TREND GROWTH: MEDIUM-TERM OUTLOOK AND ANALYSIS OF FUNDAMENTALS

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PREFACE

The Board has agreed to publish an offprint entitled *"Trend Growth: Medium-term Outlook and Analysis of Fundamentals"* jointly with this year's September *Monetary Policy Report*. The document summarizes a body of research conducted by our technical teams on the determinants of long-term economic growth. While studies on the topic have been carried out over many years, they have tended to be on a rather academic level. However, given an important slowdown in our economy's growth rate in recent years, it seemed appropriate to make an additional effort to consolidate our analysis, in an area that is not only crucial to adequately meet our legally mandated objectives, but also of general interest to the country.

This document is the product of half a year of work reviewing, updating and consolidating studies performed at the Central Bank. As such, it incorporates incoming empirical evidence that has enhanced our knowledge of the Chilean economy. It analyzes in detail the medium-term trend growth for Chile over the horizon from 2017 to 2050, with special focus on the projection of GDP growth for the next ten years.

The analysis herein was coordinated by the Central Bank's Research Division under the direction of its Director, Alberto Naudon. The project was led by the Manager of the Economic Modeling and Analysis Department, Elías Albagli, and the Head of the Economic Analysis Department, Matías Tapia.

Contributing economists were Rosario Aldunate, Mario Canales, Gabriela Contreras, Claudia de la Huerta, Emiliano Luttini and Juan Marcos Wlasiuk. The Bank's Monetary Policy Strategy and Communication Manager Enrique Orellana headed the editorial team, with the support of Pamela Barría, Cecilia Valenzuela, Tatiana Vargas and Ivonne Vera.

The Board

SUMMARY

The gap between productive capacity and effective economic activity is one of the main determinants of inflation and, as such, it appears directly or indirectly in the models used by the main central banks around the world. Chile is no exception. Despite its widespread use, it must be recognized that estimating it is a complex task and suffers from important degrees of uncertainty. Unlike actual GDP, which is measured directly through the National Accounts, productive capacity is not directly observable, so it must be inferred using various methodologies. For example, by simulating the evolution of GDP fundamentals in certain counterfactual scenarios, or from the effective movements of GDP and their relationship with different indicators, such as inflation, the unemployment rate and the real exchange rate.

The Central Bank of Chile reviews and updates its estimates of production capacity and gap size on a regular basis. However, after several years of slow growth and successive downward revisions to estimates of the country's productive capacity, the question of how much of the lost dynamism is cyclical and how much responds to structural factors is increasingly pressing and the answer to it more elusive. This situation requires a closer look at the issue and this document is an effort in that direction.

There are different notions about the economy's productive capacity, which are more or less helpful depending on the specific question or application that is in sight. In line with the literature, previous studies conducted at the Central Bank have identified two related but different concepts of potential productive capacity growth.[1] Trend growth refers to growth in the absence of short-term productivity shocks and when inputs are used at their normal capacity. It is a concept whose application is relevant at long terms (e.g. ten years), and when accumulated positive and negative transitory shocks tend to cancel out, so they can be excluded from the analysis. On the other hand, potential GDP refers to the current level of productive capacity, including the various transitory productivity shocks and resource allocation issues that describe the economy at a given moment. This concept is the one used to measure the inflationary pressures that might drive inflation away from its 3% target.

Although on average the two concepts —potential GDP and trend GDP— will tend to coincide, over time potential GDP will fluctuate around its trend counterpart, temporarily deviating as a response to the shocks that affect

[1]/ See the minutes cited in the September 2015 *MP Report*.

productive capacity in the short term.[2] This document analyzes Chile's medium-term trend GDP growth in the 2017-2050 horizon, with special attention paid to the projection of NNR[3] and total GDP growth for the next ten years. The projection of NNR GDP is based on the production function methodology. This methodology projects the evolution of productive factors (labor and capital) and total factor productivity (TFP) to forecast the evolution of GDP. The analysis of the expected evolution of the production factors and productivity is grounded on a detailed study of the historical behavior of each factor and TFP, as well as the conceptual mechanisms behind these movements. This analysis is complemented by a cross-country comparison, which places Chile in the context of countries that have already traveled through our current levels of development. This comparison is suggestive of future developments for Chile. The document also highlights the primordial importance of TFP, in explaining current differences in income levels with the developed world and, in the projection of future growth. In line with recent advances in applied research in the field, special attention is given to the role that microeconomic factors play in the determination of aggregate TFP. This research provides new evidence for Chile with productivity data at the firm level.

The main messages are presented below:

1. The baseline estimate of trend total GDP growth for the next ten years is 3.2%, in a range between 2.8% and 3.6%. This outcome depends on the different sensitivity scenarios outlined in chapter II. This is linked to a baseline projection of 3.4% for NNR GDP and 2% for Natural Resources GDP.

2. The evolution of labor, adjusted by quality and participation, explains around 0.8% of projected annual NNR GDP growth. This evolution will be driven by an expansion in the labor force, boosted by immigration and larger female participation. These forces compensate the impact of an aging population. Improvements in human capital should also make an important contribution.

3. Meanwhile, projections assume a fairly neutral role for capital, as it grows at the same speed as NNR GDP, contributing an annual 1.7% to output growth. This assumption is consistent with a constant capital to GDP ratio which remains near historic averages, a stylized fact that is also seen in other countries.

4. TFP growth for NNR sectors is projected at a 0.9% annual rate. This estimate is based on the average productivity growth of the last twenty years.

5. The analysis identifies two main policy areas that could boost trend growth and speed up the convergence to developed countries' per-capita output levels.

[2]/ See the minutes cited in the September 2015 MP Report for a detailed analysis of the differences between the two concepts and measuring methodologies.

[3]/ The acronym "NNR" stands for Non-natural resources GDP. It denotes GDP that excludes the natural resources sectors, which are: Mining and quarrying, Electricity, water and gas, and Agriculture, forestry, hunting and fishing.

a. The first area is human capital. Despite significant progress in improving educational coverage, the quality of Chilean education lags behind the standards of high-income countries' standards, as are Chilean workers' labor skills. Thus, any policies that close this gap can have first-order effects on growth and well-being. However, increasing human capital is a slow and costly process, and despite its importance, hardly any significant effects will be reaped within the projection horizon considered here.

b. The second area points directly to total factor productivity or TFP. The evidence presented for Chile suggests that there are significant inefficiencies in the allocation of resources across firms. This result implies that the more efficient firms are not necessarily employing more workers and more capital within their industry. The analysis indicates that there could be first-order gains from improvements in the allocation of productive resources among different firms. Unlike the case of human capital, factor reallocation could generate short-term gains. Among them, the literature has stressed the importance of having flexible labor markets, financial development and policies that enable the creation and dissolution of firms.

The document proceeds as follows: chapter I presents the basic methodology and reviews the main results. Chapter II details the projections of the baseline scenario for labor, capital and TFP, as well as the sensitivity scenarios for trend growth until the year 2050. Chapter III analyzes the projections of each of these variables in the light of the international evidence. This analysis serves to support the baseline scenario projections and the sensitivity scenarios analyzed. This chapter also presents alternative growth estimates based on panel regressions with international data. Chapter IV focuses on TFP. The analysis exploits new microeconomic information at the firm level, whose study allows for a more structural understanding of the determinants of aggregate productivity.

I. INTRODUCTION

The gap between productive capacity and actual activity is one of the main determinants of inflation and, as such, it appears directly or indirectly in the models used by the main central banks of the world. Chile is no exception. Despite its widespread use, estimating productive capacity is a complex excercise that entails significant degrees of uncertainty. Unlike actual GDP, which is measured directly through the National Accounts, a country's productive capacity cannot be observed directly, so it must be inferred using different methodologies. For example, simulating the evolution of GDP fundamentals in certain counterfactual scenarios, or from the effective movements of GDP and their relationship with different indicators, such as inflation, the unemployment rate and the real exchange rate.

The Central Bank of Chile reviews and updates on a regular basis its estimates of production capacity and gap size, using different methodologies. However, after several years of slow growth and successive downward revisions to estimates of the country's productive capacity, the question of how much of the lost dynamism is cyclical and how much responds to structural factors is increasingly pressing and the answer more elusive. This situation requires a closer look at the issue, and this document is an effort to advance in that direction.

Every country's productive capacity relies on its endowment of productive factors, the efficiency with which they are used and the capacity of their capital and labor markets to allocate them to firms and industries where they are most fruitful. All of these are important aspects that are addressed in the remaining three chapters. In particular, chapter II details the projections of the baseline scenario and the sensitivity scenarios for trend growth over the next three decades. The analysis is based on projections for the evolution of labor, capital and productivity. Chapter III analyzes the projections of each of these variables in light of international evidence. Finally, chapter IV focuses on the importance of correctly allocating resources for productivity growth. The analysis uses microdata at the firm level obtained from the Chilean Internal Revenue Service (SII) and is anchored in recent advances in the empirical and theoretical literature. This approach allows a more structural understanding of the determinants of aggregate productivity. Before moving on to the background analysis, let us briefly review what is meant by trend GDP growth —the focus of this document— differentiating it from a related concept: potential GDP.

I.1 STRUCTURAL GROWTH: TWO CONCEPTS

There are different notions regarding the structural production capacity of an economy, depending on the specific question or application. In line with the literature, previous studies by the BCCh have identified two related but different concepts of the productive capacity of the Chilean economy: trend growth and potential growth.[1]

Trend growth is defined as the growth in a country's productive capacity in the absence of temporary productivity shocks and when productive inputs are used at their normal capacity. It is a concept whose application is relevant at long terms (e.g. ten years), and when accumulated positive and negative transitory shocks tend to cancel out, so they can be excluded from the analysis.

Potential GDP, on the other hand, is the current level of productive capacity, including the various transitory productivity shocks and resource allocation issues that describe the economy at a given time. This is the relevant concept to measure inflationary pressures that could divert inflation from its 3% target, as the difference between the level of potential and actual GDP, the so-called capacity gap, is an important determinant of inflation in the medium term in Neo-Keynesian theory.[2] Accordingly, although on average both notions —potential GDP and trend GDP— tend to coincide, over time potential GDP will fluctuate around its trend counterpart, temporarily deviating in response to shocks that affect the productive capacity in the short term.[3]

The distinction between trend GDP and potential GDP is more visible in theory than in practice. This distinction involves identifying which part of observed GDP fluctuations are due to demand-side shocks[4], and which to supply-side ones, as well as assessing if shocks are transitory or permanent.[5] In practice, this distinction is made in light of the theory—which allows identifying the nature of the shocks by observing the main economic variables— or based on assumptions, which are made explicit along the document and, in general terms, adhere to common practices in this type of studies.

1/ In turn, the Central Bank of Chile has done previous research on these concepts. See the minutes cited in the September 2015 MP Report.
2/ See, for example, Galí (2008).
3/ A detailed analysis of the differences between the two concepts and measuring methodologies can be found in the minutes cited in the September 2015 MP Report.
4/ Unlike supply-side shocks, demand-side shocks do not alter the productive capacity, but require a more intensive factor utilization, thus creating inflationary pressures.
5/ Shocks requiring the reallocation of factors among sectors—like in the end of the commodity boom that Chile experienced since 2014— are in a way equivalent to a transitory productivity shock because, while factors are reallocated to new uses, they cause a transitory drop in productive capacity. Hence, shocks affect the measurement of potential GDP, but not of trend GDP.

1.2 METHODOLOGY USED BY THE CENTRAL BANK OF CHILE TO MEASURE TREND GDP GROWTH

The methodology used by the BCCh to forecast trend growth is based on the so-called *production-function* approach commonly used in the neo-classical theory of growth.[6] This method assumes that the creation of value added in the total economy can be written as a function where the inputs are the aggregate capital stock, the labor force and total factor productivity. Specifically, it assumes that GDP can be formulated as a Cobb-Douglas-type function in its factors:

$$(1) \qquad Y = AK^{\beta}LT^{(1-\beta)}$$

where *Y* denotes GDP, *K* is the aggregate capital stock of the economy, and LT is the labor force. The curvature parameter β corresponds, in the Cobb-Douglas function, to the share of capital in value added, assuming that the payment per unit of factor equates its marginal product, while the technological parameter A corresponds to total factor productivity. Trend growth can be expressed thus:

$$(2) \quad \Delta\%Y = \Delta\%A + \beta\Delta\%K + (1-\beta)(\Delta\%L + \Delta\%H + \Delta\%Q)$$

where Δ% is the percent change of the respective variable. Also, equation (2) breaks down the labor factor LT into its various elements i) L: the actual labor force, considering the evolution of the number of persons of working age and their share in the overall labor force; ii) H: number of hours effectively worked, and iii) Q: the quality of the labor force, i.e., the level of human capital. Chapter II explains in detail how growth of each component is projected.

Some general aspects regarding the forecasting criterion used in the estimates presented in this document need some discussion:

a. The exercise must define a forecast horizon. Since trend growth attempts to capture long-term productive conditions, growth estimates are presented up to the year 2050. In this sense, it is important to stress that the projected values are not estimates of actual GDP growth because, to the extent that there are transitory shocks, actual GDP growth will deviate from its long-term trend for some time. Thus, the effective growth projections of the Monetary Policy Report, as well as the potential GDP estimates presented therein, are more informative of the evolution of activity in the next two to three years than the growth trend projections presented in this document.

b. For the purposes of the Central Bank's analysis, it is useful to separate the Natural Resources (NR) GDP from the so-called NNR GDP. NNR GDP considers the sum of the remaining productive sectors, for which to use the approach of equations (1) and (2) is more appropiate. The medium-term evolution of value added in the NR sectors is estimated using information from the Survey of the Capital Goods Corporation, the Chilean Copper

[6]/ Solow (1956), and Swan (1956).

Corporation, the National Energy Commission, and the Economic Load and Dispatch Center, as well as the analysis of the historical evolution of copper ore. Forecasts by sector are then added up according to their relative shares in total GDP.[7]

c. Just as the components that capture the intensity of participation and quality of human capital have been differentiated within the labor factor, it is possible in principle to make a similar decomposition for capital, as in fact, several studies have done for Chile and other countries (see Caselli, 2005, and references therein). Although that is an interesting approach, the methodology for estimating capital quality is less developed than the methodology for labor. For purposes of comparability with methodologies and measurements of international variables, we opt here for treating capital with no quality adjustments. This decision should not generate first-order effects in the projections, but rather in their interpretation and composition.[8]

d. It is important to explicitly state the criteria that will be used to estimate the baseline scenario and sensitivity scenarios for each of the variables. As growth forecasts on a 35 years horizon carry a high degree of uncertainty, it is necessary to put discipline on the variables that are the more important sources of risk and at the same time can be reasonably quantified. The general criterion used is to project according to historical trends, informed when relevant, by trends in other groups of countries that are believed to provide a reference in the medium term. For example, hours worked in Chile show a sustained decline over the last twenty years. Clearly, projections of hours worked cannot assume that they will remain constant, but must acknowledge this decreasing trend. For this, the experience of other countries that have had similar patterns in the past is informative. Something similar happens for the other variables, such as the participation of different demographic groups —including immigrants— as well as the evolution of the quality of human capital.

On the other hand, the historical analysis of capital accumulation and TFP in the NNR sector does not reveal clear trends for defining a time pattern. For example, the capital to output ratio has fluctuated without a clear trend in the last twenty years. For this reason, it would be risky to project scenarios where this ratio deviates systematically from its historical average. The same occurs with TFP growth, which shows a high degree of volatility (which is to be expected since it is measured as a residual between GDP and factor utilization) without revealing systematic movements that can inform a long-term projection different from its historical trend. In these cases, the projection is based on historical averages, without offering specific quantitative sensitivity scenarios in either direction. However, and given

7/ Specifically, separate estimates are presented for NR GDP for the next ten years. For longer horizons, the analysis covers only NNR GDP.
8/ Because our TFP forecast is related to its historical average (for reasons discussed in chapters II and III). The calculation of this average will depend on the calculation of the historical growth of the factors, since the TFP is obtained as a residue. For a given series of GDP growth, changes in the definition of the factors that affect their growth are translated one on one into changes in TFP in the opposite direction. Thus, what is “gained” in terms of a higher growth forecast for capital or quality-adjusted labor, is “lost” in the lower projected TFP due to a tighter historical measurement of its growth under the alternative methodology.

the importance of these factors to forecast trend growth, an important part of the document is devoted to studying these variables' fundamentals in Chile and around the world.

e. Although the projection method based on the production function has the advantage of offering a structure that is clear and easily comparable with other studies, it is worth mentioning that it is not the only way to estimate the determinants of long-term trend growth. In previous studies, the BCCh presented forecasts using alternative empirical methods based on the determinants of growth from international evidence. Basically, this method empirically identifies the main variables that explain growth in a broad panel of countries. Subsequently, these variables are projected for the Chilean economy, and weighted by their contribution to growth in line with international evidence. This methodology is briefly described in chapter III and its growth projections are shown as an alternative source to the production function approach. The numbers obtained for Chile under both methods turn out to be similar.

1.3. MAIN MESSAGES

The results of our analysis can be summarized into five main messages:

1. The baseline estimate for the trend growth of total GDP for the next ten years is 3.2%. This estimate ranges between 2.8% and 3.6%, depending on how the different risk scenarios outlined in chapter II materialize. This result is associated with a baseline projection of 3.4% for NNR GDP and 2% for NR GDP.

2. The evolution of labor explains about 0.8% of the projected annual growth of NNR GDP. This evolution will be driven by a larger labor force, where both, increased immigration and the ongoing process of greater female participation in the labor force will play an important compensatory role to offset the negative effect of an aging population. Human capital improvements will also contribute significantly.

3. The forecast assumes a relatively neutral role of capital, as it expands at the same pace as NNR GDP, contributing 1.7% annually. This assumption is consistent with the capital to output ratio remaining close to its historical average, a stylized fact that is also observed in other countries.

4. Annual TFP growth for the NNR GDP sector is projected at around 0.9%, using its historical average for the last twenty years.[9]

5. The analysis identifies two main areas for improvement that could boost trend growth and speed up its convergence to the GDP per-capita levels of developed countries:

9/ Recall that this figure denotes TFP growth of NNRGDP, not total GDP. TFP for the overall economy has grown more slowly because of the marked deterioration of ore grade , as detailed in chapter III.

a. The first area is human capital. Despite the important advances in improving educational coverage, the quality of education in Chile still lags behind high-income countries, as are workers' skills. Thus, policies that close this gap can have first-order effects on growth and welfare. However, increasing human capital is a slow and costly process and, despite its importance, any major effects will hardly be seen within the projection horizon considered in this work.

b. The second area is total factor productivity. The evidence presented for Chile suggests that there are significant inefficiencies in the allocation of resources across firms. This result implies that the more efficient firms do not necessarily employ more workers and more capital in their sector. The analysis indicates that there could be first-order gains from a better allocation of productive resources among different firms. Unlike the case of human capital, improvements in factor allocation could generate short-term gains. Among them, the literature has stressed the importance of having flexible labor markets, financial development and policies that enable the creation and dissolution of firms. Thus, research aimed at explaining the nature of distortions and, technological or regulatory obstacles to the process of resource reallocation, should be top priority in the agenda of academic research and public policy in Chile.

II. MEDIUM-TERM TREND GROWTH IN CHILE: BASELINE ESTIMATION AND SENSITIVITY SCENARIOS FOR 2017–2050

This chapter presents the baseline forecast scenario of trend growth for the period 2017-2050. The analysis is based on forecasts of productive factors and their efficiency. In particular, as discussed in chapter I, the methodology for forecasting trend growth assumes a neoclassical Cobb-Douglass-type production function of constant returns to scale where the productive factors, labor (*LT*), physical capital (*K*), and total factor productivity (*TFP*) are related to the level of GDP (*Y*) through the expression $Y=TFP\cdot K^{\beta}(TL)^{(1-\beta)}$, where $(1-\beta)$ denotes the ratio of workers' income to GDP. In this expression, the extended labor factor, *LT*, is in turn broken down into three components: labor force, hours worked, and human capital. First, the share of labor in income, $(1-\beta)$, is calculated, and then the projections of each of the inputs and projected evolution are presented under different scenarios.

Continuing with the discussion in the Introduction, this analysis does not consider temporary fluctuations associated to specific shocks. Therefore, it does not characterize possible cyclical fluctuations but analyzes long-term trends in the economy. Thus, the exercise becomes useful for longer horizons, such as a decade, rather than as a growth outlook for the immediate future. Additionally, it is natural for these projections to change only gradually over time, since they should vary only with changes of long-term trends in the evolution of production inputs or productivity.

Although each of the fundamentals is analyzed separately, their projections, in the baseline scenario and in the sensitivity scenarios discussed, are not independent, but consistent with a general equilibrium approach. This implies that the economic mechanisms that underlie the decisions to participate in the labor market, invest in physical and human capital, or spend in technological innovation, are associated with prices and incentives that are determined simultaneously. Therefore, whatever happens with one variable will have an impact on the equilibrium value of the others.

For example, it is quite possible that changes in TFP affect investment incentives and capital accumulation of different types (physical and human), so that it would not be consistent to project sustained TFP growth without a corresponding movement in investment or education. Furthermore, forecasts must be consistent with the resource constraints faced by agents. For example, a projected increase in the schooling of younger generations should consider the impact on their labor participation when they become students.

As stated above, the projection focuses on NNR GDP, excluding sectors that rely on natural resources. These sectors have specific dynamics that depend on factors such as natural capital (e.g., the ore content of copper mines), whose inclusion in the standard neoclassical production function is more debatable. In the baseline scenario, the estimated trend growth for NNR GDP in the next ten years, is 3.4% on average, with a range associated with sensitivity scenarios that goes from 2.9% to 3.8%. For the longer term (period 2017-2050), the baseline projection is an average of 2.7%, with a range between 2.4% and 3.1%. For the next decade (2017-2026), these projections are combined with a projection of Natural Resources GDP growth of 2%. This yields a baseline projection for total trend GDP growth of 3.2%, within a 2.8% to 3.6% range.[1]

Finally, a natural question is how this trend GDP forecast compares with other similar exercises, such as the one carried out by the Trend GDP Advisory Committee convened by the Ministry of Finance. Box II.2 addresses this issue, highlighting the conceptual aspects that explain the differences; in particular, the assumptions about TFP growth that underlie the different notions of trend growth implicit in each methodology.

II.1 SHARE OF LABOR IN GDP: (1–β)

Under a Cobb-Douglas function with constant returns to scale, and assuming competitive factors markets, the sum of total payments to productive factors is identical to aggregate production, the payment to each factor being proportional to the coefficient of that factor in the production function. Therefore, the labor coefficient in the production function of NNR GDP $(1-\beta)$, corresponds conceptually to the share of labor income in the NNR sectors' output. Using National Accounts data, this parameter $(1-\beta)$ is estimated at 0.5. This calculation, following the methodology of Karabarbounis and Neiman (2014), yields the 2008-2014 average of the ratio of total wages paid by the corporate sector (financial and non-financial) to this sector's value added (net of taxes), according to the data obtained from the National Accounts.[2]

The main problem in estimating the share of labor to income is that the National Accounts information in Chile (and in many countries) does not include the income of self-employed workers, and reports only the total wage of employed workers. Therefore, if the number of self-employed workers is significant, using the ratio of total wages to value added withouth further adjustments can significantly underestimate labor participation (appendix II.1).

Partly motivated by this problem, Karabarbounis and Neiman (2014) suggest using the corporate sector to calculate labor income, since the income of self-employed workers is not imputed to the corporate institutional sector (but to household income).[3] Thus, the estimated share reflects the effective participation of labor in the corporate sector, without the need to make

1/ Box II.1 examines how the projections of this year compare with those of earlier years.

2/ The National Accounts series by institutional agent prior to 2008 are not updated with the Benchmark Compilation of 2013. For 2015 onwards, there is no information available on wages paid by the mining sector, which is data necessary in the calculation of labor income in NNR GDP.

3/ According to the authors, this method has the advantage of excluding the government sector, aside from including the income of the self employed. This is important, because the parameter $(1-\beta)$ of the Cobb-Douglas function is equal to the share of labor under the assumption of profit maximization (and perfect competition). These conditions are probably less representative of the public sector than of the private sector.

additional imputations or adjustments. It should be noted that the corporate sector contributes about 75% of total value added. The results are similar if alternative methods are used (appendix II.1).

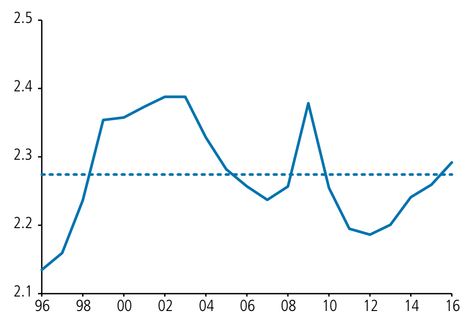
II.2 CAPITAL GROWTH

The most commonly used conceptual framework for analyzing growth dynamics is the neoclassical growth model (Solow, 1956; Swan, 1956). This model suggests that, as countries converge to their steady state, the capital to output ratio increases until it becomes constant once the economy reaches a balanced growth path. In this way, while in the transition capital grows faster than output, in a balanced steady-state growth path the two grow at a similar pace.[4]

In practice, the fact that the capital to output ratio has been fairly constant over time in several countries is one of the stylized facts highlighted by Kaldor (1957), which is confirmed by more recent literature (Jones and Romer, 2010). Even though this does not happen in all countries, in the last twenty years the capital to output ratios have been relatively stable over time in a broad sample, without significant correlation between the level of the capital to output ratio and per capita income.[5]

The baseline scenario of this document takes for the next two years the projection of capital growth that is derived from the Central Bank's investment projections. Thereafter, it considers that the capital of the NNR sectors will grow at the same pace as NNR GDP, assuming a constant capital to output ratio in the medium term. Thus, in our estimation, capital will rise to 3.6% in 2017-18[6], and will be aligned with NNR GDP growth afterwards. This is based on the fact that, although the ratio of capital to GDP in the NNR sectors rose between 1996 and 2016, such that capital has grown on average marginally more than output[7], this ratio has also fluctuated significantly around an average of 2.3[8,9], (figure II.1). This makes it difficult to extrapolate a future trend and, perhaps conservatively, we assume that in the forecast horizon the ratio remains constant. This is consistent with an interpretation of the last two decades in which NNR sectors' growth has been, on average, qualitatively similar to that described by a path of balanced growth, which we assume will continue into the future.

FIGURE II.1
Capital to output ratio, NNR sectors
(real capital, real gross domestic product)



Source: Central Bank of Chile.

4/ The neoclassical model assumes that the economy is closed, so capital if financed entirely with its own resources. In an open economy context, however, capital flows between countries should arbitrate differences in marginal profitability, with which convergence to the steady state (and, therefore, scenarios in which the capital to output ratio is constant) should be faster.

5/ The fact that there are also differences in the value of the capital to output ratio can be related to differences in the sectoral structure of the economy, as will be examined in chapter III.

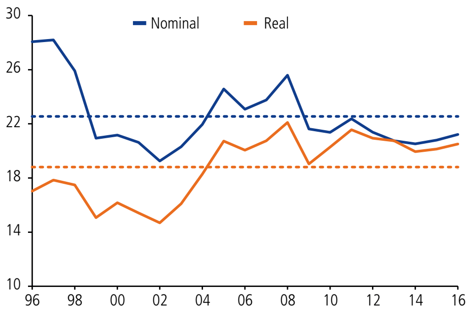
6/ This figure is very similar to what would be obtained if, instead of taking the Central Bank's investment forecast, it is assumed that the capital to output ratio will be constant from today onwards.

7/ While NNR sectors' capital rose 4.2% annually on average in the last twenty years, GDP rose 4%.

8/ Recall that here the mining sector and related capital are omitted.

9/ Both series in real values with 2013.

FIGURE II.2
Investment-to-output ratio, NNR sectors



Source: Central Bank of Chile.

Implicit in this projection is the assumption that the ratio of investment to GDP (in the NNR sector) will also be constant in the medium run, which is consistent with the fact that, in nominal and real terms, this ratio does not exhibit a clear trend either (figure II.2).

It should be noted that, in this context, the assumption that capital will grow at the same pace as output in the medium term allows expressing the rate of capital growth as follows:

$$(1)\ \Delta\%K = \left(\frac{\Delta\%TFP}{(1-\beta)}\right) + \Delta\%L + \Delta\%H + \Delta\%Q$$

where $\Delta\%$ is the percentage change of each variable. In other words, the evolution of capital is anchored to the other variables, whose projection is reviewed next.

As mentioned in the introduction, our analysis makes no adjustment for capital types, along the lines suggested by Jorgenson (2005) and applied to Chile by Corbo and González (2014). As Caselli (2005) discusses, this is a topic of high relevance, but the literature has not yet reached a full consensus regarding how this decomposition should be done. Failure to do so implies that, by construction, the role played by capital composition in the growth of NNR GDP will be implicitly imputed to TFP growth. Finally, the baseline scenario is not without risks (chapter III).

II.3 LABOR FACTOR GROWTH

A correct measurement of labor in the production function and a forecast of its long-term evolution involve a number of elements, which range from demographic patterns to the evolution of labor market participation. Additionally, the theoretical and empirical literature (see, for example, Manuelli and Seshadri, 2014; Caselli, 2005; Hall and Jones, 1999) has reached a consensus regarding the essential role of education (human capital) in explaining income differences between countries as well as the growth process. Failure to take into account the heterogeneity of skills and their growth over time, for example because educational coverage grows, can underestimate the true contribution of labor to growth. Accordingly, the extended labor factor, LT, is defined as the product of three components:

$$LT = L * H * Q$$

The first component is the labor force, *L*, defined as the country's population, adjusted by the participation rates of the various groups that comprise it (e.g., men and women, native or immigrant). The evolution of this component involves demographic factors linked to birth and mortality rates and adjustments to life expectancy; the net immigration rate, and economic processes associated with changes in the participation rate of a given group.

The second component is hours worked, *H*, and is associated with the intensive margin of labor participation. The third component is a quality index, *Q*, which is associated with human capital indicators (distribution of schooling levels, average years of schooling) adjusted by productivity measures. Conceptually, this component is driven by changes in the school level of workers and by changes in the way those levels affect workers' productive capacity (returns to education).

Growth of the labor force

The projection of the labor force until 2050 is based on the expected behavior of two variables. The first is the evolution of the working-age population (people aged 15 and over). This variable is associated with both, demographic factors (birth/mortality) of Chilean residents, and the net migratory flows that are expected to occur over the period. The second variable is the rate of labor market participation which varies among age groups, gender (men/women) and origin (native/immigrant). Therefore, movements in the labor force will be associated with changes in the size and composition of the groups that make up the working-age population and with changes in the specific participation rate of each group.

Working-age population

The central element for the expected evolution of the working-age population are the population forecasts by gender and age of the National Statistics Institute (INE) up until 2050.[10] These projections consider the demographic transition process expected for Chile in the coming decades, with increased life expectancy and decreased birth rates.[11] However, the evolution of a country's population is associated not only with the demographics of the native-born population, but also with the inflows and outflows of migrants. These have increased their importance in the last decade, with the ratio of number of immigrants to total population practically doubling in that period, reaching 2.6% in 2015.[12]

Current INE projections address this phenomenon, and predict up to 2020 a total inflow of 41,000 persons per year. From then on, and up to 2050, available INE projections do not consider immigration flows. However, it is reasonable to think that immigration will be a persistent phenomenon, since the economic forces that have motivated it —income differential with neighboring countries, labor demand not completely covered by local workers— should continue in the future (a more detailed discussion of immigration in Chile in the international context is presented in chapter III). Furthermore, the international literature suggests that a significant number of immigrants already living in a country is an important determinant of immigration flows (Card, 2001; Cortés, 2008). Clearly, moving to a country that has already incorporated immigrants of the

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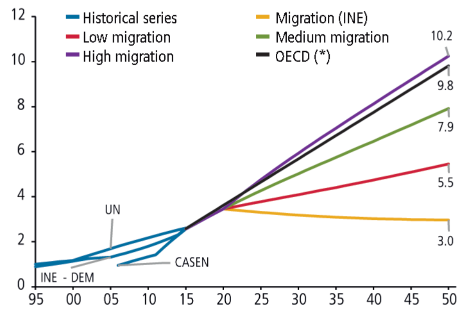
10/ For forecasts up to 2020: http://www.ine.cl/docs/default-source/demográficas-y-vitales/proyecciones-de-poblacion–2014.xlsx?sfvrsn=4; for forecasts from 2021 to 2050: http://www.ine.cl/docs/default-source/ demográficas-y-vitales/microsoftwordinforp_t.pdf?sfvrsn=4.

11/ These projections do not include data from the April 2017 Census, so they may be revised by the INE once it has that information processed.

12/ Because the last census data is as old as 2002, there is no official source from which the evolution of immigrants on the total population can be calculated with more certainty. Although different sources (UN, CASEN) deliver different series, all coincide in the strong increase of the last decade, and also in the most recent share of immigrants in the total population. The acceleration in immigration flows reflected in these numbers can also be seen in the data on work and residence visas issued by the Immigration Office. A more accurate measure will be available when the INE processes the results of last April's Census.

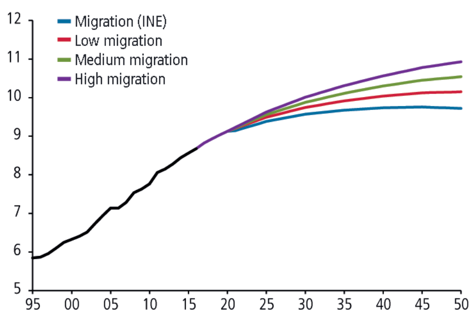
FIGURE II.3
Number of immigrants
(percentages of total population)



(*) Considers twelve OECD member countries and the year they had a number of immigrants equal to 2.6% of their population: Denmark 1972, Slovakia 2006, Spain 1995, Finland 2000, Greece 1983, the Netherlands 1976, Ireland 1960, Iceland 1981, Italy 1991, Norway 1976, Portugal 1980 and Czech Republic 2002.

Source: Central Bank of Chile using CASEN 2015, INE and UN data.

FIGURE II.4
Effect of immigration on the labor force (*)
(millions of persons)



(*) The participation of local workers and immigrants is maintained at its 2015 levels.

Source: Central Bank of Chile using CASEN 2015, INE and OECD data.

same nationality is more attractive because of, for example, the existence of peers social networks that reduce the transition costs and increase expected benefits. Thus, the recent growth of immigration in Chile will probably serve as a stimulus for future immigration, especially in those geographical areas and for those source countries that already opened the way to newcomers.

Accordingly, our projection scenario incorporates positive net migration flows that persist beyond 2020. In the baseline scenario, the number of 41,000 net immigrants per year is maintained until 2050. Given their age composition, this projection implies a net flow of 37,000 people of working age per year.[13] Additionally, two alternative scenarios are examined. In the high immigration scenario, net immigration is 50% larger, and therefore the annual net flow of working-age people is 51,000 persons. In the low immigration scenario, arrivals fall by half, and the annual net flow is now 18,000 working-age immigrants.

In any scenario, the effects of sustained immigration are not negligible. The number of immigrants grows faster than the overall population, so the ratio of immigrants to population increases over time (figure II.3). In the high immigration scenario, this ratio increases from 2.6% in 2015 to 10.2% in 2050. Although this increase in the ratio may seem high, it is quantitatively very similar to the historical evolution of OECD countries that have faced comparable migratory episodes (chapter III).[14] In the baseline scenario, the proportion of immigrants reaches 7.9%, less than the OECD countries' figure after they reached proportions similar to Chile's in 2015. In the most conservative immigration scenario, the proportion of immigrants doubles around 2050.

All of the above suggests that immigration can play an important role in the evolution of the workforce, and be an important driver of trend growth. Indeed, for the next ten years, and assuming labor participation at its current levels, the baseline scenario of immigration raises the projection of the labor force by 0.22% with respect to what it would be without migration from 2020 (figure II.4). This effect combines the direct impact of immigration on the working-age population with the higher participation rates of immigrants. In the absence of inmigration, the growth of the labor force slows down significantly towards the middle of this century as a consequence of the demographic transition process. The influx of migrants smoothes this process.

Labor participation

The second component of the labor force is labor participation. An analysis of the historical evolution of this variable by sex and age shows that, consistently with the increases in educational coverage of the past two decades, the participation of workers under 25 has fallen, especially for men (figure II.5). For women, the participation of all remaining age groups has increased significantly, reflecting the increasing female integration into the labor market.

[13]/ Based on CASEN 2015.
[14]/ Specifically, in this scenario the proportion of immigrants in Chile's overall population would be similar to the median reached over a 35-year interval for the 12 OECD countries that at some point exceeded Chile's current proportion of immigrants.

In the case of men, participation rates have remained relatively stable, except for older workers. This could be associated with a longer life expectancy that has increased the span of working-life, as well as improvements in health indicators that have enabled people to work until a later age.

How are these participation rates projected forward? Conceptually, the conundrum is that the evolution of labor participation along the output growth path is not obvious, as income and substitution effects have opposite signs. For example, as real wages grow, the opportunity cost of remaining inactive grows, which should encourage participation. On the other hand, there are greater incentives to accumulate human capital, which can reduce the participation of young people, while older workers could decide to retire earlier due to the income effect. For this reason, in addition to the trends observed in the historical series, a useful reference point is the participation rates of the OECD countries and their expected evolution over time (the detail of Chile's international comparison is presented in chapter III). In fact, the present projection is based on different scenarios of convergence to OECD countries' participation rates.

We analyze the effect on labor force growth of different participation scenarios, given the baseline assumptions for demographics and immigration (table II.1). In scenario (I), all groups converge to the ILO's projection for the OECD around 2050. In scenario (II), all groups converge to the ILO's projection for the OECD by 2050, except for young people, who maintain their historical downward trend.[15] Finally, in scenario (III), which is the baseline projection scenario, the assumption of scenario (II) with respect to young people is maintained, and older workers maintain their participation (which does not fall, as would be implied by the convergence to the OECD). The projection of this baseline scenario is very similar to the projection carried out independently by the ILO for Chile.

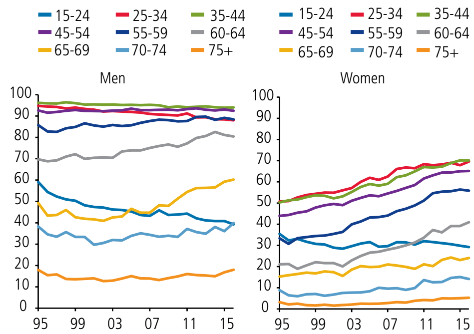
In the baseline labor force projection scenario, immigration is kept at the "intermediate" level (41,000 people per year). By 2050, all workers between the ages of 25 and 60 converge to the OECD participation rates projected by the ILO for that year. Meanwhile, workers over 60[16] and immigrants maintain their current participation, while younger workers reduce their participation due to increased schooling (table II.2).

In the "pessimistic" scenario, immigration is "low", and by 2050 only half of the gap between current participation and the OECD projection for converging groups is closed. In the "optimistic" scenario, immigration is "high", and the convergence to OECD participation of the middle-age group occurs in 2035 and then follows the ILO's projection for OECD countries.

Growth in hours worked per year

As with labor participation, the expected trajectory of hours along a growth path (in which real wages increase) is theoretically ambiguous. While the

FIGURE II.5
Labor participation by age cohort
(percentages of working-age population)



Source: National Statistics Institute (INE).

TABLE II.1
Labor force growth in different participation scenarios
(average annual change, percentages) (1)

	(I)	(II)	(III)
2017-2026	1.3	1.2	1.3
2017-2050	0.8	0.7	0.8
Convergence			
Women 15–24	Yes	No (2)	No (2)
Women 25–64	Yes	Yes	Yes
Women 60+	Yes	Yes	No
Men 15–24	Yes	No (2)	No (2)
Men 25–64	Yes	Yes	Yes
Men 60+	Yes	Yes	No

(*) Medium immigration scenario. Immigrants maintain labor participation of 2015 (CASEN).
(2) The assumption of 15-24 Chileans' convergence implies a fall in participation of 1.1% in 2050 (with respect to 2016) due to increased schooling.
Source: Central Bank of Chile using CASEN 2015, INE, ILO and OECD data.

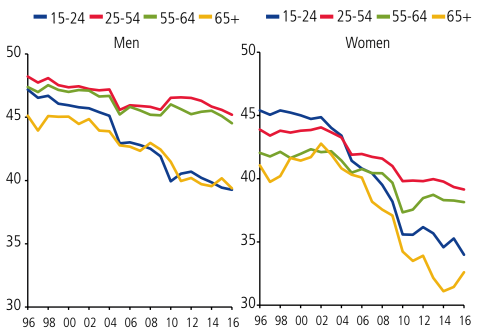
TABLE II.2
Labor force projection scenarios
(average annual change, percentages)

	2017-2026	2017-2050
Pessimistic	1.1	0.6
Baseline	1.3	0.8
Optimistic (OECD, 2035)	1.4	0.9

Source: Central Bank of Chile using CASEN 2015, INE, ILO and OECD data.

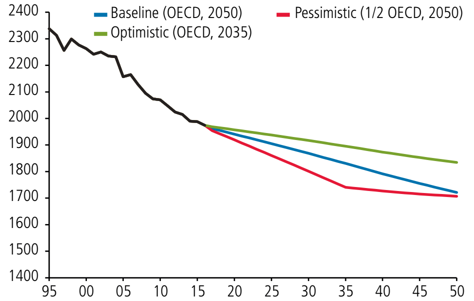
[15]/ Specifically, the participation of young people is projected based on regressions that associate participation with schooling. A discussion of the schooling projection is presented later.
[16]/ In principle, a reform to the pension system could reduce workers' participation if it increased the delivered benefits, but could raise it if, in addition, it raises the legal retirement age.

FIGURE II.6
Weekly hours worked by gender and age cohort



Source: OECD.

FIGURE II.7
Hours worked in different scenarios
(average annual hours)



Source: Central Bank of Chile using INE and OECD data.

TABLE II.3
Annual hours worked projection scenarios
(average annual change, percentages)

	2017-2026	2017-2050
Pessimistic	–0.7	–0.4
Baseline	–0.4	–0.4
Optimistic (OECD, 2035)	–0.2	–0.2

Source: Central Bank of Chile using CASEN 2015, INE, ILO and OECD data.

substitution effect encourages people to work more in the margin as wages increase, the income effect implies that people want to consume more leisure and work fewer hours.

In the data, annual hours worked in Chile show a steep downward trend, in line with the reduction in working hours in more developed countries (see, for example, the discussion in Ramey and Francis, 2006). This drop is twofold: fewer weeks worked and fewer hours per week. In fact, between 1996 and 2015, the annual hours worked in Chile fell by an average of 0.8% per year, from 2,313 to 1,988 hours (source: OECD). This reflects a drop of 0.2% in the number of weeks worked and 0.6% in weekly hours (a detailed international comparison is presented in chapter III). In addition, the fall in total weekly hours has been widespread among men and women of different ages, although more marked for women and age groups at the extremes of the age distribution, i.e., 15 to 24 years old and 65 or over (figure II.6). This pattern —a generalized fall in hours worked across various groups— tends to dominate the weekly hours effect over the composition effect derived from the change in the share of the different groups in the labor force (which would explain only an annual fall of 0.1% per year in weekly hours, from the total of 0.6% observed in the data) (appendix II.2).

Regarding the number of weeks worked per year, there are few internationally comparable statistics and there is no information on their evolution by gender or age. The baseline projection relies on the prediction of a regression that finds a negatively correlation between the average weeks worked with the share of women in the labor force, using historical data for 1996-2015. The result of the empirical model is consistent with women's greater propensity to have seasonal and/or short-term jobs. The projection of weeks then uses the baseline labor force scenario projections discussed above. The sensitivity scenario is associated with the confidence interval of the regression's estimated coefficient.

For the number of hours worked per week, we adopt a similar logic to the one for labor participation. The exercise is based on a projection for European countries towards 2050 (European Commission, 2014), with total weekly hours in Chile converging to that number.[17] In the baseline scenario, that projection of hours is converged towards 2050. The sensitivity scenarios involve an earlier convergence (2035, after which the OECD projection is followed) and one in which only half of the gap is closed towards 2050.

A faster convergence in weekly hours, or a stronger impact of the number of women in weeks worked, are "pessimistic" scenarios in the sense that they tend to reduce the trend of growth of NNR GDP (figure II.7 and table II. 3). The projection implies that between 2017 and 2026, hours worked will decrease by an average of 0.4% per year (between –0.7 and –0.2%).

[17]/ The convergence is done for total weekly hours and not disaggregated by gender and age, because there is no information that would allow for separate convergence assumptions for these groups.

Human capital growth

As mentioned in the introduction, a correct assessment of the stock of human capital associated with the labor force is crucial for calculations of the contribution of labor to growth. However, this is not a simple task and, in fact, a big body of literature has discussed various conceptual and methodological challenges. These issues range from the degree of substitution between workers of different categories, to differences in the quality of the educational systems across countries (Jones, 2014; Schoellman, 2012).

In this chapter, the baseline estimate of the human capital index follows the methodology proposed by the OECD (2001), which was also used by Magendzo and Villena (2011). Specifically, the stock of human capital is constructed as the weighted average of the wage premium of different educational groups with respect to workers without formal education, where the weights correspond to the percentage of employed individuals in each category with respect to the total number of employed workers. That is,

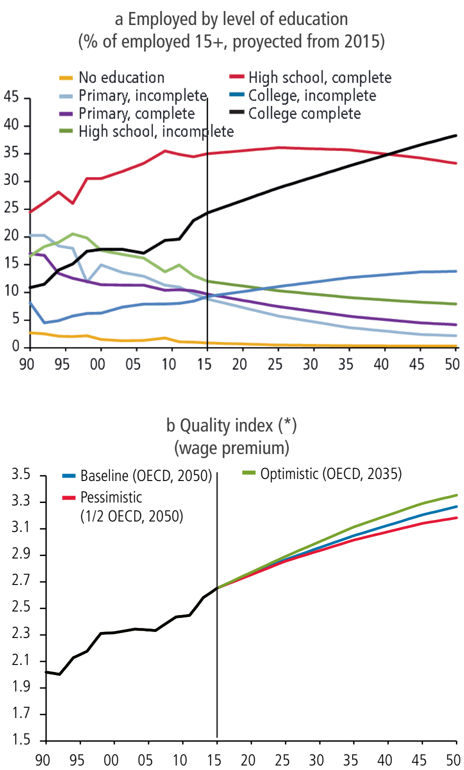
(2) $$q = \sum_{i=1}^{7} (w_i / w_1)(L_i / L)$$

where *Wi* and *Li* are the wages and number of people employed in each educational level i from the CASEN survey in the years 1990 to 2015.[18] This formula uses the average wage premiums between 1990 and 2015 (both in the historical estimation of quality and in its projection). By assuming that the premiums remain constant, the estimated quality moves only because of changes in the relative size of the educational categories in the work force. This assumption is arguable a priori, since changes in the relative supply of different groups could lead to changes in relative prices. However, wage premiums of all categories show no clear trends between 1990 and 2015, a period in which the educational composition of the workforce varied very significantly. This suggests that, in addition to changes in supply, the relative demand for workers of different categories also changed, so that relative prices remained roughly constant. This stability in Chile's educational premiums is compatible with the international evidence discussed in chapter III (Jones and Romer, 2010).

By using relative, as opposed to absolute wages, this methodology isolates the quality index from factors unrelated to education, such as capital and TFP, that affect absolute wage levels in the economy. For example, if the quality index used absolute wages, an increase in the physical capital stock in the economy that increased the marginal productivity of labor and therefore wages across all education groups, would increase the index even if the underlying skills of the workers did not change. However, relying on relative wages is not innocuous. For instance, an increase in the skills of all educational groups such that relative premiums are not affected will not change the index, even though the absolute quality of labor has actually increased.

[18]/ Educational levels are divided into the following seven categories: no formal education; primary, incomplete; primary, complete; high school, incomplete; high school, complete; college, incomplete; and college, complete. For the years without CASEN, linear interpolations are used.

FIGURE II.8
Employed by level of education and quality index



(*) Average wage premiums from 1990–2015 CASEN surveys, relative to the group with no formal education: Incomplete primary, 1.1; Complete primary, 1.3; Incomplete secondary, 1.6; Complete secondary, 2.0; Incomplete post-secondary, 2.9; and Complete post-secondary 5.3.

Source: Central Bank of Chile, based on CASEN surveys, INE, and OECD.

TABLE II.4
Projection scenarios of labor quality
(average annual change, percentages)

	2017-2026	2017-2050
Pessimistic	0.7	0.5
Baseline	0.8	0.6
Optimistic (OECD, 2035)	0.9	0.7

Source: Central Bank of Chile using CASEN 2015, INE and OECD data.

One potential solution is to adjust the index by some factor that gauges the quality of the educational system (see Schoellman, 2012; Hanushek and Woessmann, 2012). However, these indicators are typically calculated only for a specific year, thus adjusting the level of the index in a given point in time, but not its dynamics. Therefore, this study does not include this dimension in the projection scenario, although chapter III discusses how the quality of the Chilean educational system compares in the context of the OECD. Despite this limitation, we consider that this index provides a good way to measure the quality of labor.

To forecast labor quality, we proceed as follows: first, the educational level is forecast for different age groups among employed workers. Then, the different age cohorts are weighted by their share in the employed to obtain the educational composition of workers over 15 years of age. Finally, the educational composition of workers over 15 years old (the previous calculation) is used to construct the quality index of labor according to equation (2).

To project the educational level by age groups, we start from the fact that schooling achievements are almost completely determined for all generations older than 25. Therefore, convergence assumptions in the distribution of educational attainment are only made for new entrants to the labor force, taking as reference the median of OECD countries in 2015. Appendix II.3 explains in detail the convergence assumptions for those under 25 years of age.

As with previous assumptions, the convergence is gradual and is completed in the baseline scenario by 2050 (2035 in the optimistic scenario). In the pessimistic scenario, by 2050 only half of the gap between Chile and the OECD in the share of people with complete college education will be closed (figure II.8). In the projection, the quality of the labor factor grows on average 0.8% in the next ten years (between 0.7 and 0.9%) (table II.4).

The limited range of the sensitivity scenarios are associated with the fact that, by the nature of the human capital accumulation process, the effects of differences in education are observed only in the very long term. As discussed, educational attainment is already given for the great majority of current workers. Therefore, the effects of the different scenarios are observed only in the marginal group of workers who have not yet completed their schooling. Most of the change in the quality index is given simply by changes in the composition of already educated workers, as older workers who received on average less education than the younger cohorts leave the workforce. This puts the possible effects of changes to the educational system in perspective. Although the impact of higher attainment is potentially very important over the very long run, it has a limited effect in horizons of 20 or 30 years.[19]

[19]/ Additionally, and as already mentioned, the projection implicitly assumes that the quality of the educational system does not change over time. In any case, given that the projection horizon is relatively short compared to the time it takes for human capital to build up, improvements in quality would only have a significant impact in a period of time that goes beyond the projection horizon.

II.4 TOTAL FACTOR PRODUCTIVITY

Differences in the level and evolution of total factor productivity (TFP) have been identified as the main source of disparities in income levels and growth between countries and over time (Caselli, 2005). As discussed in more detail in chapters III and IV, total factor productivity is obtained as the residual from an accounting exercise of the impact of capital and labor on output. Conceptually, TFP reflects efficiency (the way in which the total factors are allocated across firms and sectors in the economy, and how close they are to their best potential use) and technology (the way in which, given a specifc allocation of aggregate factors, they become more productive through changes in the economy's production function).

These two forces are very difficult to project, as they depend on multiple factors, some of which are unobservable. Thus, we follow most of the literature and calculate TFP as the Solow residual in a standard growth equation, using measures of adjusted labor and adjusting capital by its degree of utilization. This exercise provides an estimate of historical TFP for the period 1996-2016 (figure II.9).[20]

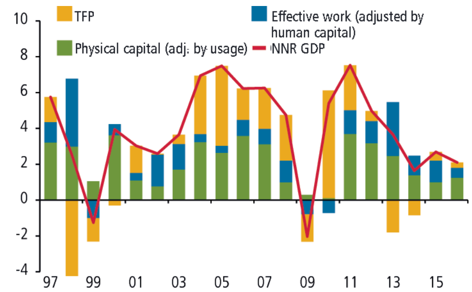
TFP growth for NNR GDP shows no clear trend, an empirical fact that has also been documented for other countries (for the US, for example, see Fernald and Wang, 2015). For this reason, TFP growth over the next decades is forecasted using its average growth since 1997, which is estimated at 0.88% (figure II.10).

We address two issues to put our results in perspective.

Several studies have estimated that productivity growth in Chile over the recent past has been close to zero (Aravena and Fuentes, 2013; Aravena and Hofman, 2014). However, these are of total TFP, including natural resources, and not of the TFP of NNR GDP. As chapter III discusses in detail, this distinction is important for Chile and other mining countries because the mining sector has consistently shown negative productivity growth (Magendzo and Villena, 2011; Corbo and González, 2014; Fuentes and García, 2014). This is confirmed by the National Productivity Commission (2016), which reports how the fall in aggregate TFP is explained by the sustained decline in mining TFP since 2000, while non-mining TFP has grown around 1% annually since 2000. Other works that estimate sectoral TFP (Magendzo and Villena, 2011) find figures near 1% when aggregating NNR sectors.[21]

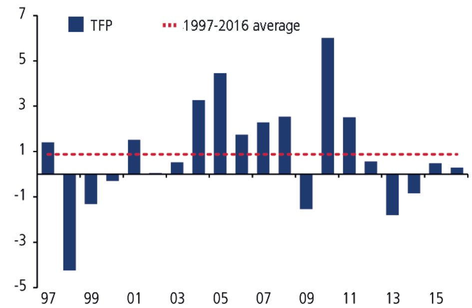
A second issue is our forecasting procedure. One concern is that some years of the 1996/2015 sample exhibit very high TFP growth rates, which may not be replicated in future years. To project the TFP in a robust way, we follow the average window (AveW) forecasting procedure suggested by Pesaran et al. (2013). This methodology consists of including all possible sub-samples from the

FIGURE II.9
Decomposition of NNR GDP growth, 1997-2016



Source: Central Bank of Chile using BCCh, CASEN, INE and OECD data.

FIGURE II.10
NNR sectors' TFP
(annual change, percentages)



Source: Central Bank of Chile using CASEN, INE y OECD.

[20]/ The production function in this case is $Y = A(KU)^{\beta}(LHQ)^{(1-\beta)}$, where U is utilization, estimated through energy consumption using the methodology of Fuentes et al. (2006).

[21]/ Corbo and González (2014) also find information on sectoral TFP aggregations that exclude the mining sector. These aggregations usually yield near-zero averages. However, the aggregation of Corbo and González (2014) does not consider the productivity component stemming from the reallocation effect, as explained in De La Huerta and Luttini (2016).

beginning of the series, keeping the end of the sample fixed and changing the beginning of the sample, and calculating an average TFP for each sub-sample. The distribution of average growth rates thus obtained helps to capture the representativeness of the full sample average.[22] For Chile, the distribution mean obtained through such procedure is virtually identical at 0.88%, suggesting that using the simple average as from 1997 is a good approximation.

As in the case of capital, the baseline TFP projection is subject to risk scenarios that are difficult to quantify. Chapters III and IV describe, in light of international evidence, possible opportunities and threats for the future growth of NNR sectors' TFP.

II.5 TREND NNR GDP AND TREND TOTAL GDP

We have discussed in previous sections the growth projections for capital, the labor factor, and NNR sectors' TFP for 2017-2050. In this section we can aggregate these exercises in order to obtain the average growth projection for NNR GDP at different horizons (table II.5). A worst-case scenario of growth for each of the previous exercises is assumed to define the pessimistic scenario. The optimistic scenario follows the same logic.

TABLE II.5
Projected trend growth
(production function method, 2017–2050

Scenario	Capital	Labor force	Hours worked	Quality index	Labor factor	TFP	NNR GDP	Natural resources GDP	Total GDP
Pessimistic									
2017–2026	**3.0**	**1.1**	**−0.7**	**0.7**	**1.1**	**0.9**	**2.9**	**2.0**	**2.8**
2017–2036	2.6	0.8	−0.6	0.6	0.8	0.9	2.6		
2017–2050	2.4	0.6	−0.4	0.5	0.6	0.9	2.4		
Baseline									
2017–2026	**3.4**	**1.3**	**−0.4**	**0.8**	**1.6**	**0.9**	**3.4**	**2.0**	**3.2**
2017–2036	3.0	1.0	−0.4	0.7	1.3	0.9	3.0		
2017–2050	2.7	0.8	−0.4	0.6	1.0	0.9	2.7		
Optimistic									
2017–2026	**3.7**	**1.4**	**−0.2**	**0.9**	**2.1**	**0.9**	**3.8**	**2.0**	**3.6**
2017–2036	3.4	1.2	−0.2	0.8	1.8	0.9	3.5		
2017–2050	3.0	0.9	−0.2	0.7	1.3	0.9	3.1		

Source: Central Bank of Chile using BCCh, CASEN, INE and OECD data.

In the baseline scenario, we estimate an average growth of trend NNR GDP of 3.4% for the decade 2017-2026 (2.9%-3.8% range). In a twenty-year horizon (2017-2036) trend growth is estimated at 3.0% annually (2.6%-3.5% range), which falls to 2.7% (2.4%-3.1% range) when the full projection horizon is considered (up to 2050).

[22]/ In the presence of structural breaks this procedure is attractive since it uses more information from observations that are found at the end of the sample.

To project total GDP growth, we must add Natural Resources plus indirect taxes. In the cases of Mining and Electricity, Gas and Water, a medium-term projection is obtained from the Survey of the Capital Goods Corporation (CBC), the Chilean Copper Corporation (Cochilco), the National Energy Commission (CNE) and the National Electrical Coordinator (CDEC), in addition to the Central Bank´s internal analysis of copper ore history. For fishery, average historical production is used. These elements, lead to a 2% expected trend growth in natural resources for the next ten years. The trend growth of indirect taxes (VAT and import duties) is assumed equal to that of NNR GDP. Finally, the same relative weights of 2016 are assumed to calculate Total GDP. That is, 12% for natural resources and 88% for NNR sectors, VAT and import duties. Therefore, the baseline scenario assumes trend Total GDP growth of 3.2% for the decade 2017-2026, with a sensitivity scenario between 2.8% and 3.6%.

II.6 CONCLUSIONS

This chapter presented the main elements behind the estimation of medium-term growth in Chile's trend GDP based on a neoclassical production function model for NNR GDP. In this model, output depends on capital, labor, and overall productive efficiency. The methodology estimates trend growth up to 2050 for each component, and combines those growth rates to project trend NNR growth. For the period 2017-2026, projections of the natural resources sectors were added in order to arrive at a trend Total GDP growth estimate.

As already discussed, these estimates must be interpreted as expected dynamics given the structural characteristics of the Chilean economy. This implies that, conceptually, they should not be affected by shocks or disturbances, unless they have long run structural implications. Therefore, they are not meant to be estimates of future gowth for a given year, but as expected average behaviors in longer horizons, such as ten years or more.

The remaining chapters address these structural characteristics with more detail, placing the behavior of Chile's factors in an international context (chapter III) and presenting new microeconomic evidence on the fundamentals of aggregate productivity growth (chapter IV).

BOX II.1

COMPARISON BETWEEN PROJECTION FOR 2017-2021 WITH PROJECTION IN SEPTEMBER 2016 MONETARY POLICY REPORT

In the Monetary Policy Reports of September 2015 and 2016, the Central Bank published its five-year projections for trend GDP,[23] using the same baseline methodology described here. This box compares the projections of trend and total GDP that are derived from this document with the exercise in the 2016 Report.

TABLE II.6

Compared trend GDP projections: 2017 and MP Report of September 2016

	Period	Capital	L	H	q	Labor Factor	TFP	NNR GDP	NNRR GDP	Total GDP
Projection 2017	2017-21	**3,5**	1,4	-0,4	0,8	**1,8**	**0,9**	**3,6**	2,5	**3,4**
Projection 2016	2016-20	**2,9**	1,3	-0,4	0,7	1,7	**1,0**	**3,3**	2,9	**3,2**
	2017-21	**2,9**	1,2	-0,4	0,7	1,5	**1,0**	**3,3**	2,9	**3,2**

Source: Central Bank of Chile using BCCh, CASEN, INE and OECD data.

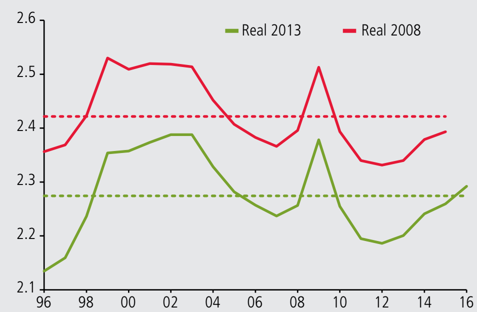
A comparison between the two projections shows that the baseline scenario in 2016 had an average growth of 3.2% for total GDP in the five-year period 2017-21 . This is lower than the 3.4% growth projected in 2017, despite a downward revision in NNRR GDP growth , from 2.9% to 2.5%. Therefore, NNR GDP growth was revised upwards, from an average 3.3% in the September 2016 Report to 3.6% in 2017. What explains this change? The main change comes from capital growth, which was projected at 2.9% in 2016, significantly below the current 3.7% projection. The labor factor, in turn, grows two tenths of a point more in the 2017 projection, while TFP growth is one tenth less (table II.6).

For capital and TFP, the change does not come from a change in methodology or the projection assumptions but rather as a consequence of the five-year revision in National Accounts, which updated the baseline year from 2008 to 2013. This revision had significant consequences in the capital to output ratio of NNRR sectors in real terms, which is now significantly lower than in previous statistics (figure II.11). A similar, though smaller, effect is observed in the investment to output ratio in real terms. These changes in the aggregate series increased the investment to capital ratio.

[23]/ As pointed out in the text, the reference horizon has been changed from five to ten years, as the latter is more appropriate for the trend GDP definition.

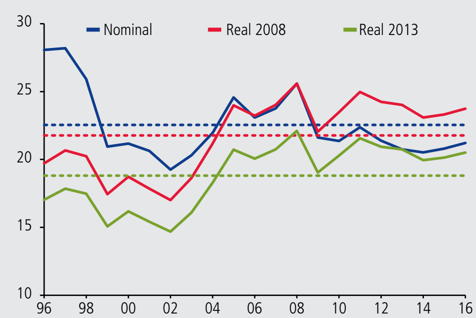
FIGURE II.11

Capital to real NNR GDP, 2008 and 2013 benchmark compilations



Source: Central Bank of Chile.

Investment to NNR GDP, 2008 and 2013 benchmark compilations



Source: Central Bank of Chile.

These revisions have first-order consequences on the projection of short-term capital growth. As described earlier, the forecast for capital growth in the NNR sector for the next three years is based on the Central Bank's projection for investment growth in the NNR sector, while a constant capital to output ratio is assumed for the rest of the projection horizon. This methodology is the same used in the 2016 Report. Thus, the 0.7% revision to NNR sectors' capital growth between 2016 and 2017, which stems from an increase in this variable's projected growth for the next three years, is not caused by an increase in investment growth with respect to the previous projection, but directly by the change in the investment to capital ratio in National Accounts.

In particular, from an accounting approach, capital growth can be expressed as a function of the investment to capital ratio, net of the depreciation rate:

$$g_k = (I / K) - \delta \qquad (1)$$

With the new National Accounts, the investment to capital ratio is significantly higher. Thus, for the same projection of investment growth, capital grows more, because the initial capital stock in terms of investment is smaller.

For example, for the year 2017, projected NNR sectors' investment growth has virtually no revision. While the 2016 projection was 2.1%, in 2017 that number was revised marginally to 2.0%. However, the effect of the change in the National Accounts on I/K ratio of NNR sectors is bigger. Using 2008 as the baseline year, in 2017 this ratio would have been 8.2%. However, under the 2013 baseline, the 2017 ratio grows to 8.8%. Since the depreciation rate has not changed, this has a first-order impact on capital growth. Using equation (1), NNR capital growth projections for 2017 using 2008 as a baseline would have been:

$$g_{(K,2017,b08)} = 8.2\% - 5.5\% = 2.7\%,$$

while using the 2013 baseline it becomes:

$$g_{(K,2017,b13)} = 8.8\% - 5.5\% = 3.3\%.$$

Therefore, the upward revision of capital growth in NNR GDP comes from improvements in the measure of the capital stock, which is lower than what was previously estimated. This has also consequences for the TFP, as under the revised National Accounts past capital growth is also larger. This implies that the residual estimate of TFP growth, which anchors its forecast, is now somehow smaller. These revisions, and their impact on the perception of historical evolution of macroeconomic series, are not unusual internationally (see, for example, McCulla et al. (2013) for the case of the United States). Revisions in the National Accounts are part of the process of improving our measurement and understanding of the economy and its aggregates.

As for the labor factor, the upward revision is explained by a better estimation of migration and minor revisions to statistics of participation and the human capital index.

BOX II.2
COMPARISON WITH THE FINANCE MINISTRY'S PROJECTIONS

The Central Bank of Chile is not the only institution projecting trend GDP. In particular, the Consulting Committee on Trend GDP (CCPT) convened by the Ministry of Finance provides a projection of trend GDP each year, which serves as an anchor for the calculation of the Treasury's structural balance. This projection has similarities with the methodology presented here, but also important differences that ultimately explain the diverging results.

The methodology that the CCPT uses for its calculations is also based on a Cobb-Douglas production function whose characteristics are similar to those presented here, but it has a different treatment to isolate cyclical fluctuations. In particular, each member of the advisory committee delivers estimates for a five-year horizon of the **effective** annual growth rates of investment, the labor force, and TFP. With this information, the Treasury computes trend series for capital, hours worked adjusted by education and TFP, using for the last two variables an HP filter (with a smoothing lambda parameter of 100). Then it proceeds to calculate trend GDP in levels for the estimates of each member of the committee, and obtains an annual average across members (eliminating in each year the minimum and maximum values of the experts' projections). Finally, the trimmed average values of trend GDP in levels are used to calculate their growth rate and the gap with respect to actual GDP.

The projections presented in this document have two main differences with this methodology. First, the projection based on the production function method is calculated for NNR GDP, to later combine it with the NNRR GDP growth projection. Given that productivity growth has been systematically lower in the mining sector, estimating TFP for the overall economy and not for NNR sectors and Natural Resources sectors separately can bias the estimation.

Second, the use of time series filters in a relatively short projection horizon is methodologically different from the empirical strategy used in this document. As a matter of fact, the use of the HP filter does not completely eliminate the cyclical variations, which results in similar series to measures of potential — not trend - GDP estimated by the Central Bank. This, of course, does not imply a criticism of the Treasury's methodology or its usefulness as an input in the structural balance, but simply establishes that there are conceptual differences with respect to what the BCCh measures, which naturally results in differences in the projected values.

III. DETERMINANTS OF TREND GROWTH IN THE INTERNATIONAL CONTEXT

Chapter II presented the projection scenarios of trend NNR GDP for the years 2017 to 2050, including a detailed discussion of the expected evolution for each of the productive factors. This chapter complements this discussion in three dimensions.

First, it puts the recent evolution of capital, labor and productivity in Chile in an international context. This comparison is an important input to define the convergence scenarios used in chapter II.

Next, it offers a brief and qualitative discussion of some risks and opportunities that derive naturally from the cross-country comparison.

Finally, it presents an alternative growth projection exercise for the coming decades which, using data from a broad sample of countries, explains Chile's growth based on the macroeconomic and institutional determinants most often described in the relevant academic literature. Interestingly, the results of this exercise are quite similar to those presented in chapter II.

The main results can be summarized as follows:

• First, international evidence shows that the capital to output ratio has no clear trend, either in time or across countries. Thus, the assumption of a constant ratio throughout the projection horizon used in chapter II seems reasonable.

• Second, immigration rates and labor market variables as female labor participation and weekly hours worked still lag behind OECD levels. However, given recent trends, it is reasonable to expect them to converge towards the OECD, as outlined in the baseline projection scenario. On the other hand, the data suggests that the human capital gaps are still very large, so there is significant room for improvement. However, any gains would only have an impact on the very long run.

• Third, international comparisons shows that, as in Chile, TFP growth is very volatile with no clear trend over time. It also shows that there is a strong correlation between the levels of TFP and per capita output, and that differences in efficiency in the use of productive factors could explain almost 50% of the difference in income per capita across countries.

Moreover, based on the large difference in efficiency levels between Chile and the OECD, we conclude that the possibility and speed of convergence towards the development levels of industrialized countries will depend critically on productivity growth. Thus, productivity growth is the focus of next chapter.

• Finally, using data from a large sample of countries, a forecasting exercise is performed based on conditional convergence regressions. The result of this excercise yields trend growth rates that are similar to those presented in chapter II, despite the different empirical methodologies used.

The rest of this chapter is structured as follows: the first section compares the evolution of the capital stock in Chile and the world. The second and third sections compare the evolution of labor and productivity. Section four presents an alternative exercise for the calculation of trend growth. The last section contains the main conclusions.

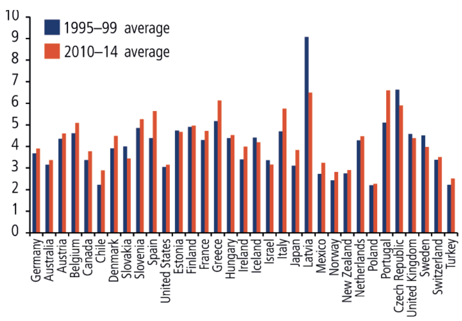
III.1 THE CAPITAL FACTOR IN AN INTERNATIONAL CONTEXT

The baseline projection in chapter II assumes that, for most of the projection horizon, the capital to output ratio will remain constant in sectors other than natural resources (NNR sectors), in line with the intertemporal stability observed in the Chilean data. Conceptually —in the context of the neoclassical growth model— this implies that the NNR sectors in Chile, at least in the last two decades, have been moving along a balanced growth path, and will continue to do so in the future.

The fact that the capital to GDP ratio was roughly constant was documented by Kaldor (1957), who noted in his review of the stylized facts of growth in advanced economies, that the growth rates of capital and output were similar over long horizons, even in economies where per capita product was growing. A review of international data, using Penn World Tables, suggests that this stylized fact has not changed in the last two decades. Figure III.1 shows the capital to output ratio for the OECD countries in the last twenty years.[1] The data shows that Chile's capital to output ratio is lower than the OECD average and, that there is great heterogeneity among countries.

The evolution of the capital to output ratio in the OECD countries has not followed a clear trend in recent years, increasing in some countries and falling in others. More importantly, its level does not correlate with the level of income[2] More specifically it is not clear that the capital to output ratio is greater in richer countries, as the neoclassical model would suggest in its most literal interpretation. This is illustrated more clearly in table III.1 which presents the extent to which income differences are explained by differences in the capital to output ratio for various cross-sections of countries. The results show that the importance of the capital to output ratio to explain income differences across countries has fallen over time, whereas factors such as TFP and human capital have become more important.[3] This result reinforces two points. First, that the relation between capital to output and income is less direct than what the neoclassical model suggests. Second, that projecting a growth trajectory for

FIGURE III.1
Capital-to-total GDP ratio, Chile and OECD countries (*)
(averages of selected years)



(*) Ratios are calculated in local currency at constant prices.
Source: Central Bank of Chile using Penn World Tables 9.0.

TABLE III.1
Dispersion in GDP per capita explained by the capital-to-output ratio (1)(2)
(percentages)

ICP year	All	OECD	Latin America	Mining
1980	0.362	0.187	0.229	0.379
1985	0.307	0.106	0.282	0.293
1996	0.270	0.410	0.225	0.242
2005	0.080	0.071	0.010	0.101
2011	0.184	0.122	0.089	0.197
Average	**0.241**	**0.179**	**0.167**	**0.242**

(1) The International Comparison Program (ICP), constructed by PWT, collects final product prices on consumer, investment, and government consumption goods among countries. The ICP benchmark years are 1970, 1975, 1980, 1985, 1996, and 2005.

(2) The exercise uses a Cobb-Douglas production function with a labor participation rate of 0.54 for all countries.

Source: Central Bank of Chile, based on data from Penn World Tables 9.0.

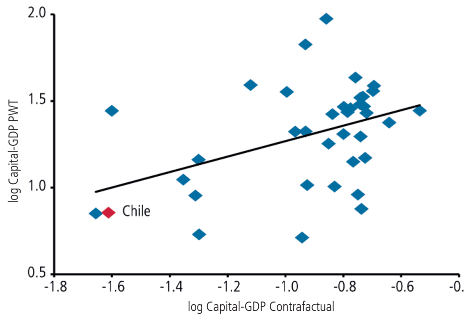
[1]/ Appendix III.1 shows similar comparisons for Latin American and mining countries. The resulting conclusions are similar to those in the OECD sample.
[2]/ In 2014, the simple correlation between per capita GDP and K/Y was 0.018 in OECD countries.
[3]/ The capital to output ratio explains less than 50% of the income variance in the cross-section.

Chile with a constant capital to output ratio is not inconsistent with sustained growth in income per capita.

The heterogeneity of the capital to output ratio across countries could be related to countries' sectoral composition. Countries whose comparative advantages lead them to specialize in technologically more capital intensive sectors should have greater capital to output ratios. However, this fact is not necessarily correlated with absolute advantage, TFP, or income level.

The empirical evidence lends some support to this hypothesis. Figure III.2 shows an exercise where capital to output ratio is built based on the sectoral composition of the economy and the intensity of capital utilization in each sector. This ratio is compared with the effective capital to output ratio.[4] As can be seen in the figure, the simulated capital to output ratio based on the sectoral composition correlates positively with the effective ratio, indicating that an important part of the differences in the ratios between countries is explained by differences in their productive structures.

FIGURE III.2
Capital to output ratio and composition by sectors



Source: Central Bank of Chile using data from Penn World Tables 9.0 (appendix III.2).

The fact that the capital to output ratio has been stable in Chile and several other economies for a long time does not guarantee that this will not change in the future. In effect, this ratio could grow due to changes in the sectoral structure, technological gains or complementarity with a more skilled workforce. All of these are scenarios where the capital growth implicit in the forecasting exercise may be too conservative. Alternatively, the capital to output ratio could fall for various reasons. The literature has identified the institutional framework as a key determinant of growth, productivity and factor accumulation. Within this institutional framework, regulatory factors play a central role. One possible risk scenario, therefore, is that regulatory changes, such as increased frictions and legal requirements for new investment projects, may have a significant impact in reducing investment rates and the capital to output ratio in the projection horizon. Permanent increases in uncertainty, from regulatory, institutional or other sources, can have negative effects on the baseline projection.

III.2 THE LABOR FACTOR IN THE INTERNATIONAL CONTEXT

Immigration

In its simplest interpretation, immigration is motivated by wage differentials between the host and the source country, net of the costs associated with moving abroad (Harris and Todaro, 1970; Borjas, 1991). These costs include the financial costs of moving (travel fares, formalities) plus the personal costs associated with arriving in a new country, which are probably larger the greater the cultural distance with the host country (e.g. language, religion) and the smaller the number of previous migrants from the same origin.

This simplified analytical framework, which ignores other considerations that may lead to migration (such as political instability or religious persecution), seems like a good description of the Chilean migratory experience of recent

[4]/ For the details of the exercise, see appendix III.2.

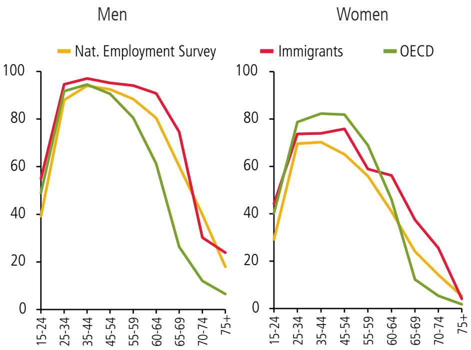
years. Starting from a very low number of migrants, the country's higher relative income in the region, its political and financial stability and the global reduction in transport costs naturally explain the strong increase in immigrant flows in the past several years. This has been reinforced, similarly to other countries' experience, by the growing presence of a larger mass of immigrants, in particular from the same country.[5] This development can increase the benefits of migrating (through the existence of social networks to access better job opportunities[6]) and reduce its costs, by providing support networks and a more friendly cultural environment. More generally, and independently of the country of origin, a greater number of foreigners generates a more diverse society, which can mitigate the social and cultural costs of migrating.

In the context of OECD countries, the number of immigrants in Chile is and has been low, given their per capita income at PPP (figure III.3).[7] The comparison with the OECD needs some caution, since many of its member countries have geographical and legal barriers to immigration that are different from Chile's. However, everything suggests that economic and cultural forces will continue to support high immigration rates in the future. Accordingly, the future trajectory of immigration in Chile can mirror, at least qualitatively, the experience of some OECD countries. Along these lines, the international experience (Peri, 2016; Abel and Sander, 2014), suggests that immigration to high-income and middle-income countries has been a steady process in the last fifty years. Moreover, there are no reasons to believe that this process will stop or be reversed in the future. However, for immigration to be sustainable, it is necessary to develop the legal and institutional framework necessary for ensuring the integration of immigrants into the local labor market.

FIGURE III.3
Number of immigrants and GDP per capita, Chile and OECD, 1960–2015

Source: Central Bank of Chile, using OECD migration statistics.

FIGURE III.4
Labor participation in Chile and the OECD, by gender and age group
(percentages)



Sources: INE, CASEN 2015 and OECD.

Participation

Figure III.4 compares labor participation in Chile (natives and immigrants) with respect to the OECD (median without Chile). However, it should be noted that, consistent with the international evidence (Peri, 2016), the labor participation of immigrants is greater than that of Chileans for men and women. This fact reflects the selection effect associated with immigration and the economic motivation behind it.[8]

There are several important differences between Chile and the OECD. While the labor market participation of men in the group aged 25-54 years is similar between Chile and the OECD, it is lower for men aged 15-24 and, increasingly higher for older men (whereas less than 10% of men 70-74 work in the OECD median, in Chile the number is close to 40%). As discussed in chapter II, the downward trend in the participation of men aged 15-24, seems to be associated with greater enrollment in tertiary schooling. Therefore, this trend

[5]/ See, for example, Lafortune et al. (2015) for an analysis of the migration patterns to the United States in the nineteenth and early twentieth centuries.
[6]/ Although in a general equilibrium model the presence of more migrants should also help to bridge the wage gaps across countries.
[7]/ As mentioned in chapter II, the figures presented in this document regarding the current number of immigrants in Chile may be revised due to new available data from the April 2017 Census. This should yield a more accurate measurement.
[8]/ A very low fraction of immigrants in Chile are refugees or asylum seekers for humanitarian reasons, and there are no social benefits comparable to those provided in many European countries.

will probably continue in the years to come. However, schooling is not the only factor explaining the lower participation rate of young workers relative to the OECD, as factors such as the characteristics of tertiary education in Chile (with long-term and full-time studies) and regulations that hinder part-time work can also play a role.

The significant differences in participation rates for older men may be partly explained by differences in pension systems and their associated replacement rates, at least for cohorts that are already close to retirement. Within the OECD, rising participation rates for older workers are expected as countries face the difficulties of sustaining PAYG pension systems, with potential incrases in retirement ages and reductions in bebefits. This process should be further enhanced by the increasing life expectancy and health-care improvements associated with greater capacity (and willingness) to work.

Participation rates for women under 25 years old are below the OECD median, while the reverse holds true for women over 60. The participation rates of women 25 to 60 are significantly lower than the median OECD rates, despite the important increase in female participation in recent decades discussed in chapter II. The relatively low participation rates for adult women in Chile compared to the OECD probably reflect long-standing cultural attitudes towards the role of women, who traditionally stayed at home doing household work and child care. However, recent trends suggest that these attitudes are waning, while economic considerations have increased the incentives for women to participate more actively. This is also reflected in a drop in natality rates and decisions to delay marriage and maternity. Thus, although the speed of the process remains uncertain, it seems reasonable to assume that the trend towards higher female participation observed in the last decades will continue in the years to come.

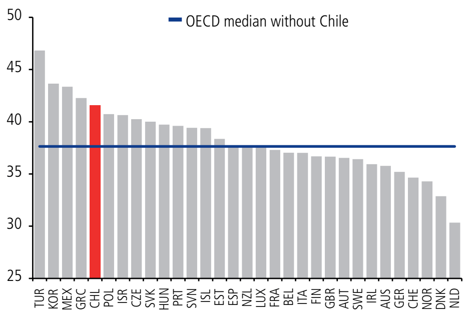
These elements lead to scenarios that could affect the participation of different groups in the future. Reforms to the educational system that shorten the duration of academic programs or make them more flexible could increase the participation of young people, counteracting the expected drop associated with larger enrollment. Changes in the pension system can also have an impact, increasing participation if the effective retirement age is raised or, reducing participation if pension payments are improved in the projection horizon. Finally, the capacity of the labor market to incorporate workers with part-time schedules or flexible hours will be important to boost the participation of groups that now lag behind international standards, including youngsters of both genders and women in their middle years. The evolution of labor regulation will play an important role.

Hours

Although the number of hours worked in Chile has fallen steadily in the past decades, it is still high by international standards, as shown in the weekly hours comparison[9] in figure III.5.

9/ As we said in chapter II, it is not feasible to directly compare weeks worked across countries using OECD data, thus it is also not possible to compare total yearly hours.

FIGURE III.5
Average weekly hours worked in Chile and OECD countries



Sources: INE and OECD.

Chile ranks fifth in the OECD in the number of weekly hours worked and is 10% above the median. The evidence of the last century, and the actual distribution of hours within the OECD, suggests that the income effect dominates the substitution effect in the determination of hours worked, so it is reasonable to expect that the number of weekly hours will continue to decline as the economy grows.[10]

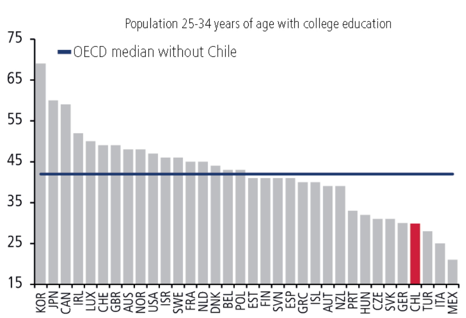
Human capital

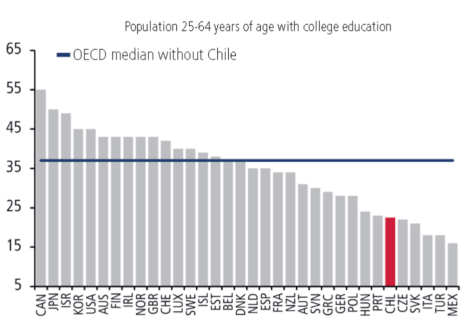
Human capital plays a key role in explaining income differences across countries (Manuelli and Seshadri, 2014; Caselli, 2005; Hall and Jones, 1999). However, due to the nature of the educational process, differences in human capital within the workforce are tremendously persistent. Changes in the coverage or quality of education will only have full impact in trend GDP after several decades. Thus, on one hand, human capital is a factor of utmost importance and one of the most direct mechanisms to achieve sustained increases in the economy's productive capacity. On the other hand, the process of improving human capital takes a long time and entails considerable costs, especially if policies attempt to boost the quality of education beyond increases in coverage.

A first important element to consider in comparing human capital across countries is to recognize that broad measures of schooling, such as average years of education, are relatively poor indicators of human capital. More complex measures, such as indicators that distinguish population shares with different educational levels, can provide a more complete picture (see Caselli and Coleman, 2006, among others).[11] Thus, although the average of 10.85 years of schooling in Chile in 2011 does not look so different from the 11.77 years of the OECD, differences in human capital are probably underestimated, as differences in composition are not considered. Figure III.6 shows the percentage of workers aged 25-34 and 25-64 years old in Chile who have completed college education and compares it with other OECD countries.

Although the coverage of college education in Chile has increased significantly, it is still comparatively low in this reference group.[12] It seems reasonable to expect that educational attainment will continue to increase towards the median of the OECD.[13] However, this increase in attainment will not change the schooling levels of adult workers already educated in the past, so the impact on the educational composition of the workforce of having more educated young people will be limited over the projection horizon. Meanwhile, as the younger cohorts have had progressively more education in the last decades, the retirement of the older cohorts has been associated to sustained growth in average attainment.

FIGURE III.6
Population with college education, Chile and OECD countries (percentages)





Source: OECD.

[10]/ As we saw in chapter II, part of the drop in hours is associated with greater female participation, but this effect is of second order compared to the across-the-board fall in hours worked in all groups as average salaries have grown.

[11]/ The conceptual argument is simple and hinges on the fact that workers with different levels of education have different productivities, and are possibly imperfect substitutes.

[12]/ The convergence process in education levels across countries is somewhat more complex than with other variables, as the final distribution of schooling reflects the interaction between the characteristics of each country's educational system and its productive structure. This explains why Germany, one of the highest income and TFP countries of the OECD has a college education coverage similar to Chile's, due to the very important role that secondary technical education plays there.

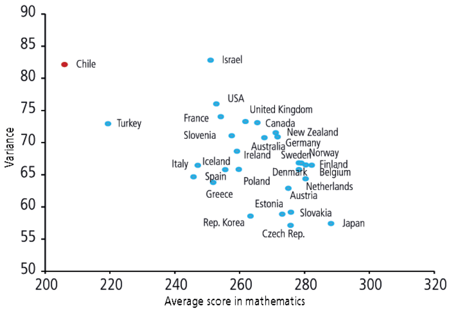
[13]/ In 2016, the OECD median (w/o Chile) was 42% for 25 to 34 year olds, and 37% for 25 to 64 year olds.

A second aspect relates to the quality of schooling. As discussed in chapter II, any indicator of human capital quality should consider the productive capacity associated with workers at each educational level. The relative salaries of groups with different levels of schooling capture part of this impact, reflecting how much more productive are workers with a certain level of education compared to a reference group. The returns on education in Chile (reflected in wage premiums) are high by international standards but, as discussed in chapter II, they have been stable in the last twenty years, even after the significant expansion of the supply of skilled workers. This is consistent with Jones and Romer (2010), who identify the stability of returns to education over time as one of the stylized facts associated with the modern growth process. In fact, the educational premium in the United States today is very similar to what it was a hundred years ago, despite the enormous changes in the supply and demand of skilled work that have taken place over the century. Therefore, in the light of international evidence, it is reasonable to assume that relative returns will remain constant in the projection horizon.

However, relative returns are not sufficient as indicators of educational quality, especially in cross-country comparisons, as they say little about the absolute level of workers' quality. Measures seeking to make up for this shortcoming, such as the *Programme for the International Assessment of Adult Competencies* (PIAAC) or the *Programme for International Student Assessment* (PISA) international tests, allow a direct comparison of the skills of workers or students from different countries. As discussed by Hanushek and Woessmann (2012), the results of this type of tests are a good measure of the productivity of the labor force, and explain an important part of the differences in per capita income between countries.

In this comparison, Chile obtains very bad results (see figure III.7).[14] Chile is the country with the worst results in Mathematics, in terms of average scores and inequality[15] (Language results are no better). This is an area of major concern and it indicates that, beyond increases in coverage and financial support, improving the quality of the Chilean educational system across social strata is paramount. This is a multidimensional process and, as such, it is extremely complex.[16] Quality gains can take a long time and in the best-case scenario, it will only begin to have some impact on trend GDP in twenty or thirty years, so potential progress on this front is not incorporated in the projection exercise. However, this is a first order issue, and in the very long term it can be a crucial factor in explaining Chile's convergence (or its failure to materialize) to the developed world. In addition to its direct impact, increases in human capital should have positive interactions with technology adoption and capital investment (see, for example, Caselli and Coleman, 2006), so potential gains are even greater.

FIGURE III.7
Results of PIAAC tests, Chile and OECD countries



Source: OECD.

[14]/ This is confirmed by other studies that suggest that, although Chilean indicators are good by Latin American standards, they are below what its per capita income would predict in a wider sample of countries.
[15]/ Using a different methodology, Schoellman (2012) infers differences in educational quality in the source countries using the relative salaries of immigrants to the United States. His results place Chile at the bottom of the list of OECD countries in the sample.
[16]/ See, for example, the discussion on quality determinants in Hanushek (2003).

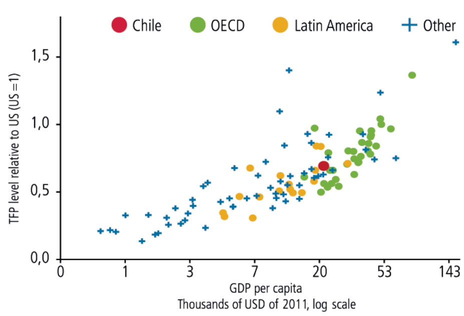
Ultimately, improving human capital presents one of the greatest opportunities for long-term growth, despite posing a great challenge. Although increases in educational coverage have been substantial and are very likely to continue, they must be accompanied by true quality improvements to become fully effective. In addition, international evidence (Heckman, 2006; Cunha and Heckman, 2007; Cunha et al., 2010) stresses the importance of allocating resources efficiently between different educational levels, as complementarities exist in the returns on the investments made throughout the life cycle. There are significant gains in investing in early-childhood education, so allocating resources and efforts to improve pre-school education should be a priority.[17]

III.3 TFP IN THE INTERNATIONAL CONTEXT

The TFP analysis in chapter II made two fundamental points. First, TFP growth of NNR sectors in Chile has outperformed total TFP in the last twenty years, due to declining TFP of the mining sector. Second, the best predictor of future growth of NNR TFP is its historical average, because of the volatility and poor predictability of the series. This section analyzes these issues in light of the international experience. In particular, we compare TFP levels and growth in Chile with respect to a large sample of countries.

International comparison

FIGURE III.8
Total factor productivity and GDP per capita, 2012–2014 average (*)



(*) Countries with more than 1 million inhabitants and average TFP no greater than twice that of the US. In blue, countries in the OECD as of 2017 (includes Mexico)

Source: Central Bank of Chile using data from PWT 9.0.

Figure III.8 correlates the 2012-14 average of each country's TFP relative to US TFP, against the level of per capita GDP[18] for a broad group of countries (using data from Penn World Tables). It should be noted that in this exercise, Chile's TFP must be calculated in a different way than in chapter II to make it internationally comparable. First, we estimate GDP at PPP. Second, we use total (as opposed to NNR) TFP, because we do not have data to calculate NNR TFP for other countries. Third, we follow the methodology of the Penn World Tables in order to estimate the factor shares (parameter β in equation (1) of chapter II), which is not identical to that used in chapter II.

The result is consistent with the notion that TFP explains much of the differences in income among countries, a pattern widely documented in the growth accounting literature (Hall and Jones, 1999; Caselli, 2005).[19] In this excercise, Chile's TFP is close to 60% of the US TFP, a level that seems to be aligned with its GDP per capita.[20] This conclusion is maintained in the comparison with OECD countries, where Chile's TFP levels are similar to the average TFP of countries in a comparable income range, but significantly lower than that of the wealthiest economies. The relationship is also maintained in

[17]/ Pre-school education not only has an impact on better future school performance and potential labor productivity, but in virtually every dimension of life, such as health indicators, risk prevention, civic behavior, and others.
[18]/ In dollars of 2011.
[19]/ Oil producers are among the countries that deviate significantly from the relationship. They show higher TFP than the Unites States despite being poorer. However, this dos not distort the main results. The general relationship and the conclusions specific to Chile remain even if a different base year or period of analyisis are chosen.
[20]/ It is worth noting that an exercise comparing Chile's NNR sectors' TFP internationally would yield a greater gap, since mining TFP is higher than non-mining TFP.

the comparison with Latin America, where Chile has one of the highest income and TFP. Therefore, although the level of Chile's TFP seems to be aligned with its income level, it is low by developed countries' standards. This result implies that there is much room for improvement.

Interestingly, the international evidence suggests that TFP differences among countries are explained by efficiency in the allocation of factors, rather than by the available technology, which can be adopted or copied at low cost (Caselli, 2005). One implication of this is that, unlike the case of the potential gains in human capital, first-order improvements in efficiency that have a significant impact on GDP could be attained in the short-run . Chapter IV elaborates in greater depth on this and other points related to TFP determinants.

TFP growth in the world

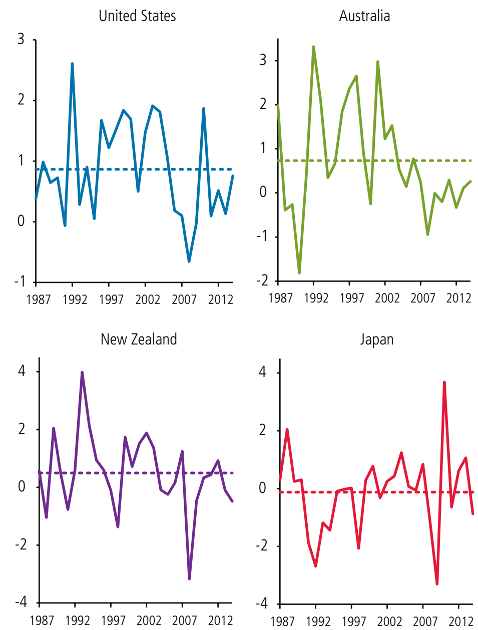
NNR TFP in Chile has been highly volatile over the last twenty years. In chapter II we contended that it is very difficult to make an accurate TFP forecast, and that the simple historical average seems to be the best forecasting. This is due to the fact that the TFP is an unobservable variable calculated as a residual, determined by multiple observable and unobservable factors.

Figure III.9 uses Penn World Tables data from 1987 to 2014 and a sample of four representative countries[21] to show that this fact is not specific to Chile. Total yearly TFP growth is extremely volatile, which makes forecasting difficult. Using the variable's historical average may be the best choice.

In the case of NNR sectors in Chile, projected TFP growth is 0.88% per year, which implies an accumulated growth of less than 35% by 2050. This growth over the next three decades is insufficient to achieve the United States' current TFP level. In other words, even if the US TFP did not grow over the next 33 years, it would still be above Chile's TFP at the end of that period. Therefore, achieving TFP gains greater than those observed in the last twenty years is a major challenge if we wish to converge to the levels of the developed world. This task seems even more challenging when noting that, in the past five years, TFP growth in Chile has been below average.

The deceleration of productivity growth is not only a local phenomenon. In fact, many recent studies suggest that TFP is slowing down in the developed world due to various causes (Gordon, 2016; Syverson, 2017). In that sense, it is important to bear in mind that the projection of future TFP growth is subject to a high degree of uncertainty. Changes in institutional factors, in the sectoral composition of the economy or in the regulation of factor markets, can significantly affect future TFP growth. As will be discussed in chapter IV, a better allocation of factors, associated with a better functioning of the labor and capital markets, can be a significant driver of efficiency gains. Conversely, regulations that hamper reallocation can be a detriment to aggregate efficiency gains. In the external scenario, a permanent fall in the technological growth component of TFP in the developed economies would have direct consequences on TFP growth in economies adopting new technologies like Chile.

FIGURE III.9
Annual TFP growth (*)
(percentages)



(*) Dotted lines show average growth in 1987-2014.
Source: Central Bank of Chile using PWT 9.0.

[21]/ The volatility of TFP growth is visible in any sample of countries.

TABLE III.2

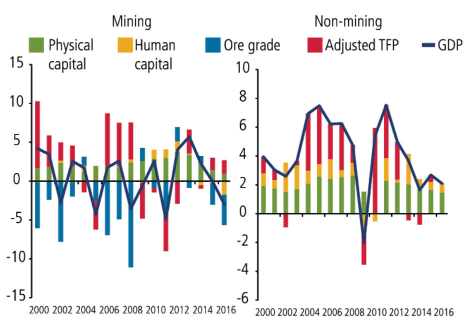
TFP growth in mining countries, 2002–2014
(percentages)

Country	Mining	Non-mining	Total
Chile	−9.01	1.73	0.77
Australia	−3.65	0.49	−0.20
Canada	−4.14	0.44	−0.05
Malaysia	−8.70	2.21	1.18
Mexico	−3.00	0.33	0.38
Norway	−6.25	0.49	−0.73
Peru	−6.90	1.80	1.14
South Africa	−3.64	1.01	0.54
Average	**−5.66**	**1.06**	**0.38**

Source: De La Huerta and Luttini (2017).

FIGURE III.10

Decomposition of growth in Chile
(percentage points)



Source: De la Huerta and Luttini (2017).

Total TFP, NNR TFP and mining TFP

Finally, we examine evidence comparing the recent evolution of NNR TFP with total TFP, explaining the role played by the TFP in the mining sector, particularly during the recent commodity super-cycle.

De la Huerta and Luttini (2017) show how, in a sample of mining countries including Chile, the commodity super-cycle was associated with sharp drops in mining TFP and gains in non-mining sectors (table III.2).

The high relative mining prices led to the reallocation of factors to the mining sector, negatively affecting average productivity growth. This is partly due to the intensified deterioration of ore in exploited deposits, as the exploitation of lower-quality deposits became profitable in the margin.[22] Figure III.10 decomposes Chile's mining TFP by explicitly including copper ore grade as an additional variable in the production function. The deterioration in extracted copper quality is a sustained process in the period of analysis. It reflects the depletion of the deposits and explains an important part of the fall in sector's TFP. In effect, when accounting for mineral ore, average TFP growth in the mining sector resembles much more closely non-mining TFP growth.

III.4 FORECASTING TREND GROWTH WITH INTERNATIONAL DATA: A CONDITIONAL CONVERGENCE MODEL

In chapter II, the exercise in the baseline scenario projects the future behavior of each determinant of NNR GDP. However, an alternative methodology, widely used in the literature, is to forecast GDP growth directly (that is, not by projecting the production factors individually), anchoring it to the analytical structure suggested by the theoretical literature. This exercise allows assessing the robustness of the projections against an alternative methodology, in addition to identifying some of the economic mechanisms behind this projection.

In particular, in the spirit of Barro (2015), the growth rate is modeled as a function of the initial income level of a country and a number of demographic, institutional, macroeconomic and external determinants that have been suggested by the literature as relevant for long-term income. Following this, the exercise is analytically framed by conditional convergence, where in the long term, the economy approaches an income level (or balanced growth path) given by its idiosyncratic characteristics. This exercise allows us to use not only information from Chile, but also the history of a very large sample of countries, to better understand the common patterns of growth dynamics around the world.

For this exercise, the panel regressions of Contreras and Pinto (2015) are re-estimated on the same sample of 89 advanced and emerging countries. The exercise also extends the estimation period to 2015 and 2016. These regressions include traditional variables of the neoclassical growth model with two types of

[22]/ The exercise in De la Huerta and Luttini (2017) is different from the one used in chapter II, for which the decompositions of non-mining TFP and NNR sectors' TFP presented earlier are different.

capital (physical and human): initial real GDP per capita (convergence effect), the ratio of gross fixed capital formation to GDP and the years of schooling of men and women (which are a proxy for the rate of investment in human capital). For international comparisons, the calculation of GDP per capita uses total GDP —not NNR GDP as in chapter II—.

Following Barro (2015), the panel regression is estimated without country-specific effects. Instead, persistent variables that affect the steady-state capital of each country are included.[23] These variables include the inverse of life expectancy, the logarithm of the fertility rate[24], a law and order indicator, a democracy indicator, variables that reflect the role of macroeconomic stability (inflation and government consumption) and the role of external shocks (terms of trade). This latter variable is interacted with trade openness, also including the effect of trade openness by itself in the regression.

TABLE III.3
Description of the data used in the conditional convergence regressions (1)(2)

Variable	Data sources	Assumptions for Chile, 2017–2026
Years of schooling, women	Barro and Lee (2013)	Section II.3 projection
Years of schooling, men	Barro and Lee (2013)	Section II.3 projection
Trade openness (3)	PWT 9,0, WDI, WEO	Data 2012-2016
Financial openness (4)	Lane and Milesi-Ferretti (2007), IFS	Data 2012-2016
Trading partners' growth(5)	UN Comtra de Database, WDI, WEO	BCCh 2017-18, WEO 2019-2021
Terms of trade growth(5)	OECDStat, UNSTAT, WDI, WEO	CF (copper and oil forecast)
Gov't consumption/GDP	PWT 9,0, WDI, WEO	WEO 2017-2022
Population growth(5)	IFS, WDI	Section II.3 projection
Democracy (6)	Freedom House (political rights)	Data 2012-2016
Time dummy	Regression result	2012-2016 result
Life expectancy (years)	WDI	2012-2016 variation rate
Exports/GDP	IFS, WDI, WEO	Data 2012-2016
Commodity exports/GDP	UN Comtrade Database, WDI, WEO	Data 2012-2016
Inflation (5)	IFS, WDI, WEO	BCCh 2017-18, Inflation Target 3% 2019-26
Investment/GDP	PWT 9,0, WDI, WEO	WEO 2017–2022
Law and order (6)	ICRG	Data 2012-2016
Real GDP per capita(7)	PWT 9,0, WDI, WEO	Data 2016 and 2021 result
Fertility rate (8)	WDI	2012-2016 variation rate

(1) CF: Consensus Forecast; INE: Chile's National Statistics Institute; ICRG: International Country Risk Guide (Political Risk Services); IFS: International Financial Statistics (International Monetary Fund); PWT: Penn World Tables; UNSTATS: United Nations Statistical Division; WDI: World Development Indicators (World Bank); WEO: World Economic Outlook (International Monetary Fund).

(2) List of countries: Emerging economies (63): Algeria, Argentina, Bangladesh, Bahrain, Bolivia, Botswana, Brazil, Cameroon, Chile, China, Colombia, Congo, Cote d'Ivoire, Costa Rica, Cyprus, Dominican Republic, Ecuador, Egypt, El Salvador, Gabon, Ghana, Guatemala, Guyana, Haiti, Honduras, Hungary, India, Indonesia, Israel, Jamaica, Jordan, Kenya, Malaysia, Malawi, Mali, Morocco, Mexico, Nicaragua, Niger, Panama, Papua New Guinea, Pakistan, Paraguay, Peru, Philippines, Senegal, Sierra Leone, Syria, Sri Lanka, South Africa, Sudan, Thailand, Taiwan, Tanzania, The Gambia, Togo, Trinidad and Tobago, Tunisia, Turkey, Uganda, Uruguay, Venezuela and Zambia.

Advanced economies (26): Australia, Austria, Belgium, Canada, Denmark, Germany, Spain, Finland, France, Greece, Ireland, Iceland, Italy, Japan, Luxembourg, Malta, Norway, New Zealand, Portugal, Republic of Korea, Singapore, Sweden, Switzerland, The Netherlands, United Kingdom and United States..

(3) Measured as the ratio over GDP of the sum of exports plus imports of goods and services.

(4) Measured as the ratio over GDP of the sum of assets plus net external liabilities.

(5) Annual growth rate.

(6) Index between 0 and 1.

(7) Constant dollars of 2005.

(8) Births per woman.

[23]/ Omitting country-specific effects reduces the downward bias in the estimation of the convergence rate that ocurrs when using a short panel in its time dimension. For details, see Barro (2015).
[24]/ This variable is included to endogeneize the growth rate of the population, which is directly (but exogenously) input in the neoclassical growth model of Solow (1956) and Swan (1956).

Factors that are especially important for small and open economies highly dependent on commodity exports, such as Chile, are included. Thus, the share of commodity exports in GDP is used as an alternative variable in the interaction with terms of trade growth, trading partners' growth, and a measure of the degree of financial openness. Trading partners' growth also interacts with the ratio of exports to GDP to capture the importance of increased demand from trading partners. Table III.3 describes the sources of the data for all the variables of the growth regression.

TABLE III.4
Panel regressions with time dummy (*)
(dependent variable: real per capita GDP growth, 1962–2016)

Variable	(1)	(2)	(3)	(4)	(5)	(6)
Convergence						
Ln(real GDP pc)	−0.020***	−0.020***	−0.020***	−0.019***	−0.019***	−0.020***
Demographic factors						
1/life expectancy	−1.847***	−1.804***	−1.803***	−1.792***	−1.751***	−1.794***
Ln(Fertility rate)	−0.027***	−0.027***	−0.027***	−0.027***	−0.027***	−0.026***
Institutional factors						
Law and order	0.012*	0.012*	0.012*	0.013*	0.013*	0.013*
Democracy	0.012	0.011	0.011	0.016	0.016	0.012
Democracy^2	−0.011	−0.010	−0.009	−0.015	−0.015	−0.011
Productivity factors						
Ratio investment/GDP	0.053***	0.053***	0.053***	0.060***	0.061***	0.056***
Women's years of schooling	0.001	0.001	0.001	0.001	0.001	0.001
Men's years of schooling	0.000	0.000	0.000	0.000	−0.001	−0.001
Macroeconomic Instability						
Ratio Gov. Consumption/GDP	−0.040**	−0.039**	−0.039**	−0.035*	−0.034*	−0.035*
Inflation	−0.003***	−0.03**	−0.003**	−0.003**	−0.003**	−0.003**
External factors						
Commercial openness	0.007***	0.009***	0.007*			
TDI growth* Com.openness	0.009**	0.009*	0.009*			
Exp. Comm./GDP				0.005	0.004	−0.006
TDI growth * Exp. Comm./GDP				0.017	0.016	0.014
TTPP growth		0.100*	0.074		0.108*	0.000
TTPP growth* Exp./GDP						
			0.073			0.309***
Financial openness		−0.000***	−0.000***		0.000	−0.000***
R2 within	0.297	0.301	0.301	0.280	0.281	0.290
N° observations / N° countries	917/89	917/89	917/89	917/89	917/89	917/89

(*) OLS estimation with time dummies (omitted), without country-specific effects and robust standard errors. The variables that take the initial value of the five-year period are the log (GDP pc), 1/(life expectancy), ln(fertility rate) and years of schooling. The rest of the variables are constructed as the average of the five-year period. * p<0,1; ** p<0,05; *** p<0,01.
See table III.3 for sources.

Table III.4 shows the results of the main regressions estimated using ordinary least squares (OLS). The regression in column (1) corresponds to the specification chosen by Barro (2015), re-estimated using the same countries, but extending the sample to 2016. The other columns show the results of including additional variables relevant to the Chilean economy.

In line with the findings of Contreras and Pinto (2015), the analysis shows suggestive evidence of convergence, which is reflected by the negative and significant effect associated with the initial GDP per capita. The coefficient indicates a convergence of 2%, as in Barro (2015). That is to say, it can be expected that, all other things being constant, countries will grow more slowly as their income increases. However, this convergence is conditional. Therefore, a richer country may grow faster than a poorer one if it is relatively further away from its long-term potential (steady state). This may happen, for example, if it has a higher rate of savings or stronger institutions that support growth.

The regressions also show negative and significant effects of the demographic variables, where the sign of the inverse of life expectancy reflects the negative effect of a higher mortality rate of the population and, in the case of the fertility rate, the negative effect of population growth. With regard to institutional factors, the law and order variable has a positive and significant effect, while the effect of democracy is not significant, despite having the expected sign.

The positive effect of factor accumulation is observed in the high significance of the investment to GDP ratio. In contrast, a greater accumulation of human capital (years of schooling) appears as not significant.[25] In the case of macroeconomic stability variables, the effects of greater inflation and a higher ratio of government consumption to GDP on growth are negative and significant.

On the external determinants of growth, a positive and significant effect of an improvement in the terms of trade is obtained when this variable interacts with the measure of trade liberalization, but not if the ratio of commodity exports to GDP is used. Trading partners' growth also has a positive and significant effect.

We use the conditional convergence model to estimate how much Chile would grow in the next two five-year periods (table III.5). Table III.3 presents the assumptions for each variable.

The effect of convergence contributes positively to growth, but as GDP per capita increases, this effect declines.[26] On the side of productive factors, the drop in the investment to GDP ratio will more than offset the increase in years of schooling, so jointly they will contribute less to growth. In turn, demographic, institutional and macroeconomic factors[27] will continue to contribute to growth in the following periods, similarly to what they do currently.

All in all, for the next ten years, the results of the conditional convergence model suggest a total GDP growth between 3.3% and 3.5% (a 2.5%-2.7% range in per capita terms).[28]

TABLE III.5
Medium-term economic growth in Chile (*)
(decomposition of average annual growth, percentages)

	2012-2016		2017-2026	
	(1)	(2)	(3)	(4)
Convergence	5.4	5.7	5.9	6.5
Demographic factors	–2.7	–2.9	–2.7	–2.8
Institutional factors	1.2	1.1	1.2	1.1
Productivity factors	1.6	1.6	1.4	1.4
Macroeconomic instability	–0.6	–0.7	–0.7	–0.8
External factors	0.1	0.5	0.2	0.5
Time dummies	–2.0	–2.3	–2.0	–2.3
GDP growth	**3.1**	**3.1**	**3.3**	**3.5**

(*) Results correspond to the minimum and maximum ranges using the six specifications in table III.4, where columns (1) and (3) come from using the coefficients of the estimate (6) (lower range) and columns (2) and (4) of estimate (1) (upper range). Convergence refers to the sum of the contribution of the initial GDP and the constant of the regression.

See sources in tables III.3 and III.4.

25/ Barro and Lee (1994) find a significant effect of years of schooling in alternative specifications. The non-significance of this variable in the regressions in table III.4 may be associated with the high collinearity between this and other variables included in the regression, or, as discussed above, the importance of the educational composition and quality factors, not captured by this measure.

26/ Due to the slowdown in GDP per capita as from 2014, the role of convergence becomes more important in the five-year period 2017–2021, compared with the previous five years.

27/ The negative effect of macroeconomic instability only reflects that, in the regressions, inflation and government consumption to GDP have negative coefficients. Therefore, any value above zero of these variables lowers the growth forecast. The effect on the estimate for Chile is small due to relatively low values of these variables compared to other countries in the sample.

28/ This growth range is obtained by using the six estimates in table III.4. It should be noted that these values do not constitute an uncertainty range, which is broader considering the uncertainty associated with the confidence intervals of the parameters and the external projections used in the calculations.

III.5 CONCLUSIONS

This chapter presented international comparisons that contextualize the analysis of the determinants of trend growth carried out in chapter II. Three main messages stand out:

First, the international comparison suggests that the assumption of a constant capital to output ratio in the projection horizon is reasonable. In particular, international evidence shows that capital to output ratios in many countries have remained fairly stable over the last twenty years and that this ratio is determined to an important degree by the sectoral composition within each country, something that changes slowly over time. Changes in this ratio will depend on the behavior of other relevant determinants of investment. These determinants include TFP growth and the relevant institutional framework for investment decisions.

Second, the international comparison supports the assumptions made regarding the evolution of the labor factor, particularly in terms of the extensive and intensive margins of participation and hours. In addition, the comparison highlights that improving the quality of education to the levels of more advanced countries is a major challenge with potentially very important positive effects, although only in a very long time horizon.

The analysis of productivity, in turn, suggests that predicting future behavior is a complex exercise and that using historical growth averages is a reasonable approximation for medium-term projections. Additionally, although Chile's TFP is in line with its current level of income, it is still far from the efficiency levels of more developed countries. Moreover, the projected growth rate is not sufficient to bridge these divides before 2050. Therefore, it is a high priority to better understand what lies behind differences in TFP levels.

Lastly, a forecasting exercise based on conditional convergence regressions delivers trend growth rates of total GDP that are similar, even somewhat higher, than those found in chapter II. This reinforces the idea that the observables of the Chilean economy are robust and that their potential for growth is still important.

IV. TOTAL FACTOR PRODUCTIVITY HOW IMPORTANT IS IT AND WHAT DO WE KNOW OF ITS DETERMINANTS?

As discussed in the preceding chapters, total factor productivity (TFP) plays a central role in the projected evolution of trend growth for Chile,[1] so analyzing its behavior is of the utmost importance. This chapter reviews the international academic literature on the determinants of TFP, with special emphasis on theory and new evidence that emerges from the analysis of microeconomic data.

The literature review is complemented by new evidence for Chile using firm level data for 2005-2015. This evidence, based on data from the Chile´s *Servicio de Impuestos Internos* (SII), the tax collection agency, is used to analyze the dynamics and distribution of the TFP of firms in Chile and its implications for aggregate TFP. The analysis of microdata not only allows for a better understanding of the determinants of TFP in Chile, but also opens many questions that will need to be addressed in the future.

The chapter's main messages are the following:

• In line with international evidence, the growth of aggregate TFP in Chile between 2005 and 2015 can be explained both by the gains of TFP at the individual firm level (intensive margin) and by the reallocation of productive factors towards more efficient firms (extensive margin).

• Additionally, there is a high and persistent dispersion in the value of marginal productivity of factors across firms, both for the aggregate economy and for particular sectors. This dispersion suggests that there are large potential gains in aggregate TFP associated with the reallocation of factors among firms.

• Although the reallocation process observed in the data goes in the right direction – factors on average move towards firms with higher productivity– it does not seem to operate with sufficient intensity. This finding suggests that there are productivity gains associated with policies that can enhance reallocation. Consistent with the findings of international literature and previous studies for Chile which have focused on the manufacturing sector, these gains would be quantitatively important. Furthermore, gains from factor reallocation could increase aggregate productivity and boost growth in the short-term, unlike improvements in the quality of education.

1/ In particular, given the assumption of a constant capital to output ratio over almost the entire forecast horizon, the estimation elasticity of trend output for TFP growth is approximately 2. Thus, if $\Delta\%K=\Delta\%Y$, output growth can be written using the equation (2) of chapter I as $\Delta\%Y=\Delta\%A/(1-\beta)+\Delta\%L$, where $\Delta\%A$ is TFP growth, and β is the share of capital in the value added.

IV.1 THE IMPORTANCE OF TFP AND THE "MEASURE OF OUR IGNORANCE"

The importance of TFP in trend growth has been widely documented in the growth literature. For example, the development accounting approach, which attempts to explain the differences in per capita income between countries based on observable differences in their physical and human capital stocks, shows that observable factors can typically explain less than 40% of the differences in development levels among countries (Hall and Jones, 1999; Caselli, 2005). The remaining 60% is explained by total factor productivity (TFP), which is basically the "residual", the share of output that cannot be explained with productive factors. This result, which is robust to various methodologies that adjust the quality of human capital and physical capital, has a striking implication: even if poor countries had workers with the same level of education as rich countries and a similar stock of machinery, equipment and infrastructure, the former would continue to produce significantly less than the latter.

Thus, a very large part of the difference in income between countries is associated to elements that we cannot observe, at least with aggregate data. It is therefore not strange that TFP is usually called "the measure of our ignorance" (Caselli, 2005). Conceptually, TFP is constructed from what cannot be measured, and there is no a commonly accepted theory to explain it. Several studies have documented that productivity differentials between countries persist even when considering differences in sectoral composition, as these differences are observed even when comparing similar sectors. For example, agriculture, a low productivity sector, has a larger share of GDP in poorer countries. However, differences in productivity between agricultural sectors are even wider across countries than in other sectors (Caselli, 2005; Adamopoulos and Restuccia, 2014). This implies that differences in sectoral intensities explain a relatively low fraction of the variance of aggregate levels of TFP in the cross-section. This line of research also highlights that access to technology —which can be imitated or directly imported in a relatively simple way— does not seem to be the first-order factor explaining productivity differentials. Instead, they seem to be more strongly associated with the efficiency with which aggregate factors of labor and capital are allocated within the set of firms in each country.[2]

These two elements —the relative importance of TFP and the scant understanding of its determinants— explain why studying its determinants has increasingly become a priority for academic research and public policies (Lagarde, 2017).

2/ Another interpretation of this phenomenon is that, although the technology of richer countries —understood as specialized machinery, software, corporate management models, etc.— can be adopted by poorer countries, returns would still be lower due to differences in the composition of human capital between countries (see, for example, Caselli and Coleman, 2006).

IV.2 TFP DETERMINANTS: FROM "IGNORANCE" TO MICROECONOMIC DATA

The growing availability of data at the micro level has brought a notorious change of focus in the investigation of growth determinants. A long list of articles generated in the last decade attempt to measure and understand TFP directly from individual firm data. The rest of the review focuses on this aspect of the literature, since individual firm data offers a great opportunity for studying the microeconomic determinants of TFP. Additionally, it serves as an introduction to the empirical analysis presented in this chapter which we undertake using Chilean data.

Conceptually, GDP or value added of the total economy is simply the sum of the aggregated values of the different firms that operate in it. If we also assume that the value added of each firm is described by a production process whose functional form is analogous to that used to describe the aggregate economy, it is possible to write the growth of aggregate TFP as the (properly weighted) average of the individual productivity growth rates of firms, plus changes in weights associated to factor reallocation.

Specifically, we can assume that the value added (net sales of intermediate costs) of an individual firm i depends on its capital and labor in a Cobb-Douglas function:

$$(1)\ Y_{it} = A_{it} L_{it}^{\beta^{jl}} K_{it}^{\beta^{jk}}$$

where L_{it}, K_{it} correspond to labor and capital of the firm, β^{jl} and β^{jk} are the technological parameters that capture the shares of of labor and capital in sector j where the firm operates[3] and A_{it} is the individual TFP of the firm. Defining the relative use of factors of the individual firm as as $\omega_{it} = L_{it}^{\beta jl} K_{it}^{\beta jk} / (L_t^{\beta} K_t^{1-\beta})$)—the ratio between the relative use of factors of the firm with respect to the aggregate of the total economy— the expression for aggregate TFP growth is given by

$$(2)\quad \Delta\% A_t = \sum_{i=1}^{c} \Delta\% A_{it} \frac{1}{2}(\omega_{it} + \omega_{it-1}) \frac{A_{it-1}}{\frac{A_{t-1} + A_t}{2}} + \sum_{i=1}^{c} \Delta\omega_{it} \frac{1}{2}\left(\frac{A_{it} + A_{it-1}}{\frac{A_{t-1} + A_t}{2}}\right)$$

$$+ \sum_{i=1}^{c} \Delta\omega_{it} \frac{1}{2}\left(\frac{A_{it} + A_{it-1}}{\frac{A_{t-1} + A_t}{2}}\right) + \sum_{i=1}^{e} \omega_{it}\left(\frac{A_{it}}{\frac{A_{t-1} + A_t}{2}} - \sum_{i=1}^{s} \omega_{it-1}\left(\frac{A_{it-1}}{\frac{A_{t-1} + A_t}{2}}\right)\right.$$

The first term on the right-hand side of equation (2) corresponds to the TFP growth rate of each firm, weighted by its relative use of factors (average between years t-1 and t) and the TFP of the firm relative to the aggregate. This term reflects the intensive margin and captures how much of aggregate productivity growth is explained by the growth of the individual productivities of firms operating both in t-1 and in t. The second term corresponds to the change in the relative use of factors of each firm, weighted by the TFP of the firm relative to the aggregate economy. This term captures the extensive

[3]/ It is usual to assume common technological parameters for firms in the same industry or sector in order to allow estimating them in the cross-section of firms. In principle, constant returns are not imposed on the technology of each industry, so βjk+βjl may be different from 1.

margin, that is, how much of the increase in the aggregate TFP is given by the growth in size of each firm —measured by the relative use of factors— given its productivity relative to the rest of the economy. To the extent that firms with higher relative TFP tend to grow more on average than less productive ones, the reallocation process will tend to increase the aggregate efficiency with which a given stock of factors is used at the aggregate level. The third term corresponds to the relative use of factors of new firms that enter the economy in period t, weighted by their relative TFP. Finally, the last term of the expression is given by the TFP of firms that cease to exist between t-1 and t and that, therefore, stop contributing their respective productivities. Thereafter, the net contribution of components 3 and 4 is referred to as the turnover effect of firms.

The relative contribution of these components has been calculated for different countries in numerous studies. For example, literature reviews by Foster et al. (2001) and Syverson (2011) find that, although the details of decomposition results depend to a great extent on the specific definition of variables and on the sample used (sector, country, period), the intensive margin tends to explain a greater part of the observed increase in productivity compared to the extensive margin. In addition, the sign of the turnover effect of firms is not obvious and can be negative. This last result is generally associated with the fact that firms that enter the market are more productive than those that exit, while the former are generally smaller in size.

It should be noted that the distinction between the three margins is useful as an analytical strategy, conceptually all of them interact, particularly in a dynamic context. For example, the entry margin may allow for the emergence of innovative firms, whose productivity increases over time, which in turn leads them to hire more factors.

Table IV.1 presents estimates of the contribution of each component based on administrative data from the SII of Chilean firms between the years 2005 and 2015.[4] The methodology used to estimate the production function parameters is based on the methodology of Levinsohn and Petrin (2003).[5] The numbers reported correspond to a measure of the economy that is similar to the definition of the NNR sector (specifically, firms in the Mining, EGW, Public administration and Housing services sectors are excluded from the sample).

The decomposition of TFP growth in equation (2) reveals several interesting results (table IV.1). First, the growth of weighted average TFP that emerges from the microdata is around 0.97%. This value is very similar to the one obtained for the aggregate NNR TFP from the sectoral national accounts presented in chapter II. Second, in line with the international literature, the intensive margin contributes more to TFP growth than of the extensive margin, but the effects are of the same order of magnitude. Third, the contribution of the turnover effect of firms is negative.

TABLE IV.1

Decomposition of productivity growth, 2006 – 2015, percentages (*)

Productivity growth	0,97
Productivity growth of firms that continue	1.23
Reallocation between firms that continue	1.03
Net turnover effect	-1.30

(*) Annual average of the decomposition of productivity growth between 2006 and 2015. Parameters estimated using the methodology of Levinsohn and Petrin (2003) calculated for 91 sectors.

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

4/ For a more detailed description of data sources, see Albagli et al., 2016, 2017. The data provided by the SII have unique identifiers for firms and workers, which guarantees the strict confidence of the tax information.

5/ The methodology of Levinsohn and Petrin (2003) allows to consistently estimate the production function parameters of a firm, using intermediate inputs and investment to control for the bias that arises due to the simultaneity between productivity (unobservable) and the firm's choice of factors. In this exercise, the parameters are estimated for 91 different sectors.

As mentioned above, the interpretation of these results must be done with caution, because the interaction between the different margins cannot be ignored. For example, the negative effect of turnover does not imply that eliminating firm creation and destruction flows would be a good policy to enhance TFP growth. The negative sign of turnover does not reflect that firms that enter are less productive than those that leave (in fact they are more productive), but that their relative size is smaller (appendix IV.1). Conceptually, the rotation margin measured here only reflects the impact of the entry/exit in the year in which it occurs. In consequence, it does not consider the dynamic consequences of creation and destruction, as firms that enter —and survive— increase their productivity and keep hiring factors. These effects are accounted for in the first two margins, so eliminating turnover would have direct consequences on the intensive and extensive margins.[6]

The rest of the chapter reviews the literature and presents new evidence obtained from SII data. It focuses on two margins. The intensive margin, which reflects increases in firms' TFP, and the extensive margin, which measures factor reallocation. As mentioned in the Introduction, the main conclusion of the chapter is that the potential contribution of the extensive margin is of greater magnitude than the actual contribution observed in the data. This is due to the high and persistent levels of dispersion in productive efficiency among different firms, measured in terms of the value of marginal factor productivities estimated for each firm. A similar pattern has been observed for many countries in recent studies, some of which are reviewed in more detail below.This suggests a promising area for research and public policies aimed at increasing aggregate productivity.

IV.3 INTENSIVE MARGIN: DETERMINANTS OF TFP GROWTH OF INDIVIDUAL FIRMS

Why are some firms more productive than others? What causes changes in productivity over time? An extensive theoretical and empirical literature has attempted to answer these questions (see, for example, the review by Syverson, 2011). A detailed review of this literature is beyond the focus of this chapter. Our review focuses therefore on two of the areas that have received most attention and that may be more relevant for the Chilean case, in terms of future research and policy. The first is related to investment activities in research and development (R&D) that improve the technology of production processes. The second is the interaction with commercial openness and the incentives that this generates for exporting firms and import-substituting firms.

Research and development and productivity

There is a wide literature that studies the impact of investment in R&D on productivity. Various authors have identified mechanisms through which technological investments improve the productive efficiency of factors, or generate new product varities. Beyond the direct impact on the technology

[6]/ Appendix IV.1 discusses this in more detail and shows how taking time windows greater than one year changes the decomposition and the relative importance of margins.

and efficiency of an individual firm, these investments may have externalities in other firms. The sign of these externalities will depend on the degree of rivalry/complementarity between the technology generated by a firm and that available to its competitors, as well as on the effects that innovations have on the degree of competition between firms in general equilibrium.[7]

Empirically, several papers have confirmed a positive relationship between R&D and productivity using aggregate data, whether in the cross-section of industries within a country, or among a sample of countries.[8] However, aggregate estimates are generally less effective in isolating the causal effect of R&D on productivity—in fact, higher R&D expenditure may also be causally affected by the firm's productivity. To deal with this problem, several studies have developed structural models that are estimated with microdata at the firm level. These estimates allow measuring the causal impact of R&D on an individual firm's productivity growth, also accounting for general equilibrium interactions. In general, there is a positive causal relationship —and in some cases of high economic significance— between R&D expenditure and productivity growth at the individual firm level. In addition, as already discussed, the intensive margin can interact with the extensive margin, as productive factors are reallocated to more innovative firms, at the expense of their competitors with lower productivity.[9]

International trade and productivity

Another area that has received much attention is the interaction between international trade and productivity. These variables can be related by a variety of mechanisms, including the selection effect of increased competition, the diffusion of innovation through greater exposure to international firms, and increased incentives to invest in technology/R&D as a result of greater trade openness.

Regarding the first channel, several studies have highlighted that greater competition from foreign firms will tend to crowd out less productive local firms, increasing aggregate productivity due to a firms' composition effect. Direct evidence of this mechanism includes Pavcnik (2002), for a sample of Chilean firms, and Melitz (2003) and Bernard et al. (2003) for firms in the US. This selection effect is more related to the extensive margin (allocation of factors to more productive firms) than to the intensive margin (productivity increases within each firm).

A second mechanism is the diffusion of innovation, which is more related to the intensive margin of productivity improvements. This mechanism can expand the technological frontier of countries through greater exposure to more advanced technologies and/or new products from trading partners. This technological diffusion operates both for non-exporting firms that learn from their new competitors, and for exporting firms that compete with local firms in their

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7/ See Romer (1990), Grossman and Helpman (1991, 1993), and Aghion and Howit (1992).
8/ See Scherer (1982), Griliches and Lichtenberg (1984), and Aghion et al. (1998) for the United States, and Frantzen (2000), Griffith, et al. (2004) and Ulku (2004) for international evidence.
9/ See Hall and Hayashi (1989), Klette (1996) and Doraszelski and Jaumandreau (2013), and Klette and Kortum (2004).

target markets.[10] Eaton and Kortum (1996, 1997) provide empirical evidence of this mechanism based on the calibration of a trade model with aggregate data, and find that an important share of productivity growth in OECD countries comes from trade integration with the more advanced countries of the group.

The third channel (related to the second) highlights the incentives to explicitly increase investment in technology and R&D in response to changes in the international trade environment. Using the Mercosur trade agreement as a natural experiment, Bustos (2011) documents that exporters in Argentina that benefited most from the reduction of tariffs experienced greater increases in specific measures of technology investments.[11] Bloom et al. (2016) provide similar evidence of an increase in specific metrics of investment on innovation for European import-substitution firms, in response to increased competition from Chinese imports in the early 2000s.

There are also several studies that try to measure the impact of trade on the measured productivity of firms, without being explicit (in either theory or measurement) regarding the mechanisms that lead to this increase in productivity. This strategy, however, can be problematic if there is reverse causality, as the most productive firms are more likely to be able to pay the fixed costs of entering international markets. De Loecker (2013) argues that endogeneity can lead to biases in estimating the causal effect of trade on productivity, which would explain why previous studies find small non-significant effects.[12] The paper finds substantial productivity gains in Slovenian export firms using instrumental variables that account for this bias. Highlighting other methodological problems, García and Voigtlander (2013) argue that the most common measurement of productivity in the data does not control for changes in prices due to the lack of deflators at the plant level. Because increases in production are generally associated with lower sale prices, this would underestimate the gains in productivity associated with exporting. Using marginal cost data as an alternative measure of productivity improvements, the authors find substantial efficiency gains in export firms.

IV.4 EXTENSIVE MARGIN: CONTRIBUTION OF THE REALLOCATION OF FACTORS

The results of table IV.1 suggest that a non-negligible part of aggregate TFP gains comes from the reallocation of factors among firms with different levels of individual productivity. However, these results show the degree of actual reallocation and not necessarily the true potential for aggregate efficiency gains that could be obtained if the process of reallocation to more productive firms was faster and on a larger scale. Estimating these potential gains and understanding the factors that facilitate or prevent their realization through the reallocation of resources has been one of the main research topics in the productivity and development literature of the last decade.

10/ See Álvarez et al. (2014), and Buera and Oberfield (2016).
11/ Keller and Yeaple (2009) find a positive relationship between imports and technological adoption, although their effect on knowledge diffusion would be lower and less robust than that estimated for foreign direct investment.
12/ See Keller (2004) and Wagner (2007).

Conceptually, different firms may have different levels of physical productivity (henceforth TFPQ, where Q stands for quantities). This measure —equivalent to the term A_{it} of equation (1)— captures total factor productivity, defined at constant prices. In the absence of frictions to hire production factors, firms with higher TFPQ should hire more factors and operate in a larger scale. In practice, the size of the firm is limited by the existence of diminishing marginal returns —for example, if the production function has diminishing returns to scale— or, alternatively, if firms have some degree of monopolistic power and must reduce the sale price to increase production. The optimal size of the firm is determined when the marginal cost of hiring more factors —determined by wages and the cost of capital— is equal to the marginal revenue of additional production. If all firms meet this condition of equality in equilibrium, the value of marginal productivity (henceforth, TFPR, where R refers to income) must be equalized across firms.[13] This value, TFPR, is equivalent to the product between physical TFP (A_{it}) and the sale price of the firm's products.

Thus, while the distribution of the TFPQ by itself does not reveal information regarding the degree of efficiency of the economy, the distribution of TFPR, correctly measured, is an equilibrium outcome that has direct implications on the way factors are allocated with respect to the best possible allocation.

It should be noted that TFPQ is an unobservable variable if only information on the firm's total sales is available, as there is usually not disaggregated data on price and quantity in such data. The TFPQ can only be measured directly if there is information on the specific prices that each firm charges for its products. Most of the measures of firms' productivity for Chile obtained from the National Annual Industrial Survey (ENIA)[14] and the SII data (which is used in this chapter), are based on data on total sales and value added of firms, so they are measures of TFPR.[15]

To the extent that the equalization of TFPR between firms does not occur, there are unexploited efficiency gains that could be attained with the same amount of aggregate resources, if capital and labor were to move from firms with a lower level of TFPR, to firms with higher levels. Using this idea, an influential article by Hsieh and Klenow (2009) shows that efficiency losses can be calculated by computing the dispersion levels that exist in the TFPR levels in the cross-section of firms. The authors estimate the TFPR dispersion with data from individual firms in the manufacturing sector for the US, China, and India. Their results are unambiguous. While for the US firms in the 75th percentile have a TFPR 1.6 times higher than those in the 25th percentile (a common measure of dispersion that is robust to outliers), the values for India and China are between 2.2 and 2.4 times higher. Under several functional assumptions, Hsieh and Klenow estimate that these dispersion levels imply that a hypothetical reallocation of resources that eliminates the dispersion of TFPR

[13]/ The TFPR level also depends on the production function, in particular on the exponents of capital and labor —their participations in income in a Cobb-Douglas function. For this reason, the condition of TFPR equalization should be tested at the level of sub-sectors that operate with similar technology (i.e., equal β exponents in equation (1)).

[14]/ For example, Busso et al. (2013) and Bergoeing et al. (2010).

[15]/ TFPQ can be inferred from TFPR based on a series of functional assumptions. For a detailed discussion of the distinctions between the different measures of productivity derived from the data, see Foster et al. (2017).

among firms would raise India's aggregate TFP by around 100% - 130%. In other words, India could double its aggregate TFP level if it would reallocate its existing factor stocks. For China, the estimated gains are of a similar order, around 86% – 110%.[16]

The authors find that even in the US there are significant gains from reallocating resources, around 30% – 40% of aggregate TFP level. However, the US is typically considered a country where frictions that prevent reallocation are relatively low, so dispersion there could reflect fundamental factors and not distortions. Thus, a more conservative exercise to measure potential gains in China and India consist in reducing the dispersion levels of TFPR in these countries to make them comparable to those of the US. There are still first order gains from this exercise, between 30% – 60% increase in aggregate TFP for India and China.

These results suggest that the inefficient allocation of resources among firms could explain an important part of the differences in aggregate TFP levels in the cross-section of countries.[17] This idea is confirmed by several studies, suggesting that the margin of reallocation of resources among firms is a leading candidate in explaining differences in GDP per capita across countries. With the same logic, several studies find that reductions in TFPR dispersion in the cross-section of firms within the same country over time are important determinants of aggregate TFP growth.[18] Several studies that use data from the manufacturing industry for Chile up to the mid-2000s have highlighted the role of reallocation in the growth process, as well as the existence of a high and persistent dispersion in TFPR.[19]

What elements can explain the persistence and prevalence of a large degree of inefficiency? Although this chapter does not intend to provide an exhaustive summary of the literature, we highlight some of the main explanations that could be relevant in the light of the data from Chilean firms that we present below. For a more general view, see the reviews of Hopenhayn (2014) and Restuccia and Rogerson (2017).

What explains the dispersion of TFPR among firms?

A first explanation for the high level of dispersion observed in microdata is that it does not reflect a true economic phenomenon, but only measurement errors. In effect, estimating productivity requires correctly computing i) the added value of each firm, ii) their hiring of labor, adjusted by some quality indicator, such as salaries, iii) their stock of capital. There are numerous errors and possible omissions in the imputation of these variables, both in surveys and in administrative data, which could lead to exaggerating the differences in TFPR between firms. Several studies have tried to evaluate the possible quantitative

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16/ The last year estimates of Hsieh and Klenov (2009) correspond to 2005 for China, 1994 for India and 1997 for the United States.
17/ See Alfaro et al. (2008), Hsieh and Klenow (2010), Kalemli-Ozcan and Sorensen (2016), and Busso et al. (2013), among others.
18/ See Ziebarth (2013) for the US, Fuji and Nowaza (2013) for Japan, Gopinath et al. (2017) for Eastern European economies, Reis (2013) for Portugal, and Calligaris (2015) for Italy.
19/ See Busso et al., 2013; Bergoeing et al., 2010; Chen and Irarrázabal, 2015; Micco and Repetto, 2012.

impacts of these errors and propose more robust measurement methodologies.[20] The general conclusion is that the magnitude of actual dispersion is still important, even after accounting for mismeasurement, and that there would still be significant potential gains in aggregate TFP from reallocation.

Another explanation has to do with the fact that firms with high marginal productivity may be unable to adjust their factors quickly for technological reasons, or optimally allow for a partial adjustment due to adjustment costs. For example, search frictions in the labor market may imply that finding and hiring suitable workers takes time. Analogously, adjustment costs in the stock of installed capital may make it desirable to increase it only gradually. Moreover, these adjustment and search costs may be more important insofar as there are information frictions that generate uncertainty about how persistent the improvement in productivity will be.[21] However, micro-studies based on firm panels find that the deviations of TFPR at individual firms' level tend to be highly persistent over time. Furthermore, methodologies that explicitly control for adjustment costs find that they only explain a small fraction of the TFPR dispersion observed in the cross-sectional data.[22]

A third explanation behind the dispersion in TFPR among firms may be due to non-technological rigidities that might have an impact in factor markets, but which are not directly associated with regulations or distorting policies. An example may be financing restrictions that limit the capacity of productive firms that are relatively young or that have little collateral to hire more factors, particularly capital. This could generate a suboptimal size of firms, to the extent that those with good performance face difficulties to increase their stock of capital and/or to finance the working capital necessary to expand their payroll of employees.[23]

Finally, there are those distortions about firms' decisions and their choice of factors that are associated more directly with the legal and regulatory environment. For example, several studies have emphasized the effects of labor legislation and how this can have heterogeneous effects on firms with different characteristics. Although the legal requirements on social security contributions, severance payments, and other regulations, might be formally identical among firms, they can have a greater actual impact on larger firms due to greater compliance (for example, because they are subject to stricter control and enforcement). This is just one example of the various types of size-dependent policies that, as various authors have emphasized, can generate "correlated distortions": implicit or explicit taxes that are positively correlated with the productivity of firms and that imply that more productive firms face larger actual distortions.[24]

20/ See, for example, Hsieh and Klenow (2009), and Bils et al. (2017).
21/ Recall that an increase in TFPR can occur either due to technological improvements (which increase TFPQ) or demand shocks for specific products of a firm that allow raising prices.
22/ See Midrigan and Xu (2014), and David and Venkateswaran (2017). However, Asker et al. (2014) present results that attribute greater importance to adjustment costs, especially for developing countries.
23/ See Buera et al. (2011), Greenwood et al. (2013), Midrigan and Xu (2014) and Moll (2014).
24/ See Restuccia and Rogerson (2013); Restuccia (2013); Hopenhayn (2014).

An important aspect of this analysis is that, by construction, the dispersion measure only captures firms that actually choose to operate at a certain point in time. However, the distortions generated by the dispersion observed in the data can also affect firms' entry and exit decisions. On the other hand, these distortions can also affect firms' incentives to invest in technology that allows them to improve their productivity levels, especially in case of correlated distortions, which act as an implicit tax to increasing productivity, reducing individual incentives. Although the quantitative impact of these margins cannot be measured directly from the data, it is possible to combine the data with structural models of dynamic business decisions to have an approximation of their possible quantitative effects on aggregate efficiency.[25] Bento and Restuccia (2017) calibrate a model with these characteristics for a large sample of countries and find that the quantitative effects on aggregate TFP can be substantial. Furthermore, they argue that this type of distortion can explain the wide differences observed in the distribution of firm sizes between countries. In particular, the existence of many small/medium firms in poorer countries, compared to a greater presence of firms of larger size in developed countries.

New evidence for Chile with census data of the SII, 2005-2015

Productivity dispersion

The first empirical exercise follows the methodology of Hsieh and Klenow (2009) and calculates the cross-sectional dispersion of firms' TFPR. As mentioned above, since there are no price data that allow us to calculate the units of goods sold by each firm, the TFPs calculated using the methodology of Levinsohn and Petrin (2003) are a measure of the TFPR. Therefore, their dispersion provides information regarding the degree of efficiency in resource allocation in the Chilean economy.

In particular, Hsieh and Klenow (2009) argue that the TFPR of any firm is an increasing function of the marginal product value of its factors. Following its nomenclature,

$$(3) \quad TFPR_i \alpha \left(\frac{\sigma}{\sigma-1}\right)\left(\frac{MPL_i}{1-\beta_i}\right)^{(1-\beta_i)}\left(\frac{MPK_i}{\beta_i}\right)^{\beta_i}$$

where β_i is the factor contribution to the value added in firm i (which is assumed equal for firms in the same sector).[26] This expression shows that the dispersion in TFPR is directly related (proportional) with differences in the marginal productivity of factors between firms. Conceptually, the dispersion in TFPR comes from two types of distortions: in the firm scale and in the relative cost of hiring capital versus labor.

Following Hsieh and Klenow (2009), the degree of dispersion in TFPR is calculated for Chilean firms (table IV.2). Dispersion is calculated through the ratio between the productivity value of the firm in the 90th productivity percentile (75th) and the firm in the 10th percentile (25th). The exercise is carried out for

[25]/ See Hopenhayn (2014) and references contained therein.
[26]/ Hsieh and Klenow (2009) assume constant returns to scale.

three samples: all firms in the economy; firms of the manufacturing sector; and large firms within this sector. This last sample is the most similar to the one calculated by Hsieh and Klenow (2009) for China, India and the United States, and is generally the sector analyzed by international literature. In any case, the differences in period of analysis, type of firms (plants) included in each country and the methodology for estimating the participation of factors make a cross-country comparison quite difficult.

TABLAE IV.2
Dispersion ratios of TFPR (*)

	Economy			Manufacturing			Large manufacturing		
Year	Std. dev.	90p/10p	75p/25p	Std. dev.	90p/10p	75p/25p	Std. dev.	90p/10p	75p/25p
2005	0.91	7.84	2.76	0.82	6.41	2.53	0.64	4.60	2.14
2006	0.85	7.13	2.61	0.82	6.41	2.53	0.60	4.16	2.11
2007	0.85	7.10	2.61	0.77	5.80	2.41	0.60	4.21	2.00
2008	0.83	6.91	2.59	0.75	5.64	2.39	0.61	4.17	2.04
2009	0.82	6.67	2.57	0.73	5.42	2.30	0.62	4.44	2.07
2010	0.82	6.93	2.64	0.77	5.57	2.31	0.61	4.20	2.08
2011	0.81	6.69	2.62	0.74	5.72	2.34	0.61	4.31	2.08
2012	0.82	6.80	2.65	0.73	5.66	2.31	0.65	4.92	2.21
2013	0.82	6.98	2.66	0.75	5.95	2.44	0.66	4.70	2.24
2014	0.84	7.13	2.71	0.77	6.00	2.54	0.71	5.02	2.29
2015	0.88	7.80	2.85	0.85	6.62	2.63	0.68	4.84	2.21
Total	**0.84**	**7.09**	**2.66**	**0.77**	**5.93**	**2.43**	**0.64**	**4.51**	**2.13**

(*) Parameters estimated using the methodology of Levinsohn and Petrin (2003) calculated for 91 sectors. The deviation of TFPR from the industry average is presented following the proposal of Hsieh and Klenow (2009). We assume constant returns to scale and that large firms have sales over 14,555 UF per year.

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

Several results are obvious. First, in line with what is expected a priori, dispersion is greater when considering the complete economy than when considering the manufacturing sector only. This dispersion, in turn, is lower among larger manufacturing firms, possibly due to a greater degree of homogeneity in their production processes. Second, dispersion shows no large changes in the ten years under study, although it has increased in the most recent period after having decreased in the middle of the decade under analysis. This suggests that, at least in first-order terms, the efficiency in the allocation of factors in the Chilean economy did not change much between 2005 and 2015. Third, dispersion is important, with firms in the 90th percentile of large manufacturing firms being up to five times more productive than firms in the 10th percentile.[27]

The extension of the exercise to more sectors, apart from the decomposition of the manufacturing industry, shows that there is heterogeneity in the dispersion, with sectors such as Agriculture, Fishery and Financial services exhibiting a high dispersion, while Pulp and paper and Chemicals exhibit lower dispersion (table IV.3). As a more general conclusion, it can be seen that the phenomenon of dispersion in marginal productivity values is widespread across the economy and not associated with specific sectors. However, a comparison of dispersions between sectors must be interpreted with care, as the different technological characteristics and competitive structure of sectors can inherently lead to more dispersion, without necessarily being associated with greater distortions.

[27]/ These results are qualitatively similar to the dispersion found by Busso et al. (2012) and Micco and Repetto (2012) with data from the ENIA for the manufacturing sector in the mid-1990s and mid-2000s.

TABLE IV.3
Average dispersion ratios by sector, TFPR (*)

	Economy			Large manufacturing		
Sector	Std. dev.	90p/10p	75p/25p	Std. dev.	90p/10p	75p/25p
Agriculture	1.04	11.34	3.27			
Fishing	1.06	12.27	3.46			
Food and beverages	0.79	6.12	2.40	0.72	5.07	2.22
Textiles	0.86	7.34	2.76	0.78	4.98	2.22
Wood and furniture	0.80	6.32	2.52	0.72	4.69	2.17
Cellulose and paper	0.74	5.94	2.45	0.66	3.99	1.99
Chemicals and oil	0.65	4.23	2.06	0.57	3.49	1.89
Non-metal minerals	0.84	7.13	2.67	0.55	4.28	2.37
Metal products	0.77	6.08	2.47	0.68	4.44	2.12
Construction	0.83	6.88	2.59			
Trade and hotels	0.82	6.83	2.62			
Transport	0.85	7.31	2.72			
Communications	0.91	8.26	2.88			
Financial services	0.95	9.30	3.02			
Personal services	0.79	6.14	2.62			

(*) Parameters estimated using the methodology of Levinsohn and Petrin (2003) calculated for 91 sectors. The average of all years of TFPR deviation with respect to the average of the industry-year is presented, in each economic sector considered. We assume constant returns to scale and that large firms have sales over UF 14,555 per year.

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

As already discussed, a natural concern arising from this analysis is that this dispersion is of less relevance if the TFPR of individual firms has little serial correlation. If all the dispersion of TFPR across firms came from measurement errors that are undone over time, or from short term disturbances that do not exhibit persistence, the efficiency implications of large dispersion in a given year could be lower, because firms of high TFPR in a particular year could have a low TFPR the following year, even without adjusting its factors.

The results show that this is not the case. First, there is a high persistence in TFPR levels at the individual, so any unrealized gains of a better allocation will remain over time. Second, dispersion measures are similar when, instead of using the TFPR of a specific year, the calculations use the average of several years (table IV.4, panel B).

Therefore, the level of TFPR dispersion observed in the data is not only a statistical curiosity coming from noisy data, but seems to reflect differences in the value of marginal productivities that are maintained over time. This fact motivates the analysis in the rest of the chapter, which focuses on answering three sets of questions. First, what is behind the dispersion in TFPR? Differences in marginal productivity of labor or capital? Is this related to size, as suggested by the theory of correlated distortions? Second, does the existence of dispersion imply that the reallocation process does not work? Third, what are the efficiency costs of this dispersion? What is the order of magnitude are the possible gains of eliminating or reducing dispersion?

Dispersion analysis

How is productivity dispersion related to the size of the firm? A priori, several options are possible. With correlated distortions, larger firms (which are larger because they have higher TFPQ) face greater de facto relative restrictions, such

TABLE IV.4
Persistence of TFPR (*)
Panel A: TFPR explained by its lags

	PTFR	
L.Prod	0.561*** (0.0124)	0.564*** (0.00710)
L2.Prod	0.140*** (0.0123)	0.166*** (0.00636)
L3.Prod	0.0676*** (0.0114)	
L4.Prod	0.0908*** (0.0112)	
L5.Prod	0.0816*** (0.00886)	

Panel B: Average TFPR in one- and ten-year windows

	Manufacturing		Large manufacturing	
Window	Average	Std. dev.	Average	Std. dev.
1	1.23	1.28	1.09	1.07
10	1.10	1.17	1.01	0.83

(*) Panel A corresponds to a regression where the TFPR of a firm is explained according to its lags. Panel B corresponds to statistics of the TFPR distribution using one- and ten-year windows to calculate the TFPR average of each firm.

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

TABLE IV.5
Firm size and TFPR: descriptive statistics (1)

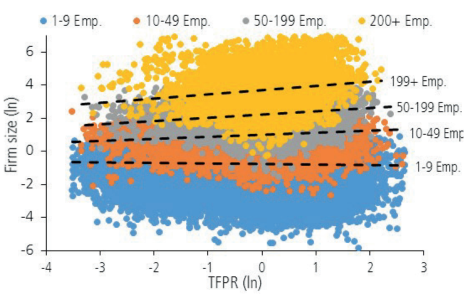
No. employees	No. firms	TFPR (ln) Average	Std. dev.	90p/10p (2)
1-9	244,710	-0.04	0.74	6.03
10-49	93,511	0.05	0.56	3.76
50-199	25,790	0.12	0.56	3.67
200+	9,093	0.14	0.64	4.65
All firms	373,104	0.00	0.68	5.19

(1) Note: Years 2005 to 2015. TFPR (ln) measured in logarithm and net of fixed effects by sector-year.

(2) The p90/p10 ratio corresponds to the original variable in levels and is calculated as Exp[p90(ln)–p10(ln)].

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

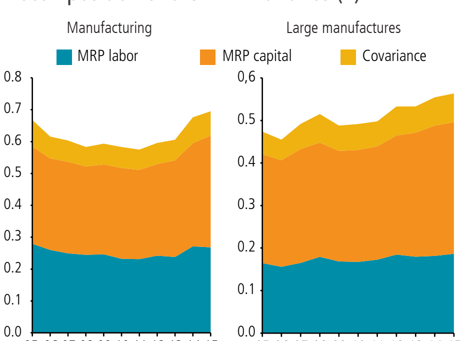
FIGURE IV.1
Firm size and TFPR (*)



(*) Firms grouped by number of employees. Size (ln) measured as the logarithm of the total worker-months in the firm, net of fixed effects by sector-year. TFPR (ln) measured in logarithm and net of fixed effects by sector-year.

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

FIGURE IV.2
Decomposition of the TFPR variance (*)



(*) The variance of the logarithm of the TFPR is decomposed into the variance of its components and the covariance between them, following the TFPR definition of equation (3).

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

as stronger enforcement of tax and labor legislation. For this reason, larger firms are relatively farther from their optimal size compared to smaller firms, so their TFPR should be higher.[28] Allowing for credit constrains, on the other hand, would suggest that smaller firms, which face greater difficulties in financing themselves, even if they are very productive, could have a higher TFPR, since they cannot hire the optimal number of factors.

The analysis of TFPR for different firm sizes, controlling for fixed effects per year and sector,[29] shows that the average level of TFPR is greater for larger firms. In addition, consistent with what might be expected, the degree of dispersion is higher among smaller firms.

The relationship between size and TFPR within each category of firms shows that, within the group of larger firms, the positive relationship between size and TFPR is clear (figure IV.1). Note that larger firms have a greater impact on aggregate TFP because of their size. The result reinforces the idea that larger firms have higher marginal productivities. Determining the extent to which these differences are due to firms' market power and to distortions that are more stringent for larger firms is a relevant research area, which has been addressed in the most recent academic literature. In fact, answering this question is of first importance for Chile.

What is behind the differences in TFPR? How much of the dispersion is explained by poor allocation of capital and how much by labor? The decomposition of the TFPR variance between firms in the manufacturing sector using equation (3) shows that, for the whole universe of firms, the importance of capital and labor in the dispersion is similar, although more often capital explains a greater part of the variance (figure IV.2). As expected, the covariance between both factors is positive —that is, firms that lack one factor, typically also lack the other. For the group of large firms, the importance of the capital factor in explaining the TFPR variance is significantly greater.

What do the differences in value of the marginal productivity of factors and size of the firms look like? The review of the relationship between the marginal productivity value of labor and capital across all firms in the economy shows interesting patterns. The value of the marginal productivity of labor is decreasing in size for all firm categories. The opposite occurs with the marginal productivity of capital (figure IV.3). Although it is difficult to determine what explains these patterns, this evidence opens an area of great interest for future research, both theoretical and empirical.

Reallocation process and persistence of dispersion

The existence of significant and persistent differences in the value of marginal productivity between firms may seem at odds with the results of the

[28]/ Hsieh an6d Klenow (2014) argue that the size distribution of firms is more unequal in the United States than in Mexico and India. This is associated with fewer restrictions on large and productive firms' growth, and explains part of the difference in aggregate TFP between these countries.

[29]/ This control accounts for differences in scale and average productivity between sectors, which can contaminate the interpretation of the size-productivity relationship. This is relevant since, if we do not control for these effects, the correlation between size and TFPR is zero. For more details, see Albagli et al (2017).

decomposition of TFP growth (table IV.1). This decomposition showed that part of the gains in aggregate TFP came from the reallocation of factors from firms with less TFPR to firms with more TFPR. This section reconciles both results, and examines the speed and magnitude of the reallocation process. In particular, three questions are answered, namely: How do labor and capital respond to TFPR at the individual firm level? Is TFPR related to the survival probability of a firm? Do these answers depend on the size of the firm?

Table IV.6 shows firm level regressions of changes in labor (columns (1) and (2)) and capital (columns (3) and (4)) on firm TFPR level in the previous year. All specifications include fixed effects by firm, sector-year and age, but differ in controls by firm size. While columns (1) and (3) only include controls for the firm's capital and employment level, the other regressions include interactions between different firm size categories and their response to TFPR. Columns (1) and (2) show that, as expected, employment grows faster in firms with higher TFPR. In addition, the sensitivity is lower in larger firms. On average, a 10% increase in TFPR generates an increase in employment of less than 3%. Also as expected, employment grows more slowly in firms with more initial employment and faster in those with more capital. The results for capital (table IV.6, columns (3) and (4)) are qualitatively similar, although the response of capital to TFPR is more moderate than that of labor (a 10% increase in TFPR increases capital by 2.2%), which may reflect differences in adjustment costs between both factors.

TABLE IV.6

TFPR and accumulation of factors (*)

(dependent variable, annual growth rate (%) of employment (or capital) of the firm in t+1)

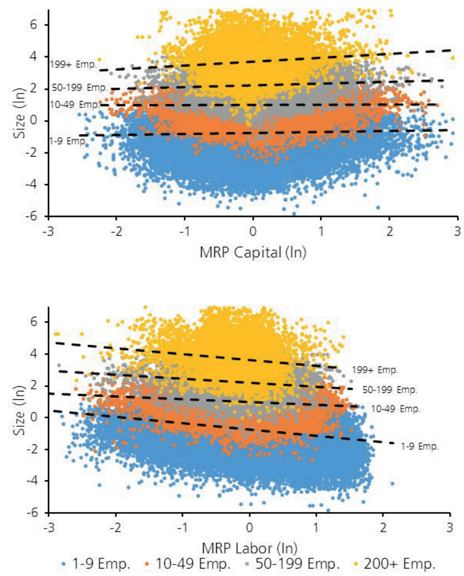
	Growth of employment (%)		Growth of capital (%)	
	(1)	(2)	(3)	(4)
Employment (ln(months-worker))	-0.27***	-0.27***	0.25***	0.27***
	(0.004)	(0.005)	(0.004)	(0.004)
Capital (ln(capital stock))	0.22***	0.22***	-0.18***	-0.18***
	(0.003)	(0.003)	(0.003)	(0.003)
TFPR (ln)	0.28***		0.22***	
	(0.004)		(0.003)	
Interaction: TFPR (ln) x				
I(Micro firm (n<10))		0.31***		0.24***
		(0.004)		(0.004)
I(Small firm (10<=n<50))		0.19***		0.16***
		(0.007)		(0.007)
I(Medium firm (50<=n<200))		0.16***		0.14***
		(0.012)		(0.012)
I(Large firm (200<=n))		0.16***		0.14***
		(0.018)		(0.018)
No. observations	334,424	334,424	334,424	334,424
R-squared	0.451	0.452	0.42	0.421
Sector-year FE	X	X	X	X
Firm age FE	X	X	X	X
Size category FE	-	X	-	X
Firm FE	X	X	X	X
No. firms	72,446	72,446	72,446	72,446

(*) Years 2005-2015. The dependent variable is the growth rate in the period t+1, and is calculated as g(t+1)=[x(t+1)–x(t)]/[0.5*(x(t)+x(t+1))], where x is, respectively, the employment and capital level of the firm. The variables TFPR (ln) and employment (ln (month-worker)) are net of fixed effects by sector-year. In regressions (2) and (4) firms are grouped according to number of workers. Robust standard errors in parentheses. *** p <0.01, ** p <0.05, * p <0.1.

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

FIGURE IV.3

Firm size and marginal revenue productivity of labor and capital (*)



(*) Firms grouped according to the number of employees. Size (ln) measured as the logarithm of the total worker-months in the firm, net of fixed effects by sector-year.MPK (ln) and MPL (ln) measured in logarithm and net of fixed effects by sector-year.

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

TABLE IV.7
TFPR and firm closure – Linear probability model (*)

	(1)	(2)	(3)
Employment (ln(months-worker))	-0.11***	-0.12***	-0.12***
	(0.002)	(0.002)	(0.002)
Capital (ln(capital stock))	-0.08***	-0.08***	-0.08***
	(0.001)	(0.001)	(0.001)
TFPR (ln)	-0.10***	-0.16***	
	(0.002)	(0.003)	
Interaction: TFPR (ln) x Employment (ln(months-worker))		0.02***	
		(0.001)	
I(Micro firm (n<10))			-0.11***
			(0.002)
I(Small firm (10<=n<50))			-0.06***
			(0.003)
I(Medium firm (50<=n<200))			-0.05***
			(0.005)
I(Large firm (200<=n))			-0.05***
			(0.008)
No. observations	334,424	334,424	334,424
R-squared	0.396	0.397	0.397
Sector-year FE	X	X	X
Firm age FE	X	X	X
Size category FE	-	-	X
Firm FE	X	X	X
No. firms	72,446	72,446	72,446

(*) Years 2005 to 2015.

Years 2005-2015. The dependent variable takes value 1 if the firm exits in period t+1 and 0 otherwise. The variables TFPR (ln) and employment (ln (worker-months)) are net of fixed effects by sector-year. In the regression (3), firms are grouped according to the number of workers. Robust standard errors are in parentheses. *** p <0.01, ** p <0.05, * p <0.1.

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII

TABLE IV.8
Gains in aggregate TFP from eliminating dispersion in TFPR (*)

	(1) Economy	(2) Manufacturing	(3) Large manufac-turing
2005	91.7	53.0	42.8
2006	78.8	40.9	36.0
2007	77.4	40.9	36.7
2008	76.7	40.3	37.4
2009	80.5	52.0	49.0
2010	86.0	49.1	45.6
2011	88.8	52.3	48.9
2012	100.2	60.4	56.6
2013	97.4	54.5	50.5
2014	108.9	55.7	50.8
2015	111.9	59.7	49.5
Average	**90.7**	**50.8**	**45.8**

(*) The values represent the increase in aggregate TFP that would be realized if it would equal TFPR in the firms of each sector-year. Values are expressed in percentages Parameters estimated using the methodology of Levinsohn and Petrin (2003) calculated for 91 sectors. Average refers to the linear average of the years.

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

Table IV.7 uses a similar analysis to analyze the effect of individual productivity on the probability of firms exiting the market. Again the results are consistent with economic intuition, and suggest that the turnover process also operates in the right direction, with a negative relationship between TFPR and the probability of closure. Higher productivity decreases the probability of firm closure to the next period, as does the size. Large firms are less sensitive to TFPR, which is consistent with the notion that these firms have a greater capacity to survive adverse shocks. Small firms, on the other hand, have a smaller buffer, and a low TFPR in a given year is a stronger predictor of exit over the following year.

Thus, the results at the individual firm level are consistent with decomposition exercise, and suggest that the reallocation process operates in the right direction, since firms that have higher TFPR accumulate more factors. Additionally, a firm is more likely to exit the lower its TFPR, suggesting that the turnover effect is also qualitatively efficient. However, the magnitude and persistence of dispersion indicates that the reallocation is not fast enough, nor as strong as it should be. This is also noted for the United States by Hsieh and Klenow (2017), who argue that reallocation is not an effective engine of growth given that the dispersion of marginal product values among firms in the United States has not decreased over time.

Understanding the reallocation process in greater detail, especially the factors that deter it, is an open research area in the literature. A detailed analysis of microdata available in Chile can therefore provide important insights.

Potential efficiency gains

In theory, eliminating TFPR dispersion generates efficiency gains by equalizing the marginal productivities of factors across firms. This is, dispersion disappears because implicitly the factors would be reallocated from firms with lower TFPR (lower value of the marginal productivity of factors) to firms with higher TFPR, until all TFPRs are equal. The new allocation would necessarily be more efficient and, therefore, would be associated with a higher aggregate TFP. With the same amount of total factors, the economy could produce more.

Making several assumptions about functional forms and the structure of supply and demand, Hsieh and Klenow (2009) develop a methodology to calculate the gains in aggregate TFP associated with eliminating the dispersion in TFPR across firms. This methodology, although susceptible to criticism in several dimensions,[30] provides an important approximation to the magnitude of potential gains associated with a more efficient factor allocation process. The main result presented by Hsieh and Klenow (2009) is that the gains are not marginal but of first order. Several papers that have replicated their methodology for other countries reach the same conclusion.

Tables IV.8 and IV.9 replicate the baseline exercise in Hsieh and Klenow (2009). This exercise calculates the hypothetical impact in TFP of completely eliminating the TFPR dispersion, for the aggregate economy and different sectoral divisions in each year of the sample. Consistent with the international evidence, and

[30]/ For more details, see Albagli et al. (2017).

given the high dispersion of TFPR in the data, the estimated gains are large. The gains in TFP are 90% on average for the aggregate economy (table IV.8). These gains imply that Chilean TFP would approach the level of developed countries. For the manufacturing sector, given the lower relative dispersion, estimated gains are around 50% and are in line with the findings of Busso et al. (2013) with data from the ENIA for the years 1996 and 2006.

TABLE IV.9
Gains in sectoral TFP from eliminating dispersion in TFPR (*)

	(1) Food and bev.	(2) Textiles	(3) Wood and furniture	(4) Pulp and paper	(5) Chemicals and oil	(6) Non-metal minerals	(7) Metal products	(8) Construction	(9) Trade and hotels	(10) Transport	(11) Communications	(12) Financial serv.	(13) Personal serv.
2005	41.2	122.5	74.3	31.5	31.4	59.7	79.2	146.1	105.1	134.9	50.1	102.9	61.7
2006	32.0	98.5	55.6	23.7	25.4	43.8	63.1	118.3	93.1	120.2	60.3	90.4	62.7
2007	39.9	98.3	71.0	13.7	26.3	75.2	54.5	125.6	87.0	105.0	32.7	100.8	62.7
2008	38.7	90.5	54.3	16.1	23.4	78.9	58.9	104.3	84.0	111.9	26.9	105.2	65.1
2009	42.2	107.8	52.1	65.1	26.2	120.8	74.2	116.4	88.8	109.7	35.8	94.9	55.4
2010	45.0	119.3	43.6	40.5	29.7	89.5	71.2	123.1	97.7	114.6	30.9	109.1	56.7
2011	60.2	93.2	45.2	37.8	24.9	89.1	60.7	110.4	109.5	109.7	102.0	101.4	54.4
2012	56.1	88.7	51.1	58.0	26.9	110.1	90.4	154.9	111.7	109.4	79.6	129.3	60.2
2013	52.6	101.9	44.7	39.6	27.7	117.2	85.9	160.0	105.4	113.6	98.0	129.5	58.3
2014	48.5	92.1	42.9	48.0	31.6	144.0	102.0	215.6	124.6	123.3	54.3	148.8	63.0
2015	49.7	135.3	55.3	41.5	36.7	154.4	124.5	181.8	112.1	138.0	126.3	176.0	68.6
Average	**46.0**	**104.4**	**53.6**	**37.8**	**28.2**	**98.4**	**78.6**	**141.5**	**101.7**	**117.3**	**63.4**	**117.1**	**60.8**

(*)Average gains that each sector of the economy would have if TFPRs of firms are equalized. Values are expressed in percentages. Gains of each sector contribute according to their value added to the total gain of the economy. Average refers to the linear average across years.

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

The analysis of sectoral gains (table IV.9) is a mirror image of dispersion in the TFPR (table IV.3), showing that sectors with greater gains are those that had greater dispersion. In fact, the estimated gains are very large, more than 100% in sectors such as textiles, although gains are more moderate in other sectors such as chemicals and petroleum.

Table IV.10 complements this analysis by distinguishing between the two distortion margins identified by Hsieh and Klenow (2009): distortions in the firm's size and distortions in the composition of labor and capital (defined as a relative distortion of the cost of capital). The exercise illustrates the gains associated with partially reducing each of the distortions, given the reduction level of the other. It can be seen that even modest reductions in distortions —around 20%— generate significant TFP gains. It can also be seen that the size distortion seems to be relatively more important, since its reduction has a much stronger impact on aggregate TFP than eliminating the distortion in the relative cost of capital.[31] Therefore, the main problem seems to be that firms operate on a different scale than the optimum, rather than the combination of factors they choose given their scale.

As already mentioned, there are several reasons to interpret these numbers with care. As such, it is better to focus on the orders of magnitude of these effects rather than on the specific value obtained from this exercise.

[31]/ A counterintuitive result that emerges from this exercise is that eliminating distortions to capital does not always have a monotonic impact on aggregate TFP. This is probably associated with the process of estimating factor participations. For more details, see Albagli et al. (2017).

TABLE IV.10
Average gains in TFP by reducing dispersions (*)

Panel A: Economy

Reduction in output distortion (size)	Reduction in capital distortion 0%	10%	20%	30%	100%
0%	-	12.1	13.2	13.7	12.3
10%	5.3	17.4	18.3	18.8	16.5
20%	12.3	24.7	25.6	26.0	22.6
30%	19.0	32.2	33.1	33.5	29.1
100%	60.2	85.1	88.2	89.9	90.7

Panel B: Manufacturing

Reduction in output distortion (size)	Reduction in capital distortion 0%	10%	20%	30%	100%
0%	-	8.6	9.5	9.9	9.4
10%	2.2	10.7	11.5	11.9	11.0
20%	5.4	14.2	15.1	15.5	14.4
30%	8.7	18.2	19.1	19.6	18.4
100%	30.3	46.3	48.1	49.0	50.8

(*) Comparison of productivity gains of reducing capital and/or size distortions by the corresponding factor. Columns indicate the reduction of capital distortions, which distort the value of marginal capital product relative to labor, with respect to their optimal level. Rows indicate the reduction of distortions of product (or size), which distort proportionally the marginal product value of capital and labor with respect to its optimum level. Panel A shows average gains between 2005 and 2015 reducing distortions for the entire economy and panel B the gains for the manufacturing sector.

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

First, the complete elimination of dispersion, implicit in the calculation of potential gains in the baseline exercise, may be conceptually undesirable. As discussed at the beginning of the chapter, part of dispersion may be the efficient response of firms to technological factors such as adjustment costs. Therefore, forcing the equalization of TFPRs may not be efficient. In this context, the estimated gains would be an upper limit of true potential gains, so the gains of partial reductions of dispersion (table IV.10) may be a better approximation.

Second, and in contrast to the previous caveat, the values presented represent a measure of static gains that does not consider possible dynamic gains associated with eliminating distortions that discourage the productivity growth in firms or the aggregate accumulation of factors (Bento and Restuccia, 2017). In that sense, these gains could be accompanied by higher future TFP growth rates and higher physical and human capital compared to what it is currently projected.

Third, the estimation is very sensitive to methodological aspects when calculating the participation of factors, or the competitive structure within each sector. These issues are more relevant for sectors where there is more heterogeneity in the type of goods or services they produce.

In any case, the exercise suggests that in Chile there are very important potential gains in aggregate TFP that could be achieved if the allocation of factors among firms was improved, in line with international evidence. Understanding better how these gains can be generated and what are the elements that prevent a better allocation of factors emerges as a high priority for research.

IV.5 CONCLUSIONS

The international literature has paid special attention in recent years to the microeconomic determinants of TFP. In this regard, the role of factor reallocation among firms, as well as the distortions that prevent achieving efficiency have been identified as a central aspect.

This chapter has reviewed the related literature, providing new evidence for Chile using census data from firms for the last decade. As it occurs in other countries, the analysis suggests that in the Chilean economy there are potential first order TFP gains that could be achieved with fewer microeconomic distortions. To put the numbers in context, the TFP growth projection in chapter II implies an expected cumulative growth of around 30% by 2050. The analysis in this chapter suggests that, in principle, gains of this magnitude could be achieved in a shorter time horizon, by reallocating the existing factors among different productive units.

Much of what is presented in this article is descriptive, providing exploratory evidence that opens many questions that should be addressed in the future. Research aimed to further explain the nature of distortions and, technological or regulatory obstacles that hinder the reallocation process, have special potential in Chile. Carrying out this research agenda is possible given the wealth of microeconomic statistics and the availability of databases of firms and workers compiled by public organizations. An effort to unify and connect all that information, often scattered, and to use it for the analysis of the issues described in this document, emerges as an urgent challenge. Important gains can be reaped through the design of public policies aimed at raising productivity and income levels.

Appendixes:

APPENDIX II.1 REVIEW OF LITERATURE AND ALTERNATIVE CALCULATIONS OF LABOR PARTICIPATION

In addition to the methodology used in the baseline scenario, the literature has calculated the labor share in GDP in other ways. A first method is simply to divide total wages paid to workers by value added considering National Accounts information for the aggregate economy. This method, when considering only employees, does not incorporate the income of self-employed workers, so the calculation without additional adjustments will tend to underestimate the labor share, a problem that is common to many countries.[1] By computing the labor share in this way for the NNR sectors, we find that the contribution of workers to GDP is 48% (2008-2014 average).[2]

A second method for correcting this omission consist in imputing the income of self-employed workers. Fuentes et al. (2006) adjust total labor income adding up employment in the informal sector (using the employment survey of the University of Chile), assuming that average incomes in both sectors are identical. Corbo and González (2014) also use this methodology. As expected, both papers find labor shares of around 60%, which is much higher than what is obtained by works that use only employees.

Based on the methodology in Fuentes et al. (2006), the share of self-employed workers in total employment is calculated using information from the INE employment survey. The historical average (1986-2016) of the percentage of self-employed workers over total employment is 21%. However, the calculation of total labor income must consider that self-employed workers earn less than their salaried counterparts. According to estimates by Barrero and Fuentes (2017), self-employed workers earn 62% of the salary of the formal sector (2010-2015 average). Incorporating this extra 21% of workers, who earn on average 62% of wage earners' income, increases labor participation to 53%. This number is smaller than that calculated by Fuentes et al. (2006), which overestimates total labor income by assuming that the income of self-employed workers is identical to that of wage earners.

However, this second method assumes that all the income of self-employed workers is payed to their labor, without considering that part of this can be payment to the capital they own. The first method, on the other hand, implicitly attributes all the income of the self-employed to capital income in the economy.

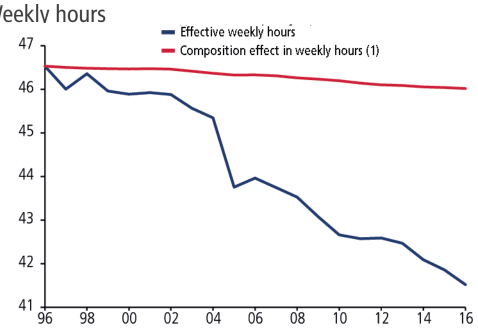
APPENDIX II.2. COMPOSITION EFFECT OF WEEKLY HOURS

The aggregate weekly hours experienced an average fall of 0.6% per year between 1996 and 2015. This fall has been widespread among men and women of different ages, although more markedly for women and for extreme age groups (between 15 and 24 and over 65). A greater labor participation of women and people over 65 years of age could explain part of the drop in aggregate weekly hours, since these groups have shorter workdays.

To understand the importance of this effect, we perform the following exercise: the initial working hours of each group are set constant, and we then calculate total hours using the actual variation of the share in the labor force for each group. This counterfactual exercise seeks to capture how much of the change in hours is only due to a change in the composition of labor force, without considering the drop in the weekly hours of each group. The results show that the change in the composition of the labor force is associated only with a fall of 0.1% per year in weekly hours (figure A.1). Consequently, most of the drop in aggregate weekly hours is due to the fact that each group has been decreasing their working hours.

[1]/ Gollin (2002) documents that measures of labor participation that do not adjust for this National Accounts problem dramatically underestimate labor participation in less developed economies.
[2]/ With the same methodology, Riveros and Vergara (2006) find that labor participation in the overall economy (i.e. the sum of NNRsectors, mining, and electricity, gas, and water) reaches 40%.

FIGURE A.1
Weekly hours



(1): Weekly hours of 1996 and composition by gender and age.
Source: Central Bank of Chile based on INE and OECD.

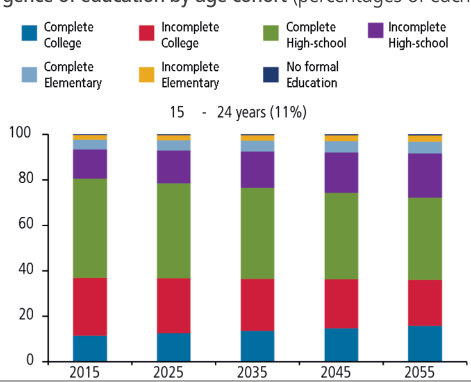
APPENDIX II.3 ASSUMPTION OF EDUCATIONAL CONVERGENCE BY AGE GROUP

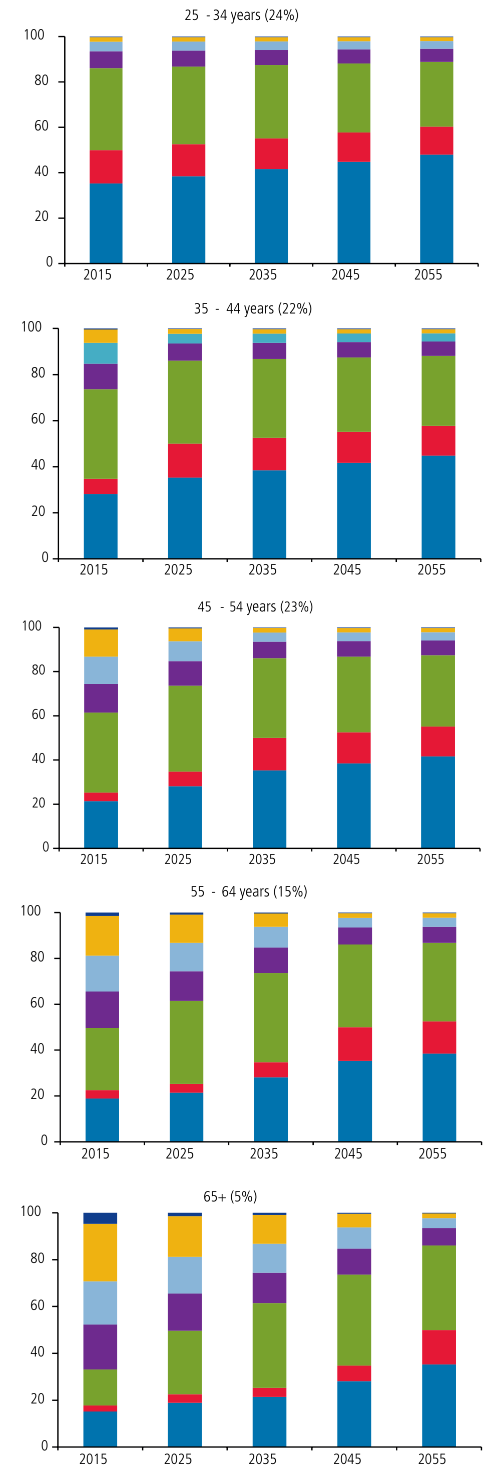
A. Group of employed between 25 and 34 years of age

The estimation of the educational level to which the employed of this age group converges is carried out in two stages: first, an assumption is made for the convergence of the population between 25 and 34 years old. Second, a factor of adjustment is applied to transform this result of the population in the convergence of the employed in this age group.

To estimate the convergence of education of the population between 25 and 34 years by 2050, the median of OECD countries is used as a reference in 2015 for the percentage of the population in this age group with complete college education.[3] The educational level of the rest of the educational categories is calculated by weighting the participation of each educational level from CASEN 2015 by the ratio between the sum of non-college education in the OECD in 2015 (58.0%) and the sum of non-college education from CASEN 2015 (70.1%).

FIGURE A.2
Convergence of education by age cohort (percentages of each group)





Source: Central Bank of Chile based on CASEN, INE and OECD.
Note: Parentheses indicate the percentages of each cohort in the employed (15+) according to CASEN (2015).

[3]/ The use of this number as a benchmark is due to the differences in the education systems of the OECD countries, which does not provide a correct equivalency for each education level.

Finally, in order to go from population projections to labor force projections, the resulting convergence of the 24–34 population is weighted by an adjustment factor for each educational bracket, calculated as the average of the ratios between employed individuals and population of this age group from the CASEN surveys from 1990 to 2015.

B. Group of employed between 15 and 24 years of age

The calculation of convergence of the youngest employed cohort is also obtained in two stages. First, a level of convergence of the population between 15 and 24 years old is estimated, and then this result is corrected by an adjustment factor to obtain the convergence of the employed in this age group.

In order to obtain the level at which the education of the 15 – 24 population converges, the estimation of the educational convergence of the population between 25 and 34 years presented in the previous point is taken as a reference. As the 15 – 24 population have already completed elementary education, the convergence assumption for the first three educational levels (no formal education, incomplete elementary and complete elementary) is set equal to the convergence of the population between 25 and 34 years. To estimate the population participation in the last four levels of education, we make the following additional assumptions:

- *Population between 15 and 17 years of age:* This group has not completed high-school, so the rest of the distribution is concentrated in the incomplete high school level.

- *Population 18 years old:* It is assumed that the rest of the distribution of this range is divided equally between the incomplete and complete high school levels.

- *Population between 19 and 22 years of age:* This group has not completed college education, so the first five segments have the same convergence assumption as the 25 – 34 population. Hence, the rest of the distribution is located in the segment of incomplete college education.

- *Population 23 years old:* This range also has the same convergence assumption as the population between 25 and 34 years old for the first five educational groups. The next level (incomplete college education) is made up of the total population of the convergence assumption for the range 25-34 years with incomplete college education plus half of the population with complete college education of that same age range. The last segment consists of the remaining half. The logic is that some of the 23-year-olds will eventually complete college education, but are not yet old enough to qualify. Given that college programs are completed at roughly this age, we assume a division of 50-50% between complete and incomplete college education for this age.

- Population 24 years old: We assume that this group finished studying so they have the same assumption of convergence as the population between 25 and 34 years for the seven educational levels.

Finally, the resulting convergence of the population between 15 and 24 years old is weighted by a correction factor for each educational group, calculated as the average of ratios between employed and total population in this cohort of the CASEN surveys from 1990 to 2015.

APPENDIX III. 1 COMPARISONS OF CAPITAL TO OUTPUT RATIO

TABLE A.1
Total capital to total GDP ratio, Chile and Latin American countries (*)

Country	95-99	10-14	95-14
Chile	2.22	2.89	2.56
Argentina	2.38	2.32	2.44
Bolivia	1.83	1.82	1.83
Brazil	4.38	4.05	4.21
Colombia	2.91	2.89	2.91
Costa Rica	2.21	2.38	2.26
Ecuador	3.14	3.36	3.23
El Salvador	1.71	2.14	1.93
Guatemala	2.68	2.63	2.72
Honduras	3.28	3.27	3.30
Mexico	2.73	3.24	2.94
Nicaragua	3.80	3.22	3.46
Panama	2.25	2.41	2.30
Paraguay	2.97	2.58	2.85
Peru	2.43	2.48	2.48
Uruguay	4.05	3.83	4.19
Venezuela	4.41	4.11	4.30
Average	**2.90**	**2.92**	**2.94**

(*) Ratios calculated in local currency at constant prices.
Source: Penn World Tables 9.0.

TABLE A.2
Total capital to total GDP ratio, Chile and mining countries (*)

Country	95-99	10-14	95-14
Chile	2.22	2.89	2.56
Australia	3.15	3.37	3.20
Bolivia	1.83	1.82	1.83
Canada	3.37	3.78	3.48
Colombia	2.91	2.89	2.91
Ecuador	3.14	3.36	3.23
Indonesia	4.92	5.14	5.23
Malaysia	2.78	2.84	2.79
Mexico	2.73	3.24	2.94
Norway	2.43	2.82	2.56
Peru	2.43	2.48	2.48
South Africa	3.28	3.21	3.14
Venezuela	4.41	4.11	4.30
Average	**3.05**	**3.23**	**3.13**

(*) Ratios calculated in local currency at constant prices.
Source: Penn World Tables 9.0.

APPENDIX III.2 COUNTERFACTUAL CAPITAL CONSTRUCTION BASED ON SECTORAL COMPOSITION

The real capital to output ratio of an economy (K/Y) can be expressed as the weighted average (with sectoral participations of real GDP, Ys/Y) of the sectoral capital to output ratios (Ks/Ys). That is,

$$\frac{K}{Y}=\sum_{S=1}^{9}\left(\frac{K_S}{Y_S}\right)\left(\frac{Y_S}{Y}\right) \quad (1)$$

Obtaining comparable sectoral capital to output ratios between countries is no trivial task. First, there are no international databases that contain data on K_s. Second, national accounts do not use homogeneous methodologies in the construction of their series. Third, there are no measures of sectoral value added that allow comparing across countries. Thus, a counterfactual capital stock is calculated using a methodology that is robust to differences in the degree of competition within economic sectors among countries.

The price of the good produced in an economic sector *(ps)* can be expressed as a margin of profit *(Mark Ups)* on the marginal cost *(Marginal Costs)* of the sector,

$$p_S = Mark\ Up_S * \ Marginal\ Cost_S \quad (2)$$

The cost minimization condition of the firm's problem implies that the marginal cost satisfies the following relationship:

$$Marginal\ Cost_S = r\ /\ Mark\ Up_{S'} \quad (3)$$

where MPKs is the marginal product of the capital stock in sector s, and r its cost of use. Assuming Cobb-Douglas sectoral production functions $K_S^{\alpha_S}\ L^{1-\alpha_S}$, where L is the number of workers in the sector), the marginal product of capital is

$$MPK_S = (\alpha_S)\ K_S/Y_S \quad (4)$$

Replacing (3) and (4) in (2), and after rearranging terms, the capital to output ratio is[4]

$$K_S/Y_S=p_S\ (\alpha_S)\ /\ r\ Mark\ Up_S \quad (5)$$

Replacing (5) in (1) we obtain our measure of counterfactual capital to output ratio (K^{CF}/Y),

$$\frac{K^{CF}}{Y}=\sum_{s=1}^{9}\frac{\alpha_s}{rMarkUp_s}*(\frac{\rho_s Y_s}{Y}) \quad (6)$$

[4]/ The sum is indexed from 1 to 9, since economic sectors at 1 digit of aggregation are used in the exercise.

APPENDIX IV.1 THE ROLE OF FIRMS' ENTRY AND EXIT IN AGGREGATE TFP GROWTH

The decomposition exercise of TFP growth (table IV.1) shows a result that, at first glance, can be somewhat surprising: throughout the sampling period, the average of the net contribution of firm entry and exit is negative. Does this imply that new firms are less productive than those that exit? Is the turnover effect harmful to the economy?

Table A.3 answers the first question. As it can be seen, the new firms are, on average, 10% more productive than the exiting ones (productivity measured as TFPR), while new firms are 20% smaller. Thus, on average, their productivity weighted by size does not compensate the productivity weighted by firm size. This explains the negative number associated with the year of rotation.

TABLE A.3
Comparison of firms entering and leaving (*)

Variable	Ratio
Productivity	1.11
Wage Bill	0.77
Sales	0.78

(*) Statistics for an average firm that enters or exits during the period of analysis. Ratio of firms that enter divided by firms that exit. Parameters estimated using the methodology of Levinsohn and Petrin (2003) calculated for 91 sectors.

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

Regarding the second question, as discussed in chapter IV, newly-created firms not only affect the TFP in that year, but TFP growth over time, as those that are successful and survive can grow and become more productive. Therefore, conceptually, taking a longer window of analysis of n years, the turnover effect will measure the cumulative contribution of firms that were created between t and t+n. In the limit, when n is very large, all the increase in TFP will come from the turnover effect, since all firms that exist in the economy —even those that are now very large, productive and consolidated— were created at some point in time,

Table A.4 explores this argument, taking longer windows, until reaching the maximum that can be done with this data (period 2005-2015). This exercise does not change the average growth of productivity, but only the decomposition accounting. According to intuition, the turnover effect becomes less negative as time passes, although the window is not long enough to make it positive. It can be seen that the reallocation margin becomes relatively less important, which is associated with size increases of the successful new firms that are now accounted for in the turnover effect.

TABLE A.4

Decomposition of productivity growth between the years 2006 and 2015 for different windows (*)

Period	1 year	2 years	5 years	10 years
Productivity growth	**0.97**	**0.97**	**0.97**	**0.97**
Productivity growth of firms that continue	1.23	1.33	1.18	1.04
Reallocation between firms that continue	1.03	0.63	0.43	0.28
Net turnover effect	-1.30	-0.99	-0.64	-0.35

(*) Average for different year windows of the decomposition of productivity growth between 2006 and 2015. Parameters estimated using the methodology of Levinsohn and Petrin (2003) calculated for 91 sectors.

Source: Central Bank of Chile based on data from forms F22 and DJ1887 of the SII.

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