Chile's Growth: Resources, Reforms, Results *

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Abstract

This paper starts by describing the stylized facts of Chile's saving, investment, and growth performance during the last four decades. A technology that combines endogenous growth with transitional dynamics (a la Jones and Manuelli 1990), broad reproducible capital (an aggregate of physical and human capital), and non-reproducible natural resources is used to account for Chile's past growth and future growth prospects under alternative investment scenarios. Next the latter production function is embedded in a comprehensive optimal growth model that combines the Ramsey rule with two sectors for goods and human capital (a la Uzawa 1965 and Lucas 1988) with endogenous sovereign risk premia for an open economy. The model is calibrated to the Chilean economy and simulated to compute future GDP growth paths for alternative depletion rates of the country's endowment of non-reproducible natural resources. Finally a parsimonious specification for growth that exhibits conditional convergence to long-term trend-stationary income and permanent as well as temporary effects of policy reforms is estimated for Chile and used to simulate the growth response to alternative future policy reforms. Microeconomic-structural policy reforms are shown to be at the core of any policy initiative that aims to restore high growth in Chile.

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1. Introduction

Major changes in policies, economic structure, and performance have taken place in Chile during the last decades. The clearest evidence of the country's better development record is its attainment of higher economic growth, supported by similarly higher national saving and investment rates and productivity growth. However achieving sustained economic success has neither been easy nor without setbacks. Severe foreign shocks and domestic policy mistakes have punctuated growth since the start of the reform efforts in the mid 1970s. Neither is the country's current growth path without risks. During the last four years since 1998, Chile's average annual GDP growth has been 2.4%, significantly lower than the average 7.7% recorded during the golden dozen years from 1986 to 1997. This downturn suggests that the country still faces formidable policy challenges to lock in high growth for the long haul.

The recent downturn in Chile's growth raises various relevant questions. First, how much of the growth decline is cyclical and which part is due to declining returns to past reforms in policies and institutions? Second, which is the contribution of factor accumulation and technical progress to past growth and future growth prospects? Third, how sensitive is the response to the latter question to the measurement of inputs and the nature of the growth process - exogenous or endogenous? Fourth, how much of current and future growth is due to depletion of non-renewable natural resources? Fifth, what has been the contribution of past reforms in major policy areas and what could be their contribution to future growth? Finally, which specific microeconomic and institutional reforms should be adopted to enhance the country's future growth prospects?

This paper has little to say on the first question; decompositions of high-frequency growth rates in Chile according to cyclical and trend components can be found in Gallego and Johnson (2001) and Contreras and García (2001). This paper does also not contribute anything on the last issue; specific proposals on microeconomic, sectoral, and institutional reforms have been put forward by academics and think tanks**.** Moreover, definition of the specific contents of a Pro Growth Agenda ("Agenda por el Crecimiento") appears currently to be very high on the list priorities of the government and the private sector.

This paper focuses largely on questions two to five, addressed in the following way. A narrative of Chile's saving, investment, and growth performance during the last four decades identifies the broad stylized facts in Section 2. Section 3 introduces a production function that combines endogenous growth with transitional dynamics (a la Jones and Manuelli 1990), broad reproducible capital (an aggregate of physical and human capital), and non-reproducible natural resources. This technology is used to account for Chile's past growth and future growth prospects under alternative investment scenarios. In section 4 the latter production function is embedded in a comprehensive optimal growth model that combines the Ramsey rule with two sectors for goods and human capital (a la Uzawa 1965 and Lucas 1988), and imperfect asset substitution and endogenous sovereign risk premia for an open economy. The model is calibrated to the Chilean economy and simulated to compute future GDP growth paths for alternative depletion rates of the country's endowment of non-reproducible natural resources. Shifting gears from natural resources to policy reforms, the following section focuses on the relations between policy reforms and growth in Chile. A parsimonious specification for growth that exhibits conditional convergence to long-term trend-stationary income and permanent as well as temporary effects of policy reforms is estimated for Chile and used to simulate the growth response to alternative future policy reforms. Section 6 concludes briefly.

2. Saving-investment-growth facts, 1961-2001

Chile's saving, investment, and growth performance reflects high annual volatility and major structural breaks during the last four decades.[1] These salient features are reflected in Figures 1 and 2 and summarized by relevant sub-periods in Table 1.

Table 1
Saving, Investment, and Growth in Chile, 1961-2001 (percentage)

	GNS/GDP at curr. prices	FS/GDP at curr. prices	GDI/GDP at curr. prices	GDI/GDP at const. prices	GFKF/GDP at const. prices
1961-74	12.5	2.3	14.8	20.9	20.8
1975-85	9.4	6.8	16.2	18.3	17.1
1986-97	20.8	3.4	24.1	28.4	25.1
1998-01	21.6	2.4	24.0	30.8	28.2
1961-01	14.7	3.9	18.6	23.1	21.7

	IA/GDP at const. prices	TFP growth	GDP growth	Per capita GDP growth
1961-74	0.1	0.9	3.3	1.1
1975-85	1.2	0.4	2.0	0.2
1986-97	3.3	2.6	7.7	5.7
1998-01	2.6	0.0	2.4	1.1
1961-01	1.4	1.1	4.1	2.2

Note: GNS is gross national saving, FS is foreign saving, GDI is Gross Domestic Investment, GFKF is Gross Fixed Capital Formation, IA is Inventory Accumulation, and TFP is Total Factor Productivity.
Source: Central Bank of Chile and author's calculations.

[1] Recent cross-country studies on the correlation and causality of saving, investment, and growth include Carroll and Weil (1994) and Attanasio, Picci, and Scorcu (1997). Reviews of causality issues and the relation between saving-investment-growth performance and policies can be found in Schmidt-Hebbel, Servén, and Solimano (1996a, b), Schmidt-Hebbel and Servén (1997, 1998) and Loayza, Schmidt-Hebbel, and Servén (2000).

The selected sub-periods reflect distinct regimes of policies and performance. The pre-reform era is characterized by increasing macroeconomic instability and worsening economic performance (1961-74). Serious stabilization efforts and deep structural reforms were started in 1974-75 and have continued to date at varying speeds and intensities as measured in section 5 below. Growth attained a low during the 1975-85 period of reforms and intense foreign shocks, followed by the golden dozen years of very high growth in 1986-97. More recently growth has declined substantially in the wake of adverse foreign shocks (1998-2001).

Chile's saving-investment-growth performance suggests six stylized facts:

1. *Shocks, policy mistakes, and slow response to reforms.* The response of the economy to the deep stabilization and structural reform efforts started in the mid 1970s was delayed by the severe consequences of both adverse foreign shocks (in 1973-75 and 1980-82) and serious domestic policy mistakes (in 1979-82) during the first reform period. Recessions of depression-like intensity hit Chile in 1975 and 1982-83, reflected in double-digit GDP losses and very high unemployment rates during the 1980s. After almost a decade of high employment, adverse foreign shocks hit again in 1998-2001, contributing to a cyclical downturn, reflected by higher unemployment, that extends through 2001.

2. *Pro-cyclical productivity, saving, and investment.* Total factor productivity growth (g_{TFP}), the gross national saving (GNS) rate, and the gross domestic investment (GDI) rate have displayed highly pro-cyclical behavior as suggested in figures 1-2. This is confirmed by the following partial correlation coefficients between the latter variables and GDP growth (g) for 1961-2001:

corr (g_{TFP}, g)	corr (GNS/GDP, g)	corr (GDI/GDP, g)
0.846	0.516	0.529

3. *The takeoff.* Chile's takeoff is reflected by significant trend breaks with past behavior observed since the late 1980s. The GNS ratio attained 20.8% of GDP during 1986-1997, more than twice the average level observed during the preceding three decades, and has remained in the last period. The current-price (constant-price) GDI ratio also jumped substantially after the mid 1980s, reaching 24.1% (28.4%) of GDP during 1990-97 and remaining at 24% (28.8%) in the last four years. The gross fixed-capital investment (GFKI) ratio rose by less, to 25.1% of GDP during 1986-97 and 28.2% for 1998-2001. Inventory accumulation jumped to 3.3% in 1986-97 and, despite its decrease to 2.6% in 1988-2001, remains well above the previous decades. TFP growth had an important role in explaining the growth upsurge of 1986-97, attaining 2.6%, more than doubling the historical (1961-74) level of 1.1%. The combination of higher investment and TFP growth explains attainment of 7.7% GDP growth in this period, a figure that almost doubles the country's historical record performance. In the 1998-2001

period, the economy has experienced a signficant decrease in TFP growth (which has become insignificant), largely explaining the decline in aggregate growth.

4. *Large foreign saving inflows*. Foreign saving (FS) played a crucial role during 1978-87, a decade when it exceeded 5% of GDP in each and every year. Voluntary private foreign resource inflows financed an exploding private investment-saving gap from the mid-1970s through early 1982. The LDC debt crisis triggered by the Mexican default in August 1982 dried up further private voluntary lending. Although the debt crisis implied a drastic regime change, Chile was able to secure substantial involuntary private capital inflows (as a result of debt rescheduling agreements) and loans from multinational financial institutions during 1983-87. But since 1988 foreign saving has fallen to less than 5% of GDP, declining to an average 3.4% between 1986 -97 and to 2.4% in 1998-2001.

5. *Significant foreign - national saving substitution*. The relations between GDI, GNS, and FS are distinctly different in 1961-77 (low FS, GNS, and GDI ratios) from the 1978-87 decade (high FS, very low NS, and moderate GDI), and from the 1988-2001 period (low FS and high NS and GDI). The 1961-2001 partial correlation coefficients for FS and NS and GDI are the following:

corr (FS/GDP, GNS/GDP)	corr (FS/GDP, GDI/GDP)
-0.511	0.022

The large negative correlation between foreign and national saving ratios reflects high substitution between both variables. The correlation between foreign saving and gross domestic investment ratios is low and non significant, reflecting -- again -- the high degree of substitution between domestuc and foreign resource use to finance capital formation.

6. *High saving-investment* correlation. Low saving-investment levels in the pre-reform period 1961-74 and high saving-investment levels in the post-reform period 1986-2001 -- with relatively constant foreign saving -- suggests that Chile should be no exception to the well-known high saving-investment correlation that is observed internationally. This is confirmed by the following Feldstein-Horioka (1980) type of regression (t-statistics in parenthesis):

$$\underset{}{GDI/GDP} = \underset{(6.79)}{7.855} + \underset{(9.98)}{0.728}\ NS/GDP \qquad R^2 = 0.72 \qquad \text{1961-2001}$$

$$\underset{}{GDI/GDP} = \underset{(3.43)}{3.647} + \underset{(15.08)}{0.933}\ NS/GDP \qquad R^2 = 0.88 \qquad \text{1961-2001 (excl. 1978-87)}$$

The saving-investment correlation is much stronger when excluding the 1978-87 decade of high resource inflows.[2]

3. Accounting for the Past and Transiting to the Future

How should Chile's recent growth experience and future growth prospects be assessed? The common framework used in the preceding section and in many previous growth studies for Chile is based on the simple exogenous-growth framework. Here I apply a broader production process that combines various features that are relevant in explaining and simulating growth in Chile.

The production technology combines endogenous growth with transitional dynamics a la Jones and Manuelli (1990) in the form used by Barroa dn Sala-i-Martin (1995), broad reproducible capital comprised by physical and human capital, non-reproducible (non-renewable) natural resources, and residual exogenous TFP growth. This specification seems appropriate for Chile because it encompasses both exogenous and endogenous growth, a dynamic transition from current growth rates to sustainable stationary growth levels, a distinction between physical and non-physical capital, and a role played by natural resources. The corresponding growth model allows for a more powerful and realistic description of growth takeoff, allowing that stationary growth is affected by changes in policies and behavior (as opposed to the Solow growth model) and transitional growth is different from steady-state growth (as opposed to the simple endogenous growth model), due to transitional growth dynamics and depletion of non-renewable resources.

As developed in more detail in Annex 2, aggregate output per capita or per unit of raw labor or per capita (*Y*) is obtained as an aggregate of three production processes or components. The first process is a Rebelo (1991)-type AK endogenous-growth process with constant returns to broad capital per worker. Broad capital is a Cobb-Douglas function of physical capital per capita (*K*) and human capital per capita *(H)*. The second sector reflects exhibits declining returns to broad capital, implying exogenous growth a la Solow (1956). The third process represents a Cobb-Douglas technology in physical capital per capita and non-renewable natural resources per capita (*R*), with declining returns to physical capital. Total factor productivity grows at a residual exponential trend rate. Hence output per capita is determined by the following equation:

$$(1) \qquad Y = Ze^{\varpi t}\left[AK^{\alpha}(uH)^{1-\alpha} + B\left(K^{\alpha}(uH)^{1-\alpha}\right)^{\beta} + DK^{\gamma}R^{1-\gamma}\right]$$

where production parameters satisfy: $0 < \alpha$, β, $\gamma < 1$; and A, B, C, Z > 0. The term $e^{\omega t}$ reflects the component of TFP that grows at a constant rate ω.

Next I assess Chile's past performance and future growth prospects, according to the exogenous and endogenous growth versions of equation (1).

[2] A number of explanations have been provided for the Feldstein-Horioka puzzle. They include national barriers to international capital flows, binding foreign source constraints, domestic policies targeted at low current accounts, home bias in international portfolio selection, and common factors affecting both national saving and foreign investment in the same direction (Obstfeld and Rogoff 1996).

Exogenous Growth

Let's start with a conventional exogenous-growth version of equations (1) where output is produced by the second technology. This requires setting $Z = 1$, $A = C = 0$, and $\gamma = 1$. An income share of physical capital (α) equal to 0.45 is used.[3] Two measures of labor are considered: raw labor and quality-adjusted labor or human capital.[4] Total factor productivity (TFP) grows at the exogenous rate ω or g_{TFP}. The latter rate -- the standard Solow growth residual -- is obtained by subtracting the contribution of the increase in physical capital and labor (either raw or quality-adjusted labor) from GDP growth.

Table 2
Sources of Past Growth according to the Exogenous Growth Model, 1961-2001

	Capital Growth	Labor Growth	TFP Growth	GDP Growth
1. With Raw Labor				
1961-1974	3.3%	1.7%	0.9%	3.3%
1975-1985	1.6%	1.6%	0.4%	2.0%
1986-1997	6.6%	3.8%	2.6%	7.7%
1998-2001	4.7%	0.6%	0.0%	2.4%
2. With quality-adjusted Labor				
1961-74	3.3%	1.8%	0.8%	3.3%
1975-85	1.6%	4.9%	-1.4%	2.0%
1986-97	6.6%	6.4%	1.2%	7.7%
1998-01	4.7%	2.1%	-0.8%	2.4%

Source: author's calculations.

Table 2 reports standard growth accounting results for relevant sub-periods in Chile. The first is the pre-reform period that extends from 1961 to 1974, prior to the adoption of radical economic reforms in the second half of the 1970s. The second is the 1975-1986 transition period, which includes the structural reforms of the 1970s as well as the severe recession of 1982-83 and its aftermath. The next period spans 1986-1997 and comprises the recovery from the recession and the response to policy reforms. The last

[3] This figure is consistent with the share of capital in Chilean national accounts and in other studies (cf. Corbo, Lüders, and Spiller 1997, De Gregorio 1997, Roldós 1997, Morandé and Vergara 1997).
[4] The labor quality index is a weighted average of relative wages (as a proxy for productivity) of workers with different levels of educational attainment. Capital is not adjusted for quality due to lack of convincing methods and data. (Roldos 1997 reports quality-adjusted capital series, where the quality index in 1995 attains the level of 1960).

period, characterized by a significant slowdown in growth, covers Chile's experience since the Asian crisis.

Overall results suggest that it took Chile more than a decade of post-reform experience before investment and TFP growth (and labor factor quality growth) responded to the policy reforms started in the mid 1970s. Capital growth attained a large rate of 6.6% per year and TFP growth reached 2.6% per year (when labor is unadjusted for quality) or 1.2% per year (when labor is quality-adjusted) during 1986-97. Labor quality grew at 6.4% during the same period. Total growth attained 7.7% per year, for Chile a historically unprecedented period of growth that is also close to the high growth records in the cross-country dimension. However since 1998 average growth has fallen to less than a third of the former figure, a result of a significant decline in employment growth and large decline in labor and/or overall factor productivity growth.

The Solow growth equation can be slightly restated by decomposing the growth rate of physical capital into the rate of physical investment (*inf*), the average product of physical capital ($apf \equiv$ y/f), and the rate of capital depreciation (δ):

$$g = \varpi + \alpha \ [invf \ \ apf - \delta] + (1 - \alpha) \ n \qquad (2)$$

where g is aggregate GDP growth, and n is employment growth.

The latter equation allows to explain Chile's growth takeoff -- in the frame of the simple exogenous-growth model -- under a slightly different perspective (see Table 3). The significant increase in the rate of growth of physical capital -- from 3.3% in the 1960s to 6.6% in the 1990s -- is the result of a higher gross fixed capital investment (GFKI) ratio to GDP and a larger average productivity of capital. GFKI/GDP, which declined during the 1975-85 reform period, increased by 4.3% in the high growth 1986-97 period when compared to 1961-74, and has marginally increased in the 1998-01 period. However, the average product of capital -- which was fairly stable between 1961 and 1985 and increased significantly during the decade of explosive GDP growth- has fallen since 1998, but still remains significantly above its average 1960s level.

Steady-state growth is determined by the sum of exogenous TFP growth ω and employment growth in the Solow model. When using each period's observed values for the latter variables it is straightforward to conclude that actual GDP growth during 1961-74 (3.3%) was only slightly above the stationary growth level that could be achieved under pre-reform conditions (2.6%). This stands in contrast to the high growth period, when actual growth (7.7%) exceeded by more the steady-state growth level for that period

[5] Roldos (1997) constructed quality adjusted series for both capital and labor. However, their statistical properties are somehow disturbing, particularly in the case of capital, in which the quality index suggests that capital in 1995 had the same quality as in 1960. Therefore, and as reliable data on the determinants of capital quality is not available, we only make a quality adjustment for labor. The quality index is a weighted average of the relative wages (as a proxy for productivity) of workers with different levels of educational attainment within the labor force.

(6.4%). This is not surprising as the rate of investment rose significantly during 1986-97, raising temporary growth rates above stationary levels.

Table 3
Past and Future Growth in the Exogenous Growth Model

	GFKI/ GDP (*invf*)	GDP/ capital (*apf*)	Deprec. Rate (δ)	Capital growth (g_K)	Empl. growth (n)	TFP gr. (g_{TFP})	Current GDP growth (g)	Steady-state GDP gr. (g^*)
1961-1974	20.8%	34.4%	3.9%	3.3%	1.7%	0.9%	3.3%	2.6%
1975-1985	17.1%	34.5%	4.3%	1.6%	1.6%	0.4%	2.0%	2.0%
1986-1997	25.1%	40.0%	3.6%	6.6%	3.8%	2.6%	7.7%	6.4%
1998-2001	28.2%	37.1%	6.0%	4.7%	0.6%	0.0%	2.4%	0.6%
1989-2001	27.5%	39.8%	4.3%	6.6%	2.1%	2.1%	6.3%	4.3%
Higher investment.	30.0%	39.8%	4.3%	7.7%	2.1%	2.1%	6.8%	4.3%

Source: author's calculations.

The rise in stationary growth from 2.6% in 1961-74 to 6.4% in 1986-97 is spectacular. Even more spectacular has been the recent fall in stationary growth, attaining only 0.6% in 1998-2001. However the latter figure is misleading because it corresponds to a short time span dominated by a cyclical downturn. A better indication of stationary growth is provided by the complete 1989-2001 period that comprises a full economic cycle, including both the cyclical expansion and high growth of 1986-97 and the contraction and low growth of 1998-2001. For the latter 13 years stationary growth stands at 4.3%, a figure almost twice as large as the historical average stationary growth rate of 2.3% observed in 1961-1985.

How much could Chile's growth rise if fixed-capital investment is increased by, say, another 2.5% of GDP, from 27.5% during 1989-2001 to 30% in the near future? The answer provided by the simple Solow growth model is straightforward: short-term GDP growth would increase by 0.5% to attain 6.8% (Table 3). However the long-term stationary growth level is unaffected by any change in the investment rate -- a result of declining returns to capital in the Solow model.

Endogenous Growth with Transitional Dynamics

To overcome the limitations of the simple Solow model, I now make use of the full endogenous-growth model with transitional dynamics, broad capital, and non-renewable natural resources, embedded in the production function of equation (1) above. The corresponding growth equation is the following:

$$(3)\quad g = \varpi + \frac{mpf}{apf}\left[invf\ \ apf - (n+\delta)\right] + \frac{mph}{aph}\left[invh\ \ aph - (n+\delta)\right] + \frac{mpnr}{apnr} g_{nr} + n$$

where *mpf* (*mph*, *mpnr*) is the marginal product of physical capital (non-physical capital, natural resources), *apf* (*aph*, *apnr*) is the average product of physical capital (non-physical capital, natural resources) and g_{nr} is the rate of growth of non-renewable resources per capita.

Chile's growth between 1989 and 2001 can be explained according to the contribution of the growth determinants reflected by this model. This requires calibration of production coefficients, sector shares, and factor growth rates to the data of the last 13 years. The full detail on parameter assumptions and calibration is provided in Annex 2; let's briefly refer here to some key parameters.

In the absence of data or strong priors on the relative size of the endogenous and exogenous production components in aggregate output, I consider three alternative shares of the Solow component (component 2): 5%, 25%, and 45% of aggregate GDP. The share of component 3 (production based on non-renewable natural resources) is estimated at 13.9%, the sum of the current share of mining and fisheries in GDP (9.6% during 1989-2001) [7] and an estimate of 4.3% for the GDP share of manufacturing sub-sectors based directly on elaboration of non-renewable natural resources. The growth rate of the aggregate sector of non-reproducible natural resources (g_{NR}) is 6.7%, slightly below the 7.8% weighted average rate of growth of mining and fisheries during 1989-2001. The ratio of investment in non-physical capital (that is human capital, R&D, ideas, etc.) to GDP is estimated at 10% of GDP, twice the share of education and health in GDP during the 1990s.

Transitional growth in eq. (3) exceeds stationary growth for two reasons. First, the marginal products of all factors of production are larger during the transition than at the steady-state growth equilibrium due to declining rates of return to reproducible resources used in components 2 and 3 of the aggregate production process. Second, by the very definition of non-reproducible natural resources (mostly comprised by mining deposits and non-renewable fishing stock in the case of Chile), the growth rate of the latter converges to

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[7] Not all fisheries included in GDP are based on non-renewable resources. In fact, 70% of the sector's current production is based on sustainable sea and water farming (largely salmon). Here we consider only the fraction of fisheries based on non-renewable resource extraction.

zero in steady state. Hence stationary GDP growth is characterized by the following equation:

$$(4) \qquad g^* = \varpi + \frac{mpf^*}{apf^*}\left[invf \;\; apf^* - (n+\delta)\right] + \frac{mph^*}{aph^*}\left[invh \;\; aph^* - (n+\delta)\right] + n$$

where asterisks denote steady-state values of the corresponding variables defined above.

Table 4 reports the main variables governing GDP growth since 1989 and its long-run convergence toward the steady-state level consistent with this model's structure and parameter values. The relative size of growth component 2 (decreasing returns to broad capital) represents the distance of the economy from its steady state. If the latter share (s_2) is small (5% in the simulation) the economy is close to its steady state and hence the decrease in growth in transition to the steady state is mainly due to convergence of the stock of non-renewable natural resources to zero. When s_2 increases, the fraction of the economy's current growth that comes from exogenous growth rises and hence the wedge between the economy's current and stationary growth rates is larger. When the model is simulated with exogenous-growth shares of 5%, 25%, and 45% of GDP, steady-state growth (g*) goes from 4.9% to 3.1% and finally to a low 1.3% (almost zero growth in per capita terms).

Table 4
Past and Future Growth under Endogenous Growth
with Transitional Dynamics, Broad Capital, and Non-Renewable Resources (percentage)

	Initial GDP share of component 2 (s_2)	Physical investment rate (*invf*)	Non-physical investment rate (*invh*)	Non-renewable nat. resource growth (g_{NR})	TFP Growth (ϖ)	Factor accum. growth	Steady-state GDP growth (g^*)
1989-	5%	27.5%	10%	6.7%	-0.6%	6.8%	4.8%
-2001	25%	27.5%	10%	6.7%	-0.2%	6.4%	3.1%
	45%	27.5%	10%	6.7%	0.3%	5.9%	1.3%
Higher	5%	30.0%	12.5%	6.7%	-0.6%	7.3%	5.2%
Invest.	25%	30.0%	12.5%	6.7%	-0.2%	6.8%	3.4%
	45%	30.0%	12.5%	6.7%	0.3%	6.2%	1.5%

Figure 3 depicts the corresponding interpretation of Chile's growth increase from the 1960s (i.e., 1961-74) to the 1990s (i.e., 1989-2001) and the subsequent transitional convergence to a stationary growth equilibrium consistent with a 25% share of the

[8] This figure is consistent with the share of capital in Chilean national accounts and is widely used by other studies (cf. Corbo. Lüders, and Spiller 1997, De Gregorio 1997, Roldós 1997, Morandé and Vergara 1997).
[9] The quality adjustment follows the methods and series reported in Roldós (1997).
[10] One should note that these results are short-term potential growth rates, not steady-state growth rates.

exogenous-growth component. Assuming the latter share and considering Chile's structural conditions reflected in the calibration of equation (3), aggregate GDP growth would gradually converge gradually from 6.3% during the last 13 years to 3.1% in the distant future.

Which effect does higher investment in both physical and human capital have on current and steady-state GDP growth? If the GFKI ratio is raised by 2.5% (from 27.5% to 30.0% of GDP) and spending on human capital, technology, and ideas is also expanded by 2.5% (from 10% to 12.5% of GDP), short-term and steady-state growth would increase (Table 4). In the intermediate case of a s_2 share of 25%, current GDP growth would be raised from 6.3% to 6.8% and stationary growth would rise by a similar amount, from 3.1% to 3.4%. Under a lower (higher) s_2 share, the growth impact effect is the same but stationary growth is higher (lower).

Non-renewable resource-based growth -- which contributed by 0.9% to Chile's growth in 1989-2001 -- will gradually vanish as a long-term source of growth. How fast this will occur depends on the rate of depletion of the underlying resource stock. To this issue we turn next.

4. Non-Renewable Resource Depletion and Optimal Future Growth Paths

In this section I derive an optimal growth model that builds on the production function introduced above and apply the model to simulate future growth or different paths of depletion of Chile's stock of non-renewable natural resources.

The Model

The model combines the following features. Intertemporal consumption follows the Ramsey (1928) rule, based on CRRA preferences. There are two sectors of production in the Uzawa (1965) - Lucas (1988) mode: for goods and for human capital. Production of goods follows the specification introduced in section 2: Jones-Manuelli transitional endogenous growth, broad capital defined by reproducible physical and human capital, and non-renewable natural resources. Non-renewable resources follow an exogenous rate of depletion, i.e., there is no optimal Hotelling rule of resource extraction in this model. Physical and human capital are allowed to jump due to the absence of convex adjustment costs.

The government raises distortionary taxes rebated by lump-sum transfers. The economy is financially semi-open in the sense that domestic and foreign assets are imperfect substitutes, with an endogenous sovereign risk premium determined by the country's net foreign asset position relative to its domestic wealth. The latter feature allows for a permanent endogenous spread between the international interest rate and the domestic subjective rate of discount (given by the risk spread) and avoidance of hysteresis effects. Population grows exogenously.

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[11] Among the tax reform proposals are Serra (1997) and Vergara and Larraín (1997).

Variables are defined as follows:

C Consumption
Y Output
I Physical capital investment
K Physical capital stock
H Human capital stock
F Stock of foreign assets
R Stock of non-renewable natural resources
u Fraction of human capital used for production of goods
r Domestic interest rate
r* Foreign interest rate
ty, tc, ti, th, tax rates (ad valorem) on production, consumption, physical investment human investment.
TR* Foreign transfers
TR Domestic transfers
n Population growth
s,τ Time indexes

Coefficients are defined as follows:

Z, A, B, D goods production efficiency coefficients
E Human capital investment coefficient of efficiency
α Share of fixed capital in production with human capital
β Coefficient of decreasing returns to human and physical capital in production (β<1)
δ Share of fixed capital in production with resources
ψ Country risk premium coefficient
ρ Subjective rate of discount
θ Consumption risk aversion coefficient
δ Physical capital rate of depreciation
ε Human capital rate of depreciation
φ Non-renewable natural resource depletion
p Shadow price of human capital
q Shadow price of physical capital.

All stock and flow variables (other than rates) are in per-capita terms.

The representative consumer chooses optimal paths for his three control variables (consumption, the share of human capital devoted to goods production, and physical capital investment) by maximizing:

(5) $$\underset{\{C,u,I\}}{Max} : \int_{s=t}^{\infty} e^{-(\rho-n)s} \frac{C^{1-\theta}}{1-\theta} ds$$

subject to the following equations (6) to (13).

Technology for goods production:

$$(6) \qquad Y = Z\left[AK^{\alpha}(uH)^{1-\alpha} + B\left(K^{\alpha}(uH)^{1-\alpha}\right)^{\beta} + DK^{\gamma}R^{1-\gamma}\right]$$

Government budget constraint:

$$(7) \qquad TR = ty\ \ Y + tc\ C + ti\ I + th\ H$$

Consumer (or private-sector) budget constraint:

$$(8) \qquad \dot{F} = Y(1-ty) - C\,(1+tc) - I\,(1+ti) - p\ Hth + TR + TR^{*} + \ (r-n)\,F$$

Physical capital investment:

$$(9) \qquad \dot{K} = I - (\delta + n)K$$

Human capital investment:

$$(10) \qquad \dot{H} = E(1-u)H - (\varepsilon + n)H$$

Exogenous depletion of resources:

$$(11) \qquad \dot{R} = -(\phi + n)R$$

Imperfect international asset substitution with endogenous risk premium:

$$(12) \qquad r = r^{*} - \psi \ \ \frac{F}{qK + p\ H}$$

No-Ponzi Game condition:

$$(13) \qquad \lim_{\tau \to \infty} \mathrm{e}^{\left[-\int_{0}^{\tau} r(\upsilon)d\upsilon + n\tau\right]} F = O$$

The steady-state solution of the dynamic optimization problem for this model is presented in Annex 3. Stationary growth is largely determined by the exogenous rate of human capital growth (E). The model does not have an analytical solution. A numerical model solution is obtained for the steady-state growth equilibrium and transition, after calibrating the model to fit average 1989-2001 data for Chile.

Growth Simulations of Resource Depletion Paths

The model is used to derive transitional growth trajectories under alternative resource depletion paths. Non-renewable natural resources are completely depleted in the steady state. Hence stationary growth is only determined by reproducible capital accumulation. Transitional growth depends, among other things, on the rate of resource depletion.

The rate of natural depletion is 1% in the base case, consistent with a half-life of 50 years of the current stock of non-renewable natural resources in Chile. Next I consider three alternative paths of natural resources that deviate quite extremely from the base-case rate of natural resource depletion.

Path 1: Unanticipated Discovery of Resources at Year 15. The initial steady-state stock of resources is doubled but the base-case rate of depletion is maintained.

Path 2: Faster Rate of Resource Depletion. The base-case rate of resource depletion is increased so that the half-life of resources is shortened from 50 to 20 years.

Path 3: Very fast Rate of Resource Depletion. The initial rate is increased so that the half-life of resources is shortened from 50 to 5 years.

Growth dynamics, relative to base-case growth, are depicted in Figure 4 for each resource trajectory. Under path 1, relative growth is increased on impact by 0.6%, slightly above the latter figure in subsequent years, and then starting gradual convergence to zero. At year 50 growth is still 0.45% higher than in the base case.

Under paths 2 and 3, growth falls relative to the base case by similar amounts, close to 0.6% at the beginning, to gradually converge toward base-case growth over time. At year 50, aggregate growth is still 0.4% lower than in the base case.

The assumption of high persistence in the stock of natural resources - a reflection of the relatively low rate of resource exploitation net of discovery of new resources in Chile - is reflected in high growth persistence of any deviation from a reasonable base scenario. However, the results reported here show that under quite radical departures from base-case resource depletion, the impact on future growth is only small to moderate. This suggests that Chile's growth potential lies elsewhere: in accumulating broad capital and raising technical progress. The latter sources of growth depend on policies - a relation to which we turn next.

5. Policy Reforms and Growth Transition

Both mainstream economic theory and the empirical evidence seem to suggest that factor accumulation and technical progress are largely determined by policies and institutions and only marginally by good or bad luck stemming from foreign shocks (such as terms-of-trade or capital flow shocks), natural resource endowments (such as oil or nice beaches), geography (such as latitude or the distance from industrial countries), and culture (such as Confucianism or protestant ethics). This section takes the latter assertion as granted and hence narrows its focus on the relation between policies (and institutions) and economic growth in Chile.

There are two main approaches to analyze the relation between policies and growth.

(i) Linking specific policies, regulations and institutions to specific markets, factors of production, and their accumulation. This approach ranges from microeconomic and sector studies (that relate regulatory and policy features to the incentive structure in a specific market) to macroeconomic studies on the influence of specific policy variables on accumulation of physical capital, human capital, and technology.

(ii) Linking specific policies and institutions to aggregate growth. This widely popular approach pre-defines a narrow set of specific policy variables or institutions and relates them to aggregate economic growth. This reduced-form approach has spanned an industry of empirical cross-country and country growth studies, with every additional study identifying new potential growth variables. Its main drawbacks – omission bias and lack of robustness – has been recognized early on, since Levine and Renelt (1992) to Sala-i-Martin (2000). Due to high correlation of potential growth determinants – in both the cross-country and country time-series dimensions – many studies based on this approach overestimate the contribution of the researcher’s pet variable included in her growth study.

A case in point are the studies that identify key determinants of Chile’s high growth in the golden period of 1986-1997, in comparison to Chile's performance recorded from the 1960s through the mid-1980s (or to the relevant cross-country experience). Many of the 17 studies on growth in Chile summarized in Annex 4 identify only a limited number of potential growth determinants and estimate their contribution to factor accumulation, TFP growth, or aggregate growth. A random partial selection of the empirical results reported there allows to identify a small number of factors that could fully explain the 5% rise in GDP growth, from 2.7% in 1961-1985 to 7.7% in 1986-1997. For instance, combining the growth contributions of trade reform (plus 1.1% from Rojas et al. 1997), smaller government (plus 0.8% from Barro 1999), larger political rights (plus 1.6% from Jadresic and Zahler 2000), and the mid-1980s tax reform (plus 1.4% from Bergoeing et al. 2001) roughly add up to the aforementioned 5% growth gain. But hardly anyone would seriously argue that growth is due only to the latter set of four randomly selected growth factors.

As an alternative to the two latter approaches, I propose here to focus on a sparse number of broad policy variables that represent the combined effect of many different policy, regulatory, and institutional factors that determine growth. This approach is close to the framework of Gallego and Loazya (2001) that identifies the role of policy complementarities in explaining Chile's growth performance in a cross-country sample.

The model presented next is a parsimonious reduced-form equation that relates growth to broad policy variables and structural variables, allowing for conditional income convergence to a trend-stationary income level. The equation nests three potential roles of policy variables in explaining growth: permanent income effects, temporary income effects, and effects on the speed of convergence to stationary income trend levels.

Define:

y	log of per capita GDP
X	vector of domestic state policy variables
Z	vector of exogenous variables
t	time index

The following equation for per capita growth under conditional convergence nests the different effects of policy and structural variables:

$$(14) \qquad y_t - y_{t-1} = a_o + (a_1 - 1)y_{t-1} + X_t^{'}b_1 + \Delta X_{t-1}^{'}b_2 + \Delta X_{t-1}^{'}y_{t-1}b_3 + Z_{t-1}^{'}c + \varpi\, t + \mu_t$$

where a_o, a_1, a_2, and ϖ are coefficients; b_1, b_2, and b_3 are vectors of coefficients; and μ is a zero-mean constant-variance i.i.d. error term.

Equation (14) embeds various hypotheses about short and long-term income level and growth determinants. Policy variables (X) have three potential effects: a permanent effect on income (if b_1 is positive and significantly different from zero), a temporary effect on income (if b_2 is positive and significantly different from zero), and a positive temporary effect on the speed of conditional convergence to the stationary income level (if b_3 is positive and significantly different from zero). In addition, exogenous variables could have positive effects on permanent income levels (if c is positive and significantly different from zero). Finally, as long as both domestic policy and exogenous variables do not exhibit long-term trends and/or their trends are not sufficient to account for explaining trend GDP stemming from omitted growth determinants, a separate trend variable is included.

Equation (14) exhibits trend stationarity in income levels, represented by the following equation (stars denote stationary or trend-stationary variables):

$$(15) \qquad y^* = \frac{1}{1-a_1}\left[a_o + (X^*)^{'}b_1 + (Z^*)^{'}c + \varpi\,\mathrm{t}\right]$$

The long-term income level is trend stationary as long as a_1 is strictly smaller than 1. Stationary income converges to a level determined by a constant, (trend) stationary levels of policy and exogenous variables, and a residual time trend.

Equation (14) is estimated for Chile's per-capita income growth during the last four decades. As discussed above, this sample period features major policy changes, structural shifts, and external shocks that make it both a fascinating and a difficult period to test for conditional convergence. In defining a testable version of equation (14), it is key to identify the relevant components of the X and Z vectors. The approach followed here is parsimonious in the sense of choosing short vectors including very broad, representative variables for policy and structure. This is opposite to most of the previous empirical growth literature for Chile, as discussed above.

For the policy variable vector I select only two broad macro and micro-structural policy variables that are supposed to represent the combined influence of macroeconomic stabilization policies, on one hand, and structural, sector, microeconomic, and regulatory policies and institutions, on the other hand.[12] For the former I choose an index (MAC) defined by an inverse function of the rate of inflation (1/(1+inflation), bounded between 0 and 1)) which appears to be the most general proxy available for macroeconomic policy progress. For the microeconomic-structural policy index (MIC), I choose the most comprehensive structural reform index that is available, initially built by Lora (1997) and subsequently extended by Morley et al. (1999)[13], and extended further for this study (following Morley et al.) for the 1960s and the most recent years up to 2001. The corresponding time series for MIC and MAC are depicted in Figure 5, reflecting the massive improvement recorded by both indexes since the early 1970s to date.

For the vector of structural variables (Z), I pre-identify two variables (terms-of-trade shocks and population growth) that are popular and relatively robust growth determinants found in the empirical growth literature. However due to systematic lack of significance of population growth, this variable was dropped early on from the estimations.

The OLS results for per-capita GDP growth (1961-2001 sample of annual data) are reported in Table 5. Six alternative specifications are reported there.

Model (1) includes, in addition to the permanent effects of MAC and MIC and the temporary role of MAC, the terms-of-trade shocks and the temporary effect (i.e. the change) of MIC. The two latter variables are not significant; hence they are dropped from

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[12] Among studies of Chile's policy reforms are Edwards and Edwards (1987), Bosworth, Dornbusch and Labán (1994), Larraín (1994), Corbo, Lueders, and Spiller (1997), and Cortázar and Vial (1998). Among studies that focus more specifically on the relation between Chile's policies and SIG performance are Marfán and Bosworth (1994), Larraín and Rosende (1994), Morandé and Vergara (1997) and the papers therein, and Marshall and Velasco (1998).

[13] Among the studies that report and/or apply the structural reform indexes developed at the World Bank and the IDB are Burki and Perry (1997), Loayza and Palacios (1997), Lora (1997), and Inter American Development Bank (1996).

subsequent models. The temporary effect (i.e. the change) of MAC on growth is positive but does not attain conventional significance levels. Yet it is included in all regressions.

Interaction terms of lagged income and MAC and MIC were included to test for the effects of policies on the speed of convergence. They were systematically found to be non-significant (due to high collinearity with MAC and MIC, respectively) and therefore dropped from the reported results.

A major problem - common to all empirical growth studies for Chile that include the 1970s and early 1980s - are the very deep 1975 and 1982-83 recessions in Chile. This leads to (unpleasant) inclusion of two or three annual dummy variables for the latter years. If they are not included (as in model (3)), not only the MIC variable drops in significance but also the lagged income level, implying a (much more unpleasant) unit root for income. Hence I opt for the lesser evil by including dummies in all other models. The overall fit is good and residuals do not exhibit first-order correlation.

There is very large collinearity between the time trend and MIC. This is serious because it makes separate identification of the two latter variables very hard. Hence I attempt three specifications: with MIC and no trend (model 2), without MIC and with trend (model 4), and with a pre-determined trend coefficient (equal to 0.0007) to estimate freely MIC's coefficient, estimated at an almost standard significance level (model 5).

Further to the statistical problem of high collinearity between MIC and the time trend, their respective exclusion has implications for inference. If MIC is included but not the time trend (model 2), stationary income does not exhibit a time trend. If the time trend is included but not MIC (model 4), policy reforms have temporary but no permanent effects on income levels – a very unlikely case. Hence I choose a model that predetermines a partial contribution of the time trend and estimates freely the residual contribution of MIC (model 5).

As a final alternative, model (6) includes the first two income lags and a combined role of contemporaneous MAC and the third lag of MIC, in addition to a common dummy for the 1975 and 1982 recessions. While this result dominates statistically all previous models, its drawback lies in the fact that policy variables have only temporary effects on income levels.

In sum, the preferred result is model 5, with statistically strong effects of lagged income (implying conditional convergence) and the MAC policy variable. Positive but statistically weaker effects on growth are obtained from the MIC policy variable and the change in MAC. All these results are conditional to pre-determining the influence of a trend variable that, given the coefficient of the lagged dependent variable, implies (low) stationary per capita growth of 1%.

Figure 4 depicts actual and fitted growth values based on model 5. The results reflect that predicted growth is much smoother in the 1990s than actual growth and, moreover, that predicted growth rates decline significantly during the last decade, from 5-6% in the late 1980s to approximately 4% around 2000.

A simple out-of-sample simulation for aggregate GDP growth illustrates the potential contribution of future reforms. They will certainly not lie in the macro policy area, where an independent central bank (supported by a conservative fiscal policy reflected in pursuing a structural budget surplus) has attained a stable level of 2-4% annual inflation (implying a MAC index close to its maximum level of 1.0). Policy reforms have to lie in the structural-microeconomic area, where major weaknesses have recently prompted the government and the private sector to develop a "Pro Reform Agenda" with specific reform proposals.

The simulation results are based on the regression results for model 5 (in Table 5) and are depicted in Figure 7 for three MIC reform scenarios:

(i) No further reforms (MIC is held constant),
(ii) Further reforms at a pace that raises MIC at the average 1991-2001 rate of MIC improvement, and
(iii) Further reforms at a quicker pace that raises MIC at the average 1974-2001 rate of MIC improvement.

If no further microeconomic reforms were adopted, Chile's aggregate GDP growth would decline quickly to rates below 3% per year toward the end of the 2002-2015 period. Note that this growth path does not entail a growth projection but is used here only to reflect a base-case scenario of no reform, against which the following reform cases should be assessed.

Further micro-structural reforms at the pace of the 1990s would help to slow down the decline in growth rates. If reforms were adopted at the average pace of the last 27 years, GDP growth would exceed no-reform growth by almost 1 percentage point toward 2015. In concluding, microeconomic-structural policy reforms have to be at the core of any policy initiative that aims to restore high growth in Chile.

Table 5
Estimation Results for Per-Capita GDP Growth, 1961-2001

	(1)	(2)	(3)	(4)	(5)	(6)
Constant	0.30 (2.2)	0.28 (2.2)	0.13 (0.6)	0.50 (2.8)	0.36 (2.2)	0.31 (2.3)
Lagged GDP per Capita (Y(-1))	-0.06 (-2.4)	-0.06 (-2.4)	-0.03 (-0.8)	-0.10 (-2.9)	-0.07 (-2.5)	1.24 (17.8)
Twice-lagged GDP per capita (Y(-2))						-0.29 (-4.2)
Macroeconomic Stability (MAC)	0.07 (1.6)	0.07 (2.5)	0.11 (2.4)	0.09 (3.4)	0.08 (3.6)	
Structural Reform Index (MIC)	0.07 (2.1)	0.07 (2.4)	0.03 (0.5)		0.04 (1.5)	
MAC-MAC(-1)	0.06 (1.1)	0.06 (1.3)	0.10 (1.3)	0.05 (1.2)	0.06 (1.5)	
MIC-MIC(-1)	-0.05 (-0.3)					
(MAC(-1)-MAC(-2)) *(MIC(-3)-MIC(-4))						0.13 (5.2)
Lagged Terms of Trade Change	0.01 (0.4)					
Trend				0.0020 (2.7)	0.0007	
Dummy 1975	-0.14 (-4.4)	-0.15 (-4.8)		-0.14 (-4.7)	-0.15 (-13.5)	
Dummy 1982	-0.20 (-6.2)	-0.20 (-6.9)		-0.19 (-7.0)	-0.20 (-28.0)	
Dummy 1983	-0.10 (-3.4)	-0.10 (-3.5)		-0.11 (-3.7)	-0.10 (-11.7)	
Dummy 1975 + Dummy 1982						-0.19 (-17.2)
R^2	0.79	0.79	0.28	0.80	0.80	0.99
R^2 A	0.75	0.75	0.20	0.76	0.75	0.99
DW	1.91	1.91	1.59	1.88	1.91	2.36
Sample	1962-2001	1961-2001	1961-2001	1961-2001	1961-2001	1964-2001

Note: OLS estimates with Newey-West t-statistics in parenthesis.

6. Conclusions

This paper has analized Chile's past growth performance and future growth prospects. It started by identifying stylized of the behavior of saving, investment, and growth during the last four decades. A broad production function that combines endogenous growth with transitional dynamics (a la Jones and Manuelli 1990) with broad reproducible capital (an aggregate of physical and human capital), and non-reproducible natural resources was applied to account for Chile's past growth and future growth prospects under alternative investment scenarios. Raising physical and human capital investment can boost short-term growth substantially but will have smaller long-term effects - the smaller the larger is the exogenous-growth component of aggregate growth. Moreover, long-term growth will not rely anymore on non-renewable natural resource exploitation which currently contributes 0.9% to Chile's growth rate.

In section 4 the latter production function was embedded in a comprehensive optimal growth model that combines the Ramsey rule with two sectors for goods and human capital (a la Uzawa 1965 and Lucas 1988), and imperfect asset substitution and endogenous sovereign risk premia for an open economy. The model was calibrated to the Chilean economy and simulated to compute future GDP growth paths for alternative depletion rates of the country's endowment of non-reproducible natural resources. The results show that even quite radical departures from base-case resource depletion have only small to moderate effects on aggregate growth in Chile. This suggests that Chile's growth potential lies elsewhere: in accumulating broad capital and raising technical progress.

The latter sources of growth depend on policies - the focus of the paper's last section. There a parsimonious specification for growth that exhibits conditional convergence to long-term trend-stationary income and permanent as well as temporary effects of policy reforms was estimated for Chile and used to simulate the growth response to alternative future policy reforms. The results show that if further micro-structural reforms were adopted at the average reform pace of the last 27 years, GDP growth would exceed no-reform growth by almost 1 percentage point toward 2015. Hence microeconomic-structural policy reforms have to be at the core of any policy initiative that aims to restore high growth in Chile.

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Appendix 1: Data

This appendix provides a description of the data used in this paper.

The capital stock is built according to the perpetual inventory method applied to a weighted average of investment in machinery and construction investment. The rate of capital depreciation is a weighted moving average of machinery depreciation (10%) and construction depreciation (2%). Physical capital growth is calculated as the growth rate of the effective capital stock, defined as the capital stock adjusted by the arte of utilization. Utilization is defined as a function of the difference between the current and the 1960-2001 unemployment rate. The relation between effective and total capital is given by $K^{eff} = K^{tot}(1-(U-U^{*}))$.

The human capital stock is based on an index that reflects the educational level and productivity of the labor force, taken from Gallego and Loayza (2001). This index is scaled to GDP following Braun and Braun (1999), which report the level of the human capital stock for 1995.

Labor employment growth (n) is defined as the percent change in the number of employed people. Quality-adjusted employment growth adjusts this rate by weighting the educational level of employed people, and the productivity level (proxied by average wages) associated to each level.

The share of natural resources in GDP is the sum of the share of mining and fisheries sectors in GDP with an estimation of the share of the manufacting sub-sector that is based on non-renewable natural resources. For the case of fisheries, the share is adjusted downward to account for exclude sustainable sea farming and other farming of aquatic resouces. Non-renewable resource growth is the weighted growth rate of the aforementioned sectors.

Appendix 2: Endogenous Growth with Transitional Dynamics, Broad capital, and Non-Renewable Natural Resources

The Model

Gross domestic product (Y) is obtained as an aggregate of three production processes or sectors. The first embeds an AK-type endogenous-growth process with constant returns to broad capital (*K*). The second sector reflects a Cobb-Douglas technology in broad capital and raw labor (*L*) with declining returns to broad capital. The third represents a Cobb-Douglas technology in physical capital (*F*) and non-reproducible natural resources (*NR*) with declining returns to physical capital as well. By contrast L is raw labor. Hence:

(A1) $$Y = Ze^{\varpi t}\left[AK + BK^{\alpha} L^{1-\alpha} + CF^{\beta} NR^{1-\beta}\right]$$

K represents here a broad form of capital that encompasses physical and human capital, as well as technology and ideas:

(A2) $$K = F^{\gamma} H^{1-\gamma}$$

where $0 < \alpha, \beta < 1$; and A, B, C, Z > 0.

The advantage of this production process is that it nests four desirable features for characterizing Chile's current growth process: constant returns to capital in the long run (and hence endogenous growth), a convergence toward the steady state along which the returns to broad capital and hence growth decline until reaching the stationary growth level, a distinction between physical and other forms of non-physical capital, and a role for non-reproducible natural resources in transitional growth.

Using small-case letters to denote variables per worker and after substituting equation (2) in (1), output per capita (that is, per unit or raw labor) can be written as:

(A3) $$y = Ze^{\varpi t}\left[A\, f^{\gamma} h^{1-\gamma} + B\left(f^{\gamma} h^{1-\gamma}\right)^{\alpha} + C\, f^{\beta} nr^{1-\beta}\right]$$

The growth rate of physical capital per capita g_f (non-physical capital per capita g_h) is determined by the exogenous physical investment ratio to output *invf* (non-physical investment ratio to output *invh*), the average product of physical capital *apf* (average product of non-physical capital *aph*), and the rates of raw labor or population growth (n) and capital depreciation (δ):

(A4) $$g_f = invf\ \ apf - (n+\delta)$$

(A5) $$g_h = invh\ \ aph - (n+\delta)$$

The growth rate of aggregate output is:

(A6) $$g \equiv \varpi + g_y + n = \frac{mpf}{apf}\, g_f + \frac{mph}{aph}\, g_h + \frac{mpnr}{apnr}\ g_{nr} + n$$

where *mpf* (*mph, mpnr*) is the marginal product of physical capital (non-physical capital, natural resources) per capita.

After substituting equations (A4)-(A5) into (A6), obtain output growth as:

(A7) $$g = \varpi + \frac{mpf}{apf}\left[invf\ \ apf - (n+\delta)\right] + \frac{mph}{aph}\left[invh\ \ aph - (n+\delta)\right] + \frac{mpnr}{apnr}\, g_{nr} + n$$

Note that average products and marginal products (as well as their ratios) of physical capital, human capital, and natural resources can be written as functions of the shares of sector 2 (s_2) and sector 3 (s_3), as follows:

(A8) $$apf = \frac{Ze^{\varpi t} A\,(h/f)^{1-\gamma}}{1 - s_2 - s_3}$$

(A9) $$s_2 = \frac{Z^{\varpi t} B\left(f^{\gamma} h^{1-\gamma}\right)^{\alpha}}{y}$$

(A10) $$s_3 = \frac{Z^{\varpi t} C\, f^{\beta}\ nr^{1-\beta}}{y}$$

(A11) $$\frac{mpf}{apf} = \gamma\ (1 - s_2 - s_3) + \gamma\, \alpha\, s_2 + \beta\, s_3$$

(A12) $$aph = \frac{Ze^{\varpi t} A (f/h)^{\gamma}}{1 - s_2}$$

(A13) $$\frac{mph}{aph} = (1-\gamma)(1-s_2) + (1-\gamma)\alpha\, s_2$$

(A14) $$\frac{mpnr}{apnr} = (1-\beta)s_3$$

Transitional growth exceeds stationary growth for two reasons. First the marginal and average products of all factors of production are larger during the transition than at the steady-state equilibrium. Second, by the very definition of non-reproducible natural resources (mostly comprised by mining deposits and fishing stock in the case of Chile), the growth rate of the latter is zero in steady state. Hence stationary GDP growth is characterized by the following equation:

(A15) $$g^* = \varpi + \frac{mpf^*}{apf^*}\left[invf\ \ apf^* - (n+\delta)\right] + \frac{mph^*}{aph^*}\left[invh\ \ aph^* - (n+\delta)\right] + n$$

where starred variables denote steady-state values of the corresponding variables defined above. Their stationary values are the following (recall that $s_2^* = 0 = s_3^*$):

(A16) $$apf^* = Ze^{\varpi t} A\left(h/f\right)^{1-\gamma}$$

(A17) $$\frac{mpf^*}{apf^*} = \gamma$$

(A18) $$aph^* = Ze^{\varpi t} A\left(f/h\right)^{\gamma}$$

(A19) $$\frac{mph^*}{aph^*} = 1-\gamma$$

<u>Model Parameterization</u>

Coefficient values: γ = 0.5, α = 0.45, β = 0.2, s_3=0.139, δ = 0.05. Three different shares are assumed for the sector with exogenous growth: s_2=0.05; s_2=0.25; s_2=0.45.

Values of exogenous variables : *n* = 1.8% (1989-2001 average) , *invf* = 27.5% (1989-2001 average), *invh* = 10%, *apf* = 0.453 (consistent with g_f = 6.6%, 1989-2001 average), *aph* = 1.07 (consistent with g_h = 4.0%), g_{nr} = 6.7% (1989-2001 average).

Hence the following values for endogenous variables are obtained:
For s2 = 0.05, *mpf/apf* = 0.443, *mph/aph*= 0.486, , *apf** = 0.324, *aph** = 1.024.
For s2 = 0.25, *mpf/apf* = 0.390, *mph/aph*= 0.431, , *apf** = 0.244, *aph** = 0.808.

For s2 = 0.45, *mpf/apf* = 0.333, *mph/aph*= 0.376, , *apf** = 0.164, *aph** = 0.593

Note that, for all values of s2, $mph^*/aph^* = mpf^*/aph^* = 0.5$.

Substituting the preceding values in the current growth equation (A7) and the steady-state growth equation (A15) allows to obtain the corresponding values for 1989-201 and the higher-investment scenario, reported in Table 4.

Appendix 3: Steady-State Solution of Dynamic Optimization Model

Define: $\hat{x} \equiv \frac{\dot{x}}{x}, \forall x$. Steady-state levels of all variables x are denoted by an asterisc (x*).

At steady state:

$$\hat{C} = \hat{Y} = \hat{K} = \hat{H} = \hat{F}$$
$$\hat{R} = R = \hat{p} = O.$$

Steady-state equations:

(12)* $$\hat{C}^* = \frac{1}{\theta}\left(r^* - 2\psi\left(\frac{F}{qK + pH}\right)^* - \rho \right)$$

(13) $q = (1+ti)$

(14)* $$Z\left[\alpha A\left(\frac{uH}{K}\right)^{*(1-\alpha)}\right](1-ty) + \psi\left(\frac{F}{qK + pH}\right)^{*2}(1+ti) = r^* - 2\psi\left(\frac{F}{qK + pH}\right)^* + (1+ti)\delta$$

(15)* $$p = \frac{Z}{E}\left[(1-\alpha)A\left(\frac{K}{uH}\right)^{*\alpha}\right](1-ty)$$

(16)* $$\psi\left(\frac{F}{qK + pH}\right)^{*2} p = r^* - 2\psi\left(\frac{F}{qK + pH}\right)^* + \varepsilon + E - th$$

(6)* $$\hat{H}^* = E(1-u) - (\varepsilon + n)$$

$$\left(\frac{\dot{F}}{F}\right)^{*} \equiv \hat{F}^{*} = \left(\frac{Y}{F}\right)^{*}(1-ty) - \left(\frac{C}{F}\right)^{*}(1+tc) - \left[\left(\frac{K}{K}\right)^{*} + (\delta+n)\right]\left(\frac{K}{F}\right)^{*}(1+ti) - p\left(\frac{H}{F}\right)^{*} th$$

$$+\frac{TR}{F} + \frac{TR^{*}}{F} + (r-n)$$

Therefore:

$$\hat{F}^{*} = ZA\left(\frac{uH}{K}\right)^{*1-\alpha}\left(\frac{K}{F}\right)^{*} - \left(\frac{C}{F}\right)^{*} - \left[\hat{K}^{*} + (\delta+n)\right]\left(\frac{K}{F}\right)^{*}$$

(4)*

$$+\left(\frac{TR^{*}}{Y}\right)^{*} ZA\left(\frac{uH}{K}\right)^{*(1-\alpha)}\left(\frac{K}{F}\right)^{*}$$

There is an additional relation between consumption and foreign assets in steady state. Forward integration of the budget constraint, application of the NPG condition, and of the Euler eq. (12) yields the following standard consumption function of wealth:

$$C = \left[\frac{1}{\theta}\rho + \left(1-\frac{1}{\theta}\right)r\right]W = \left[\frac{1}{\theta}\rho + \left(1-\frac{1}{\theta}\right)\left(r^{*} - \psi\frac{F}{qK+pH}\right)\right]\left\{qK + pH + F + \frac{TR^{*}}{r+n}\right\}$$

Hence:

(17)* $$\left(\frac{C}{F}\right)^{*} = \left[\frac{1}{\theta}\rho + \left(1-\frac{1}{\theta}\right)\left(r^{*} - \psi\frac{F}{qK+pH}\right)\right]\left\{\frac{qK+pH}{F} + 1 + \frac{TR^{*}/F}{r^{*} - \psi\frac{F}{qK+pH} + n}\right\}$$

Appendix 4
Accounting for and Explaining Chile's Growth in 16 Recent Studies

Study	Methodology	Time Period	Results on Sources of Growth	Results on Underlying Growth determinants
Marfán and Bosworth (1994)	Growth Accounting, Simple Econometrics	1960-1992	However the authors do not report specific values, they argue that there is no clear evidence that observed recovering in the period after 1983 was due to an improvement in PTF. Authors suggest that it was a cyclical recovery from a big recession combined with higher capital accumulation. Only in the 1989-92 period it was observed an increase in TFP.	
De Gregorio (1997)	Growth Accounting, Cross-country regressions	1975-1997 1960-1997	The GDP growth decomposition for 1990-97 reports the following values (in parenthesis the change regarding 1975-89): GDP growth: 6.7% (3.4%); Physical capital contribution: 2.7% (1.7%); Labor contribution: 1.5% (-0.3%); and TFP contribution: 2.6% (2.1%).	The exercise using the results of cross-country regressions suggest that the increase of growth in the 1990s regarding 1960-85 can be mainly explained by higher human and physical capital accumulation (the reduction of inflation has also a positive, but secondary, impact). Physical capital contributes with an increase of 1.1-1.5% per year, and human capital with 1.3-1.4% per year.
Roldós (1997)	Growth Accounting, Time Series Econometrics	1966-1995	The GDP growth decomposition adjusting for utilization and quality of inputs for 1991-95 reports the following values (in parenthesis the change regarding 1971-90): GDP growth: 7.5% (4.7%); Physical capital contribution: 4.1% (2.8%); Labor contribution: 1.9% (-0.5%); and TFP contribution: 1.4% (2.3%).	The estimated econometric model suggests the imported capital goods had an important impact on growth rates. This impact works especially trough higher TFP growth
Rojas, Jiménez, and López (1997)	Time Series Econometrics	1960-1996	The *potential* GDP growth decomposition using regression results for 1991-96 reports the following values (in parenthesis the change regarding 1961-96): GDP growth: 6.5% (2.7%); Physical capital contribution: 2.0% (0.4%); Labor contribution: 3.1% (0.8%); and TFP contribution: 1.4%	The increase in TFP can be mainly decomposed in the effect of trade openness (1.1%), and terms of tarde (0.1%). Actually, an increase of 1% in trade openness increases GDP growth by 0.62%

			(1.4%).	
Lefort (1997)	Cross-country regressions	1960-1995		Cross-country regressions imply that the increase of GDP growth rate in 1975-95 regarding 1960-75 (2.3%) can be almost fully explained by policy reform variables (2.0%).
Barro (1999)	Cross-country regressions	1965-1995		Regression results are used to explain why Chilean per-capita GDP was 1.5% higher than the world average in the 1965-95 period. This is mainly due to the impact of two variables: relatively small government (0.8%) and fertility rates (0.6%).
Coeymans (1999)	Growth accounting, time series econometrics	1960-1998	The GDP growth decomposition for 1989-97 reports the following values (in parenthesis the change regarding 1961-98): GDP growth: 7.8% (3.7%); Physical capital contribution: 2.0% (0.8%); Labor contribution: 1.6% (0.1%); and TFP contribution: 4.2% (2.9%).	Regression results imply that the most important factors behind the increase in TFP are related with trade openness, the terms of trade, and the availability of external financing measured several indicators.
Schmidt-Hebbel (1999)	Endogenous growth model with dynamic transition and natural resources	1961-1997	The increase in growth in Chile in 1990-97 with respect to 1961-74 was a consequence of higher investment in physical capital and higher TFP growth.	The increase in the investment rate (13 p.p. of GDP) was mainly a consequence of better structural policies (6.4 p.p. of GDP) and lower corporate rate on retained profits (3.2 p.p. of GDP). The increase in TFP growth was (2% per year) was driven by better structural policies (1.6%) and macroeconomic stability (1.3%). The transition dynamics emerges mainly from natural resources depletion
De Gregorio and Lee (1999)	Cross-country regressions	1965-1995	The GDP growth decomposition for 1990-97 reports the following values (in parenthesis the change regarding 1960-97) for the TFP contribution: 3.6% (2.2%).	The authors explain the annual difference in per-capita GDP growth of Chile with respect Latin America (1.4% per year). The difference can be explained by almost equal contributions of better human resources (1.3%) and better institutions (1.0%) than the average country in Latin America.
Jadresic and Zahler (2000)	Time series econometrics	1961-1998		Difference in per worker GDP growth in the 1990s with respect to the 1960s (2.5%) can be mainly explained by structural reforms (2.5%).

				Other factors that contribute to the increase are the reduction of inflation (0.7%) that is exactly compensated with a reduction in political rights. While, the difference in growth in the 1990s with respect to the 1970s (4.6%) can be explained by lower inflation (4.5%), better structural policies (1.7%), and higher political rights (1.6%). The negative impact of higher foreign interest rates on growth compensates the above-mentioned impacts (-3.2%). In turn, higher political rights mainly explain the differences of the 1990s with respect to the 1980s
Bergoeing and others (2001)	Calibrated general equilibrium model	1981-2000	Per-worker GDP growth in the recovery period of 1983-2000 (4.43%) is mainly explained by TFP growth (3.57) and the reminder is explained by employment (1%).	Results of a calibrated model suggest that the tax reform of 1984 had an impact on per-worker GDP growth (1.41%), which can be decomposed affecting both capital accumulation (almost 1%) and employment growth (the remaining 0.4%)
Chumacero and Fuentes (2001)	Growth accounting and time series econometrics	1961-2000	Growth accounting exercises show that the growth rates of the sixties are mainly due to the accumulation of human (54%) and physical (37%) capital, while the booms of the mid seventies and the one from 1985 until 1998 are mainly due to TFP growth (which increased its contribution from almost zero to rough one third of total growth).	The most important determinants of the evolution of TFP are the evolution of terms of trade, improvements on the quality of capital, and the presence of distortions (measured as the ratio of government expenditure to GDP.)
Corbo and Tessada (2001)	Growth accounting	1951-1997	In the period of high growth (1986-97) rough a half of total GDP growth can be explained by TFP growth. While, the increase of GDP growth (2.1% per year) in 1996-97 was explained by a big jump of the contribution of capital accumulation (from 1.6% to 4.8%, that compensates a decrease of TFP of almost 1%)	
Hofman (2001)			Growth accounting exercises show that the growth rates of the nineties are due to the contribution of labor (21%), capital physical (29%), but mainly by TFP growth (51%). The relative contribution of TFP is quite similar to the	

			1950-73 period, however the contribution of labor increases notably (from 7%). Of course, the TFP growth almost doubled during the 1990s.	
Hsieh and Parker (2001)	Microeconometrics and partial equilibrium model	1982-92		Authors argue that the mid 1980s reduction in the tax rate on retained profits was the main cause of the Chile's investment and growth boom that began in the mid 1980s. This is interpreted in the context of a model of investment with underdeveloped financial markets.
Gallego and Loayza (2001)	Growth Accounting, VAR analysis, and cross-country regressions	1960-2000	The GDP growth decomposition adjusting for utilization and quality of inputs for 1986-2000 reports the following values (in parenthesis the change regarding 1960-85): GDP growth: 6.6% (4.1%); Physical capital contribution: 2.5% (1.5%); Labor contribution: 2.3% (0.8%); and TFP contribution: 1.9% (1.8%).	VAR analyses suggest that investment, and domestic and foreign saving do not cause, but follow, growth. Results from cross-country regressions re used to decompose the increase of GDP-growth in 1986-1998 regarding 1971-85 (4.74%). The most important factors are the following: - Human capital: 1.2% - Policy complementarities: 1.1% - Civil liberties: 0.6% - Financial development: 0.5% - Government distortions: 0.8% - Infrastructure: 0.4% It remains a 1.5% p.p.of per-capita growth unexplained (however, it is statistically not significant)

Figure 1
Real GDP Growth, TFP Growth, and Unemployment Rate
(Chile, 1961-2001)
(percentage)

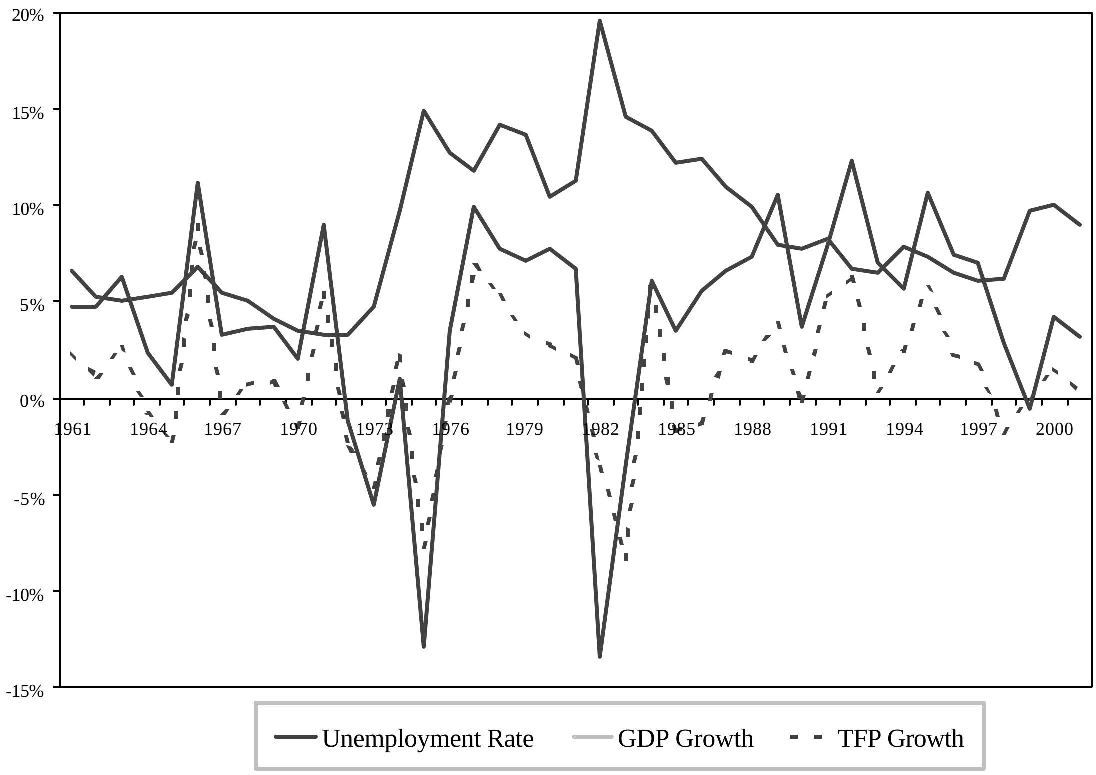


Figure 2
Gross Domestic Investment, National Saving, and Foreign Saving Rates
(Chile, 1960-2001)
(percentage of GDP)

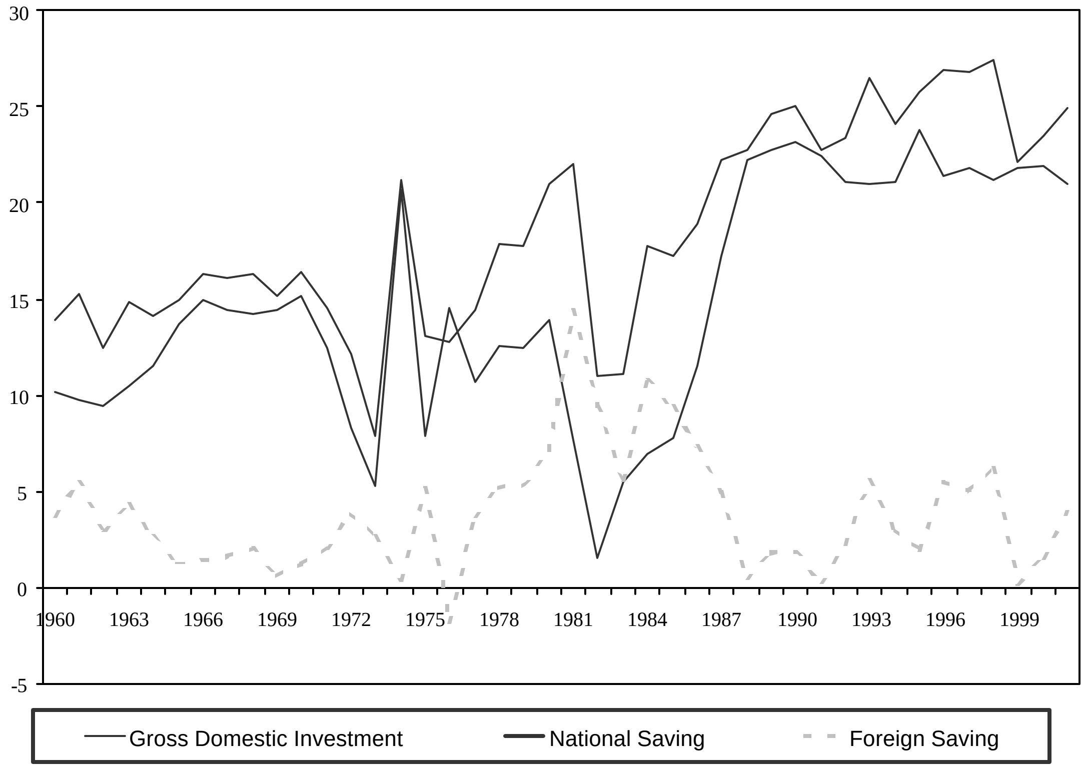
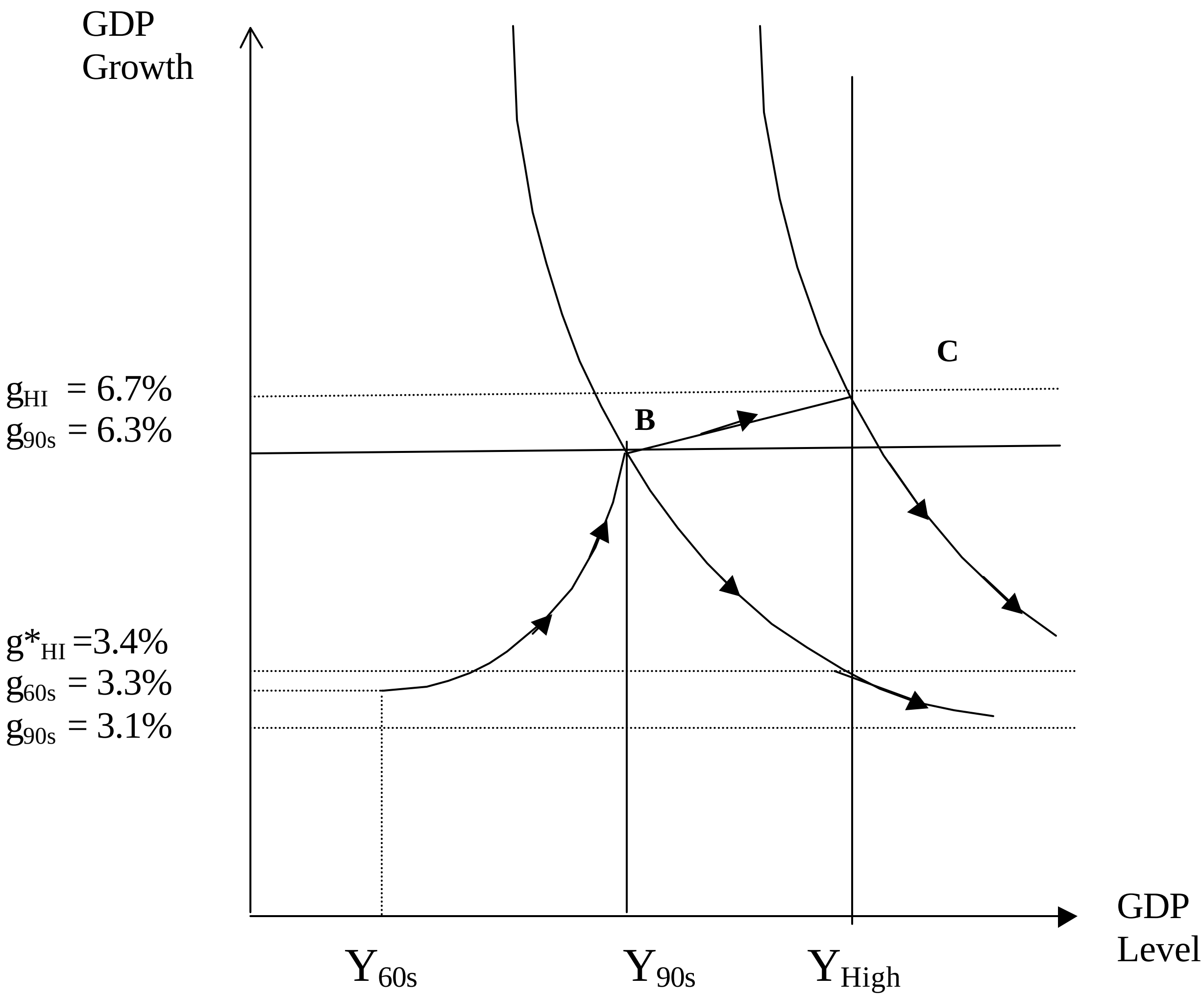
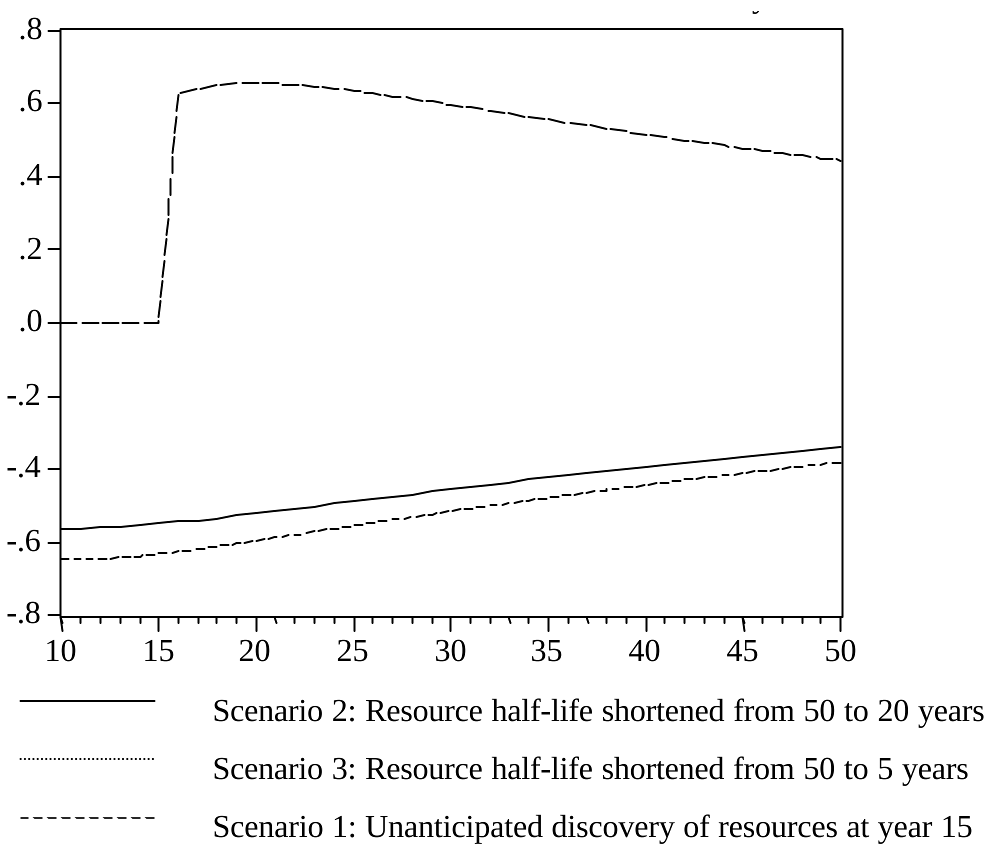


Figure 3
Past Growth and Future Growth Prospects
under Endogenous Growth with Transitional Dynamics



Note: this figure corresponds to the intermediate simulations reported in Table 4, with a 25% share of the exogenous growth component.
g_{60s} and g_{90s} is average actual GDP growth in 1961-74 and 1989-2001, respectively, while g^*_{90s} is steady-state growth consistent with growth in the 1990s. g_{HI} and g^*_{HI} are initial and steady-state growth rates consistent with higher investment rates.

Figure 4
Optimal Future Growth Transitions under Alternative Paths of Resource Depletion
(Percentage Growth Deviations from Base Case)



Note: Simulation results based on the optimal growth model of section 4.

Figure 5
Macroeconomic Stabilization and Micro-Structural Reform Indexes
(Chile, 1960-2001)

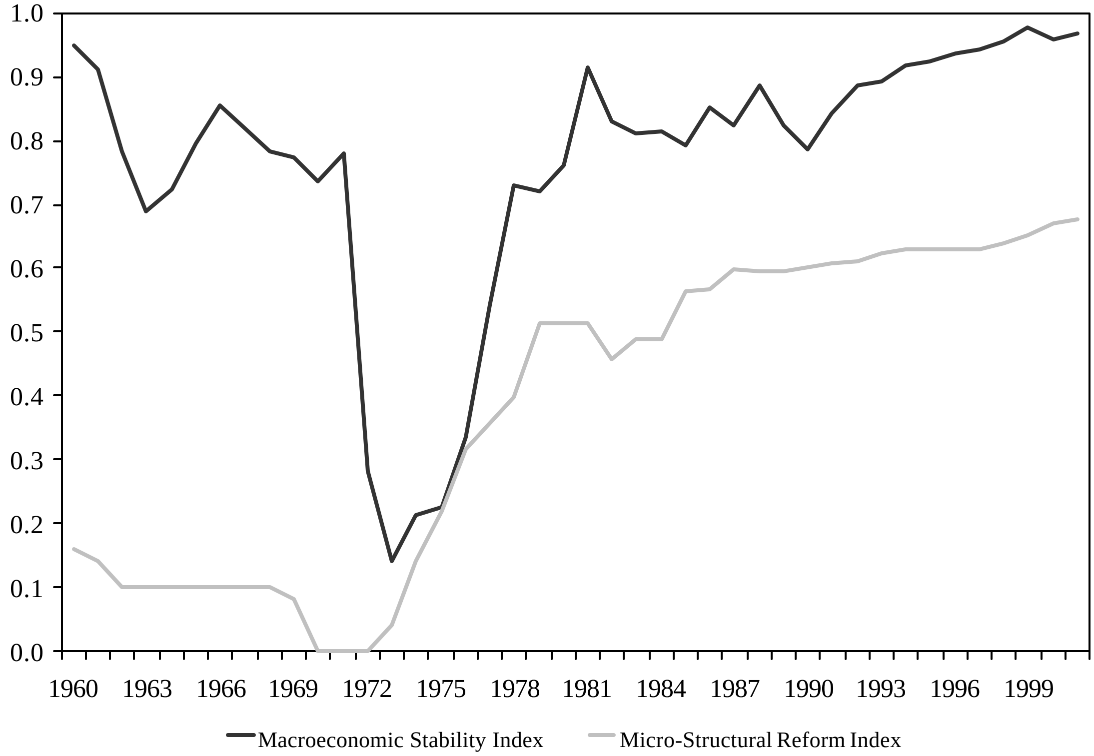


Figure 6

Equation 5: Actual and Fitted Values of Per Capita GDP Growth (Chile, 1961-2001)

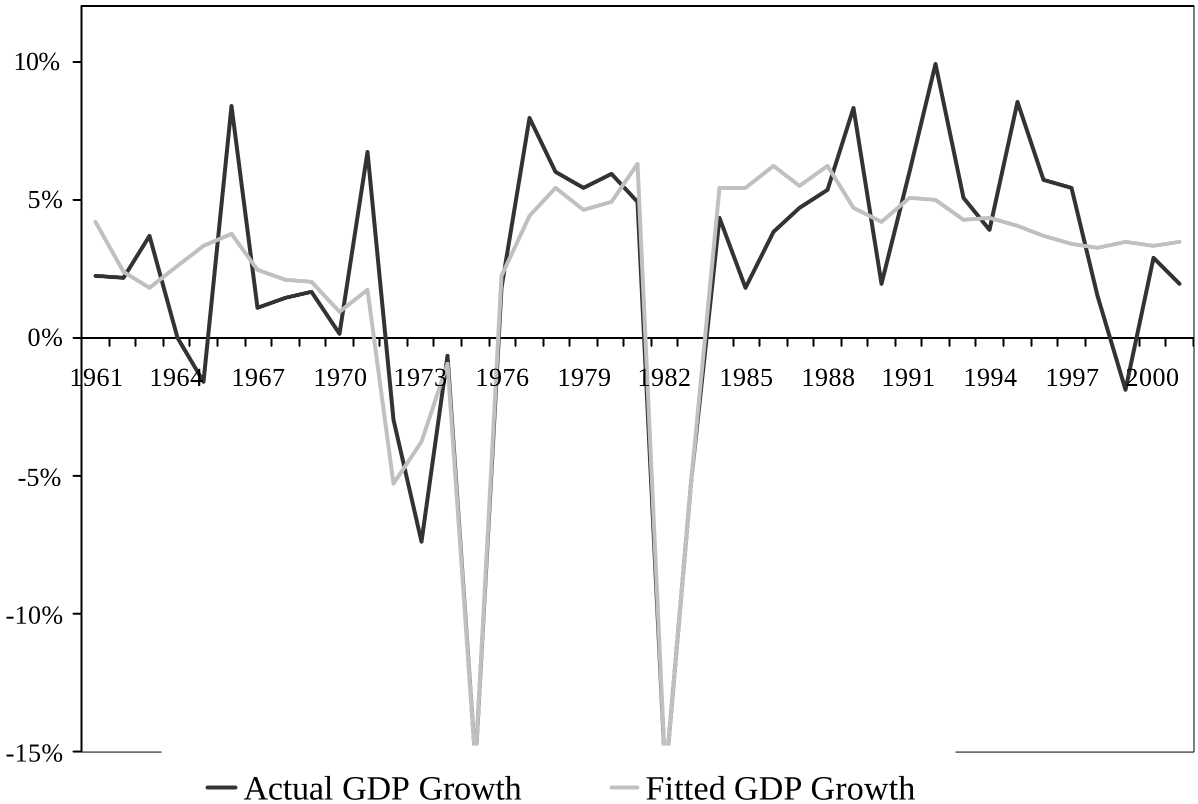


Figure 7
Actual and Simulated GDP Growth with
Alternative Paths of Micro-Structural Reforms
1997-2015

Equation 5