, agricultural employment is not stable over the course of the year. Bauer (1975), for example, shows that, in the case of one large farm in 1870–72, 58 percent of the year corresponded to a season with "high" demand for labor and also notes that the importance of the "high" season rises with the diversification of production and the increase in the average annual productivity of employed agricultural workers.[11]

[9]Employment Survey, conducted by the Economics Department of the University of Chile.

[10]One example of this is the legislation discussed in 1948, regulating the additional daily wage paid to workers working the full week (including "holy Monday" as this day off was called). As is often the case with regulation, this extended an already existing private practice, making it compulsory at the general level.

[11]In this sense, the situation bears similarities with Allen and Weisdorf's (2011) "industrious revolution" in England, with the stability of employment increasing over the years as a result of product diversification and other innovations.

A third aspect refers to changes in labor contracts. In the nineteenth century, daily contracts were widely used and were associated with a migrant or "nomadic" labor force. Their relative importance began to decline slowly and Bauer (1975) suggests that longer contracts, in many cases "for life," were a means to increase the established population.

Taking all these aspects together, we suggest that our employment measure constitutes an imperfect but reasonable approximation to the expansion of this factor since, although hours of work per day declined in some periods, this was offset (or more) by the evolution of working days per year, at least through to 2000.

The human capital index, (h), is developed in two stages. First, average years of education (n) are determined and these are then translated into a human capital indicator. Average years of education are obtained from years of schooling (n_s) except for the base year, 1833, where wage differentials are used to construct the stock of equivalent years of education, which we assume to be an outcome of "learning by doing" in firms and other production units.[12]

Years of schooling (n_s) are taken from educational data while average years of "learning by doing" (n_f) are determined on the basis of wage differentials and the distribution of the working population. Total years of education can, therefore, be expressed as $n = n_s + n_f$ (Díaz *et al.*, 2016, pp. 613–614).

The second stage assumes that the human capital index (h) follows the criteria of Bils and Klenow (2000) and the return on education is conditioned by years of education (n), so that:

$$h = \exp\left\{\frac{\theta}{1-\psi} n^{1-\psi}\right\}, \tag{6}$$

where θ and ψ are assumed to be equal to 0.32 and 0.58, respectively (taken directly from Bils and Klenow, 2000, p. 1168). This formulation reflects the efficiency of a unit of labor with n years of education relative to one with no education (Hall and Jones, 1999).

The last input required for the growth accounting exercise are weights transforming input expansions into contributions to growth. These are usually taken from national accounts but, as Gollin (2002) shows, these accounts often do not separate income by factor in the case of self-employed labor, mixing returns generated by labor with income derived from physical capital services. This is the case of Chile's national accounts.

Although growth accounting estimates traditionally use constant shares, the possibility that these may rise or fall has received more attention recently (Gollin, 2002; Karabarbounis and Neiman, 2014; Piketty, 2014). As regards shares, our growth accounting measurement departs from previous Chilean estimates and three sources are considered: first, Alarco (2014) for labor's participation based on national accounts and GDP data from 1950 to 2010; second, Restrepo and Soto (2006) for a constant returns growth accounting exercise that provides both capital

[12]In their historical overview of Chilean education, Serrano et al. (2012) put forward plausible arguments in favor of the existence of the "learning by doing" channel for human capital accumulation.

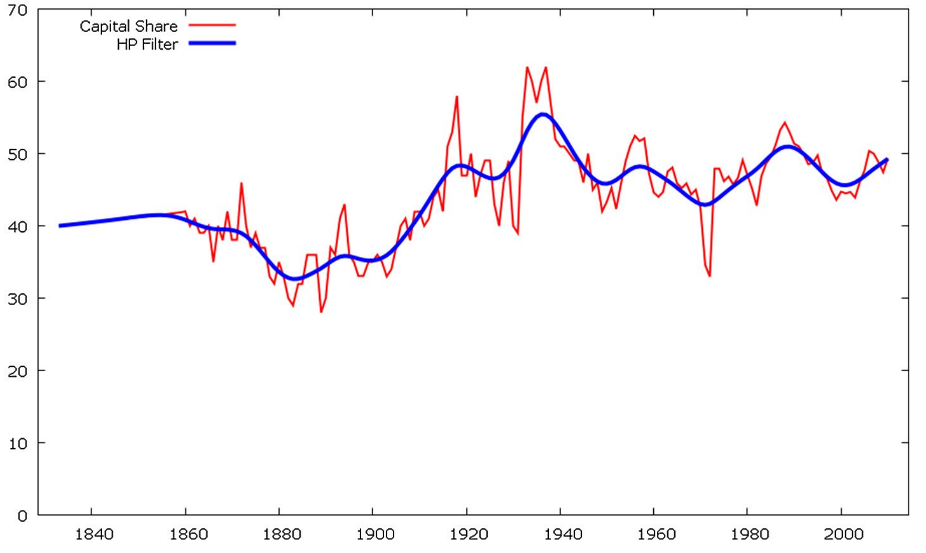

Figure 2. Capital share, 1833–2010, as a percentage of GDP
Source: Prepared with data from Alarco (2014), Restrepo and Soto (2006), and Rodríguez-Weber (2009, 2014) as explained in the text. [Colour figure can be viewed at wileyonlinelibrary.com]

and labor shares for 1986–2003; and, finally, Rodríguez-Weber (2009, 2014) who, in a monumental effort, constructs labor shares with yearly wage data for different types of employment, skills, and gender and the corresponding number of workers in each of these categories for the period back to 1860.

Our procedure follows Alarco's figures based on national accounts. These supposedly do not consider shadow wages for employers and the self-employed and are, therefore, adjusted to Restrepo and Soto (2006) levels in order to generate values for 1950–2010. For 1950, this procedure provides a share that is almost identical to that of Rodríguez-Weber (2014) and, from this year back to 1860, variations implicit in Rodríguez-Weber (2014) are followed. For the years between 1833 and 1860, a linear interpolation assuming a capital share equal to 40 percent for 1833 is supplied.[13] The results obtained are then smoothed with a standard Hodrick-Prescott filter ($\lambda = 100$).

The capital share obtained in this way remains approximately constant from 1833 to 1860 but then begins to fall, reaching its lowest level in the mid-1880s. This is followed by an underlying positive trend that persists through to the late 1930s after which there are gentle fluctuations (Figure 2). In general, the average for the twentieth century is somewhat above that for the nineteenth century while more recent levels, at close to 50 percent, are 10 points above 1840–60.

Our main estimations use the variable labor share but, occasionally and mainly for comparisons, the median for these two centuries (0.43) is used. This fixed share provides estimations that can be useful as a reference point given that most current estimates for the Chilean economy operate with fixed shares.

[13]All basic data was kindly provided by the mentioned authors.

Table 1 provides an overview of the evolution of our series, showing that, over the whole period, capital stock per employee (C/E) expands most while service-adjusted capital per worker (K/L) increases 40-fold. With GDP per employee increasing 20-fold over the whole period, human capital per employee is currently three times higher than in 1833.

2.3. *Completeness of the production function: natural resources*

Long-period growth accounting raises issues that, in estimations for shorter periods, can be left implicit or simply not mentioned. Some of these issues have already been mentioned when discussing the data, but there remains one, the completeness of the underlying production function, that merits additional attention.

As already mentioned, K and L are "produced" factors. However, their productivity also depends on the presence of a broad category of "given" or "non-produced" factors, particularly natural resources. Many resources—from the quality and beauty of beaches through to the distribution and intensity of rainfall and sunlight and endowment with mineral resources—play a fundamental role in determining the location and productivity of capital and labor. Some minimum basket of such resources is required since production does not occur in a "cloud" or "nowhere" and the relative abundance or scarcity of certain natural resources may eventually have an impact on the composition of production.

Some of these resources may remain constant over time but, due to underlying "supply" or "demand", others may be rapidly exhausted. Moreover, at a given time, the levels and location of a given resource may be unknown, either because its existence has not been discovered or the knowledge required for its exploitation is lacking. The existence of copper deposits may, for example, be well known, at least among experts, but the technology for its extraction still be decades away.[14]

In practice, most growth accounting estimations consider such resources only implicitly, a procedure that is equivalent to assuming their constancy and that they, therefore, play no role in determining rates of change of contribution by factors.[15] However, this constancy of natural resources should be understood at a general level and it is technical progress, innovation, and adaptation to new circumstances that are ultimately behind long-period growth.

3. Productivity growth decomposition, 1833–2010

This section focuses on the growth of GDP per employee, identifying the contributions of factors and residuals over the whole 1833–2010 period as well as the corresponding average growth rates obtained from year-to-year log differences. The

[14]At the beginning of the second half of the nineteenth century, Chile was one of the world's leading suppliers of copper. A few decades later, the supply of high ore content dried up and, with it, Chile's copper exports. It was not until the 1900s that this changed drastically and the country again began to be a major exporter (Meller, 1996).

[15]Suppose factor K is made up of two components, one being produced capital, our capital series, while the other is natural resource capital, K_{NR}. Expressing this in terms of growth rates implies that $g_Y(t) = \alpha(t)\left(g_K(t) + g_{KNR}(t)\right) + \beta(t) g_L(t) + g_A(t)$. Insofar as growth arising from the natural resource capital was equal to zero, ignoring this capital would have no consequences for growth accounting results. On the other hand, the level of the factor's productivities depends on its presence.

TABLE 1
Capital, Labor, and Average Productivity, 1833–2010: (1905 = 100)

Year	GDP per employee	GDP per capita	Capital stock per employee (*C*/*E*)	Quality-adjusted capital stock per adjusted labor (K/L)	Capital stock composition (q)	Human capital (h)
1833	26	34	7	9	92	76
1845	32	42	9	10	92	78
1865	50	62	13	16	95	81
1885	70	77	37	41	100	90
1905	100	100	100	100	100	100
1925	149	125	172	150	104	119
1945	167	133	186	152	103	126
1965	252	173	259	201	113	146
1985	288	162	295	190	115	178
2005	514	239	466	291	135	215
2010	522	235	552	365	147	223
1905/1833	3.82	2.90	13.33	10.97	1.08	1.32
2010/1905	5.22	2.35	5.52	3.65	1.47	2.23
2010/1833	19.95	6.81	73.59	40.05	1.59	2.93

estimates are accompanied by discussion of the impact of distributional shares and outcomes are obtained with both the variable share implicit in the data and the corresponding fixed average. In addition to the results based on these distributional shares drawn directly from the data, we also estimate outcomes using "arbitrary" fixed shares that are significantly above and below the evidence-based average.

Estimations with evidence-based factor shares distinguish between α_1, the variable capital share, which is a smoothed version of the observed factorial distribution, and α_2, a fixed share for capital, which is the median of the distributional data over the whole period, that is, 0.43. These outcomes are later compared with results based on our arbitrary alternatives, that is, $\alpha_3 = 0.33$ and $\alpha_4 = 0.50$, both of which differ markedly from the median for the real data (0.43) but are not entirely out of the range of estimations for Chile and other economies (see the Online Appendix).

Table 2 summarizes the main results. The first and second columns show the corresponding compound annual growth rate and the average of log differences per year for all variables. For instance, the average annual growth of GDP per employee is 1.71 percent with the first method and 1.69 percent when using average log differences. Given their long-period similarity, only the average of log differences per year is used when showing contributions to growth in what follows.

A second finding is that the increase in average productivity over the whole period is around two-thirds a matter of perspiration, a result that is almost independent of whether the variable capital share (α_1) or the fixed one ($\alpha_2 = 0.43$) is used to decompose growth of GDP per employee (Table 2, Columns 3 and 4). In both cases, growth of capital per employee (capital deepening) contributes over 60 percent of the growth of GDP per employee. The gross residual obtained (gross TFP growth) is a little below 40 percent. The capital composition index–the service-stock transformer–plus growth arising from human capital contribute around 27 percent of growth of GDP per employee, with increases in human capital accounting for 74 percent of this contribution (=20/27). This implies that net TFP accounts for 10–11 percent of average growth of GDP per employee measured over this long time span.

The third finding arises from the results obtained when using fixed arbitrary counterfactual capital shares ($\alpha_3 = 0.33$, $\alpha_4 = 0.5$). As shown in the last two columns of Table 2, a higher than average capital share, α_4, raises the contribution of capital per employee to growth, as one would expect, and reduces the contributions of the other growth elements, that is, human capital, TFP, and the service-stock transformer. When estimating with α_4, the role of net TFP almost vanishes, explaining only 2 percent of the growth of GDP per employee.

However, our main inference from these results refers directly to the importance of accurate data for growth accounting decomposition. Suppose, for example, there was no data for these shares and, as a solution, international data was used as a reference on the grounds that shares do not differ much between countries, an argument frequently found in some literature. Our results suggest that this could lead to some quite confusing conclusions, depriving growth accounting of its representative capacity.

To sum up, Chile's average productivity growth over the whole period is explained mainly by capital deepening or, in other words, the growth of capital

TABLE 2

Annual Growth Rates and Contributions to Growth: 1833–2010

	(1) Comp. annual growth rate (%)	(2) Log diff.	(3) Capital share, raw data HP filtered (α_1)		(4) Constant capital share, the median of raw data ($\alpha_2 = 0.43$)		(5) Constant low capital share ($\alpha_3 = 0.33$)		(6) Constant high capital share ($\alpha_4 = 0.5$)	
			Cont.	Share	Cont.	Share	Cont.	Share	Cont.	Share
GDP per employee (*Y*/*E*)	1.71	1.69		100		100		100		100
Capital per employee (*C*/*E*)	2.46	2.43	1.07	63	1.04	62	0.80	47	1.21	72
Gross TFP			*0.62*	*37*	*0.65*	*38*	*0.89*	*53*	*0.48*	*28*
Capital composition index (q)	0.26	0.26	0.13	7	0.11	7	0.09	5	0.13	8
Average human capital (h)	0.61	0.61	0.32	19	0.35	20	0.41	24	0.30	18
Net TFP			*0.18*	*10*	*0.19*	*11*	*0.40*	*23*	*0.04*	*2*
Total GDP	3.33	3.27		100	100	100	100	100	100	100
Gross TFP			0.62	19	0.65	20	0.89	27	0.48	15
Net TFP			0.18	5	0.19	6	0.40	12	0.04	1

Note: from $\frac{Y_t}{E_t} = \left(\frac{C_t}{E_t}\right)^{\alpha} q_t^{\alpha} h_t^{1-\alpha} A_t$, $g_{Y/E} = \alpha g_{C/E} + \alpha g_q + (1-\alpha) g_h + g_A$, where g_x is the growth rate of x. A is net TFP and $q_t^{\alpha} h_t^{1-\alpha} A_t$ is gross TFP.

The contribution to growth is the weighted growth rate while the share is the contribution to growth as a percentage of the rate of growth of GDP per employee. For example, the contribution to growth of *C*/*E* is $\alpha g_{C/E}$, and the share is $\frac{\alpha g_{C/E}}{g_{Y/E}} \times 100$.

per employee. This outcome is obtained using both the variable and fixed capital share (α_2 = 0.43). When looking at the role played by human capital, we find that the growth of human capital's contribution reaches 0.32 percent with α_1 and 0.35 percent with the fixed α_2, implying that this element explains around 20 percent of the growth of capital per employee in both cases, giving a net TFP share of 10–11 percent.

The bottom rows of Table 2 show the results obtained when total GDP growth decomposition is calculated (see equation (1)). With α_1, gross and net TFP growth account for 19 percent and 5 per cent of total GDP growth, respectively. Given that the denominator of these shares (g_Y) is different from that used before ($g_{Y/E}$), these results are not surprising.

4. Opening up the long period

Going beyond the long period of the previous section, we now seek to convey an impression of the evolution of growth components over time. Instead of encapsulating the Chilean economy's experience in a unique long-period average, two strategies are used to provide a flavor of the underlying sequence of expansions: the evolution of growth rates over time and, second, average annual growth rates for a priori selected sub-periods, using Maddison's world growth phases (Maddison, 1995, 2007). The main objective of these breakdowns, therefore, is to provide a picture of the type of fluctuations seen in Chile's economic growth.

Finally, in a bid to provide a more integrated description of Chile's economic growth, this section reports briefly on the evolution of per capita income as an outcome of product per employee, that is, average productivity and, on the other side, employees as a percentage of the total population.

4.1. *The overall trend*

Year-to-year contributions to growth from 1833 through to 2010 can be seen in Figure 3 (variable share estimates; equation (3)). The overall trend for the main component, capital deepening, is positive but characterized by two periods with substantially higher rates: from around 1850–1855 through to World War I or somewhat later, and from 1975 or the late 1980s onwards. In the twentieth century, there is, in other words, a long period when capital deepening showed little growth.

Figure 3 also shows that, in the nineteenth century and possibly through to the 1930s, both gross and net TFP expanded at relatively low rates, if at all. Here, however, it is useful to look at Figure 3 in conjunction with Table 3 and, particularly, its last four columns, which show gross and net TFP growth rates, including the corresponding decompositions. The upper two blocks of Table 3 show average annual growth averages by decades and the corresponding Maddison time subdivisions. Leaving aside the initial decades of growth of TFP and particularly net or true TFP, these elements do not play a significant role in Chile's growth. However, the expansion of the human capital index, one of the components of gross TFP, has grown steadily from the very beginning (Table 3, column h).

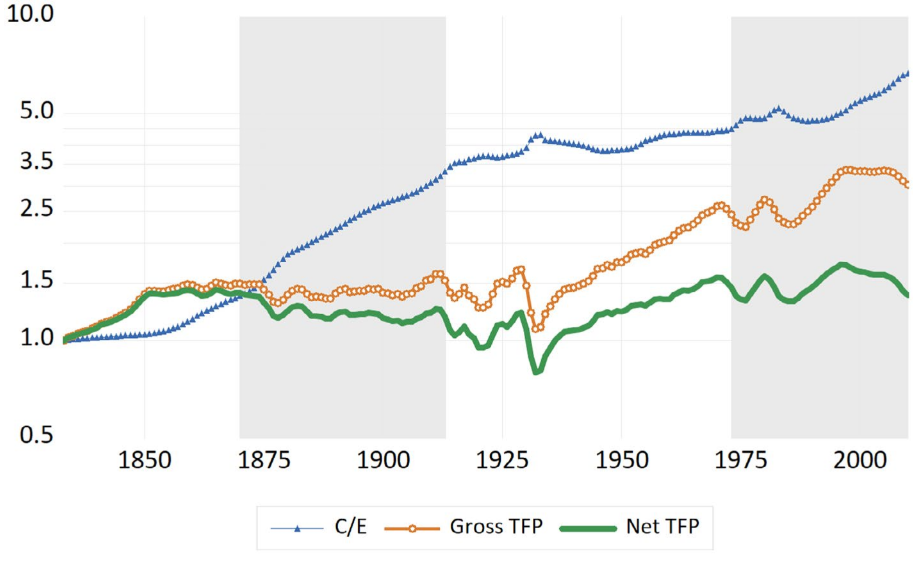

Figure 3. Capital deepening, net TFP, and gross TFP, 1833–2010. (1833 = 1, log, three-year moving averages)
[Colour figure can be viewed at wileyonlinelibrary.com]

4.2. *Growth breakdown: Maddison phases*

The Maddison (1995, 2007) breakdown seeks to describe the evolution of the world economy as seen by this author. Although Chile is part of the world economy, its small relative size makes the Maddison subdivision more or less exogenous to its development and, in this sense, our growth accounting estimates provide a first impression of relative performance. Tables 3 and 4 show estimates obtained using the variable capital share (α_1) and the fixed capital share (α_2 = 0.43), respectively.

Average growth rates for the different components of growth of output per employee (Y/E) during these phases are shown in the upper rows of Table 3.[16] The first, fourth and, possibly, fifth phase show similar growth, with expansion rates in a range of 1.71 percent to 1.96 percent. The second phase, 1871–1913, is above this level, but the really exceptional phase is the third one, 1914–1950, with average productivity growth of only 0.67 percent per year.

As already shown, over 60 percent of the growth of product per employee between 1833 and 2010 was a result of capital deepening, but it can now be seen that this result varies substantially across the different phases. For example, in 1914–1950, 65.2 percent (0.43/0.67) of Y/E growth is a result of capital deepening while, in 1871–1913, the phase with the highest average productivity growth, the figure reaches 94 percent. Tables 3 and 4 both present descriptive devices whose

[16]Table 4 shows the equivalent results obtained using the fixed capital share (α_2 = 0.43).

TABLE 3

Income per Employee Growth Decomposition and Income per Capita Growth, 1833–2010 (α_1, variable)

	Y/*N*	*E*/*N*	*Y*/*E*	*C*/*E*	Gross TFP	q	h	Net TFP
1833–2010	1.74	0.04	1.69	1.07	0.62	0.13	0.32	0.18
1833–1870	1.92	−0.05	1.96	0.84	1.12	0.03	0.15	0.94
1871–1913	2.05	−0.13	2.18	2.05	0.13	0.09	0.36	−0.32
1914–1950	0.56	−0.11	0.67	0.43	0.23	0.01	0.24	−0.02
1951–1973	1.29	−0.65	1.94	0.61	1.33	0.13	0.60	0.60
1974–2010	2.64	0.93	1.71	1.08	0.64	0.37	0.36	−0.09
1833–1840	1.97	0.07	1.90	0.24	1.66	−0.01	0.12	1.55
1841–1850	2.42	0.03	2.38	0.22	2.16	−0.01	0.11	2.05
1851–1860	1.44	−0.32	1.76	1.10	0.65	0.10	0.12	0.43
1861–1870	1.87	0.07	1.80	1.62	0.18	0.02	0.24	−0.08
1871–1880	2.49	0.28	2.21	2.96	−0.75	0.16	0.28	−1.20
1881–1890	1.37	−0.45	1.81	1.78	0.04	0.09	0.30	−0.35
1891–1900	1.25	−0.37	1.62	1.87	−0.25	0.00	0.28	−0.53
1901–1910	3.00	0.07	2.94	1.43	1.51	0.09	0.52	0.91
1911–1920	−0.66	−0.71	0.05	1.79	−1.74	0.00	0.45	−2.19
1921–1930	1.32	−0.36	1.68	0.67	1.01	0.12	0.17	0.73
1931–1940	0.82	0.61	0.21	0.33	−0.12	−0.08	0.03	−0.07
1941–1950	1.29	−0.05	1.33	−0.39	1.72	0.04	0.42	1.27
1951–1960	1.42	−1.26	2.68	1.06	1.62	0.36	0.28	0.98
1961–1970	1.89	−0.54	2.44	0.27	2.16	−0.03	0.90	1.29
1971–1980	0.96	−0.67	1.63	0.90	0.73	0.06	0.31	0.36
1981–1990	1.23	2.17	−0.94	−0.18	−0.76	0.12	0.19	−1.07
1991–2000	4.62	0.50	4.12	1.40	2.71	0.50	0.91	1.30
2001–2010	2.61	1.73	0.88	1.93	−1.05	0.67	0.09	−1.80
1833–2010			100.0	63.2	36.8	7.4	18.9	10.4
1833–1870			100.0	42.8	57.2	1.5	7.6	48.0
1871–1913			100.0	94.0	6.0	4.2	16.3	−14.5
1914–1950			100.0	65.2	34.8	1.2	36.6	−3.0
1951–1973			100.0	31.3	68.7	6.9	30.7	31.1
1974–2010			100.0	62.8	37.2	21.7	20.7	−5.2
1833–1840			100.0	12.8	87.2	−0.6	6.2	81.6
1841–1850			100.0	9.4	90.6	−0.2	4.7	86.2
1851–1860			100.0	62.8	37.2	5.8	6.7	24.7
1861–1870			100.0	90.1	9.9	1.3	13.3	−4.7

TABLE 3 (CONTINUED)

	Y/N	*E/N*	*Y/E*	*C/E*	Gross TFP	q	h	Net TFP
1871–1880			100.0	134.1	−34.1	7.5	12.7	−54.3
1881–1890			100.0	98.0	2.0	5.1	16.3	−19.5
1891–1900			100.0	115.3	−15.3	−0.2	17.3	−32.4
1901–1910			100.0	48.6	51.4	2.9	17.6	30.8
1911–1920			100.0	3,547.1	−3,447.1	3.9	886.7	−4,337.6
1921–1930			100.0	39.6	60.4	7.3	9.8	43.3
1931–1940			100.0	159.1	−59.1	−38.3	12.6	−33.4
1941–1950			100.0	−29.2	129.2	2.7	31.5	95.0
1951–1960			100.0	39.4	60.6	13.4	10.6	36.6
1961–1970			100.0	11.2	88.8	−1.2	37.0	53.0
1971–1980			100.0	55.2	44.8	3.4	19.3	22.1
1981–1990			100.0	19.5	80.5	−13.2	−19.8	113.4
1991–2000			100.0	34.1	65.9	12.2	22.1	31.5
2001–2010			100.0	219.8	−119.8	76.0	9.9	−205.7

TABLE 4
INCOME PER EMPLOYEE GROWTH DECOMPOSITION AND INCOME PER CAPITA GROWTH, 1833–2010 (α_2, CONSTANT)

	Y/N	E/N	Y/E	C/E	Gross TFP	q	H	Net TFP
1833–2010	1.74	0.04	1.69	1.04	0.65	0.11	0.35	0.19
1833–1870	1.92	−0.05	1.96	0.88	1.09	0.03	0.14	0.91
1871–1913	2.05	−0.13	2.18	2.18	0.01	0.10	0.35	−0.43
1914–1950	0.56	−0.11	0.67	0.39	0.28	0.01	0.26	0.01
1951–1973	1.29	−0.65	1.94	0.69	1.25	0.14	0.57	0.55
1974–2010	2.64	0.93	1.71	0.77	0.94	0.31	0.49	0.14
1833–1840	1.97	0.07	1.90	0.44	1.47	−0.01	0.10	1.37
1841–1850	2.42	0.03	2.38	0.43	1.95	0.00	0.09	1.86
1851–1860	1.44	−0.32	1.76	1.05	0.70	0.10	0.12	0.48
1861–1870	1.87	0.07	1.80	1.45	0.34	0.02	0.25	0.08
1871–1880	2.49	0.28	2.21	2.55	−0.34	0.16	0.31	−0.82
1881–1890	1.37	−0.45	1.81	2.34	−0.52	0.12	0.25	−0.89
1891–1900	1.25	−0.37	1.62	2.33	−0.70	0.00	0.25	−0.94
1901–1910	3.00	0.07	2.94	1.48	1.46	0.09	0.50	0.87
1911–1920	−0.66	−0.71	0.05	1.39	−1.34	−0.01	0.55	−1.88
1921–1930	1.32	−0.36	1.68	0.53	1.15	0.11	0.20	0.84
1931–1940	0.82	0.61	0.21	0.00	0.21	−0.08	0.14	0.14
1941–1950	1.29	−0.05	1.33	0.19	1.15	0.05	0.25	0.84
1951–1960	1.42	−1.26	2.68	0.83	1.85	0.32	0.36	1.17
1961–1970	1.89	−0.54	2.44	0.74	1.70	0.02	0.74	0.93
1971–1980	0.96	−0.67	1.63	0.40	1.23	0.01	0.54	0.69
1981–1990	1.23	2.17	−0.94	−0.58	−0.36	0.07	0.48	−0.90
1991–2000	4.62	0.50	4.12	1.88	2.24	0.54	0.60	1.10
2001–2010	2.61	1.73	0.88	1.18	−0.30	0.50	0.41	−1.21
1833–2010			100.0	61.7	38.3	6.7	20.5	11.1
1833–1870			100.0	44.6	55.4	1.6	7.3	46.5
1871–1913			100.0	99.6	0.4	4.4	16.0	−19.9
1914–1950			100.0	58.7	41.3	1.0	39.2	1.2
1951–1973			100.0	35.5	64.5	7.0	29.4	28.2
1974–2010			100.0	45.1	54.9	18.0	28.7	8.2
1833–1840			100.0	23.0	77.0	−0.3	5.1	72.1
1841–1850			100.0	18.0	82.0	0.1	3.8	78.1
1851–1860			100.0	60.1	39.9	5.8	7.0	27.1
1861–1870			100.0	80.8	19.2	0.9	13.9	4.4

TABLE 4 (CONTINUED)

	Y/N	*E/N*	*Y/E*	*C/E*	Gross TFP	q	H	Net TFP
1871–1880			100.0	115.6	−15.6	7.3	14.2	−37.1
1881–1890			100.0	128.8	−28.8	6.5	13.8	−49.2
1891–1900			100.0	143.3	−43.3	−0.3	15.1	−58.2
1901–1910			100.0	50.3	49.7	3.1	17.1	29.6
1911–1920			100.0	2,750.3	−2,650.3	−20.3	1,100.5	−3,730.6
1921–1930			100.0	31.7	68.3	6.3	12.0	49.9
1931–1940			100.0	0.6	99.4	−37.8	68.3	68.9
1941–1950			100.0	14.0	86.0	3.8	18.9	63.3
1951–1960			100.0	30.8	69.2	11.9	13.5	43.7
1961–1970			100.0	30.4	69.6	0.8	30.5	38.3
1971–1980			100.0	24.4	75.6	0.6	32.9	42.0
1981–1990			100.0	62.2	37.8	−7.0	−50.6	95.5
1991–2000			100.0	45.7	54.3	13.1	14.6	26.6
2001–2010			100.0	134.2	−34.2	57.0	46.6	−137.8

meaning differs. While their upper blocks refer to average growth rates per period, the lower block reports the above rates as shares of per employee GDP growth.[17]

The evolution of the service-stock transformer of capital (q) warrants additional examination. In the first phase, its growth is almost negligible but it rises in all others, except for the third one. This growth component is related to the cost of capital where the length of the asset's productive life or, in other words, its depreciation rate plays a significant role, increasing with the relative importance of machinery and equipment in total capital.[18]

By construction, the phases reflect world growth conditions. However, these conditions do not necessarily translate into similar growth periods for Chile and many differences can arise within the same phase. To illustrate this, Table 3 also shows the growth rates of the different variables by decades, providing a rough impression of what is going on inside the phases. Take, for example, the first two decades of the nineteenth century when capital deepening growth rates were quite similar but the behavior of gross TFP is rather different. Similarly, in the 1974–2010 phase, the significant differences in q growth between decades are evident.

Table 3 shows that average productivity alternates between decades of high and low growth. For example, in 1911–1920, productivity shows almost no growth (0.05 percent) while, in 1921–1930, product per employee grew by 1.68 percent, a rate almost identical to the long-period average, and, in the 1930s, again showed little growth (0.21 percent).

In a quest for additional insight, we now use the data to determine the stability of our estimates, taking the standard deviation of the corresponding annual growth rate per decade as a measure of volatility. Figure 4 shows the standard deviation of the rates of growth of capital per employee and gross and net TFP. In the subdivision by decade, it is seen that the observations located at the extremes of the 1833–2010 period exhibit the lowest variability of TFP growth and that the per-decade standard deviation for growth by capital deepening is significantly below the corresponding level for TFP, gross and net.

4.3. *Productivity expansion and per capita income growth: a changing employment bonus*

Annual growth of per capita product in 1833–2010 reached 1.74 percent while income per employee grew at an annual rate of 1.69 percent, with the difference

[17]As an illustration of this distinction, consider the 1951–73 phase when annual growth of capital deepening reached 0.61 percent, a rate that corresponds to a share of 31.3 percent of total Y/E growth. This phase is exceptional since almost 69 percent of average productivity growth is due to growth of gross TFP and only 31 percent to growth of capital deepening. When decomposing the former, it can be seen that its increase reflects unprecedented growth of human capital as well as the also exceptional expansion of net TFP.

[18]The composition of investment or, in other words, the relative importance of machinery and infrastructure, is influenced by projects, with the proportions of these two goods depending on the corresponding production functions. The point here is that, in the Chilean case at least, infrastructure tends to be more non-tradable than machinery, which has a high import content. Our conjecture, therefore, is that the evolution of the q index is also conditioned by import restrictions and the exchange rate. This makes q's near-zero growth in 1914–50 plausible because this period was characterized by trade difficulties in Chile and the rest of the world.

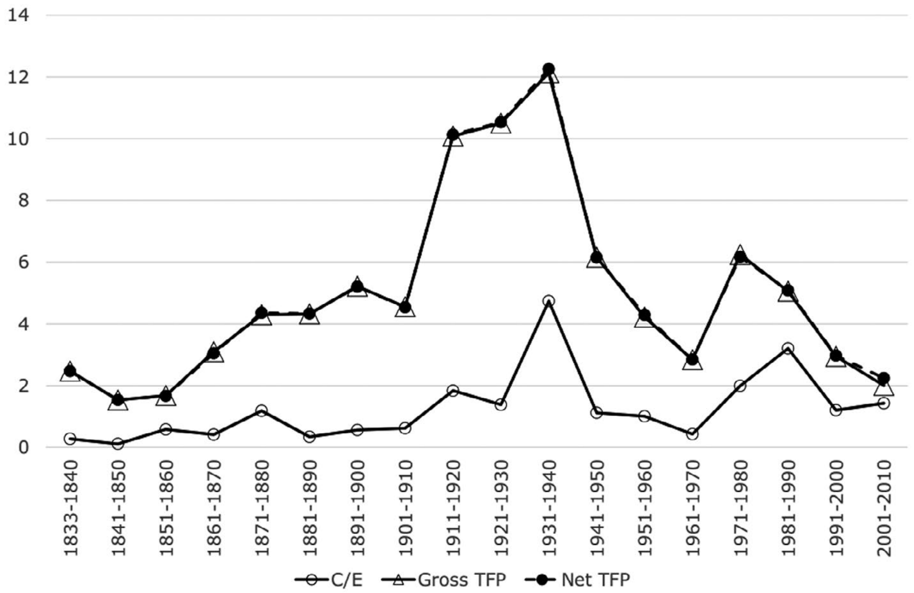

Figure 4. Capital deepening, net TFP, and gross TFP, 1833–2010. Volatility per Decade. (Std. Dev.) Net and gross TFP volatility are almost identical due to the stable growth of *h* and *q* [Colour figure can be viewed at wileyonlinelibrary.com]

explained by the expansion of the employment-population ratio (*E*/*N*). As seen in Tables 3 and 4, the overall 1833–2010 *E*/*N* growth rate is low, but variable through phases. *E*/*N* changes are negative in all except the last phase when the positive *E*/*N* bonus is concentrated.

At least in the Chilean case, we understand that the role played by the *E*/*N* coefficient has not received much attention. However, it emerges as an important determinant of growth in the most recent phase. Exploring its evolution would take us into the field of demographics and, in general, into issues about the allocation of time and the eventual impact of human capital accumulation.[19] However, this discussion seems crucial if we are to achieve a better understanding of per capita income growth, not only in the most recent phase but also in previous ones.[20]

[19]The available long-period data suggests that *E*/*N*'s evolution over these 177 years is compatible with the broad trends of Chile's demographic process, the spatial reallocation of population from rural to urban settings and rising educational levels (Díaz *et al.* 2016). In around 1970, the age structure of the population began to change, with the over-15 to 64 age group growing rapidly, accompanied by a corresponding decrease in the 0 to 14 age group. In addition, women's workforce participation declined from 1850 onwards until 1930–1940 and only began to increase as from 1980; the initial decline is associated with the increase in urbanization rates and loss of relative importance of agriculture. The total labor force, male and female, declined in practice until the 1970s but, since then, has tended to increase, due mainly to the increase in women's participation. See Cox (2009) for additional information.

[20]Expansions of the *E*/*N* coefficient are different from the "industrious revolution" of Allen and Weisdorf (2011). It points to an increase in hours worked per year per worker while the evolution of the *E*/*N* coefficient points to a change in the participation ratio, making it compatible with any change or no change at all in hours.

5. Productivity and growth: Chile in the world, 1850–2010

In the final stage of this long-period description, this section offers an overview of Chile's growth decomposition as compared to a small sample of other economies, selected mainly on the basis of the availability of yearly data. The main purpose of this exercise is to obtain additional reference points as a means of achieving a better understanding of Chile's growth process.

The sample includes countries for which long-period growth decompositions with yearly estimates are available: Great Britain (GBR), the United States (USA), Sweden (SWE), Spain (ESP), Italy (ITA), and Turkey (TUR) (for data sources, see Table 5). The sample includes countries that were front-runners by 1850 as well as latecomers whose per capita income at that time was not so different from that of Chile. Their growth performance over the next 160 years was, in some cases, similar to that of Chile but, in others, was quite different (for levels in selected years, see Table 6).

For all these economies, growth decomposition follows the productivity per employee approach of previous sections. Before presenting the results, it is worth mentioning three characteristics of the sample. First, the information used in previous sections could not be assembled for all of these countries and the human capital index (h) and the flow-stock conversion element (q) are not incorporated. These two elements, therefore, play no explicit role in estimations and their incidence in determining production is captured directly by the corresponding residual of the estimation, that is, they are incorporated into gross TFP. Second, estimations are calculated using fixed and country-specific capital shares, with coefficients ranging from 0.31 to 0.5 (Table 5, last column). At last, the data and, therefore, the estimations begin with the year 1850. Table 6 shows stylized information on GDP, population, and employment for each economy and specific years. Chile (CHL) and TUR are the countries with the lowest per capita GDP in 1850 and 2010.

The results obtained in this comparative exercise are presented below: (i) for the complete long period of 1850–2010, and (ii) subdivided according to Maddison's world growth phases.

5.1. *Chile and the sample in long-period growth*

Over the long period, the average annual growth of product per worker reached 1.69 percent (excluding CHL). SWE has the highest Y/E growth rate and the lowest ones are found in TUR and GBR (Table 7).

The economies in the sample differ markedly as regards the composition of their growth. At least three types of long-period growth structures can be distinguished, that is, economies with high, medium, and low contributions of gross TFP (Table 7, bottom block). At one extreme, in USA and GBR, it explains almost two-thirds of the growth of product per worker while, at the other, in CHL and TUR, growth depends heavily on the expansion of capital deepening. In between, in ITA and ESP, capital deepening and gross TFP growth make similar contributions. In this context, SWE appears as an exception, with the contribution of the gross residual below the level seen in ITA and ESP, but somewhat higher than in TUR and CHL.[21]

[21]Fuentes (2010) and Corbo and González (2015) suggest that, in the second half of the twentieth century, the composition of Chile's growth differs from that of higher-income counterparts, something we may synthesize in the clearly lesser importance of the residual, that is, TFP growth.

TABLE 5
Comparative View: Data Sources

	Time span	GDP and Population	Capital	Employment	α
United Kingdom	1850–2010	Hills and Thomas (2010)			0.32
United States	1850–2010	Johnston and Williamson (2010)	1925–2010, data from U.S. Bureau of Economic Analysis; 1850–1925, Gallman (1992) Table 2.4, Indexes of U.S. Capital Stock, 1860 Prices (interpolated)	Data from U.S. Bureau of Labor Statistics and Kurian and Chernow (2007)	0.35
Sweden	1850–2010	Data generously provided by Professor L. Schön, based on Krantz and Schön (2007)			0.40
Spain	1850–2010	Data generously provided by Professor L. Prados, based on Prados de la Escosura and Rosés (2009 and 2010)			0.31
Italy	1861–2010	Baffigi (2011)	Broadberry, Giordano, and Zollino (2011)		0.35
Turkey	1880–2010	Data generously provided by Professor S. Pamuk, based on Altug, Filiztekin, and Pamuk (2008)			0.50

The aggregate production functions are country-specific, and the corresponding distributive shares are those employed by the respective authors (capital share in a range from 0.31 to 0.5).

TABLE 6
GDP, Population and Employment: 1850–2010

Year	Chile	Great Britain	United States	Sweden	Spain	Italy	Turkey
Per Capita GDP (1990 Int GK$)							
1850	910	2,330	1,849	1,076	1,079	1,481	790
1913	2,988	4,921	5,301	2,874	2,056	2,305	1,213
1950	3,670	6,939	9,561	6,739	2,189	3,172	1,623
1973	5,034	12,025	16,689	13,494	7,661	10,414	3,477
2010	13,883	23,777	30,491	25,306	16,797	18,520	8,225
Per Employee GDP (1990 Int GK$)							
1850	2,334	5,939	5,469	2,824	3,123		
1913	8,358	12,046	13,925	7,240	5,627	4,696	3,236
1950	10,733	15,020	24,630	15,155	5,854	7,200	4,049
1973	17,043	27,082	41,582	32,500	19,807	28,169	10,057
2010	34,330	49,733	65,913	64,262	38,368	43,971	27,824
Employment/Population (%)							
1850	39.0	39.2	33.8	38.1	34.5		
1913	35.8	40.8	38.1	39.7	36.5	49.1	37.5
1950	34.2	46.2	38.8	44.5	37.4	44.1	40.1
1973	29.5	44.4	40.1	41.5	38.7	37.0	34.6
2010	40.4	47.8	46.3	39.4	43.8	42.1	29.6
Employment (1913 = 100)							
1850	45	58	21	60	69		
1913	100	100	100	100	100	100	100
1950	168	122	159	139	133	111	148
1973	240	134	230	151	182	110	237
2010	574	157	376	164	250	135	426
Population (1913 = 100)							
1850	41	60	24	62	74		
1913	100	100	100	100	100	100	100
1950	176	110	156	125	138	126	141
1973	291	123	218	145	172	147	257
2010	493	136	319	167	225	162	520
Population in 2010 (thousands)	17,094	62,262	309,808	9,396	45,639	60,340	77,982

Sources: Per capita GDP from The Maddison-Project (2013). Employment and population figures, Table 5.

TABLE 7
Annual Growth Rates and Contributions to Growth: 1850–2010 (%)

Period	Chile	Great Britain	United States	Sweden	Spain	Italy	Turkey	Average	Chile/Average
Per Capita GDP (*Y*/*N*)									
1850–2010	1.68	1.52	1.89	1.91	1.73	1.71	1.38	1.69	1.00
1850–1913	1.92	1.18	1.69	1.56	1.02	0.89	0.94	1.21	1.59
1914–1950	0.56	1.08	2.08	2.30	0.19	0.86	0.34	1.14	0.49
1951–1973	1.29	2.82	2.50	2.80	5.41	5.17	2.70	3.57	0.36
1974–2010	2.64	1.74	1.68	1.57	2.19	1.54	1.98	1.78	1.48
Employment-Population Ratio (*E*/*N*)									
1850–2010	0.04	0.11	0.17	0.01	0.10	−0.12	−0.07	0.03	1.29
1850–1913	−0.13	0.06	0.18	0.05	0.10	0.00	0.34	0.12	−1.08
1914–1950	−0.11	0.27	0.05	0.29	−0.08	−0.34	0.14	0.06	−2.02
1951–1973	−0.65	−0.07	0.14	−0.27	0.38	−0.68	−0.58	−0.18	3.62
1974–2010	0.93	0.15	0.30	−0.18	0.12	0.27	−0.32	0.06	15.75
Per Employee GDP (*Y*/*E*)									
1850–2010	1.64	1.41	1.72	1.90	1.63	1.83	1.44	1.66	0.99
1850–1913	2.05	1.12	1.51	1.51	0.92	0.90	0.60	1.09	1.88
1914–1950	0.67	0.81	2.03	2.01	0.27	1.20	0.20	1.09	0.61
1951–1973	1.94	2.89	2.36	3.07	5.02	5.85	3.29	3.75	0.52
1974–2010	1.71	1.59	1.38	1.75	2.07	1.27	2.29	1.72	0.99
Capital Deepening $(C/E)^{\alpha}$									
1850–2010	1.11	0.54	0.59	1.17	0.86	0.86	0.93	0.83	1.34
1850–1913	1.88	0.39	0.74	1.18	0.9	0.61	0.44	0.71	2.66
1914–1950	0.39	0.05	0.48	0.98	0.29	0.42	−0.02	0.37	1.07
1951–1973	0.69	1.22	0.72	2.01	1.21	2.22	1.87	1.54	0.45
1974–2010	0.77	0.87	0.38	0.82	1.15	0.82	1.74	0.96	0.8
Gross TFP ($\tilde{A}$)									
1850–2010	0.53	0.87	1.13	0.74	0.77	0.97	0.51	0.83	0.64
1850–1913	0.17	0.74	0.77	0.33	0.03	0.29	0.16	0.39	0.45
1914–1950	0.28	0.76	1.55	1.03	−0.02	0.79	0.22	0.72	0.38
1951–1973	1.25	1.68	1.64	1.06	3.82	3.63	1.42	2.21	0.57
1974–2010	0.94	0.72	1.00	0.93	0.91	0.45	0.55	0.76	1.24

TABLE 7 (CONTINUED)

Period	Chile	Great Britain	United States	Sweden	Spain	Italy	Turkey	Average	Chile/Average
Gross TFP/Per Employee GDP (%)									
1850–2010	32.31	61.62	65.68	38.6	47.13	52.87	35.39	50.22	0.64
1850–1913	8.38	65.98	51.21	21.99	3.12	32.01	26.18	33.42	0.25
1914–1950	41.32	94.17	76.57	51.17	−6.85	65.33	111.45	65.31	0.63
1951–1973	64.53	58.06	69.39	34.48	75.98	62.02	43.15	57.18	1.13
1974–2010	54.95	45.29	72.68	53.04	44.17	35.53	24.09	45.80	1.20
Capital share (α)	0.43	0.32	0.35	0.40	0.31	0.35	0.50		

Average: simple average excluding Chile.

This range of one-third to two-thirds for the contribution of the gross TFP residual is a practical way of characterizing the sample. However, in searching for a gross pattern, it is necessary to answer another question: why use shares, rather than the corresponding growth rates of these contributions? The latter is, after all, a more straightforward indicator.

Shares are growth rates weighted by the growth of product per worker and the contribution to growth is merely the numerator of this share. As mentioned, both concepts are closely related, but they highlight different aspects and, although both are informative, they answer different questions.

If growth rates are used directly rather than shares, Swedish growth appears in a new light, revealing its similarity with the middle group. However, given the Italian economy's high gross TFP growth, this middle group also emerges as less uniform than it previously appeared (Table 7, fifth block).

In the case of Chile, we find that, considering the whole 1850–2010 period, it had the sample's second-highest capital deepening growth rate while the growth of gross TFP was the lowest in the sample. In other words, gross TFP expansion played very different roles in the long-period growth of this sample of economies and, in Chile's case, was particularly weak. Finally, although relative positions within the sample change over time, TUR and CHL are the less affluent economies, both in 1850 and at the end of the sample period.

5.2. *Chile and the sample: growth decomposition according to Maddison's phases*

Dividing the long period into Maddison's phases, we find that CHL's high average capital deepening growth is heavily influenced by its expansion rate in the first phase (1850–1913) and, as a consequence, it is also the economy whose capital deepening growth does not accelerate in the twentieth century. The following phase, 1914–1950, shows a general, albeit highly differentiated, decline in the contribution of capital deepening to growth. In USA, SWE, and ITA, there are reductions of up to 40 percent in its contribution while, in GBR, CHL, ESP, and TUR, the decline reached 70 percent or more (TUR's rate is slightly negative). In the next phase, 1951–1973, this growth element shows a vigorous recovery in all countries and, in the last phase, continues, although at a clearly lower rate in all economies, except CHL, the only country where it accelerates on the previous phase.

In the context of this sample, CHL's economic growth shows two overall exceptionalities concerning capital deepening: first, its high expansion rate in 1850–1913 and, second, the behavior by this variable in the last phase when it shows an increase in relation to 1951–1973. As already mentioned, the sharp decline in the rate of growth of capital deepening in the second phase is not exclusive to Chile.

In general, and Chile is no exception, gross TFP growth increases throughout these phases until 1973 when a general reduction sets in. Compared with the 1951–1973 phase, the following one shows a drop of gross TFP growth to a lower level, 88 percent in the case of SWE and 75 percent in Chile as well as 24 percent in ESP and 12 percent in ITA (Table 7). However, when examining changes in gross TFP growth shares, instead of growth rates, a different picture emerges (Table 7, last block). CHL's share falls only 9.6 percentage points while, in the cases of USA and SWE, it actually increases in this last phase, 1974–2010. As already discussed, using either shares or contributions may make a difference in comparisons over time or between economies and it is, therefore, important to be clear about the phenomena to be measured.

5.3. *Volatility of growth contributions*

Because of the importance they attach to stability, financial analysts and the literature tend to pay great attention to variations in asset prices and returns, price inflation, exchange rates, and so on and tend to group economies according to their behavior in these fields. Financial variability and fluctuations of the real economy—GDP, labor, capital stock, and so on—are not necessarily independent phenomena. The sample used here, comprising different economies, provides an opportunity to explore an additional dimension of growth: volatility (Table 8).

Considering *Y*/*E* growth standard deviations for the 1850–2010 period, we find that CHL, ITA, and TUR are at one extreme of the sample, with values reaching 5 or more, while values for the other countries are significantly lower, ranging from 2.25 to 3.55. Leaving aside ITA as a special case because its high variability coefficient seems to be influenced by its 1914–1950 phase, it is in the low-income economies, CHL and TUR, where variability is most marked. In both these economies, capital deepening and gross TFP variability are well above average.

Y/*E* growth volatility is, in general, highest in the 1914–1950 phase (the sample average more than doubles). When examining the components of this volatility, we see that gross TFP growth accounts for a significant fraction of the instability.[22]

The variability of Chilean capital deepening tends to be relatively high, reaching close to 60 percent above the sample average. At first sight, this is a surprising outcome since capital is a long-lived asset influenced by an underlying trend. However, capital deepening is also influenced by its denominator and part of the variability may be the result of variations in employment. To sum up, the incorporation of this variability measure provides more information about the characteristics of economic performance over the long run.

5.4. *From product per employee to per capita GDP*

The growth of *Y*/*E*, together with eventual variations in the employment/population ratio, accounts for changes in per capita income, the most popular indicator of overall development. Our goal here is to show that these changes are empirically relevant for our long-period analysis and the economy's behavior across phases.

Table 4 shows employment participation rates, *E*/*N*, for 1850, 1913, 1950, 1973, and 2010, the limits of the Maddison phases. These coefficients vary between 29.6 percent and 47.8 percent for the different years and countries while the average for the sample increases from 36.9 percent in 1850 to 41.3 percent in 2010. A steady upward trend is observed only in USA and ESP while all the other countries have at least one phase characterized by a decrease. In CHL's case, the coefficient

[22]Net TFP growth is the natural recipient of volatility. The human capital index (h) is a construction with an important trend element while the growth of the stock-service transformer (q) seems to be stable.

TABLE 8
Volatility of Annual Growth Rates: 1850–2010, standard deviation (%)

Period	Chile	Great Britain	United States	Sweden	Spain	Italy	Turkey	Average	Chile/Average
(1) Per Employee GDP									
1850–2010	4.99	2.44	3.57	2.84	2.25	5.07	7.27	3.91	1.28
1850–1913	3.66	1.62	3.55	2.89	0.62	2.42	1.81	2.15	1.70
1914–1950	7.97	3.88	5.57	3.55	1.61	8.90	12.33	5.97	1.33
1951–1973	3.87	1.54	1.66	1.74	1.72	1.86	3.96	2.08	1.86
1974–2010	3.57	1.81	1.21	2.38	2.64	1.98	4.44	2.41	1.48
(2) Capital Deepening									
1850–2010	1.71	0.83	0.92	0.87	1.48	1.05	1.25	1.07	1.60
1850–1913	0.89	0.74	0.9	0.88	1.36	0.64	0.39	0.82	1.08
1914–1950	2.23	1.06	1.38	1.00	1.84	1.46	0.92	1.28	1.74
1951–1973	0.63	0.40	0.45	0.18	1.39	0.45	0.81	0.61	1.03
1974–2010	2.14	0.38	0.41	0.62	1.19	0.50	1.35	0.74	2.89
(3) TFP									
1850–2010	5.75	2.41	3.73	3.01	2.15	4.74	6.95	3.83	1.50
1850–1913	3.95	1.51	3.70	3.18	1.57	2.27	1.49	2.29	1.73
1914–1950	9.61	4.04	5.80	3.73	2.30	8.64	12.03	6.09	1.58
1951–1973	4.02	1.53	1.76	1.77	1.29	1.71	3.96	2.00	2.01
1974–2010	4.02	1.84	1.35	2.48	1.54	1.79	3.98	2.16	1.86
(4) (3)/(1): Vol. TFP / Vol. Per Employee GDP (%)									
1850–2010	1.15	0.99	1.04	1.06	0.96	0.93	0.96	0.99	1.17
1850–1913	1.08	0.94	1.04	1.1	2.53	0.94	0.83	1.23	0.88
1914–1950	1.21	1.04	1.04	1.05	1.43	0.97	0.98	1.08	1.11
1951–1973	1.04	0.99	1.06	1.02	0.75	0.92	1.00	0.96	1.09
1974–2010	1.13	1.02	1.12	1.04	0.58	0.90	0.90	0.93	1.21

Average: simple average excluding Chile.

drops in three of the four phases and it is only in the last one that it recovers to its 1850 level. In TUR, it drops sharply in the last two phases. These results suggest that the behavior of this labor participation rate is far from constant and this is the empirically relevant issue (for implicit average annual rates of change, see the second block of Table 7).

The example of GBR in the 1914–1950 phase serves to illustrate the main issue. In this phase, its capital deepening growth rate is slightly above zero (0.05 percent) while the growth of per capita income (*Y/N*) reaches 1.08%. How was this possible? First, thanks to gross TFP growth, GBR's *Y/E* increases at an annual rate of 0.81 percent, significantly above CHL, ESP, and TUR. Additionally, due to the extraordinary rise in the employment-population ratio, which increased by 0.27 percent per year, the growth of per capita income reached 1.08 percent. (0.81 + 0.27). In other words, around a quarter of per capita income growth is explained by this relative expansion of employment. Although far from being representative, this case underlines the importance of the timing of changes in this participation rate.

Chile serves as a second example. In the 1951–1973 phase, its employment coefficient dropped from 34.2 percent to 29.5 percent and capital deepening growth, albeit higher than in the previous phase, was low compared to the rest of the sample. In this period, CHL's *Y/E* was growing at 1.94 percent, possibly higher than one would expect when considering only the corresponding capital deepening expansion rate of 0.69 percent. The explanation lies in the high gross TFP growth rate of 1.25 percent, which was exceptional by Chilean standards. However, the growth of per capita GDP in this phase reached only 1.29 percent or, in other words, only 86 percent of the *Y/E* expansion. The drop in the employment-population ratio explains the difference (0.69 + 1.25 – 0.65 = 1.29). In the last phase, Chile experiences the reverse phenomenon and around one-third of its per capita income growth is explained by an increase in the employment-population coefficient.

These examples illustrate features of the long-period approach under which product growth decomposition is accompanied by demographic evolution. They suggest that the role of the employment-population ratio should not be underestimated.

6. Final reflections: impressions and conjectures

This paper views economic growth as a process that dates far back into the past and our growth breakdown focuses on that part of the period for which systematic evidence is presently available. We believe that the paper's main contribution is its estimates of Chile's long- period growth, which provide abundant material for a fresh reading of this country's growth experience, one in which both old and eventually new interpretations can be viewed from a different perspective. In this context, the aim of this section is to suggest examples whose identification and subsequent analysis will, we think, be facilitated by our estimates, opening up new avenues of research.

Comparisons across time and countries are fundamental for an appreciation of growth accounting outcomes and, combined with the estimates presented in previous sections, raise some questions and, even, puzzles. We start with estimates of "world" growth or, to be more precise, sample averages.

In this general context, Chile's average productivity growth (Table 7, first line, last column) is, at 1.64 percent, almost exactly the same as the sample's average annual expansion rate in the long 1850–2010 period (1.66 percent). The underlying growth structures, however, differ and, while the expansion of capital deepening in Chile is 34 percent above the sample's average growth rate, this is offset by the country's gross residual growth, which reaches only two-thirds of the corresponding sample-"world"- average (0.64 = 0.53/0.83, Table 7).

When using the Maddison phases, it can be seen that this exceptional contribution of the growth of capital deepening occurred mainly in the nineteenth century and through to 1913 (Table 7). In the following phase, the growth contributed by capital deepening showed a considerable decline but, since this was also the case in other countries, capital deepening in Chile remains still slightly above the corresponding sample average. Viewed in this comparative fashion, the low expansion of capital deepening in the twentieth century is a more recent phenomenon, occurring in the third and, to a lesser extent, fourth phases. In this last phase, there is an important revival of capital deepening, albeit only to 80 percent of the sample average (=0.77/0.96, Table 7). The exceptional feature of this last phase in Chile's case is the expansion of gross TFP, which is 24 percent above the sample average; in absolute terms, the gross TFP growth rate is 0.94 percent or, in other words, clearly below the corresponding level in the previous phase (1.25 percent). This example, thus, illustrates the importance of the corresponding reference, either to the same economy's growth in another period or to another economy.

In this general context, we have selected some examples where growth accounting outcomes provide evidence that may be useful, not only in the detection of these somewhat surprising episodes, but eventually also as a general guide for their future exploration. The exceptional expansion of capital deepening in Chile in the nineteenth century and through to 1913 serves as a first example and is a topic whose dimension in itself requires further investigation. A second example is the substantial decrease in Chile's average productivity growth in the second phase when the sample average remains constant, although Chile is not the only economy experiencing this decrease. Why, then, was there such a sharp decline in the Chilean case and a few other cases, when other economies were affected positively? Do these differences help to understand growth in later phases?

Third, capital deepening growth in Chile was slightly above the sample average for the same period. However, when compared with its previous nineteenth century–1913 expansion rate, Chile is seen to have lost 80 percent of its previous capital deepening growth rate and, viewed from this perspective, is one of the most affected economies, along with GBR and TUR. Why this extreme impact? The relation between capital deepening, trade and finance may eventually help to clarify these impacts. GBR lost more than 80 percent of its capital deepening expansion rate in the same period, raising the question of whether the factors behind this sharp decline also affected other economies where GBR's presence in these areas was important.

A fourth example is the drop in Chile's relative average productivity growth in the 1951–1973 phase and the sharp decline in relative capital deepening which, after growing in line with the sample average in the second phase, dropped to only 45 percent of it. Is this just a casual correlation or is there something specific behind it? A possible explanation that could be explored is, for example, trade policy.

Fifthly, in the last phase, Chile's Y/E growth is almost equal to that of the world, a recovery obviously helped by the behavior of capital deepening. However, viewed in this relative way, Chile's capital deepening, although nearly doubling its relative position, was still 20 percent below the "world" average. How can this be understood? As an expression of the role of frictions and "time to build" restrictions?

Sixthly, what is behind the relative contribution of gross TFP growth in Chile in the last phase, which is 24 percent above the "world" average? Table 3 suggests that the corresponding net TFP growth is not the answer. We know that the composition of gross TFP in the Chilean case and in several of these phases is not determined by net TFP growth, but by the incidence of human capital accumulation and the capital service transformer. The exceptional phase, on the other hand, is the third one where positive net TFP growth is found. This seems to be another puzzle.

Finally, returning to the third phase, this was a period of recovery across all the sample and was, moreover, the phase with the highest average growth of world capital deepening. In this period, however, Chile's relative capital deepening growth declines from 61 percent to 52 percent; in other words, the extraordinary world expansion had only a partial impact on Chile, if it affected it at all. However, and this may be another puzzle, this all seems to change as from 1974 onwards. Average sample capital deepening declines in all economies, except for Chile. Did potential investment opportunities, already implicit in the previous phase but not taken advantage of, survive and become profitable once policy changes were implemented? And, if this were the case, should economic growth in this period be seen as exceptional and enhanced by opportunities that were postponed in the past?

These examples merely seek to illustrate one attribute of growth accounting measurements: as a light to illuminate new insights into the complexities of the growth process.

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