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Investment-Specific Productivity Growth: Chile in a Global Perspective

Gabriel Di Bella and Martín Cerisola

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Abstract

By the end of 2007, Chile's total factor productivity was lower than ten years earlier, a performance that contrasted sharply with the previous decade, when productivity grew by a cumulative 30 percent. This paper assesses productivity trends in Chile, by decomposing productivity into investment-specific technological change (associated with improvements in the quality of capital) and neutral technological change (related to the organization of productive activities). It concludes that investment-specific technological improvements have contributed significantly to long-term growth in Chile, in line with trends observed in other net commodity exporters, while neutral technological change has been slow.

JEL Classification Numbers: E13, O30, O41, O47, O51

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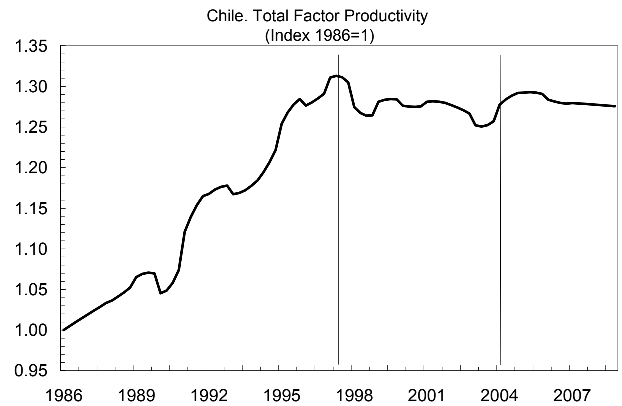
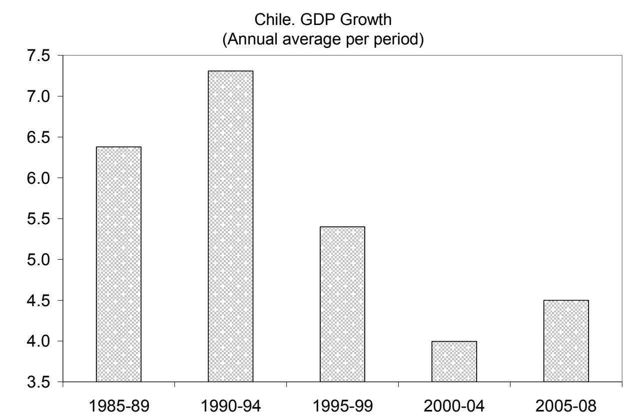
I. Introduction

The issue of productivity growth has received considerable attention over the past twenty years, most notably in advanced economies. Much has been written and said in academic and policy fora about the underlying sources and persistence of the productivity boom observed in the United States during the 1990s (Gordon, 1990, 2003, 2006). And the consensus seems to be that the sharp rise in investment, particularly the one associated with the adoption and incorporation of new technologies, has made an important contribution to U.S. productivity over the long term.





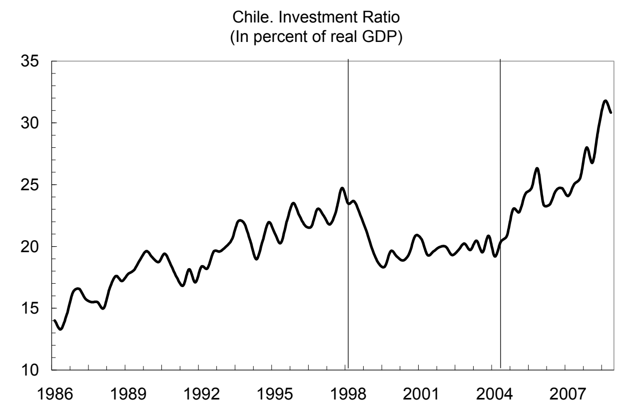
Against this background, the lackluster performance of Chile's productivity growth is somewhat surprising. According to official estimates, total factor productivity (TFP) at end-2007 was about 2 percent lower than that at end-1997, (Ministerio de Hacienda, 2008). This performance contrasts sharply with the performance during 1986–97, when productivity grew by a cumulative 30 percent. Most importantly, the decline in TFP growth in the past decade has occurred in tandem with a deceleration in average GDP growth.

Aside from the clear change in trend observed in 1998, the behavior of Chile's TFP has been especially puzzling since 2004. Given Chile's strong integration with the world economy, some attributed the post-1997 slowdown in productivity growth to the effects of the Asian crisis and the September 11 aftermath. Indeed, beginning in 1998, investment rates in Chile decreased with respect to those observed earlier in the decade. However, since 2004 investment has picked up markedly, but measured productivity growth has continued to be lackluster.

The productivity slowdown in Chile is more puzzling because it coincides with a marked increase of investment in machinery and equipment. In particular:

- *Investment in machinery and equipment has almost doubled (as percentage of GDP) from 2004, and by end-2008 amounted to about half of total investment:* The strong increase in investment in machinery and equipment observed since late 2004 is part of a longer trend that started in the 1980s, and which has coincided with a secular decrease in the relative price of machinery and equipment in terms of consumption goods, as technological advances made machinery and equipment less expensive. A similar trend seems to be present in several high income and emerging economies (Figure 1).

- *New machinery and equipment usually incorporates the latest technological advances.* New M&E is embedded with investment-specific productivity (ISP) improvements that make them more productive than the existing stock of M&E; this is especially true in Chile, where more than 80 percent of M&E purchases are imported. In addition, investment in M&E is also tends to be more productive than other types of investment, like housing. However, as explained by Hornstein and Krussell (1996), an increase in the rate of investment-specific technological improvements may lead to a decrease in measured productivity performance, resulting from learning and quality mismeasurements associated with new technologies.



This paper looks at Chile's productivity trends since the mid-1980s, including from a global comparative perspective. Chile's experience with investment and productivity is compared with a group of OECD countries, including net commodity exporters (Australia, Canada, and Norway), as well as importers (Korea and Netherlands). A more accurate measure of total factor productivity, that explicitly accounts for the productivity embedded in Chile's large share of investment in M&E, allows to decompose growth in output per (effective) hour in two sources: (i) Investment-specific productivity increases (linked with technological improvements in M&E); and, (ii) neutral factor productivity changes (associated with changes in the organization of productive activities). The rest of the paper is organized as follows. Section II presents the general equilibrium model adapted from Greenwood et al. (1997) Section III estimates the balanced growth path conditions and calibrate the model to Chile and other net commodity exporters. Section IV assesses the productivity trends for Chile in a global comparative perspective. Section V discusses the potential role of several factors that could help explain the slowdown in productivity growth. Section VI concludes.

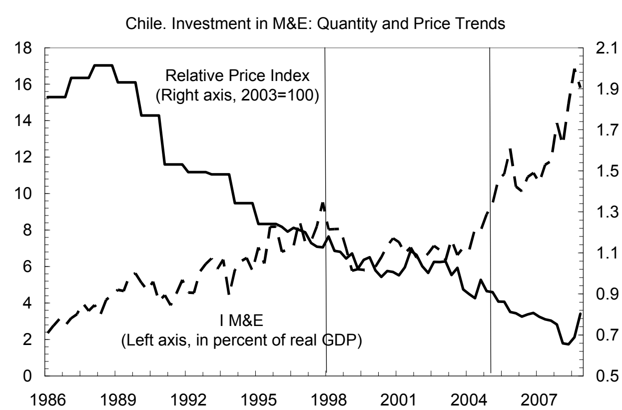
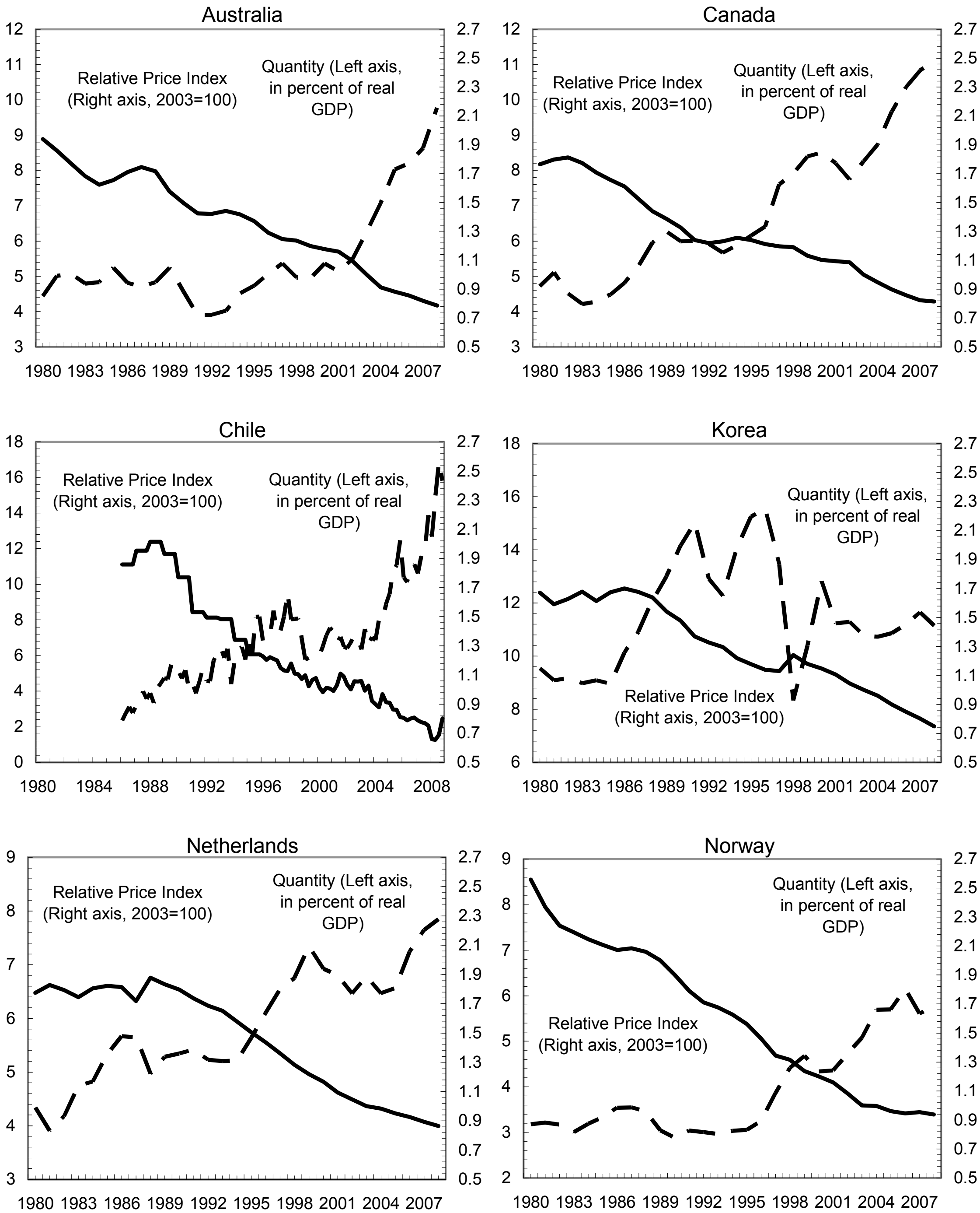


Figure 1. Investment in Machinery and Equipment:
Quantity and Relative Price Trends



Source: Fund Staff calculations.

II. The Economic Environment

Productivity trends are analyzed in the context of a general equilibrium model. The model used here adapts that used by Greenwood, Hercowitz and Krusell (GHK, 1997) to analyze similar developments for the U.S economy, following the work by Chan-Lau and Cerisola (2000) applied to compare productivity trends in the United States and Canada. The production function in GHK was modified to allow for (exogenous) increases in labor-specific productivity, as well as to incorporate an index of utilization of the capital stock. Both modifications were introduced in order to better account for country-specific issues, and to make the results more comparable to those produced by the Chilean authorities (Ministerio de Hacienda, 2008).

The economy is deterministic and is populated by a representative household, a representative firm and a government. The representative household maximizes (discounted) utility over leisure and consumption:

$$\sum_{t=0}^{\infty} U(c_t, l_t) \tag{1}$$

$$U(c_t, 1-l_t) = \theta \ln(c_t) + (1-\theta)\ln(1-l_t), \tag{2}$$

where c_t is consumption, l_t is labor effort and $0 < \theta < 1$.

Final output is produced by a representative firm that maximizes profits operating a constant returns to scale Cobb-Douglas production function:

$$y_t = z_t F(u_{k,t}k_{e,t}, u_{k,t}k_{s,t}, l_t) = z_t (u_{k,t}k_{e,t})^{\alpha_e} (u_{k,t}k_{s,t})^{\alpha_s} (l_t)^{1-\alpha_e-\alpha_s}, \tag{3}$$

where, y_t is output of final consumption goods, z_t is a measure of total-factor, or neutral, productivity and $0 < \alpha_e, \alpha_s, \alpha_e + \alpha_s < 1$. There are two types of capital: machinery and equipment, $k_{e,t}$, and non-housing structures $k_{s,t}$; the utilization of the capital stock is denoted by $u_{k,t}$, which is assumed to be known, exogenous, and the same for both equipment and structures. Note that $z_t = \gamma_z^{\,t}$, where γ_z denotes the (gross) growth rate of neutral productivity.

Final output can be used for consumption and investment in equipment and machinery, $i_{e,t}$,and in structures, $i_{s,t}$:

$$y_t = c_t + i_{e,t} + i_{s,t}. \tag{4}$$

The stock of structures evolves according to,

$$\gamma_{H,N} k_{s,t+1} = k_{s,t}(1-\delta_s) + i_{s,t}\,, \tag{5}$$

where, $\gamma_{H,N} = \gamma_H \gamma_N$ denotes the combined growth (gross) rate of working age population, γ_N , and human capital, γ_H , both assumed to be exogenous and known, and δ_s is the depreciation rate of structures.

The stock of machinery and equipment evolves according to,

$$\gamma_{H,N} k_{e,t+1} = k_{e,t}(1-\delta_s) + q_t i_{e,t}\,, \tag{6}$$

where, q_t is an index of investment-specific productivity (ISP), that measures the quality of new equipment, and δ_e, is the depreciation rate of equipment. There is also a government that levies taxes on labor income, τ_l ,and on both forms of capital, τ_k . The government transfers back to the consumer, in the form of a lump-sum transfer, τ , the revenue raised from taxes:

$$\tau = \tau_k \left(r_{e,t} k_{e,t} + r_{s,t} k_{s,t} \right) + \tau_l w_t l_t\,, \tag{7}$$

where, r_e represents the return for the services of equipment, r_s represents the return for the services of structures and w denotes wages paid to labor.

III. Balanced Growth Path Conditions and Model Calibration

The variables y, c, i_e, i_s, k_e, k_s in (1)-(7) are normalized in terms of effective available labor, e.g., in the case output, $y_t = Y_t / N_t H_t$, where Y_t is aggregate output, N_t denotes non-leisure hours of the working age population and H_t represents a measure of human capital. Note that $N_t = \gamma_N{}^t$ and that $H_t = \gamma_H{}^t$. As finding a balanced growth path (BGP) requires an adequate transformation of variables, note that (4) implies that, along a BGP, output, consumption, and investment all grow at the same rate, γ_y; note also that γ_y denotes the (gross) growth rate of output per available effective hour. From (5) the stock of structures should also grow at rate γ_y; however, (6) implies that the stock of equipment will grow faster, at (gross) rate γ_e. The production function (3) implies that $\gamma_y = \gamma_z \gamma_e{}^{\alpha_e} \gamma_y{}^{\alpha_s}$; thus, as GHK point out, the following restrictions are imposed on a BGP:

$$\gamma_y = \gamma_z{}^{1/\left(1-\alpha_e-\alpha_s\right)} \gamma_q{}^{\alpha_e/\left(1-\alpha_e-\alpha_s\right)}\text{, and,} \tag{8}$$

$$\gamma_e = \gamma_z{}^{1/\left(1-\alpha_e-\alpha_s\right)} \gamma_q{}^{(1-\alpha_s)/\left(1-\alpha_e-\alpha_s\right)}\,, \tag{9}$$

where γ_q is the (gross) growth rate of q_t. In turn, if one is interested in output per available hour, equation (8) should be modified to incorporate the rate of growth of human capital, as follows:

$$\gamma_y = \gamma_z^{1/(1-\alpha_e-\alpha_s)} \gamma_q^{\alpha_e/(1-\alpha_e-\alpha_s)} \gamma_H \, . \tag{10}$$

Using (8)-(9), the transformation of the problem into one in which all variables are stationary, requires first defining $\tilde{x}_t = x_t / \gamma_y^{\,t}$, with x equal to output, consumption, investment and the stock of structures; then one should define $\tilde{k}_{e,t} = k_{e,t} / \gamma_e^{\,t}$, $\tilde{z}_t = z_t / \gamma_z^{\,t}$ and finally $\tilde{q}_t = q_t / \gamma_q^{\,t}$. Assuming that the economy behaves competitively, the BGP conditions for the transformed problem are as follow:

$$\gamma_q = (\beta / \gamma_{H,N}\gamma_y)[(1-\tau_k)\alpha_e \cdot \tilde{y} / \tilde{k}_e + (1-\delta_e)] \, , \tag{11}$$

$$1 = (\beta / \gamma_{H,N}\gamma_y)[(1-\tau_k)\alpha_s \cdot \tilde{y} / \tilde{k}_s + (1-\delta_s)] \, , \tag{12}$$

$$\tilde{i}_e / \tilde{y} = \tilde{k}_e / \tilde{y}\left[\gamma_q \gamma_{H,N}\gamma_y - (1-\delta_e)\right] , \tag{13}$$

$$\tilde{i}_s / \tilde{y} = \tilde{k}_s / \tilde{y}\left[\gamma_{H,N}\gamma_y - (1-\delta_e)\right] , \tag{14}$$

$$(1-\tau_l)(1-\alpha_e-\alpha_s)\frac{\theta(1-l)}{(1-\theta)\tilde{c}/\tilde{y}} = l \, , \tag{15}$$

$$\tilde{c} / \tilde{y} + \tilde{i}_e / \tilde{y} + \tilde{i}_s / \tilde{y} = 1 \, , \tag{16}$$

The 18 unknowns associated with the balanced growth conditions are γ_y, γ_N, γ_H, γ_q, θ, β, τ_K, τ_L, δ_e, δ_s, α_e, α_s, l, $\tilde{c}/\tilde{y}$, $\tilde{i}_e/\tilde{y}$, $\tilde{i}_s/\tilde{y}$, $\tilde{k}_e/\tilde{y}$, and $\tilde{k}_s/\tilde{y}$; thus, the solution of the system (11)-(16) requires calibrating 12 parameters. Following GHK, the calibration procedure implies choosing the values of the unknowns in the BGP so they coincide with their average values observed during the period considered. The variables chosen for calibration are: γ_y, γ_N, γ_H, γ_q, τ_K, τ_L, δ_e, δ_s, $(\alpha_e+\alpha_s)$, l, $\tilde{i}_e/\tilde{y}$, and $\tilde{i}_s/\tilde{y}$. In particular, with respect to γ_q, note that ISP is proxied by the ratio of the implicit price deflator for personal consumption expenditures to the implicit price deflator for equipment and machinery.

Once the parameters are determined, total neutral productivity, z, can be calculated from equation (3), and the contributions to long-term growth can be calculated either from (8) or

(10), depending on whether one is interested in output per *effective* hour worked, or output per hour worked. The calibration results are shown in Table 1.[2]

Table 1.Calibration Results

	Australia	Canada	**Chile**	Korea	Netherlands	Norway
ie/y	0.06	0.07	**0.07**	0.12	0.06	0.04
is/y	0.07	0.07	**0.08**	0.14	0.08	0.08
alfa e + alfa s	0.40	0.33	**0.40**	0.40	0.35	0.40
tao L	0.52	0.44	**0.32**	0.45	0.62	0.57
tao k	0.30	0.46	**0.15**	0.29	0.33	0.28
l	0.21	0.24	**0.23**	0.33	0.19	0.25
delta e	0.15	0.15	**0.13**	0.15	0.15	0.13
delta s	0.04	0.04	**0.04**	0.04	0.04	0.04
gamma y	1.01	1.01	**1.03**	1.04	1.02	1.02
gamma H	1.01	1.01	**1.01**	1.01	1.00	1.00
gamma N	1.02	1.01	**1.02**	1.02	1.01	1.01
gamma q	1.03	1.03	**1.04**	1.03	1.03	1.04
gamma H,N	1.02	1.04	**1.03**	1.04	1.00	1.04
c/y	0.87	0.86	**0.85**	0.73	0.85	0.88
theta	0.45	0.42	**0.38**	0.52	0.45	0.53
k s / y	0.97	0.99	**0.84**	1.34	1.24	1.20
k e / y	0.26	0.37	**0.31**	0.50	0.31	0.21
beta	0.89	0.98	**0.96**	0.99	0.95	0.90
alfa e	0.13	0.16	**0.14**	0.18	0.12	0.09
alfa s	0.27	0.17	**0.26**	0.22	0.23	0.31

Source: Fund Staff calculations.

A numerical approximation of the contribution of each factor to output growth is relevant to assess several macroeconomic questions, including long-run fiscal policy, the solvency of entitlement programs, as well as potential GDP growth forecasting (Gordon, 2003).

[2] Datasets and program codes used in this calibration are available upon request.

IV. Assessing Productivity trends: Chile in a Global Comparative Perspective

The results from the calibration suggest that improvements in investment-specific productivity have contributed significantly to long-term growth in Chile. In particular:

- *As in all countries analyzed, ISP growth in Chile has been significant.* It has averaged about 3.8 percent per year, similar to that of Norway (3.6 percent per year). ISP growth in rest of the countries analyzed averaged about 3 percent per year.

- *Neutral, factor productivity (TNP) growth has been, on average, lower than ISP growth in all countries.* In the case of Chile, it has averaged 0.7 percent per year, similar to that in Norway. For the net commodity exporters in the sample (Australia, Canada, Chile and Norway) the lower average TNP growth masks differing behaviors in two periods, with TNP growth being positive until late 1990s or early 2000s and turning negative afterwards (Figure 2).

Output, ISP and TNP Growth
(Average percent per year)

	Ouput per effective hour	Ouput per hour	ISP	TNP
Australia	1.0	1.6	3.3	0.1
Canada	0.7	1.3	2.8	0.2
Chile 1/	**2.8**	**3.9**	**3.8**	**0.7**
Korea	4.3	4.9	2.9	2.4
Netherlands	1.5	1.9	2.6	0.9
Norway	1.6	2.1	3.6	0.7

Source: Fund Staff calculations.

1/ 1986-2008

- *ISP growth accounted for about 45 percent of the long-term growth in output per effective hour in Chile.* ISP contribution to growth seems to have been the largest in Australia and Canada (above 70 percent), and the lowest in Netherlands and Korea.[3]

- *ISP growth contribution to the long-term growth of output per hour was 28 percent in Chile.* However, TNP contributed to 37 percent, and growth in human capital (HK) the remaining 35 percent. The contribution of HK to long-term output per hour in Chile is similar to those obtained for Australia and Canada, and higher than in the other three countries.

Long-Run Contribution to Growth
(In percent)

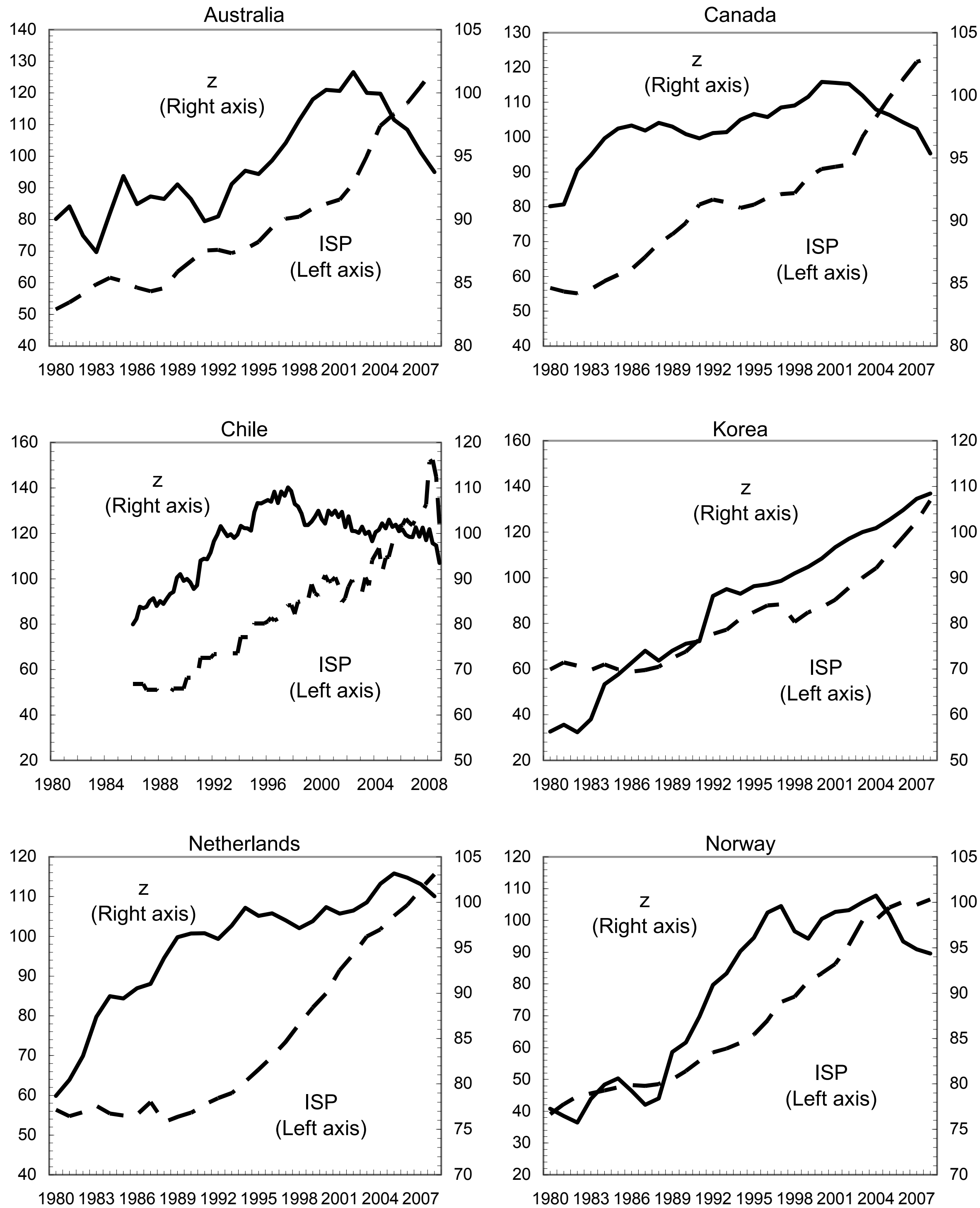
	Ouput per effective hour		Ouput per hour		
	ISP	TNP	ISP	TNP	HK
Australia	74	26	46	16	38
Canada	73	27	44	17	39
Chile 1/	**43**	**57**	**28**	**37**	**35**
Korea	18	82	16	73	12
Netherlands	26	74	21	61	18
Norway	32	68	25	54	21

Source: Fund Staff calculations.

1/ 1986-2008

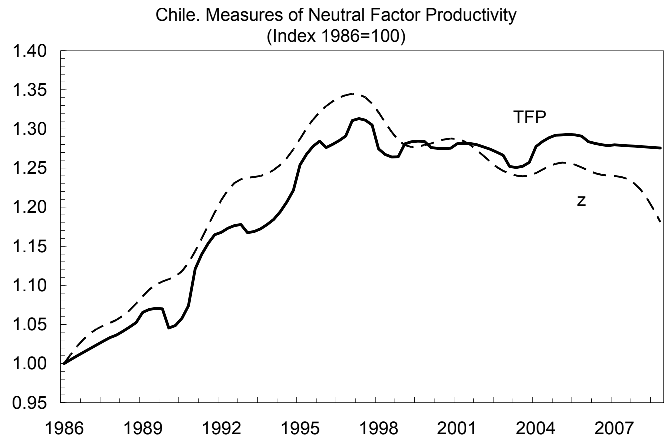
[3] Output per effective hour is defined as output per hour deflated by an index of human capital, which is proxied by the average number of schooling years of the labor force, (Ministerio de Hacienda, 2008).

Figure 2. Investment-Specific Productivity (ISP) and Total Factor Productivity (z)
(Index Average 2003=100)

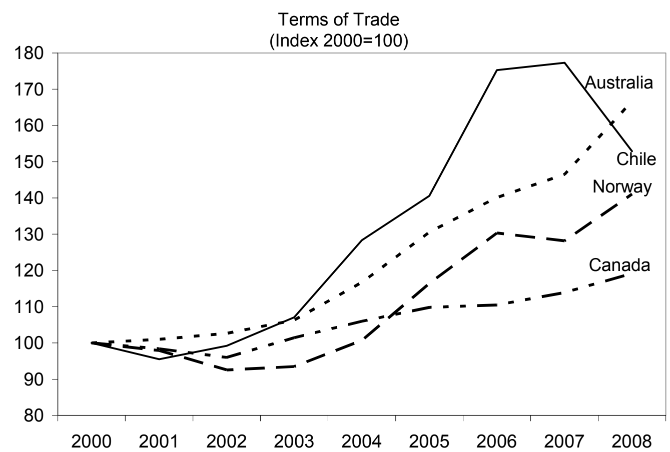


Source: Fund Staff calculations.

- *The contribution of ISP to output growth has increased significantly since the mid-1990s.* This increase was particularly large in Chile and the net commodity exporters. (Figure 2). However, the contribution of TNP to growth decreased during the last decade. In the case of Chile, this decrease results in a productivity measure that is consistently below the official estimates (depicted as TFP).



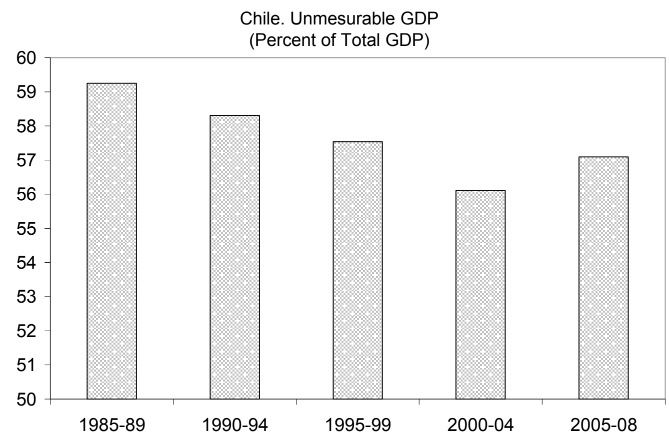
- *There appears to be some simultaneity in the behavior of TNP of net commodity exporters, especially since the mid-2000s*. As Figure 2 shows, TNP decreased in Australia, Canada, Chile and Norway since about 2004. In all cases, the observed declines in z were accompanied by significant increases in investment in M&E as percentage of GDP (Figure 1) and with sharp improvements in their terms of trade.



V. WHAT COULD EXPLAIN THE PRODUCTIVITY SLOWDOWN?

There are a number of possible explanations for the slowdown of TNP observed in Chile. Most notably:

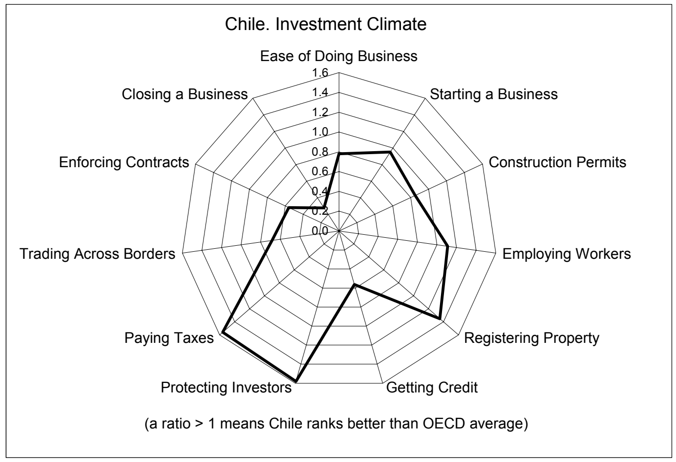
- *The effective capital stock (both in structures and M&E) could be overestimated.* Growth accounting exercises usually assume that current investment is incorporated immediately to the capital stock. However, the construction of some investment projects require more than one year. In such cases, the investment corresponding to those projects should not be incorporated to the economy's capital stock until the project is finalized and ready to operate. Failure to do so would result in an overestimation of the contribution of capital to growth, and a simultaneous underestimation of TFP contribution. In the case of Chile, the Ministry of Finance reports that during the period 2006-08, there was an increase in the number and relative importance of projects with long maturity, in particular in the Energy and Mining Sectors (Ministerio de Hacienda, 2007). In this connection, and according to official estimates, the amount of contemporaneous investment that should be added to the effective capital stock decreased from an average of about 75 percent during 2001-2005, to less than 60 percent in 2008. This could also help explain decreasing TNP in other net commodity exporters which have also undertaken sizable commodity-related projects with maturity periods exceeding one year.



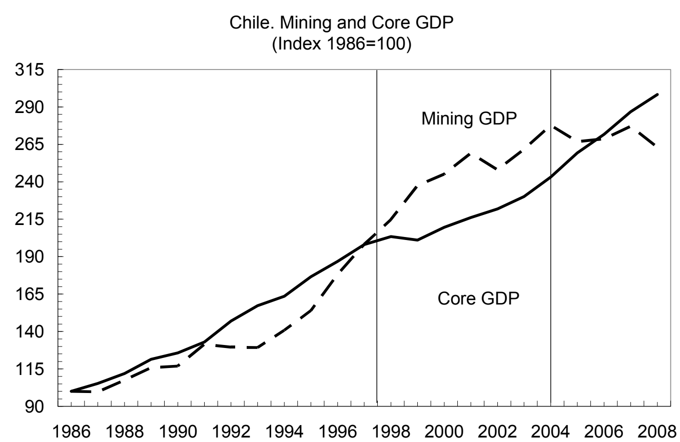
• *Output could be underestimated.* Hornstein and Krusell (1996) underscore that in certain economic activities (including construction, trade, finance, insurance, real estate, other services and government), in output as well as quality improvements are more difficult to measure than in other activities such as agriculture, mining, manufacturing, transportation, and communications. Griliches (1994) calls the former group of activities the "unmeasurable sector" of the economy and the latter the "measurable sector". From this perspective, productivity slowdowns may reflect mismeasurements in output, a problem that would be compounded if the unmeasurable sector in total output were to increase over time. However, this does not appear to be the case for Chile, as the proportion of the unmesurable sector in total GDP (at factor cost) has remained relatively stable.

• *Labor and business management might be adapting to the introduction of new, more productive, technologies.* Hornstein and Krusell (1996) and Greenwood and Yorukoglu (1997) point out that the adoption of new technologies involves a significant cost in terms of learning; only when labor has developed the necessary skills, technology could be successfully implemented. In other words, as the learning needed to fully take advantage of a new technology occurs, there is a transition period in which output and TFP growth could decline. Such transition period would be characterized by a higher wage dispersion and an increase in the premium paid for skilled labor. Available wage data for Chile indicate that the premium paid to the most skilled workers (upper firm/public sector management and liberal professions) with respect to that of unskilled workers increased by about 10 percent during the period 1997-2008, while the relative wage of technical workers (machine operators and artisans) to that of unskilled workers has remained fairly constant. Even though these results suggest some increase in wage dispersion, the stability of the relative wage of technical to unskilled workers seems to suggest that costly learning has not been the primary cause of the productivity slowdown.

• *Business regulations might be constraining growth.* There is abundant literature linking lackluster productivity performance with excessive and/or inadequate regulations affecting the investment climate (e.g., World Bank, 2004). The rationale is that heavy regulation makes it more difficult for business to operate smoothly, which results in poorer economic outcomes. The results of the 2009 World Bank's *Doing Business* survey indicate that Chile outranks the countries in Latin America, but it ranks below the OECD average in the (general) "Ease of doing business" indicator. Moreover, Chile ranks below the OECD average in several areas. A closer look at the components of each of the specific categories shows that Chile has not made significant gains in those categories during 2004-2009. This has also been the case for Australia, Canada and Norway, which also experienced productivity slowdowns, but whose rankings exceed those of Chile for most indicators. Based on this evidence, it could be argued that a better regulatory environment in Chile would not have necessarily prevented a productivity slowdown (i.e., productivity slowdowns may occur for reasons different than a poor regulatory environment). That said, the indicators for Chile also suggest that there is scope to improve existing regulations, so they would not affect the functioning of some markets, especially at times of economic stress. In this connection, the increase in the average rate of unemployment after 1998 appears to suggest that there still are some rigidities that might be affecting the economy's capacity to absorb shocks, which could have a bearing in the productivity behavior.[4]



- *The growth of traditional sectors might have entered a "declining stage".* This could be significant for economies in where non-renewable resources constitute a large share of output. The exploitation of such resources usually implies that marginal costs eventually rise, with production and productivity eventually decreasing. Ewing et al. (2007) present some evidence of declining productivity in the mining sector in Australia. In the case of Chile, mining GDP has fluctuated around a constant level since 2004 (in line with copper production), while a measure of "core" GDP (excluding mining, electricity gas and water and fishing), has increased at an annual average



[4] Regulatory rigidities may be behind the observed increase in the natural rate of unemployment after 1998 (See Restrepo, 2008).

rate of 5.2 percent. However, it is important to note that the productivity slowdown in Chile started around 1998, when mining GDP, and the physical production of copper, were expanding very strongly. Indeed, during 1998-2004, mining GDP increased at an average annual rate of 4.9 percent, while the physical copper production expanded at annual average rate of 6.9 percent. This seems to suggest that the marked decline in trend productivity observed in 1998 may have also been caused by other factors. That said, it is worth noting that for the commodity exporters in the sample (Australia, Canada, Chile and Norway), there seems to be some simultaneity between the large increases in commodity prices of 2005-2008 and decreases in productivity. These decreases could also be partially explained by the expansion of commodity production in areas (fields or mines) of lower marginal productivity, as the larger commodity prices make such production profitable.

- *Market concentration might be stifling competition and growth:* Acemoglu, Aghion and Zilibotti (2002) argue that limits on product market competition are important for middle-income countries trying to converge to the world technology frontier. In this connection, according to the World Economic Forum's *Global Competitiveness Report* for 2008, Chile ranks 28 among 137 countries, better than any country in Latin America, but below the OECD average. As Engel and Navia (2006) indicate, corporate activity in Chile is dominated by a limited number of conglomerates, and it is frequently the case for key industries to be dominated by a small number of corporations (Chile ranks 57th in the "market dominance" indicator). In particular, they point to scarce competition in the financial sector (banks and pension fund manager companies); this may be constraining the access to funds for middle and low-sized firms, perpetuating market concentration, and limiting the economy's dynamism. However, market concentration does not preclude intense competition; indeed Chile has made important progress since the creation of an "Anti-monopoly Court" in 2004 (Chile ranks 19th in the "intensity of local competition" indicator).

VI. Concluding Observations

The evidence presented in this paper suggests that the marked increase in the level and quality of new capital goods experienced in Chile augurs well for future productivity growth. Nevertheless, the slow growth in neutral technological change would also suggest the need to consider additional reforms.

The productivity slowdown in Chile is a phenomena also observed in other net commodity exporters and may reflect a number of potential factors. Regulatory rigidities, that limited the capacity of the economy to absorb the external shocks of 1998 and 2001, were likely behind the initial phase the productivity slowdown. Beginning in 2004, a combination of factors probably compounded the problem, including the slowdown in the mining sector, as well as some overestimation of the effective capital stock. Other factors, including costly learning following the adoption of new technologies, as well as market concentration, may have also had a bearing, and deserve to be investigated in more detail.

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