Sectorial Decomposition of Total Factor Productivity in Chile (1996-2010)

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Abstract

This article uses information from the input-output matrixes available for Chile for 1996, 2003 and 2010 for calculating Total Factor Productivity (TFP) and breaking it down by economic sector into three effects: the effect of the change on sectorial demand; the effect of change on the production formula and intersectorial transactions, and the effect of sectorial technological change. As a result, one can appreciate that the latter two effects dominate in the explanation of the changes in productivity that have taken place during the period considered. The following sectors stand out as three that have led positive changes in the country's productivity: (i) *manufacturing industry, (ii) electricity and gas and (iii) financial intermediation and business services.* Meanwhile, the *personal services sector* emerges as the sector that could be behaving as a constraint on the grown of productivity. These results are qualified and contextualized in the discussion section.

Key Words: Total Factor Productivity; Input–Output.

Introduction

Two statements stand out in the articles written by Prescott (1998) and Easterly and Levine (2002). The first is empirical: the best *construct* for identifying growth rates and levels of Gross Domestic Product (GDP) among countries is Total Factor Productivity (TFP), Solow (1957). The second is theoretical: there is no common agreement regarding the theory that determines TFP so that it could be defined and measures with clarity.

These two statements have generated a great deal of discussion and research in the academic sphere. This research document contributes to this exchange by adding an

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additional measurement of TFP for Chile but with two innovations in relation to prior measurements. First, TFP is measured using input-output matrixes. Second, the TFP for the entire economy is broken down based on the contributions of 12 economic sectors.

The study of TFP in Chile has been conducted for different periods at the macro, meso and micro-economic levels using existing information. Greater availability of aggregate information reflects a greater amount of research on TFP in macroeconomics. Fuentes, Larraín and Schmidt-Hebbel (2006) show that the increase in productivity during the high and moderate growth periods that last from 1990 to 1997 and 1998 to 2005, respectively, explain over 60% of economic growth.[3] The authors find that TFP is related to structural and cyclical components of the economy. While structural factors such as macroeconomic stability had an important role before the 1990s, this situation reverted over the past 20 years in which TFP was led by cyclical effects such as exchange terms (price of copper) and the devaluation of the real exchange rate. Chumacero and Fuentes (2006) find that an exogenous growth model is the best instrument for explaining economic data. In it, the TFP series has a stationary tendency with temporal increases determined by improvements in the quality of capital measured as the relative price of the prices of capital goods over consumption goods, improvements in terms of exchange and reduction in the government distortions measured as government spending. The authors state that when these increases are consequences of policies the change they can be long-term. They also note that transitory changes originate fluctuations in productivity.

Progressively, while the improvements in productivity that led to macroeconomic stability began to run out, research began to explore microeconomics and its complementarity with institutional stability for affecting TFP. Based on the good availability of data in the Annual National Industrial Survey, studies were developed connecting companies to productivity. Pavcnik (2002) found evidence that commercial openness increased companies' productivity. The channels for these improvements are hypothesized to be: (i) greater specialization, (ii) expansion of potential markets in order to make use of economies of scale, (iii) dissemination of technological innovations and best administrative practices, and (iv) reduction in anti-competitive practices that may exist at the local level. Bergoeing, Hernando and Repetto (2005) state that the improvement in TFP at the business level came from improvements produced within the companies rather than the relocation of factors that could have been generated by a Schumpeterian process of the death and birth of firms. The structure of the job market and its effect on productivity was studied by Álvarez and Fuentes (2009) in which the authors state that the increase in the minimum salaries may have had effects on the reduction of TFP over the past few years, mainly affecting businesses that have greater participation of low training jobs.

[3] This result reports the figure using measure 8 in Fuentes et al. (2006).

The country's mesoeconomics[4] and their relationship to productivity was the area that received attention later. This is represented by the works of Álvarez and Fuentes (2004), Vergara and Rivero (2006) and Fuentes (2011). Fuentes (2011) shows the presence of a structural break in labor productivity in many sectors in the late 1990s (agriculture, fishing and forestry, mining, retail, restaurant and hotel, and transportation and communications). This seems to be related to structural changes and cyclical components on the productivity observed in the macro economy (Fuentes et al. (2006). When he breaks down the growth of job productivity into productivity within a sector and productivity as a result of the reassignment of employment among sectors, the author finds that over 97% of the increase has its origin within the sectors, with only 3% for reassignment. The tradable goods sectors (mining and manufacturing industry) show an expansion in the use of capital as a motor of growth of job productivity, while the TFP played an important role in labor productivity in the trade, restaurant and hotel, and transportation and communications sectors. In line with these results, Álvarez and Fuentes (2004) show that the tradable goods sector (mining, manufacturing, and fishing, agriculture and forestry) grew during the 1990s as a result of the accumulation of capital and TFP while the non-tradable goods sector was mainly driven by the accumulation of capital during that same decade. Vergara and Rivero (2006) present some results that show the diversity of functioning of tradable sectors. Two sectors of tradable goods (agriculture, fishing and forestry and mining) present higher TFP growth rates than the accumulation of capital during the period 1996-2001 and that only the industry sector presents greater growth as a result of accumulation of capital. Fuentes (2011) states that the construction and financial services sectors could have had a very low TFP growth rate,[5] while Vergara and Rivero (2006) explain why financial services is the sector with the second highest level of TFP growth during the period 1986-2001.

This wide variety of results invites us to engage in a three-part reflection. First, there is considerable diversity of technical criteria and data sources used to measure the country's productivity, even when the conceptual basis for these measures continues to be the breakdown of growth accounting. Second, Harberger's hypothesis (1998) regarding the growth of productivity as *mushrooms* in which reduced costs potentially caused by "1001 possible causes" in different sectors show a great diversity of productivity growth, seems to be functioning for the Chilean case. Third, the diversity of results also invites us to connect what occurs in the productivity of the micro-economy, meso-economy and macro-economy so that the different results can have more integrated readings with a broad perspective.

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[4] We use the concept of meso-economy to describe organizations that have a clear identification in the economy (e.g. economic sectors, regions) but that generally they are not specified with micro fundaments or describe properties of the entire economic system.

[5] This proposal is presented as potential given that this conclusion is obtained by Fuentes (2011) when he states that there was a process of intensification in the use of capital with nearly null growth of labor productivity.

This article presents two technical innovations for the analysis of sectorial TFP in Chile. First, information provided by the Central Bank in input-output matrixes for 1996, 2003 and 2010 is used. Second, total TFP is broken down based on each sector's contributions, the effects of demand and the effect of interaction among the sectors. This analysis is presented within the framework of analysis of Solow's growth accounting and the observations made by Baumol and Wolf (1984) in order to compare productivity among sectors.

The results of this research allow one to build a taxonomy of sectors based on their effort to push the economy and changes in sectorial productivity. In this taxonomy, the sectors of *manufacturing industry, electricity and gas and financial intermediation and business services* emerge as three sectors that led the increase in TFP during the period 1996-2010. These sectors increased their productivity and disseminated it throughout the entire productive fabric.

The *personal services* sector emerges as a sector that could be limiting the growth of productivity in the economy because it has represented decreased growth of productivity throughout the period and has a great impact on the entire productive fabric.

The relevant contents of the article are developed in two sections. First, and following this introduction, we present the breakdown method to be used to analyze productivity. The second key section explains the origin of the data and analyzes the results obtained as a result of the breakdown. The article ends with the section containing conclusions and also has an appendix with greater development of the techniques used to make the calculations.

Breakdown of Total Factor Productivity

Total Factor Productivity represents increases in production that do not have their origin in the increase of the primary production factors: capital and labor. There are multiple measurement strategies, and a great deal of literature summarized in literary reviews such as those of Del Gatto, Liberto and Petraglia (2011).

In order to conduct a sectorial breakdown of TFP, we begin with the method used by Wolff (1984 and 1985) to describe the composition of changes in production that affected the reduction in growth of productivity in the United States following World War II.

The following variables are defined using the formal model:

$\boldsymbol{x}_t$ = column vector that has the sectorial gross product during period t

$\boldsymbol{y}_t$ = column vector with the final demand of each sector during period t

$\boldsymbol{A}_t$ = matrix of inter-sectorial coefficients during period t

$\boldsymbol{l}_t$ = row vector of the labor coefficients during period t, showing the employment necessary for each production unit

$\boldsymbol{k}_t$ = row vector of capital coefficients during period t, showing the amount of capital required for each production unit

$\boldsymbol{p}_t$ = row vector of prices during period t, showing the price for each unit produced in the different industries

The following scales also are defined,

w_t = is the average salary rate through the sectors during period t

r_t = is the rate of benefit that the stock of capital produces during period t

$Y_t = \boldsymbol{p}_t\boldsymbol{y}_t$ = is the national gross product at current prices during period t

$L_t = \boldsymbol{l}_t\boldsymbol{x}_t$ = is total employment in the economy during period t

$K_t = \boldsymbol{k}_t\boldsymbol{x}_t$ = is the total stock of capital in the economy during period t

Taking the technique of growth accounting adopted by Solow (1947), which requires only the suppositions of constant performance to scale and perfect competition as a point of departure, Total Factor Productivity is defined as

$$\rho = \frac{dY}{Y} - \frac{wL}{Y}\frac{dL}{L} - \frac{rK}{Y}\frac{dK}{K}$$

These values can be expressed in terms of the information provided using the input-output model as follows

$$\rho = \frac{(\boldsymbol{p}d\boldsymbol{y} - wdL - rdK)}{Y} \tag{1}$$

Keeping in mind that it is possible to express sectorial demand as the difference between gross production and intermediary purchases, one finds that

$$\boldsymbol{y} = (\boldsymbol{I} - \boldsymbol{A})\boldsymbol{x}$$

Such that differentiating,

$$d\boldsymbol{y} = (\boldsymbol{I} - \boldsymbol{A})d\boldsymbol{x} - (d\boldsymbol{A})\boldsymbol{x}$$

Similarly, differentiating employment and capital,

$$dL = \boldsymbol{l}d\boldsymbol{x} + (d\boldsymbol{l})\boldsymbol{x}$$

$$dK = \boldsymbol{k}d\boldsymbol{x} + (d\boldsymbol{k})\boldsymbol{x}$$

And substituting in (1) one obtains

$$\rho = \frac{(\boldsymbol{p}(\boldsymbol{I} - \boldsymbol{A})d\boldsymbol{x} - \boldsymbol{p}(d\boldsymbol{A})\boldsymbol{x} - w\boldsymbol{l}d\boldsymbol{x} - w(d\boldsymbol{l})\boldsymbol{x} - r\boldsymbol{k}d\boldsymbol{x} - r(d\boldsymbol{k})\boldsymbol{x})}{Y} \tag{2}$$

In order to simplify this expression, the identity that states that the price of a good covers the cost of intermediary goods and payment of factors is used. Formally,

$$\boldsymbol{p} = \boldsymbol{pA} + w\boldsymbol{l} + r\boldsymbol{k}$$

or

$$\boldsymbol{p}(\boldsymbol{I} - \boldsymbol{A}) = w\boldsymbol{l} + r\boldsymbol{k}$$

and replacing in (2)

$$\rho = \frac{-(\boldsymbol{p}d\boldsymbol{A} + w\, d\boldsymbol{l} + r\, d\boldsymbol{k})\boldsymbol{x}}{Y} \qquad (3)$$

In the work of Miller and Blair (2009), the productivity of a sector j is defined as follows,

$$\pi_j \equiv \frac{-\left(\boldsymbol{p}d\boldsymbol{a}_{.j} + wdl_j + rdk_j\right)}{p_j}$$

where $\boldsymbol{a}_{.,j}$ is the column j of matrix $\boldsymbol{A}$, and represents how many units are necessary of each intermediate good i to produce a final good j. Similarly, l_j and k_j represent how many units of work and capital, respectively, are necessary to produce a unit of good *j*. Note that the productivity of sector j, increases when fewer inputs and factors for the production of a unit of production are used, keeping prices steady.

With this definition, one can express the aggregated productivity of (3) as follows,

$$\rho = \frac{\boldsymbol{\pi}\widehat{\boldsymbol{p}}\boldsymbol{x}}{Y}$$

where $\boldsymbol{\pi}$ is the column vector of sectorial productivity and $\widehat{\boldsymbol{p}}$ is the diagonalized price vector.

Then, using the equation $\boldsymbol{x} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{y}$ and the identity $\boldsymbol{I} = \widehat{\boldsymbol{p}}^{-1}\widehat{\boldsymbol{p}}$, it is possible to express aggregate productivity as

$$\rho = \frac{\boldsymbol{\pi}\widehat{\boldsymbol{p}}(\boldsymbol{I} - \boldsymbol{A})^{-1}\widehat{\boldsymbol{p}}^{-1}\widehat{\boldsymbol{p}}\boldsymbol{y}}{Y}$$

which to simplify the notation can be expressed as follows

$$\rho = \boldsymbol{\pi}\, \boldsymbol{S}\, \boldsymbol{\beta} \tag{4}$$

Where $\boldsymbol{\pi}$ is a row vector in which each component j represents the productivity of the corresponding sector. The matrix $\boldsymbol{S} = \widehat{\boldsymbol{p}}(\boldsymbol{I}-\boldsymbol{A})^{-1}\widehat{\boldsymbol{p}}^{-1}$ captures the economic effects of the operations among the industries. Each term $s_{i,j}$ of matrix $\boldsymbol{S}$ can be expressed as $s_{i,j} = \frac{l_{i,j}p_i}{p_j}$ in which the technical multiplier[6], $l_{i,j}$ represents the direct and indirect increase generated in the physical production of good i, as a consequence of increasing the demand for good j. As such, $s_{i,j}$ represents the multiplier of good i, as a consequence of increasing the demand of good i, expressed in the relative term of the price of good j. In order to fix the ideas, if in place of taking the multiplier $l_{i,j}$ which takes direct and indirect effects we consider only the direct effect of the technical coefficient $a_{i,j}$ of the matrix of technical coefficients $\boldsymbol{A}$, the economic effects would be expressed as $\tilde{s}_{i,j} = \frac{a_{i,j}p_i}{p_j}$, in which $\tilde{s}_{i,j}$ represents the cost of input i relative to the price of good j.

Finally $\boldsymbol{\beta} = \frac{\widehat{\boldsymbol{p}}\boldsymbol{y}}{Y}$ is a row vector in which each position j represents the participation in the final demand of the economy of sector j. This vector also may be interpreted as the spending preference among the sectors that the country's demand has.

Returning to the breakdown expressed in equation (4), and leaving aside second order effects, it is possible to lineally approximate the change in TFP as follows,

$$\Delta\rho = \boldsymbol{\pi S}\Delta\boldsymbol{\beta} + \boldsymbol{\pi}\Delta\boldsymbol{S\beta} + \Delta\boldsymbol{\pi S\beta} \tag{5}$$

in which the first term on the right side considers the change in productivity as a consequence of change in preference of demand, the second term is the change that has its origin in the intersectorial effects, and the third term represents the changes that have their origin within the sectors.

Data and Results

The information used to make the calculations in this article is taken from the National Accounting Databases of the Central Bank for 1996, 2003 and 2010. In addition, we used information from the National Statistics Institute in order to calculate average hourly salaries for each year and data on the sectorial stock capital calculated by Henríquez (2008).

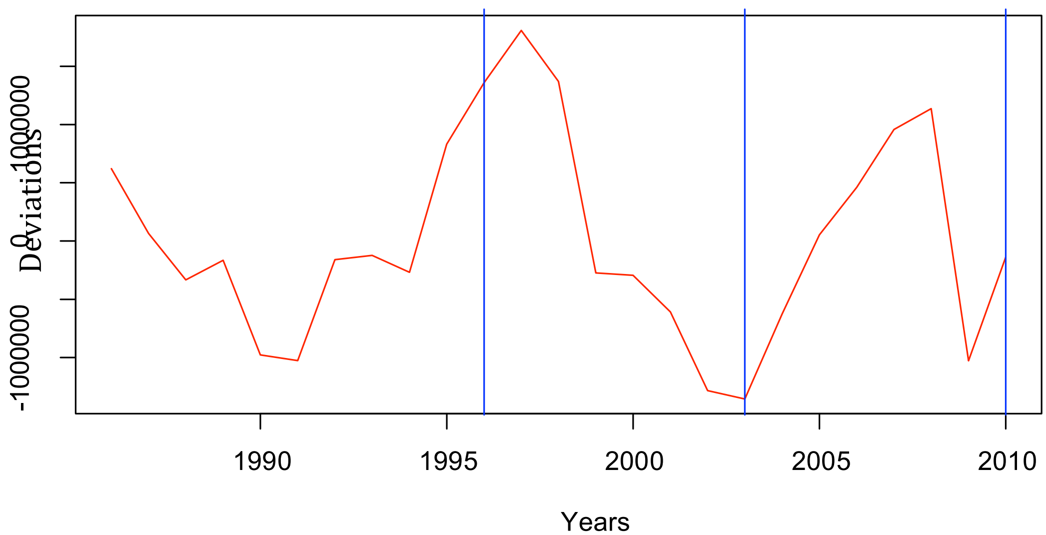
Fuentes et al. (1996) present evidence suggesting that the behavior of TFP is linked to the cyclical components of the economy. As such, in order to have a frame of reference of analysis, Figure 1 presents the cyclical component obtained by applying Hodrick and Prescott's filter of GDP at constant prices. The figure presents vertical

[6] In terms of Leontief's standard annotation, $\boldsymbol{L} = (\boldsymbol{I}-\boldsymbol{A})^{-1}$, and as such $l_{i,j} \in \boldsymbol{L}$.

bars for 1996, 2003 and 2010, the years for which product input information was available for this article.

While the economy grew at an annual rate of approximately 3.5% between 1996 and 2003, one can see that this growth took place during a contractive phase. During the next period, 2003-2010, the economy grew at a rate of 4.5% but the availability of information on input-output is nearly between the two depressive phases of the economy of that cycle.

Figure 1: Economy Cycle for 1986-2010



Source: Developed by the authors using Central Bank data.

Table 1 presents Gross Production Value (GPV) growth for each sector for the two periods considered. Three sectors have average annual rates of over 5% during the two periods considered: *mining, electricity and water, and financial intermediation and business services.* A second group that maintained moderate growth rates during the two periods are *public administration, personal services, retail, hotels and restaurants,* and a third group of sectors shows considerable slowing in production, namely *fishing, transportation and communications, and the manufacturing industry*.

Table 1: Annual Growth of Gross Production Value (GPV)

	1996-2003	2003-2010
Livestock and Forestry	3.2%	1.6%
Fishing	5.5%	-2.8%
Mining	7.2%	11.0%
Manufacturing Industry	3.8%	0.9%

Electricity, Gas and Water	5.3%	9.2%
Construction	0.4%	3.9%
Retail, Hotels and Restaurants	3.3%	3.6%
Transportation and Communications	8.9%	1.0%
Financial Intermediation and Business Serv.	7.4%	6.1%
Home Services	1.1%	2.5%
Personal Services	5.6%	3.8%
Public Administration	3.5%	4.6%

Source: Developed by the authors.

Total Factor Productivity

Applying the procedure of rules of calculations that is described in the Appendix, the technical coefficient matrixes necessary for obtaining the change in TFP among the three periods using equation (4) was obtained from the use and production matrixes.

The results are summarized in Table 2, along with the added value growth rates for the same period.

Table 2: Aggregate TFP and Its Participation in Growth

	Growth of Economy (1)	**Growth of TFP** (2)	**%TFP** (2)/(1)
1996/2003	27.15%	4.95%	18.23%
1996/2003 (annual)	3.491%	0.693%	
2003/2010	36.07%	5.65%	15.66%
2003/2010 (annual)	4.498%	0.788%	

Source: Generated by the authors using Central Bank and INE statistics.

While the TFP was lower in 1996-2003 than it was in 2003-2010, participation as source of growth was greater during the first period, as one sees in the last column in the table.

Table 3 presents TFP calculations for Chile reported in other works during similar periods. The wide variability of the results is noteworthy and is due to the different sources of data and methods applied.

Specifically, the calculations presented in Table 2 are similar to the calculation for 1996-2003 TFP presented in Fuentes et al. (2006) for the same period. This similarity is observed in two areas. First, the annual growth of TFP for 1996-2003 is 0.6%. Second, the TFP participation in growth of the economy during 1996-2003 is 18.92% (see Table 7 in the Appendix).

Table 3: TFP Calculated for Similar Periods

Period and Reference	Annual TFP	Annual GDP	TFP/GDP
1990-2005, Fuentes R., Larraín R. and K. Schmidt-Hebbel (2006)	3.06%	5,65%	54,16%
1998-2005, Fuentes R., Larraín R. and K. Schmidt-Hebbel (2006)	1.89%	3,90%	48,46%
1998-2005 Fuentes R. and M. Morales (2011) (Using growth accounting)	1.77%	3,90%	45,38%
1998-2005 Fuentes R. and M. Morales (2001) (Using space of states)	0.66%	3,90%	16,92%
1996-2003, Fuentes R., Larraín R. and K. Schmidt-Hebbel (2006)*	0.60%	3,62%	16,57%
1996-2000, Vergara and Rivero (2006)	0.2%	3,91%	5,12%
2000-2003, Vergara and Rivero (2006)	-0.1%	3,24%	-3,09%
2000-2008 I. Magendzo (2013) Universidad Adolfo Ibáñez.	1.0%	4,62%	21,65%
2003-2005, Fuentes R., Larraín R. and K. Schmidt-Hebbel (2006)*	1.74%	6,60%	26,36%

Source: Developed by the authors using the publications listed in the table.
(*)The authors do not report growth for TFP in these two periods. However, they do report annual TFP indexes. The data reported in this table were obtained using said indexes. Specifically, the index reported as Number 4 was used given that the adjustment of use of capital is conducted utilizing labor.

In order to understand the source of the change in TFP in Table 4, the breakdown developed using equation (5) is presented. In the second row of the first column, one sees the difference between the productivity of 1996-2003 and that of 2003-2010. The value is broken down based on the contributions presented in the next three columns. The third row presents the participation of each component in the change. Most of the change in TFP during the two periods is due to changes in productivity among sectors and within each sector, which taken together represent an impact of approximately 80% of the change.

Table 4: Breakdown of TFP

	Changes in sectorial demand (1) $\pi S \Delta \beta$	Changes in interaction among sectors (2) $\pi \Delta S \beta$	Changes of TFP in each sector (3) $\Delta \pi S \beta$	Total (1)+(2)+(3)
$\Delta\rho = 0.0565 - 0.0495$	0.001344	0.003134	0.002474	0.006949

%	19.34%	45.1%	35.6%	100.06%*

Source: Generated by the authors.
* The value does not add up to 100% due to second order approximation errors.

Table 5 presents a breakdown of that which occurs within the 35.6% of the change that was observed in TFP for the entire economy. The second column presents the results of $\boldsymbol{w} = \boldsymbol{S\beta}$, which is an intermediate vector of 12 sectors. Keeping in mind that the vector $\boldsymbol{\beta}$ can be interpreted as the distribution of the spending of society of a monetary unit among all sectors, the position i of vector *w(i)*, represents how much economic activity of sector i increases, with sector i measured in terms of the price of the good of that sector when the aggregate demand of the economy increases by one unit. In other words, the vector can be interpreted as a means of linking back that each one of the sectors produces as a result of increasing aggregate demand of the economy on a unit. This linking may increase because the price of the sector increases in relation to the price of all other sectors or because there is a technological change that makes the technical multiplier of the sector greater. Returning to the table, the *manufacturing industry* is the sector with greatest linkage back measured in monetary terms followed by the *Retail, hotels and restaurants* sector. The third column represents the technological change produced within each sector. One can see that the sector that increased its productivity the most was *electricity and gas* followed by *fishing* and the *financial intermediation and business services* sector.

Finally, the fourth column is the result of the combination of the effects. One can see that four sectors contributed positively with similar levels of intensity: *electricity and gas, financial intermediation and business services, home services and manufacturing industry.* Meanwhile, the *personal services and* construction sectors generated the most negative contribution to technological change.

Table 5: Analysis of the 35.6% of Change

	$\boldsymbol{w} = \boldsymbol{S\beta}$ (1)	$\Delta\boldsymbol{\pi}$ (2)	(1)*(2)
Livestock and Forestry	0.1042	-0.0033	-0,00034
Fishing	0.0196	0.0373	0,00073
Mining	0.1218	0.0075	0,00091
Manufacturing industry	0.3466	0.0066	0,00229
Electricity, gas and water	0.0828	0.04	0,00331
Construction	0.1078	-0.0264	-0,00285
Retail, hotels and restaurants	0.2138	0.0009	0,00019
Transportation and communications	0.1406	-0.009	-0,00127
Financial intermediation and business services	0.1146	0.0278	0,00319

Home services	0.2003	0.0149	0,00298
Personal services	0.2096	-0.0255	-0,00534
Public administration	0.0618	-0.0216	-0,00133
		Total effect due to changes in intra-sectorial TFP	0.00247

Source: Developed by the authors.

The other important component in the change in TFP is analyzed in Table 6. Continuing with the previous method, the composition of the term $\boldsymbol{\pi \Delta S \beta}$ was analyzed, breaking it down into two parts. First, the intermediate vector $\boldsymbol{z} = \boldsymbol{\pi}\Delta\boldsymbol{S}$ of dimension (12x1) was analyzed. It is composed of the vector of sectorial TFP $\boldsymbol{\pi}$y of the matrix of changes in the linkages $\Delta\boldsymbol{S}$. Each element $\Delta s_{i,j}$ represents the change in linking back measured in monetary terms that each sector j has on sector i was a result of producing an additional unit of j to satisfy demand. If $\Delta s_{i,j} < 0$, ($\Delta s_{i,j} > 0$) this would mean that in the new period, sector j is less (more) important for sector i. Each column $\Delta s_{\cdot,j}$ represents the change in the entire productive fabric measured through the monetary multipliers of sector j. With this information, one can interpret z(i) as the diffusion of technological changes in all sectors in sector i as a result of the change in multipliers. The larger z(i), the more important the technological effect that sector i disseminates.

Column 4 of Table 6 can be interpreted as the technological improvement that was disseminated throughout the productive fabric, maintaining technology and consumer preferences constant.

Table 6: Analysis of the 45.1% of the Change in TFP

	$\boldsymbol{z} = \boldsymbol{\pi}\Delta\boldsymbol{S}$ (1)	$\boldsymbol{B}$ (2)	(1)*(2)
Livestock-Forestry	0.0059	0.0351	0.00021
Fishing	0.0209	0.0033	0.00007
Mining	0.0044	0.0824	0.00036
Manufacturing industry	0.0099	0.0963	0.00095
Electricity, gas and water	0.0278	0.0179	0.00050
Construction	-0.0008	0.0933	-0.00007
Retail, hotels and restaurants	-0.0044	0.1376	-0.00061
Transportation and communications	0.0031	0.0603	0.00019
Financial intermediation and business services	0.006	0.027	0.00016
Home services	0.0037	0.2003	0.00074
Personal services	0.0041	0.1872	0.00077

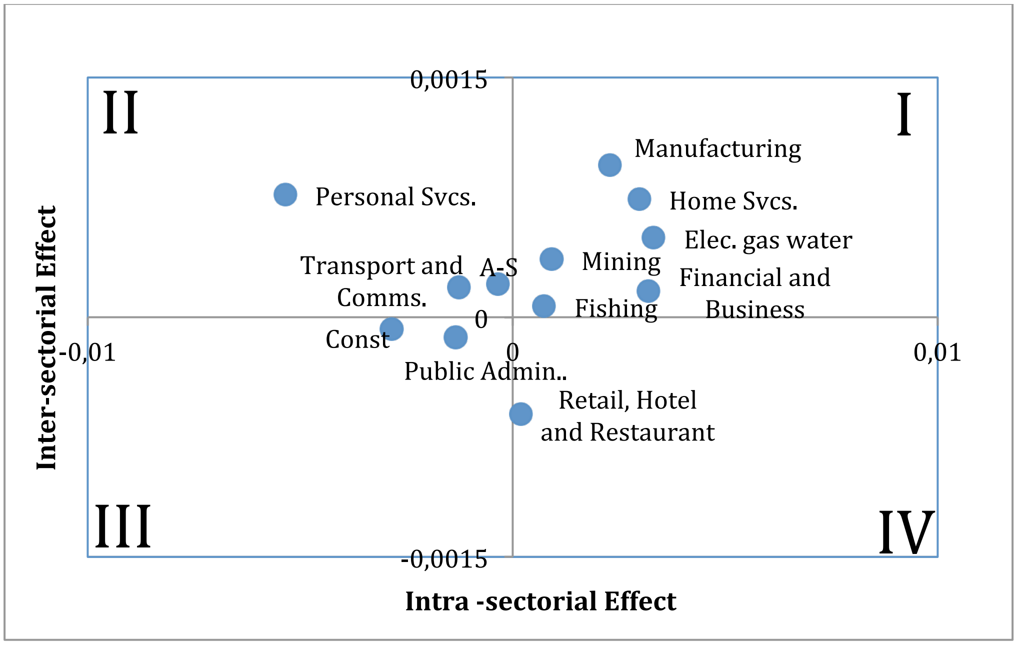
Public administration	-0.0021	0.0592	-0.00012
Total effect due to inter-sectorial effects on change of TFP			0.00314

Source: Developed by the authors.

The *manufacturing industry* is the one that best disseminates technological improvements throughout the entire productive fabric along with *home services* and *personal services*. The *construction*, *public administration* and *retail, hotels and restaurants* sectors apparently reduced their influence on the productive fabric. As such their interaction effects are lower.

Figure 2 presents a summary of the effects of the two most important components for the breakdown. The horizontal axis presents the intra-sectorial effects of each sector on TFP while the vertical presents the effects of inter-sectorial dissemination of the sectors. Keeping these two dimensions in mind, one can identify four quadrants. Quadrant I represents the sectors that increased TFP and increased the effects of technological linkages with other sectors. In addition to improving their technologies, these sectors disseminate it through the economy. Quadrant II is composed of sectors that had a decrease in total factor productivity but increased the intensity of their linkages with other sectors. These sectors may be behaving as limiting factors for technological growth given that their low productivity is disseminated throughout the entire productive system. Quadrant III is composed of sectors with negative TFP but diminished effects on the entire economy. These sectors do not behave as limiting factors for growth of productivity. Finally, Quadrant IV represents sectors that increased sectorial productivity but reduced the effects on the rest of the economy. These sectors must become more integrated into the economic fabric.

Figure 2: Intra- and Inter-sectorial Effects of TFP



Source: Developed by the authors.

In Quadrant I, five sectors stand out due to their increase in productivity and impact on the productive system: *manufacturing industry; home services*[7]*; electricity, gas and water; financial intermediation and business services,* and, to a lesser extent, *mining.*

The presence of the *personal services* sector is strong in Quadrant II. The most important personal services are education, health, social services and associations, recreation, waste management and a wide range of services such as cleaning of clothing and leather, hair salons, funeral services, other personal services and domestic service. These services are mainly consumed by households.

Two sectors are contained in Quadrant III: *construction* and *public administration*. While the change in the impact on the productive fabric of the *construction* sector is low, there is a significant drop in the sector's TFP.

The *retail, hotels and restaurants* sector falls into Quadrant IV. It has a very limited increase in sectorial productivity but an important decrease in the impact on the economy.

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[7]Following the definition of the Chilean Central Bank, home services activities include the services provided in homes to be utilized for residential purposes. In practice, it measures the value of rents paid by renters plus a value for homes that are inhabited by their owners. This sector has a significant participation in the final demand. An increase in productivity of this sector is mainly affected by the increase in added value, which is calculated as a proportion of the net valorized stock of homes. The information that this sector provides should thus be treated with caution in order to consider the effect on productivity.

Comments

The results obtained in this article invite one to engage in a reflection in two areas. First, one considers the intensity of the change in productivity. Second, one can engage in a hypothetical analysis of the motives that generated the changes in productivity.

The intensity of the change in productivity is represented by the result obtained using the equation (4)

$$\Delta\rho = \rho_{03,10} - \rho_{96,03} = 0{,}0565 - 0{,}0495 = 0{,}007 = 0{,}7\%$$

in which $\rho_{03,10}$ and $\rho_{96,03}$ represent the TFP calculated for 2003-2010 and 1996-2003, respectively. The result signals that the increase in productivity between the two periods was 0.7%. Note that this increase in efficiency was produced in 2003-2010, when the growth of GDP was greater than the one registered during 1996-2003 (see Table 2). As such, in relative terms, the participation of the growth of efficiency was lower during the second period than during the first. These results confirm the observation presented in the growth accounting analysis literature for Chile (see Fuentes et al (2006)) in regard to poor growth due to "inspiration" that the economy has presented.

There are two hypotheses that are not necessarily mutually exclusive that explain the changes in TFP. First, given the pro-cycle nature of TFP presented in Fuentes et al. (2006), the years during which the input-output tables used in this article and the behavior of the Chilean cycle as shown in Figure 1, it is possible that the absolute increase in TFP has had its origin in cyclical factors. This first hypothesis, which is macroeconomic, is complemented by the second hypothesis, which is microeconomic, which describes a specific channel that may have contributed to sustaining TFP.

The second hypothesis emerges from combining the breakdown by sector conducted in this article and summarized in Figure 2 with the results presented in the article by Fernandes and Pauno (2012). While in the summary presented in Figure 2 shows the positive effect of the *manufacturing, electricity, gas and water, and financial intermediation and business services* sectors on changes in productivity, in their article, Fernandes and Pauno (2012) connect these three services through the considerable increase in Direct Foreign Investment (DFI) in the services sector during the period under study. During the 1990s, the DFI in services represented approximately 60% of total DFI in Chile. As such, through price reduction mechanisms, improved quality, increased diversity and dissemination of knowledge, it generated a positive effect on the TFP of manufacturing sector companies.

Conclusions

The purpose of this article was to study the sectorial composition of the changes in Total Factor Productivity from 1996 through 2010 in Chile in the context of Solow Growth Accounting and considering interaction among sectors. In order to do this, the information from the Input and Output matrixes for 1996, 2003, and 2010 provided by Chile's Central Bank were used. In the first part of the article, we developed the breakdown method. In the second part and appendixes, we discussed the treatment of the data that was conducted in order to obtain basic information. In the third, the results obtained were analyzed.

The breakdown of TFP was conducted in three parts: intra-sectorial productivity, the effects of dissemination between the productivity among other sectors, and the changes in demand that generate effects on productivity. It was found that only the two former factors explain over 80% of the change in productivity reported during the period under study.

The results of this research allow for the construction of a taxonomy of sectors based on their ability to drive the economy and changes in sectorial productivity. This taxonomy highlights the *manufacturing industry, electricity and gas and financial intermediation and business services sectors* as the three areas that led TFP during the period under study. These sectors increased their productivity and disseminated it throughout the entire productive fabric.

The personal services sector appears to be limiting growth of productivity in the economy because it has presented a decrease in productivity throughout the period and has had a large impact on the entire productive fabric.

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Appendix: Calculation of TFP in the Literature

The table below presents calculations of TFP obtained from the study by Fuentes et al. (2006) for one of the periods considered in this article.

Table 7: Participation of TFP in Production in Fuentes et al (2006)

	GDP	TFP*	TFP*
1996	31,237,289	123.68	160.83
2003	38,900,435	128.99	166.61
Growth for period	24.53%	4.29%	3.59%
Annual growth	3.18%	0.6%	0.51%
% TFP in Growth (TFP/GDP)		17.5%	14.65%
% TFP in Annual Growth (TFP/GDP)		18.92%	15.88%

Source: Generated by the authors based on Fuente et al. (2006)
* The basis of these indexes is the year 1960.

Two measures of TFP are used. TFP4 is an index of TFP that adjusts the use of capital based on employment, and TFP8 is an index that adjusts the use of capital based on consumption of electricity.

Appendix: Description of Data and Calculation Methods

In this appendix, we describe the calculations used to obtain the results. Three different methods will be used.

Obtaining Technical Coefficients

The data provided by Chile's Central Bank come in the form of production and use indexes (see Miller and Blair, 2009). These matrixes constitute the most important primary materials for producing data on intersectorial transaction matrixes.

The model led by industry demand developed by Miller and Blair (2009) was used with technology determined by the production structure of the goods independently of the industry in which they are produced in order to generate total requirement matrixes. Analytically,

$\boldsymbol{U}$: Matrix of uses of 13 products by 12 sectors.

$\boldsymbol{V}$: Sectorial Production Vector with 12 sectors by 13 products

$\boldsymbol{s} = \boldsymbol{V} * \boldsymbol{i}$: Industrial or sectorial production vector (12x1)

$\boldsymbol{q} = \boldsymbol{V}' * \boldsymbol{i}$: Production by commodities vector (13x1)

Where for simplicity's sake, the temporal sub indexes were left aside.

Using this information, the intersectorial transaction matrix was calculated as follows

$$\boldsymbol{B} = \boldsymbol{U} * \hat{\boldsymbol{s}}^{-1}$$

$$\boldsymbol{D} = \boldsymbol{V} * \hat{\boldsymbol{q}}^{-1}$$

$$\boldsymbol{Z} = \boldsymbol{D} * \boldsymbol{B} * \hat{\boldsymbol{s}}$$

In which the hat above the vectors (e.g. $\hat{\boldsymbol{s}}$) represents the diagonalization of said vector.

In order to calculate the coefficient matrix $\boldsymbol{A}$**,** national purchase matrixes were added to that of national purchases.

As such, the following information, which also is provided by Chile's Central Bank, is added to the transaction matrix obtained as discussed above.

$\boldsymbol{M}$: Import matrix for each sector of 12x12

$\boldsymbol{l}_v$: row vector of added salary by sector of 12x1

$\boldsymbol{k}_v$: row vector with added value of capital by sector of 12x1

$\boldsymbol{t}_v$: row vector of indirect taxes of 12x1

The column vector of total production is obtained as

$$\boldsymbol{x} = \boldsymbol{i}'\boldsymbol{Z} + \boldsymbol{i}'\boldsymbol{M} + \boldsymbol{l}_v + \boldsymbol{k}_v + \boldsymbol{t}_v$$

And the column vector of final demand is calculated, obtaining the total products by sector and subtracting intermediate sales by sector.

$$\boldsymbol{y} = \boldsymbol{x} - \boldsymbol{i}'\boldsymbol{Z}' - \boldsymbol{i}'\boldsymbol{M}'$$

Calculation of Salary and Technical Labor Coefficients

In order to calculate the labor coefficients, the distribution of employment for the 12 sectors for 1996, 2003 and 2010 was obtained from data available from the National Statistics Institute.

First, a vector with the number of people working in each sector $\boldsymbol{l}_n$ was obtained for each year. The number of people who work in each sector is thus determined by:

Table 8: Number of Workers per Sector (thousands)

	1996	2003	2010
Agricultural-Forestry	723.17	710.96	703.24
Fishing	66.17	81.30	45.62
Mining	92.37	79.33	199.17
Manufacturing industry	844.89	822.73	799.31
Electricity, gas and water	39.22	26.20	58.88
Construction	406.21	461.70	562.50
Retail, hotels and restaurants	925.96	1129.12	1746.53
Transportation and communications	387.21	484.38	522.57
Financial intermediation and business services	353.08	471.12	574.64
Home services	0.00	0.00	0.00
Personal services	1137.82	1257.89	1497.94
Public administration	204.92	263.79	391.74
Total Employment	5181.02	5788.52	7102.14

Source: National Statistics Institute and Central Bank. Developed by the authors.

Complementing this information, the average number of hours worked per week during those periods was obtained. Using Central Bank data, it was determined that approximately 46, 43.3 and 40 hours were worked per week in 1996, 2003 and 2010, respectively.

Using the number of workers for each sector and hours worked, the average salary of the economy was calculated as follows

$$w = \frac{\boldsymbol{l}_v \boldsymbol{i}}{\boldsymbol{l}_n \boldsymbol{i}}$$

Where **i** is a unitary column vector, and $\boldsymbol{l_v}$ is a row vector with the number of payments made to the work factor and $\boldsymbol{l_n}$ is a row factor that has the number of hours worked in each sector.

Each one of the components of the work coefficients vector $\boldsymbol{l}$ is calculated as follows

$$l_i = \frac{l_{n,i}}{x_i}$$

Where $l_{n,i} \in \boldsymbol{l}_n$ are the hours worked in sector i and $x_i \in \boldsymbol{x}$ is the gross product of sector i, expressed in constant terms.

Calculation of the Price of Service of the Capital and Technical Coefficients of the Capital

In order to calculate the indicators of the capital, we first obtained data from the Statistical Economic Study presented by Henríquez (2008) from the Central Bank updated through 2010.

There are two significant differences for the availability of stock between the data required and those available, as the table below shows:

Sectors Included in the Study	**Capital with Different Sectors Available in Henríquez (2008)**
Agriculture and Forestry	Agriculture, Forestry and Fishing
Fishing	
Mining	Mining
Manufacturing industry	Industry
Electricity, gas and water	Electricity, gas and water
Construction	Construction
Retail, hotels and restaurants	Retail, restaurants and hotels
Transportation and communications	Transportation and communications
Financial intermediation and business services	Financial and business services
Home services	Home services
Personal services	Municipal and social services
Public administration	

1. The capital of the Agriculture and Forestry and Fishing sector is aggregate. In order to distribute it among those areas, it is assumed that the capital-product ratio is the same for the two sectors. As such, the capital for each is calculated as follows:

   $$k_1 = k_{asp} \frac{x_1}{x_1 + x_2} \qquad k_2 = k_{asp} \frac{x_2}{x_1 + x_2}$$

   In which k_{asp} is the capital stock of the Agriculture and Forestry and Fishing sector, x_1 and x_2 are the gross product reported for the sectors, respectively. Finally, k_1 and k_2 are the capital values calculated for each sector.

2. The public administration sector does not have reported capital stock in the article by Henríquez (2008). In order to estimate it, the capital-product ratio is calculated for all sectors except for public administration.

   $$v = \frac{\sum_{i \neq g} k_i}{\sum_{i \neq g} x_i}$$

Next, it was assumed that this is the same capital-product ratio that exists for the public sector. It was obtained in this way based on the product of the government in relation to capital.

$$k_g = v * x_g$$

Where x_g is the gross production reported in national accounts, and k_g is the capital stock estimated by the government.

Next, the price of the service of capital is defined as follows:

$$r = p_k \left(r_o + \delta_k - \frac{\dot{p_k}}{p_k} \right) \quad \text{(a1)}$$

Where r_o, δ_k and p_k are the interest rate (cost of opportunity), depreciation rate and the price (or surplus) of the capital, respectively.

The aggregate value of the capital reported by the Central Bank can be defined as follows

$$k_v = r\phi K \quad \text{(a2)}$$

Where r is the price of the service of the capital, ϕ represents the factor of use, noting how much was used (for example, in hours), the capital stock available K is a monetary measurement of the capital stock available for production (equipment, cars, properties, etc.), purchased in the past.

In order to obtain the coefficient of use of capital, physical quantities must be used. In other words,

$$k = \frac{\rho_k \phi K}{\rho_x x} \quad \text{(a3)}$$

In which ρ is a deflactor for putting in relation to a base year 0 (zero) the measurements of capital K, and gross product x, y ϕ is the rate of use of capital. As such, the interpretation of the coefficient k is the requirement of physical capital necessary for each production unit. Note the physical concept in the sense of production techniques.

In order to calculate the price of the capital service, the following method is used:

$$r = \frac{k_v}{\phi K} \quad \text{(a4)}$$

Where it is simple to understand that by dividing by the effective use of capital, ϕK, one obtains the price given that $r = \frac{k_v}{\phi K} = \frac{r\phi K}{\phi K} = \frac{r\phi}{\phi}$.

Calculation of the Sectorial Productivity Vector

Given that productivity is calculated over discrete periods of time, an estimate like the one set out in Wolff (1984) will be used:

$$\beta_i = \frac{y_i}{Y}$$

$$v_L = \frac{wL}{Y}$$

$$v_K = \frac{rK}{Y}$$

and the average values between the two periods are represented as follows

$$\bar{\beta}_i = \frac{\beta_{i,t} + \beta_{i,t+1}}{2}$$

As such, aggregate TFP can be estimated as follows

$$\rho \cong \sum_j \bar{\beta}_j \, \Delta \log y_j - \bar{v}_L \, \Delta\log L - \bar{v}_K \, \Delta\log K$$

and TFP for sector *j* is estimated similarly as

$$\pi_j \cong -\left(\sum_i \bar{\alpha}_{i,j} \left(\Delta \log a_{i,j} \right) + \bar{v}_{L,j} \left(\Delta \log l_j \right) + \bar{v}_{K,j} \left(\Delta \log k_j \right) \right)$$

In which $\alpha_{i,j} = \frac{p_i a_{i,j}}{p_j}$, $v_{L,j} = \frac{w l_j}{p_j}$, $v_{K,j} = \frac{r k_j}{p_j}$, and the bar above the variables represents the use of the weights from the Turnquist-Divisia index between the two periods.