

Growth Accounting and Determinants of Total Factor Productivity in Chile: The End of the Golden Period?*

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Abstract This study uses three methodologies to analyze why, from a production factor perspective, Chile's economic Golden Period did not last into the 2000s. First, by using growth accounting, it identifies total factor productivity as the most influential among production factors in terms of the end of the Golden Period. Second, it theoretically enhances the former findings by implementing the convergence test. Third, the decreased total factor productivity was mainly due to industrial structure that was biased toward primary industry, which caused R&D expenditure to be lowered, a high dependence on foreign direct investment inflows in the mining sector, and the unproductive use of open door policies. Last, it concludes that Chile still can boost its economic growth.

Key words Chile, Economic Growth, Golden Period, Total Factor Productivity

* This study is excerpted from the master's thesis of the author.

I. Introduction

From the 1970s to the 1990s, as some East Asian countries succeeded in boosting their economies, most Latin American countries lost their competitiveness and suffered from severe debt crises mainly because of the failure of import substitution industrialization policies. Consequently, some countries such as Mexico had to declare a moratorium or to default at that moment. However, there was a case in Latin America that achieved high economic growth. According to Gallego and Loayza (2002), between 1986 and 1998, Chile's GDP growth rate ranked fourth among those of the countries worldwide. Furthermore, the change in Chile's average GDP per capita growth rate between 1974-1986 and 1986-1998 was substantially large. Hence, this period has been defined as "the Golden Period" for Chile.¹⁾

However, this Golden Period did not last into the 2000s. The average Chilean GDP growth rate from 1999 to 2014 decreased by 46% compared with the rate in the Golden Period, as shown in <Table 1>. Additionally, although Chile's rate was more than twice as high as that of the major countries in the Golden Period, the difference between these countries in

<Table 1> Average GDP Growth Rate of Chile Compared with that of Other Countries

1986-1998 (A)		1999-2014 (B)		(B-A)/A
Country	%	Country	%	
Chile	7.28	Chile	3.95	-46%
Major countries ²⁾	2.92	Major countries	3.30	13%

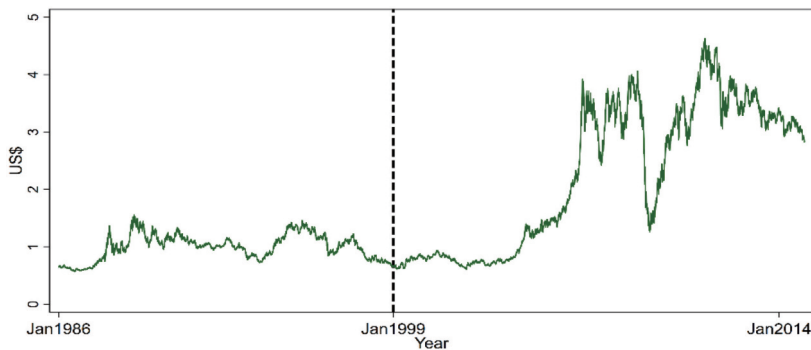
Source: Penn World Table 8.1 and World Economic Outlook

1) Surprisingly, Chile also experienced a debt crisis in the early 1980s similar to other Latin American countries.

2) In that sample period, the major countries were Argentina, Brazil, Mexico, Peru, Venezuela, and Colombia because they accounted for a majority of GDP in Latin America.

1999-2014 was only 0.65% points. Then, what made Chile's economy dramatically worse?

Interestingly, external conditions were more favorable for Chile in 1999-2014 than during the Golden Period. For example, besides large demands for raw materials from newly industrialized countries such as China, the prices of raw materials including copper, which was the main source of income, were substantially higher than before as shown in <Figure 1>. Furthermore, Chile carried out active open-door policies such as Free Trade Agreements from the mid-1990s. That is to say, the external conditions were favorable for Chile to sustain its high degree of economic performance.³⁾



<Figure 1> Copper prices between 1986 and 2014

Source: Macrotrends, "<https://www.macrotrends.net>"

Considering these facts, this study evaluates why the Golden Period did not last into the 2000s through a different approach, namely, a production

3) There were also negative external conditions including high energy prices. For example, since Chile was heavily dependent on energy imports, the increased prices gave a negative impact on the Chilean economy. In addition, although the copper prices were dramatically increased between 1999-2014, they were unstable compared to the previous years.

factor perspective. To perform this analysis, this study used growth accounting analysis, convergence test, and ordinary least squares (OLS) regression. The first two identified which production factor was most decisive in ending the Golden Period, and the third identified determinants that increased the decisive production factor.

This study provides three main contributions to this research. First, this study derived the effects of each production factor specifically by combining quality effects and demographic factors in the growth accounting model that previous literature did not perform. Second, it examined whether the end of the Golden Period was related to the accumulation of capital stock per labor toward its steady state (S.S) in terms of the economic growth theory suggested by Solow (1956). Third, to overcome the limitations of yearly data, two different sample periods were used: 1971-1998 and 1971-2014. This indirectly observed changes in determinants of Chile's key production factor, which was its total factor productivity (TFP).

The rest of this study is organized as follows: Section 2 introduces the previous literature related to subjects in this study. Section 3 implements growth accounting analysis and convergence test to determine Chile's core production factor. Section 4 documents the OLS regression model and interprets its results. Section 5 draws conclusions and implications.

II. Literature Review

This study divides the previous literature into two categories. First, it examines research on the qualitative aspects of the Golden Period. Second, it reviews research on the quantitative features in terms of growth accounting and regression analysis.

Qualitatively, there were three major explanations for the sudden

decrease in Chile's GDP growth rate in the 2000s. The first reason was related to increased labor market regulations, which were an augmented minimum wage, unemployment insurance, and compensation for worker dismissal (Fuentes and Morales, 2011; Espinoza and Fuentes, 2011; Pagés and Montenegro, 1999; Lora, 2001). The second reason was the sudden cessation of capital inflows and the large amount of capital outflows in Chile. Specifically, several international crises in Asia, Russia, and Brazil forced an adjustment of production factors (Nishijima, 2002; Damill *et al.*, 2013; Fuentes and García, 2014). The third reason was increased electricity prices that negatively impacted the manufacturing, mining, electricity, gas, and water sectors (Huneus, 2007; Sosa *et al.*, 2013).

From the quantitative perspective, most of the previous literature presents the concordant conclusion that TFP accounted for the biggest part of Chile's economic decline in the 2000s (Gallego and Loayza, 2002; Fuentes *et al.*, 2006; Sosa *et al.*, 2013).⁴⁾ In this regard, some researchers conducted regression analyses to figure out the determinants of Chile's TFP. Vergara (2002) implemented six types of multiple OLS regressions by inserting additional control variables one by one. They found that education quality, regulatory burden, and R&D expenditure were positively significant on the TFP at the 5% level.⁵⁾ Fuentes *et al.* (2006) introduced 1 or 2 years lagged explanatory variables to reduce an endogeneity problem and elaborated the dependent variable, which was the TFP, by adjusting capital with the energy consumption rate and labor with working hours and wages. Consequently, terms of trade,

4) Interestingly, according to Sosa *et al.* (2013), this finding is only applicable to Chile among Latin American countries. The authors stated that the accumulation of production factors, specifically the labor force, was more crucial than the TFP to economic growth in case of the other Latin American countries.

5) Conversely, GDP per capita growth rate and bureaucracy had negative impacts on the TFP at the same significance level.

macroeconomic instability, and the civil liberties index had significant impacts on the TFP at the 1% level.

III. The Growth Accounting and Convergence Test

This study re-verifies whether the TFP was the most decisive factor at the end of the Golden Period. First, it re-implemented the growth accounting analysis because some previous literature did not adjust the quality effects of production factors and did not include demographic factors, which made the derived results incorrect. Second, this study verified and enhanced the findings from growth accounting analysis by conducting the Solow growth model's convergence test.

1. Growth Accounting

Generally, the equation for growth accounting is derived through the Cobb-Douglas production function. This study introduced its growth accounting model as follows:

$$Y = A(\omega K)^\alpha (\tau L)^{1-\alpha} \quad (1)$$

where Y indicates GDP; A is the TFP; K and L denote the production factors, which are capital and labor stock, respectively; ω and τ are the qualities for K and L , respectively; and α is the capital share of the GDP. In this study, K and L were adjusted respectively for quality by the energy consumption rate and the index of years of schooling and returns on education.⁶⁾ Additionally, this study included demographic factors, which were key elements in a country's growth, in Equation (1) as follows:

6) For detailed information regarding the quality adjustment, refer to Fuentes *et al.* (2006) and Barro and Lee (2010).

$$y = \frac{Y}{L} \frac{L}{N} = A(\omega k)^{\alpha} \tau^{1-\alpha} \frac{L}{L_f} \frac{L_f}{Fif} \frac{Fif}{N} \quad (2)$$

where y is the GDP per capita, N is the total population, k is the capital stock per labor, L_f is the labor force, and Fif indicates 15 years and more.⁷⁾

As shown in <Table 2>, in terms of growth accounting, the GDP over the labor growth rate first affected to a greater degree than the labor over the total population growth rate to the fluctuation of GDP per capita before and after the Golden Period. Second, the TFP growth rate was the most decisive among the production factors that consisted of GDP over the labor stock growth rate. Last, the adjusted capital stock per labor, the labor force over 15 years and more, and the 15 years and more over the total population growth rates increased in 1999-2014 compared with those in the Golden Period. Thus, from the perspective of growth accounting, this study regards the decline of TFP as the main cause of the end of the Golden Period.

<Table 2> Results of Growth Accounting

Period	dy	$\frac{dY}{L}$	$\frac{dL}{N}$	dA	d ωk	d τ	$\frac{dL}{L_f}$	$\frac{dL_f}{Fif}$	$\frac{dFif}{N}$
71-85	0.14	-0.13	0.20	-1.45	0.65	0.67	-0.30	-0.41	0.91
86-98	5.52	3.67	1.85	2.20	1.04	0.43	0.51	1.07	0.26
99-14	2.87	1.46	1.40	-0.41	1.56	0.31	0.00	0.78	0.61

2. The Convergence Test

This study introduced the convergence test⁸⁾ suggested by Solow (1956)

7) L_f was interpreted as the economically active population and Fif as the sum of economically active and inactive population.

8) Solow (1956) proposed that all countries worldwide would converge on the same economic level at some time because of the law of diminishing returns to the capital stock. Because developed countries normally have more capital stock than developing

to verify and reinforce the results of growth accounting from a theoretical perspective. For instance, if the decline of GDP was attributable to the capital stock per labor approaching its S.S, analyzing why capital stock accumulated so much in Chile after the Golden Period is necessary. Because the purpose of the test was to confirm the degree of convergence of capital stock per labor, this study applied the stylized capital accumulation equation as follows:

$$dk = zf(k) - (\eta + \delta)k \quad (3)$$

where z , η , and δ denoted the investment, labor growth, and depreciation rates, respectively.⁹⁾ Because dk at S.S was equal to 0, Equation (3) was rearranged:

$$k^* = h \cdot \left[\frac{zA}{\eta + \delta} \right]^{\frac{1}{1-\alpha}} \quad (4)$$

where k^* denotes the capital stock per labor at the S.S.

As shown in <Table 3>, this study observed how the ratio of capital stock per labor to its S.S was changed before and after the Golden Period. According to the results of the convergence test, first, capital stock per labor in the Golden Period was almost the same as in the former period, whereas capital stock per labor at S.S increased from 76,411 to 109,880. Thus, the ratio between the two periods decreased from 0.56 to 0.39. Second, unlike the former two periods, the capital stock per labor increased by 84.5% between the Golden Period and 1999-2014. However, as capital

countries, a developing country's growth rate will continuously decrease in the process of becoming a developed country. In other words, all countries are converged on the specific point at S.S where the capital stock per labor corresponds to its S.S.

9) To derive Equation 3, constant returns to scale, market clearing conditions, and the assumption that the savings rate is equal to the investment rate were applied. Because the detailed explanation of the model is not the subject of this study, please refer to other references.

<Table 3> Results of the Convergence Test

Period	K	k^*	k/k^*
71-85	43,166	76,411	0.56
86-98	43,152	109,880	0.39
99-14	79,636	334,032	0.24

stock per labor at S.S grew explosively through an augmented investment rate and a declining labor growth rate, the ratio decreased from 0.39 to 0.24. Consequently, the beginning and end of the Golden Period were not relevant to the increased accumulation of the capital stock per labor. This was the same conclusion derived from growth accounting that emphasized the role of TFP. Therefore, this study investigates TFP in depth in Section 4.

<Table 4> Description of Data for Growth Accounting and the Convergence Test

Variables	Definition	Source
Y	Real GDP at constant 2005 national prices (2005 US\$)	PWT 8.1*
K	Capital stock at constant 2005 national prices (2005 US\$)	PWT 8.1*
L	Number of people actually working (labor force times the employment rate)	Fuentes <i>et al.</i> (2006)*
ω	Sum of consumption of the five main energy sources in Chile: hydroelectricity, coal, natural gas, oil, and wood	Fuentes <i>et al.</i> (2006) and Minister of Energy in Chile
α	Capital share in GDP	Fuentes <i>et al.</i> (2006)
τ	Index of human capital per person, based on years of schooling and returns to education	PWT 8.1*
N	Total population	NSI
L_f	Economically active population	WDI*
Fif	Sum of economically active and inactive population	NSI*
z	Investment share of PPP converted GDP per capita at 2005 constant prices	PWT 7.1*
δ	Average depreciation rate of the capital stock	PWT 8.1*

Note: * means that the data were additionally constructed by the author. PWT indicates Penn World Table, NSI is the National Statistics Institute, and WDI denotes World Development Indicators.

IV. Determinants of TFP

1. OLS Regression Model and Data

To figure out which factor had an impact on TFP, this study introduced the multiple OLS regression model:¹⁰⁾

$$\ln TFP_t = \beta_0 + \beta_1 \ln GDP_PC_t + \beta_2 R\&D_{t-1} + \beta_3 \ln MAC_t + \beta_4 FDI_{t-1} + \beta_5 \ln OPEN_{t-1} + \varepsilon_t \quad (5)$$

where the dependent variable was the TFP growth rate at time t ($\ln TFP_t$). When it comes to the explanatory variables, this study used the GDP per capita growth rate at time t ($\ln GDP_PC_t$), R&D expenditure in GDP at time $t - 1$ ($R\&D_{t-1}$), the macroeconomic stability growth rate at time t ($\ln MAC_t$), FDI net inflows in GDP at time $t - 1$ (FDI_{t-1}), and the growth rate of openness in GDP at time $t - 1$ ($\ln OPEN_{t-1}$). Because an endogeneity problem or lagged effects were suspected in some variables, this study applied from time t to time $t - 1$ to them.¹¹⁾ Last, ε_t was the robust standard error at time t , to correct problems due to heteroscedasticity.

<Table 5> Descriptive Statistics

Variables	Obs.	Mean	Std. dev.	Min	Max
$\ln TFP$	44	0.000	0.034	-0.094	0.068
$\ln GDP_PC$	44	0.027	0.052	-0.150	0.103
$R\&D$	44	0.004	0.001	0.002	0.007
$\ln MAC$	44	0.031	0.218	-0.639	0.761
FDI	44	0.036	0.035	-0.050	0.120
$\ln OPEN$	44	0.023	0.108	-0.195	0.377

10) This study constructed Equation (5) with references to Vergara (2002) and Fuentes *et al.* (2006).

11) This study assumed that the effects of R&D expenditure, FDI net inflows, and the growth rate of openness in GDP would occur to TFP after 1 year because the transfer of techniques requires time.

This study provides three reasons for selecting these variables. First, the GDP per capita growth rate was included to control the general effects regarding business cycle factors. Because the GDP per capita generally moved in the same direction as TFP, it could capture something that the other explanatory variables could not catch. Second, the R&D expenditure in the GDP was regarded as one of the most decisive factors on TFP because it stimulates innovations that cause TFP to rise. Solow (1956) also placed great emphasis on innovations in techniques for economic growth. Similarly, macroeconomic stability was important because a stable economic atmosphere was very favorable for the business operations of

<Table 6> Description of Data

Variables	Definition	Source
<i>ln TFP</i>	TFP growth rate	Author*
<i>ln GDP_PC</i>	GDP per capita growth rate	Author*
<i>R&D</i>	R&D expenditure in GDP	Alvarez <i>et al.</i> (2010), Ministry of Economy, Development and Tourism of Chile, and CEPAL
<i>ln MAC</i>	Growth rate of macroeconomic stability constructed by $1/(1+\text{inflation rate})$ where inflation is measured by GDP deflator. The range of macroeconomic stability is from -1 to 1. Higher values indicate more macroeconomic stability	WDI*
<i>FDI</i>	The sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments	WDI and CEPAL*
<i>ln OPEN</i>	Growth rate of openness constructed by the sum of exports and imports of goods and services measured as a share of GDP	WDI*

Note: * means that the data were additionally constructed by the author. CEPAL indicates Comisión Económica para América Latina y el Caribe, and WDI denotes World Development Indicators.

most companies. Third, the FDI net inflow and the growth rate of openness in GDP were considerably helpful in increasing the TFP in two ways. On the one hand, Chile could receive better techniques from developed countries through the transfer of technology. On the other hand, as Chile was one of the countries that adopted open door policies, the allocation of resources could be efficiently realized. <Table 6> represents detailed information regarding the data.

Lastly, this study conducted regression analyses for the two different sample periods, 1971-1998 and 1971-2014. It was mainly because when respectively analyzing the Golden Period and the period after, the degree of freedom sharply decreased when yearly data were used. That is why it is considered two different periods. Although the direct changes in the explanatory variables could not be determined, it was possible to observe their indirect changes.

2. Results

<Table 7> summarizes the estimates from the OLS regression for both 1971-1998 and 1971-2014. Primarily, this study concludes that the results were credible because of the high values of adjusted R^2 , which were 0.6994 and 0.5624.

First, the effects of R&D expenditure at time $t - 1$ were positively significant in 1971-1998 and 1971-2014, although the estimated coefficients were considerably changed from 16.658 to 5.925, and the significance level decreased from 1% to 10%. This finding was consistent with that of Alvarez and Fuentes (2006), which concluded that the competitiveness of the Chilean secondary industry was diminished under trade liberalization because Chile implemented the active open door policies after the mid-1990s. In other words, the sectors that were relevant to natural resources

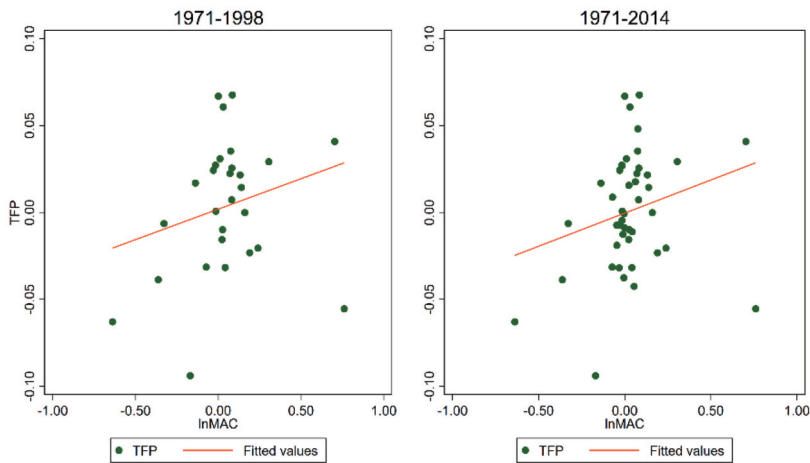
<Table 7> OLS Estimates

Dependent variable: $\ln TFP_t$	(1) 1971-1998	(2) 1971-2014
$\ln GDP_PC_t$	0.447***	0.431***
$R\&D_{t-1}$	16.658***	5.925*
$\ln MAC_t$	0.022	0.028***
FDI_{t-1}	-0.480**	-0.127
$\ln OPEN_{t-1}$	-0.014	-0.014
Constant	-0.073***	-0.033**
Adjusted R ²	0.6994	0.5624

Note: ***, **, and * denote the 1%, 5%, and 10% significance levels, respectively.

were more developed than other sectors, because the former had a comparative advantage in the world. That is why the influence of R&D expenditure was less in 1971-2014 than it was in 1971-1998.

Second, the impact of the macroeconomic stability growth rate at time t was positively significant at the 1% level in 1971-2014, whereas in 1971-1998, it was insignificant at the 10% level. However, as illustrated in the left panel of <Figure 2>, the linear relation between macroeconomic stability and TFP in 1971-1998 was positive, and the impact was significant



<Figure 2> Scatter Plot between Macroeconomic Stability and TFP

at the 15% level.

Third, the effects of FDI at time $t - 1$ were negatively significant at the 5% level in 1971-1998. Therefore, it was not empirically established that Chile was able to accept better techniques from developed countries through the transfer of techniques through FDI inflows. In the findings of Ilboudo (2014), the low productivity of the mining sector, which was one of the main destinations of FDI inflows, was mainly responsible for the negative effect of FDI because of aging mines, lower ore grades, deeper mines, and longer hauling distances. Thus, in the Golden Period, FDI inflow was a factor that contributed to the decreased TFP in Chile.

Finally, the impact of the growth rate of openness in GDP was not significant even at the 10% level for both sample periods. In other words, transfers of techniques through exports and imports did not occur in Chile. Similar to the conclusion on FDI inflows, these results were mainly due to the structural limitation that is focused on primary industries rather than on high value added industries.

V. Conclusion

This study analyzes why the Golden Period in Chile came to an end in the 2000s through growth accounting, convergence test, and OLS regression. First, this study re-identified TFP as the most influential among other production factors at the beginning and the end of the Golden Period in terms of growth accounting analysis. Second, this study theoretically examined whether the decline of economic performance was attributable to the capital stock per labor approaching its S.S. Consequently, the ratio between the two factors decreased from 0.56 to 0.39 between 1986-1998 and 1999-2014. Thus, it became clear that Chile's decline in growth was due to the deteriorated TFP. Third, this study empirically

found the determinants on TFP. From a comprehensive perspective, the decreased TFP was mainly due to the industrial structure being biased toward the primary industry, which caused a lower contribution of R&D expenditure, a high dependence on FDI inflows in the mining sector, and the unproductive use of open door policies.

This study concludes with suggestions and limitations. Based on the findings of this study, Chile still has the possibility of boosting its economic growth. First, it will be helpful to accumulate more capital stock because the capital stock per laborer has not yet been close to its S.S. Second, it would be recommendable to reform the industrial structure in the direction of higher value added. Third, it would be advisable to re-examine the use of trade agreements. Additionally, a few limitations remain in this study. First, there must be more precise adjustment methodologies for quality in growth accounting. Particularly, if it is possible to have the real operating capacity to adjust capital stock, the derived results would be better. Second, part of the data was partially constructed through interpolation or extrapolation because of the absence of that data. Last, the direct change of the estimates could not be observed before and after the Golden Period because of the lack of degrees of freedom. If quarterly or monthly data could be collected, the better the results would be.

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Contabilidad del Crecimiento y Determinantes de la Productividad Total de los Factores en Chile: ¿El Final del Período Dorado?

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Resumen Este documento tiene como objetivo analizar por qué el Período Dorado de la economía Chilena no duró en la década de 2000, desde la perspectiva de los factores de producción mediante el uso de 3 metodologías que fueron el análisis de contabilidad del crecimiento, la prueba de convergencia, y la regresión de Mínimos Cuadrados Ordinarios múltiples. En primer lugar, este documento identificó que la productividad total de los factores fue la más influyente entre otros factores de producción al final del Período Dorado. En segundo lugar, teóricamente mejoró el primer hallazgo al implementar la prueba de convergencia. En tercer lugar, la disminución de la productividad total de los factores se debió principalmente a la estructura industrial sesgada hacia la industria primaria que provocó una menor contribución del gasto en Investigación y Desarrollo, una alta dependencia de las entradas de inversiones extranjeras directas del sector minero, y el uso improductivo de políticas de puertas abiertas. Por último, concluyó que Chile aún tiene posibilidades de impulsar su crecimiento económico.

Palabras Claves Chile, Crecimiento Económico, Período Dorado, Productividad Total de los Factores