Commodity Prices, Growth and Productivity: A sectoral view*

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Abstract

We construct TFP series at a sectoral level for Chile and analyze how commodity price shocks affect these measures. The Dutch-Disease literature is concerned by that possible fall in productivity in the industrial sector after a commodity boom, as that sector may be a mayor driver of TFP improvements for the economy as a whole. Our results provide evidence that indeed Industrial TFP is negatively affected by positive commodity price shocks, both after either temporary or permanent shocks. However, despite this effect, TFP at the aggregate level is not necessarily reduced. In particular, Aggregate TFP does not seems to be significantly affected by the shock, while if we exclude Commodities and Utilities, or if we just focus on non-tradeable sectors, TFP actually tends to increase. This results holds even controlling for the possibility that sectoral relocations of resources and changes relative prices might affect measured TFP at an aggregate level.
Keywords: Commodity prices, Total factor productivity, Dutch-Disease, Sectoral growth.

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1 Introduction

When a country that specializes in the export of some commodities faces a persistent rise in the international price of those goods, at the same time people acknowledge that the economy will likely experience higher growth (at least temporarily), many start worrying about the Dutch-Disease. This is the name generally used to describe a situation where, after a commodity boom, productive resources tend to be relocated away from the Industrial/Manufacturing sector towards both the Commodity and the Non-tradeable sectors. As a consequence, the Manufacturing sector suffers a contraction while these others sectors are expanding.

From a welfare perspective, this situation should be a concern (i.e. the "Disease" is actually a disease), if this relocation is socially costly. In particular, one of the major arguments along these lines is that a contraction in the industrial sector leads to a slowdown in growth (either in the medium or the long run), as this sector is one of the mayor drivers of improvements in total factor productivity (TFP). This could happen, for instance, in the presence of some learning-by-doing mechanism that would imply a reduction in TFP (or a smaller TFP growth) as activity in this sector is contracting. [1] Thus, if the industrial sector experiences a contraction, the potential for sustained long-run growth may be in jeopardy.

However, even if we assume that the reduction in industrial activity leads to a contraction in TFP for those firms, other sectors are expanding at the same time and (by the same channels trough which productivity might decrease in the industrial sector) TFP might increase in those other sectors. Thus, it is not clear which will be the overall effect. Quantifying this tends to be a complicated task: while it is generally feasible to compute TFP at an aggregate level, calculating such a measure at a sectoral level is usually more difficult, mainly because capital-stock data at a sectoral level is generally not available.

In this paper we take advantage of the data availability in Chile, where sectoral capital is indeed computed, to construct TFP for the nine sectors that compose aggregate GDP. Chile is an interesting case of study in this literature for being an exporter of Copper; a commodity whose international price experienced a higher average level after 2005, relative to its values in the 90's and the beginning of this century. Our goal is to characterize the effects generated by a shock to the international price of Copper on TFP and activity (GDP), both at a sectoral level and at different levels of aggregation.

After carefully computing TFP measures for each sector and for several groups of sectors (the groups we consider are aggregate, aggregate excluding commodities and utilities, and non-tradeable), we use both VAR and VEC models to identify the effects of copper price shocks. In particular, we try to distinguish between temporary and permanent shocks to commodity prices.

Our results show that, although at the aggregate level there is mild effect of commodity price shocks on TFP, the sectoral responses are quite heterogeneous. In particular, TFP in the industrial sector seems to be negatively affected by the shock, while the opposite happens in the main non-tradeable

[1] See, for instance, the literature review in Magud and Sosa (2103). Some recent studies of the normative implications of commodity booms in models where this productivity effect is present are Lama and Medina (2012), Hevia et al (2013), and García-Cicco and Kawamura (2015).

sectors. In this sense, Dutch-disease-related concerns could be relevant in the case of Chile.

However, we also decompose the effect on measured TFP computed for groups of sectors in two parts: "true" TFP improvements in the individual sectors and movements in measured TFP due to either relocation of resources across sectors within the group or to changes in relative prices. At the aggregate level, it seems that the estimated effect on measured TFP is mainly due to relocation of resources and to changes in relative prices. But when we exclude Mining and Utilities, or if we just consider non-tradeables, the effect on measured TFP (which increases after a commodity boom) does not appear to be influenced by these other effects. Overall, while it is seems that for Chile a positive commodity price shocks reduces TFP in the industrial sector, the aggregate effect (once we exclude mining and energy-related goods) is more benign than what conceptually the Dutch-Disease-related concerns would imply.

This paper is related to several strands of the literature. Many paper empirical study the effects on activity of capital inflows. The work by Magud and Sosa (2013) presents a meta-analysis summarizing the results in the literature, distinguishing between the source of capital inflows (commodities, remittances, financial aid, etc.). Raddatz (2007) shows evidence of the effect of commodity price shocks (among other external shocks) on growth in low-income countries, using panel-VAR techniques. Collier and Benedikt (2008) use panel-VEC models to separate the medium- and long-term effects on growth. Finally, IMF (2015) analyzes the impact for Chile on GDP, TFP and capital accumulation of commodity-price booms. All these examples, however, focus the attention on aggregate activity or TFP, but there is no sectoral analysis. In that sense, our paper contributes to this literature by analyzing sectoral implication as well, both for GDP and TFP. Some papers do study sectoral implications of commodity price shocks on either activity or labor productivity (e.g. Pieschacon, 2010, Naudon and Medina, 2012, and Bjornland and Thorsrud, 2014). None of them, however, study the effects on sectoral TFP. Additionally, several studies compute aggregate and sectoral TFP for Chile (e.g., Corbo y Gonzalez, 2012, Magendzo and Villena, 2011, Fuentes et al., 2006, Vergara y Rivero, 2006, Roldos, 1997, Chumacero and Fuentes (2001), and Beyer and Vergara, 2002). None of them study how these measures are affected by commodity price shocks.

The remainder of the paper is organized as follows. Section 2 describes the data and the methodology used to compute TFP. Section 3 presents the empirical strategy and discusses the results. Section 4 concludes, including a discussion on the implications of our empirical results for several assumptions used in the related theoretical literature.

2 Data

The main task for our empirical analysis is to construct TFP series for the different sectors in the Chilean economy. National accounts data decompose total GDP in the following sectors: Agriculture (including also livestock and fishing), Mining (mainly copper, including copper-related manufactures), Industry and Manufactures, Utilities (Electricity, Gas and Water), Construction, Retail (including

Tourism), Transportation and Communications, Financial Services, and Personal and Other Services. In addition to each of these sectors, we also characterize three groups of sectors: Aggregate (combining all sectors), Excluding mining and utilities (in the figures and tables this is labeled as 'No Co-Ut'), and Non-tradeables (Construction, Retail, Transportation, Financial and Personal Services). The main constraint to select the sample is the availability of capital-stock data. For the aggregate economy we have information available from 1991 to 2013, but for the different sectors the sample is from 1996 to 2013.[2]

As we mentioned in the introduction, there are several studies for Chile that construct sectoral TFP series. While they share a basic common framework, there are some methodological differences between them. Drawing from this related literature, we describe our approach for constructing the TFP measures. The starting point is the Neo-classical production function that allows to construct TFP by means of Solow residuals. In particular, the following functional form is assumed

$$GDP_{it} = TFP_{it}(L_{it})^{\alpha_i}(K_{it})^{1-\alpha_i},$$

where i represents either a sector or one of the groups of sectors we consider. Here L_{it} denotes the labor input, K_{it} is the capital stock, GDP_{it} is real gross domestic product,[3] and α_i is the share of labor income.[4]

We use a different labor income share to calculate aggregate and sectoral TFPs. For the aggregate economy we use $\alpha = 0.6$, taken from Fuentes et al. (2006).[5] The values of sectoral income shares are taken from Corbo and Gonzalez (2012)[6]. The labor income share for the other groups of sector is computed as a weighted average of the share of remunerations of each sector on total value added of the sectors considered. These are reported in Table 1.

The capital stock data for different sectors comes from Henriquez (2008). In the growth accounting literature, capital is generally adjusted by utilization. Unfortunately, we do not observe capital utilization directly in Chile. Instead, we use as proxy data on energy consumption, as proposed by Costello (1993).[7] We compute capital utilization as deviations of energy consumption from its trend,[8] as in Fuentes et al. (2006).

[2] The details of variable definitions and sources are described in the appendix.

[3] In the case of Chile, real GDP is constructed using chain-weighted indexes.

[4] We should notice that this measure of TFP might not necessarily reflect true technological improvements, as it is widely recognized in the literature. For instance, the choice of functional form for the production function, as well as assumptions regarding market power, can lead to different results (e.g. Barro, 1999). Also, technological change can manifest itself not as variation in total factor productivity but as changes in the production function itself (for instance, new technologies might affect the ways capital and labor are combined to produce, changing the α's overtime). Finally, issues on data collection can also affect the measure of TFP. Still, our approach continues to be the most widely used in the growth accounting literature.

[5] There are several methodologies to compute income factor shares. However, most studies of TFP for Chile have estimated a labor income share for the aggregate economy that ranges between 0.5 and 0.6.

[6] See the appendix for a table with the selected values of the labor income shares used for each sector.

[7] Other studies for Chile use the unemployment rate as an alternative proxy for capital utilization under the assumption that labor and capital have the same rate of utilization e.g., Gallego and Loayza (2002), Vergara and Rivero (2006).

[8] Computed with the HP filter with parameter $\lambda = 6.25$

The labor input is composed of three parts. The first is the number of people employed, the second is hours worked (computed as the sum of the average weekly hours worked in a year), and the third is an adjustment for quality. For the last one we follow Magendzo and Villena (2011), to construct a quality index for labor that accounts for differences in productivity across workers with diverse levels of education.[9] The first two components are computed for each sector and groups of sectors, while the third one is assumed to be the same across sectors, as we do not have sectoral data to construct it.

The data on GDP and employment is available at a quarterly frequency, while all other variables are annual. To obtain quarterly data we use a linear interpolation for data on capital stock adjusted by energy utilization, the education premium, and average hours.[10] Figures 1 to 3 display the data used to construct the TFP series, while Figure 4 displays the obtained TFP for each sector and groups of sectors. Additionally, Figure 5 shows the nominal shares of each sector (computed relative to the group that excludes Mining and Utilities), and Figure 6 presents the two international variables that will be used for the analysis: GDP of Chile's commercial partners, and the international price of Copper.[11]

As can be seen, although aggregate TFP seems to have increased on average during the sample, there are many sectoral differences. For instance, Mining, Utilities and Transportation display a negative trend, while TFP seems to increase on average in Agriculture and Financial services. The Retail sector seems to have experienced a decrease during the first half of the sample (until 2003 approximately), growing on average afterwards. Finally, TFP in Construction and Personal services does not show a clear trend over the period.

We finish this section by summarizing a battery of unit roots tests, as well as co-integration tests between the different TFP series with the international copper price and with Aggregate TFP. These test are relevant to determine the identification strategy described below. The summary of these tests can be found in Tables 2 and 3.[12] In terms of the unit root test, most TFP series seem to be non-stationary, although controlling for the possibility of structural breaks changes the conclusions for some variables. This last feature is relevant because, as we will argue later, the Commodity price series also exhibit a structural break. Finally, it is also the case that some of the TFP series seems to be co-integrated with Commodity prices, a feature that will be considered in the estimation exercises presented in the next section.

[9] In particular, the index is computed as $\sum_i \left(\frac{n_i}{n}\right)\left(\frac{w_i}{w_o}\right)$ where n_i denotes workers with educational attainment i, n is the total amount of employed workers, w_i are the average wages obtained by worker type i and w_o is the average wage of workers with no formal education. This methodology assumes that differences in labor productivity are evidenced by earning differentials, and that workers with more years of education contribute more to productivity growth than their less educated counterparts. We apply the HP filter with parameter $\lambda = 6.25$ for to the quality index to correct for cyclical fluctuations, and use the trend component.

[10] We experimented with other interpolation techniques, such as quadratic matching and splines. For capital we also explored an interpolation based on the movements in quarterly sectoral investment. We decided to use the linear approach as that method yields TFP series that are closer to those computed in the related literature.

[11] All variables are in log's.

[12] The details of each of the tests are available from the authors upon request.

3 Methodology and Results

In this section we first describe the details of the empirical models used and the identification strategy. We then show the estimated effects of both temporary and permanent shocks.

3.1 Models and Identification

As stated in the introduction, the goal is to identify the effects of shocks to the international price of commodities in several aggregate and sectoral variables. From a theoretical point of view, not all surprise changes in commodity prices will have the same effect. In particular, we separate these shocks along two dimensions. One is duration: the effect of a commodity price shock should be different if it is temporary (although persistent) or if it has a permanent effect (the more persistent the change, the large the increase in lifetime income that is expected, and thus the wealth effect generated).

The other is the international context in which the change in commodity price occurs. In particular, the effect on domestic variables should be different if, for instance, a rise in commodity prices happens simultaneously with an increase in global activity, relative to a case in which commodity prices increases but global demand remains constant. In principle, if commodity prices increase but global demand also rises, the typical sectoral relocation in the Dutch-disease literature may not appear; for the increase in global demand will likely generate a boom in the domestic industrial sector as well. Thus, controlling for the evolution of global demand is key to identify the effect of commodity price shocks.

Given this conceptual distinctions, we use the following identification strategy. In terms of duration, the series of world price of copper in our sample displays a break on its unconditional mean in 2005.Q1.[13] However, as our sample contains just one break, we cannot directly identify the effect of that change. Therefore, we proceed as follows. To identify the temporary shock we estimate a VAR with variables in levels that also include a constant, a linear trend, a dummy variable that takes value of one after 2005.Q1, and the dummy interacted with the linear trend. The idea is that, by controlling for the change in mean and trend we will be left with temporary shocks only.

On the other hand, to identify the effects of permanent shocks we estimate a VEC model allowing domestic variables to be co-integrated with international series.[14] If the low-frequency behavior of copper price is mainly driven by the structural break, the shock identified using the VEC should be a good approximation of permanent shocks.

Both VAR and VEC models include two international variables, in the following order: the GDP for Chile's commercial partners (trade weighted) and the international price of copper deflated by the PPI in the US. Thus, using a Cholesky order, the second will be the shock that we want to characterize. In other words, we want a shock to commodity prices that is not contemporaneously affected by a shock to

[13] This can be found, as in Garcia-Cicco and Kawamura (2015), using both the Andrews-QLR structural-break test and the Bai-Perron methodology to detect break dates. In addition, using a Markov Switching model, Garcia-Cicco and Montero (2012) also find a change in the unconditional mean of the copper price in 2005

[14] Additionally, we constrain the matrix that determines how deviations from the long-run equilibrium affect the variables in the system. In particular, we assume that errors from the long-run relationship cannot load into international variables, in line with the block-exogeneity assumption for international variables.

global activity. These two international series will be combined in the models with domestic variables, assuming that they are block-exogenous relative to domestic ones.[15]

In terms of estimation, because we want to study the effect of these shocks on a large number of variables, including all of them in either a VAR or a VEC model would imply loosing many degrees of freedom, reducing the power of inference. Therefore, we separate the dataset by types of variables (TFP, GDP and Shares) and run different VAR/VEC models. In that way, for example, one VAR will include the TFP for all the sectors, plus TFP for three groups (Aggregate, excluding Mining and Utilities, and Non-Tradeables), as well as both international variables, adding up to 14 series. Overall, we run three VAR and three VEC models.[16] Finally, inference is performed by a bootstrap procedure, drawing randomly (with replacement) 500 samples from the reduced-form residuals of the VAR/VEC model to construct confidence bands.

3.2 Temporary Shocks

We begin by displaying the responses of international variables to the identified temporary commodity shock, in Figure 7.[17] As we can see, a typical shock has a standard deviation of roughly 12%, and its half-life is about six quarters. In addition, while the identification strategy imposes a zero-contemporaneous reaction of GDP for Chile's commercial partners, the identified shock tends to increase that measure of global activity, with a significant peak of 0.2% around five quarters after the shock. One possible explanation for this increase in Chile's relevant measure of global activity might be that, as many of Chile's commercial partners are also commodity exporters, the impact in Copper price generates a positive effect on activity in these countries as well, as the shock is likely correlated with other commodity prices.

Given this shock, we now describe the effects on the different GDP measures, as shown in Figure 8. We can see that Aggregate GDP does not seems to be significantly altered by this shock until around the eight quarter when it displays a significant increase that last approximately five quarters, with a peak response of 0.4%. However, if we focus on the GDP excluding commodities and utilities we can see a significant hump-shaped response, with a maximum impact close to 0.9%, which remains significant for 10 quarters. This difference can be attributed by the response of Mining GDP, which displays a negative response, while Utilities GDP does not seem to be significantly altered by the shock.

Regarding the other tradeable sectors, both Agriculture and Industrial GDP significantly rise after the shock, with maximum responses, respectively, of around 1.1 and 1%. The response is qualitatively similar in the non-tradeable sectors (both individually and aggregating them), with the largest effects

[15] This is, that domestic variables cannot affect international series at any time.

[16] Notice that, although we include in the same VAR sectoral variables as well as groups of variables (e.g. the GDP for each non-tradeable sectors as well as the GDP for the non-tradeable group), there are no issue of co-linearity, because the group measures are not simple sums of the individual variables. For real GDP this is true because we are using chain-weighted indexes. In the case of TFP, our measure is not additive (this is why we then decompose the effect on TFP of a given group between "true" TFP effects and relocation of resources across sectors; see also the appendix). Finally, for sectoral shares this is not a problem because we are taking logs.

[17] This come from the VAR that include GDP variables. Results are quite similar with the other VAR models

appearing in Construction and in Retail (close to 2%).[18]

In a sense, after these responses one could argue that the typical Dutch-disease effect is not present; for the industrial sector rises after the increase in commodity prices. However, in relative terms this expansion is smaller than that in the major non-tradeable sectors. This relative reduction does not occur only at the real level but also in terms of nominal shares (relative to the GDP that excludes Mining and Utilities). As can be seen in Figure 9, the share of industrial sector decreases after the shock, with a significant response between the fifth and fifteenth quarter, reducing the share by at most 1.5 percentage points.[19] In contrast, the nominal shares of the two main non-tradeable sectors (Retail and Construction) seem to increase after the shock. The other non-tradeables (Transportation and both services) either shrink or do not show a significant response. Overall, it seems that not only in real terms the industrial sector increase by less than the major non-tradeable sectors, but the change in relative prices also goes in the direction suggested by theory.

In terms of TFP, the impulse responses are displayed in Figure 10. At the aggregate level, we can see that TFP seems to decrease initially after the temporary commodity shock, while it then recovers and rises after 10 quarters. In contrast the TFP excluding Commodities and Utilities display a positive and significant increase after the shock, rising TFP by almost 0.6% relative to the pre-shock level. An even larger response but with a similar shape can be observed in the Non-tradeable group.

Examining sectors individually, we can see that TFP display a significant, hump-shaped, and positive response in Agriculture, Retail and Financial services. The effect is not significantly different from zero in Mining, Utilities, Construction, and Personal Services. Finally, in the Industrial and Transportation sectors the response seems to be significantly negative. The response in the industrial sector and the increase in the largest non-tradeable sector seems to be in line with Dutch-disease related concerns.

An important issue to address is that, as TFP computed for a given group of sectors is not equal to a fix-weighted sum of the TFP in the individual sectors, there is a chance that the response of TFP in the group as a whole might not be due to TFP changes but instead to relocation of resources between sectors in the group or due to change sin relative prices. Therefore, we compute a decomposition proposed by Bernard and Jones (1996), that separates the change in TFP in a group of sectors by changes in TFP for a given sectoral weight (or "pure" TFP changes) and changes due to either the relocation of resources between sectors or relative prices changes.[20] The results computed using the point estimate of the impulses responses are depicted in Table 4.[21]

As can be seen, the effect on Aggregate TFP is highly influenced by relocation of resources across sectors and/or changes in relative prices, and in many cases this effect compensates the changes in productivity triggered by the shock. On the other hand, for the two other groups the effect of TFP

[18] The response that is somehow different within this group is the Transportation sector. The initial response is not significant, a positive and mild significant effect is experienced after a couple of quarters, and in the medium term (after 10 quarters) the response is mildly negative.

[19] The share of Agriculture sector does not display a significant response.

[20] As we are interested in "true" TFP changes, our decomposition just separates changes in measured TFP between changes in "True" TFP and other sources of change. The details of this decomposition can be found in the Appendix.

[21] Of course, the same argument can be raised for each individual sector, that is composed by the sum of firms within each sector. Unfortunately, we do not have access to the required firm level data to calculate TFP for each firm.

improvements within the members of each group seem to be most relevant in explaining the responses previously described. Therefore, as TFP in the industrial sector is negatively affected by the shock, the observed positive responses in TFP for these two last groups seems to be mainly driven by Retail and, to a smaller extent, to the effect on Agriculture and Financial services.

3.3 Permanent Shocks

We now turn to the analysis of a permanent shock to commodity prices, identified with the VEC methodology outlined above. Figure 11 shows the response of international variables. As can be seen, the shock generates a permanent and significant increase in commodity prices of almost 12%. At the same time, while it seems that the shock also generates an increases in external GDP, the effect does not seem to be significant.

The response of the different GDP measures is displayed in Figure 12. The shock generates a positive and significant response for Agriculture, Industry, Construction, Retail, Financial Services, as well as in the group that excludes mining and utilities and the Non-tradeable group. However, the statistical significance is only observed in the initial periods; afterwards the confidence bands become too wide to distinguish the responses from zero. At the aggregate level, as well as for the Utilities, Transportation and Personal services sectors, real GDP does not appear to significantly move after the shock. Finally, production in the Mining sector suffers a significant and quite persistent contraction.

As observed with the temporary shock, the industrial sector seems to grow by less than most non-tradeable sectors. However, as shown in Figure 13, in nominal terms it is not obvious that the industrial sector loses market share relative to the aggregate that excludes mining and energy. The sectors whose nominal shares seem to significantly increase are Retail and Financial services, while Personal services experiences a reduction in nominal terms after the shock. Overall, the nominal share of all Non-tradeable sectors together is not significantly altered after the shock.

Focusing on the effects of TFP, we can see that the permanent commodity shock generates a persistent reduction in both the Industrial and Utilities sectors that is statistically significant. On the contrary, Retail and Construction, as well as the Non-tradeable group, experience significant improvements in TFP. For the other sectors, the responses do not appear to be statistically significant.

Here we can also implement the same decomposition used before to asses the role of sectoral relocation of resources and of relative prices to determine the effects on TFP computed for the alternative groups of sectors. Similarly to what we observed with a transitory shock, at the Aggregate level the shock generates relocation and relative-price effects that are as large or even larger than the improvements in productivity. At the same time, for the group that excludes Mining and Utilities and the one with Non-tradeables the relocation between sectors seems to be less important to determine the identified effect on TFP for those particular groups.

4 Conclusions

In this paper we took advantage of the data availability for Chile and computed sectoral TFP measures to assess how commodity prices affect this measure of productivity, as well as to identify the effect on aggregate activity. In particular, motivated by the Dutch-disease literature, one goal was to identify the possibly negative effect that such a shock could generate in the Industrial sector. From that perspective, the result we found were somehow mixed. On one hand, real GDP in the Industrial sector seems to either increases or not significantly move after shocks that rise commodity prices. On the other, relative to non-tradeable sectors the Industrial sector experience a reduction, both in nominal and in real terms. Moreover, TFP in the industrial sector appears to be negatively affected after the shock.

Looking at the economy as a whole, it is not clear that aggregate TFP is significantly altered by the shock to commodity prices. However, we also detected that the effect on the measure of aggregate TFP is highly influenced by relocation of resources across sectors and by relative price changes. In this respect, both the Commodities and the Utilities sectors experience a drop in output and in TFP in response to an increase in commodity prices. In fact, once we measure TFP for an aggregate that excludes these two sectors we found significant improvements in TFP, with a minor role for sectoral relocations. Therefore, while it is true that TFP in the industrial sector is negatively affected by a rise in commodity prices, the positive effect in non-tradeable sectors (particularly in Retail) seems to generate an aggregate expansion in TFP.

The results of this empirical analysis might offer some guide to model builders that are interested in capturing both aggregate and sectoral effects of commodity price shocks. The simplest models assume that commodities are an endowment and therefore the effect of a rise in commodity prices is modeled as a wealth effect. In such a model, generally a commodity price shock tend to decreases GDP in the industrial sector (because domestic agents can substitute them with imported goods), while increasing it in the non-trade sector. However, we have seen here that GDP in the industrial sector rises after a positive shock. To make the model closer to this empirical results, several modifications are available. First, one can consider (as in our empirical results) that the commodity price shock tends to increase (with a delay) global activity, which can also rise the demand for industrial goods as well. Another alternative is to consider sectoral interactions, where both the commodities and non-tradeable sectors use industrial goods as intermediate input. Thus, the expansion in these sectors will further raise the demand for industrial goods.

Another model choice that needs to be carefully selected is the endogeneity of TFP. Most models use some variant of a learning-by-doing model, where TFP tends to increase with the scale of the sector. But such a mechanism is at odds with the empirical results we have obtained, for TFP in the industrial sector is reduced despite the increase in GDP in that sector. One alternative could be to explicitly model the R&D process in all the sectors, where R&D firms decide in which sector to invest looking not at the individual GDP of the sector but instead based on its expected performance relative to other sectors. Thus, although GDP in the industrial sector might increases, R&D is redirected towards the other sectors as they expand in relative terms, generating a contraction in TFP in the industrial sector.

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Appendix - TFP decomposition

Let TFP_t denote total factor productivity in a group of N sectors. By definition,

$$TFP_{it} = \frac{GDP_{it}}{(L_{it})^{\alpha_i}(K_{it})^{1-\alpha_i}}, \text{ for } i\text{=1,...,N and } \quad TFP_t = \frac{GDP_t}{(L_t)^{\alpha}(K_t)^{1-\alpha}}$$

Additionally, notice that due to the chain-weighted structure of real GDP data in Chile, we have $GDP_t = \sum_{i=1}^{N} GDP_{it}\beta_{it}$, where $\beta_{it} = P_{it}/P_t$.[22]

Given the definition of TFP_t and GDP_t we can write

$$TFP_t = \frac{\sum_{i=1}^{N} GDP_{it}\beta_{it}}{(L_t)^{\alpha}(K_t)^{1-\alpha}} = \sum_{i=1}^{N} \frac{GDP_{it}}{(L_{it})^{\alpha_i}(K_{it})^{1-\alpha_i}}\beta_{it}\frac{(L_{it})^{\alpha_i}(K_{it})^{1-\alpha_i}}{(L_t)^{\alpha}(K_t)^{1-\alpha}} = \sum_{i=1}^{N} TFP_{it}\omega_{it}$$

where $\omega_{it} = \beta_{it}\frac{(L_{it})^{\alpha_i}(K_{it})^{1-\alpha_i}}{(L_t)^{\alpha}(K_t)^{1-\alpha}}$. With this, comparing TFP_t versus that in a reference period TFP_0,

$$\begin{aligned} TFP_t - TFP_0 &= \sum_{i=1}^{N} TFP_{it}\omega_{it} - \sum_{i=1}^{N} TFP_{i0}\omega_{i0} \\ &= \sum_{i=1}^{N} TFP_{it}\omega_{it} - \sum_{i=1}^{N} TFP_{i0}\omega_{i0} - \sum_{i=1}^{N} TFP_{it}\omega_{i0} + \sum_{i=1}^{N} TFP_{it}\omega_{i0} \\ &= \sum_{i=1}^{N}(TFP_{it} - TFP_{i0})\omega_{i0} + \sum_{i=1}^{N} TFP_{it}(\omega_{it} - \omega_{i0}) \end{aligned}$$

Therefore, the change in aggregate TFP can be decomposed in two terms: the first due to pure TFP changes, while the second is due to relocation and changes in relative prices. Finally, if we divide the expression by TFP_0, we get

$$\begin{aligned} \frac{TFP_t - TFP_0}{TFP_0} &= \sum_{i=1}^{N}\left(\frac{TFP_{it} - TFP_{i0}}{TFP_{i0}}\right)\frac{TFP_{i0}}{TFP_0}\omega_{i0} + \sum_{i=1}^{N}\frac{TFP_{it}}{TFP_{i0}}\frac{TFP_{i0}}{TFP_0}(\omega_{it} - \omega_{i0}) \\ &= \sum_{i=1}^{N}\left(\frac{TFP_{it} - TFP_{i0}}{TFP_{i0}}\right)\gamma_{i0} + \sum_{i=1}^{N}\frac{TFP_{it}}{TFP_{i0}}\frac{TFP_{i0}}{TFP_0}(\omega_{it} - \omega_{i0}) \end{aligned}$$

where $\gamma_{i0} = \frac{GDP_{i0}P_{i0}}{GDP_0 P_0}$ is the nominal share of sector i in period 0.

To compute this decomposition, for each group of sectors (Aggregate, Excluding Mining and Utilities, and Non-Tradeables) we compute $\frac{TFP_t - TFP_0}{TFP_0}$ and $\frac{TFP_{it} - TFP_{i0}}{TFP_{i0}}$ using the impulse responses. For the shares γ_{i0} we report results using the average in the whole sample.[23] With these we can compute

[22] When national accounts are not chain-weighted but computed instead using a base year, it holds that $GDP_t = \sum_{i=1}^{N} GDP_{it}$ by definition.

[23] Alternatively, we have computed the results using the average share between starting in 2000 and also starting in 2006, but results are quite similar, and thus we omit them.

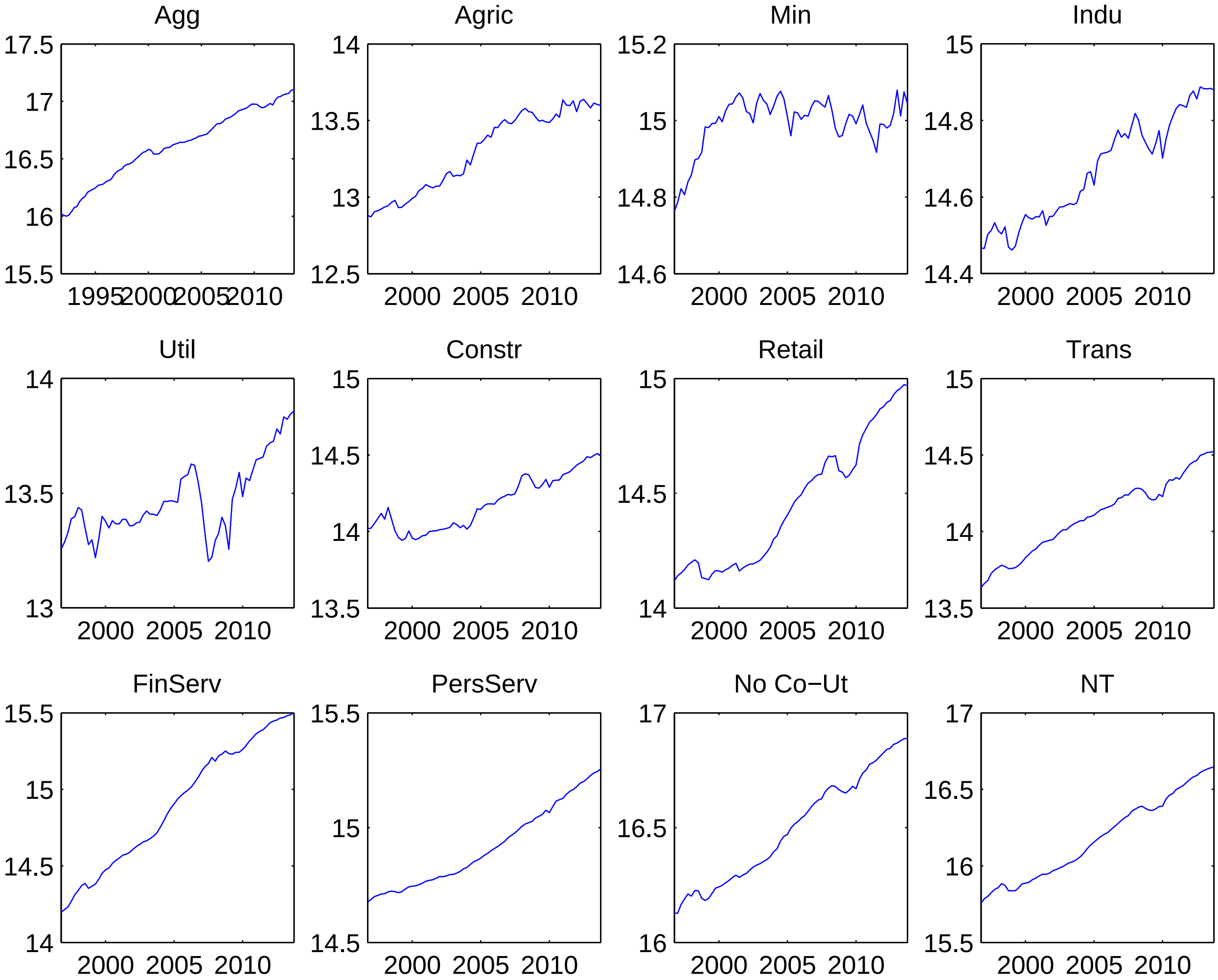
the first term in the decomposition, and we obtain the second as the difference.

Data Definitions and Sources

Variable	Definition and Methodology	Data Source
GDP	Real GDP in millions 2008.	Central Bank of Chile, Compilación de Referencia 2008.
Employment	Number of workers in the labor force.	INE, old and new Employment Surveys. Series joined formerly by the Central Bank of Chile.
Aggregate labor share	Share of capital in national income for period 1960-2005 with correction for income share of independent workers.	Taken from Fuentes et al.(2006) with data from National Accounts, Central Bank of Chile.
Sectorial labor share	Total labor remunerations to value added of each sector Corbo and Gonzalez (2012).	Data from the Income Accounts from the old National Accounts, Central Bank of Chile, Compilación de Referencia 2003.
Hours worked	Sum of hours worked in a year. Average weekly hours worked multiplied by the number of weeks in a year.	INE old and new Employment Surveys.
Labor quality index	Average wage of workers with educational attainment i relative to average wage of workers with no education multiplied by the share of workers of a certain educational attainment i to the total amount of workers.	CASEN Survey, Ministry of Planification and Cooperation.
Capital stock	Real capital stock in millions of pesos 2008. Data for the year 2013 are estimates.	Capital stock series constructed by Henríquez (2008), Central Bank of Chile.
Capital utilization	Deviations of energy consumption from its trend. The cycle is obtained with a HP filter with $\lambda = 6.25$ for annual data and $\lambda = 1600$ for quarterly data. Data on final energy consumption includes: hydroelectricity, coal, natural gas, oil and wood (teracalories).	National Energy Balances, Ministry of Energy.

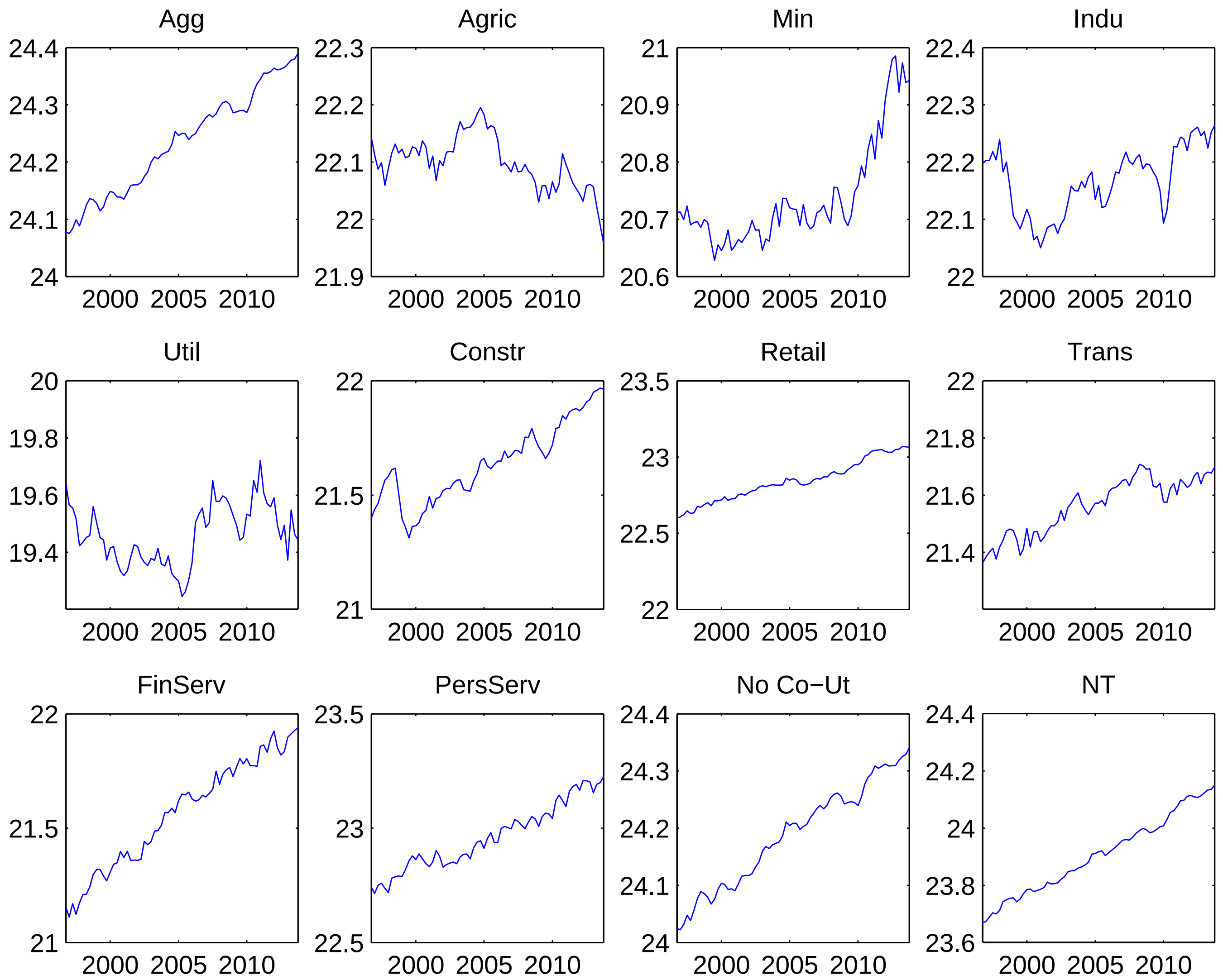
Appendix - Figures

Figure 1: Real GDP data.



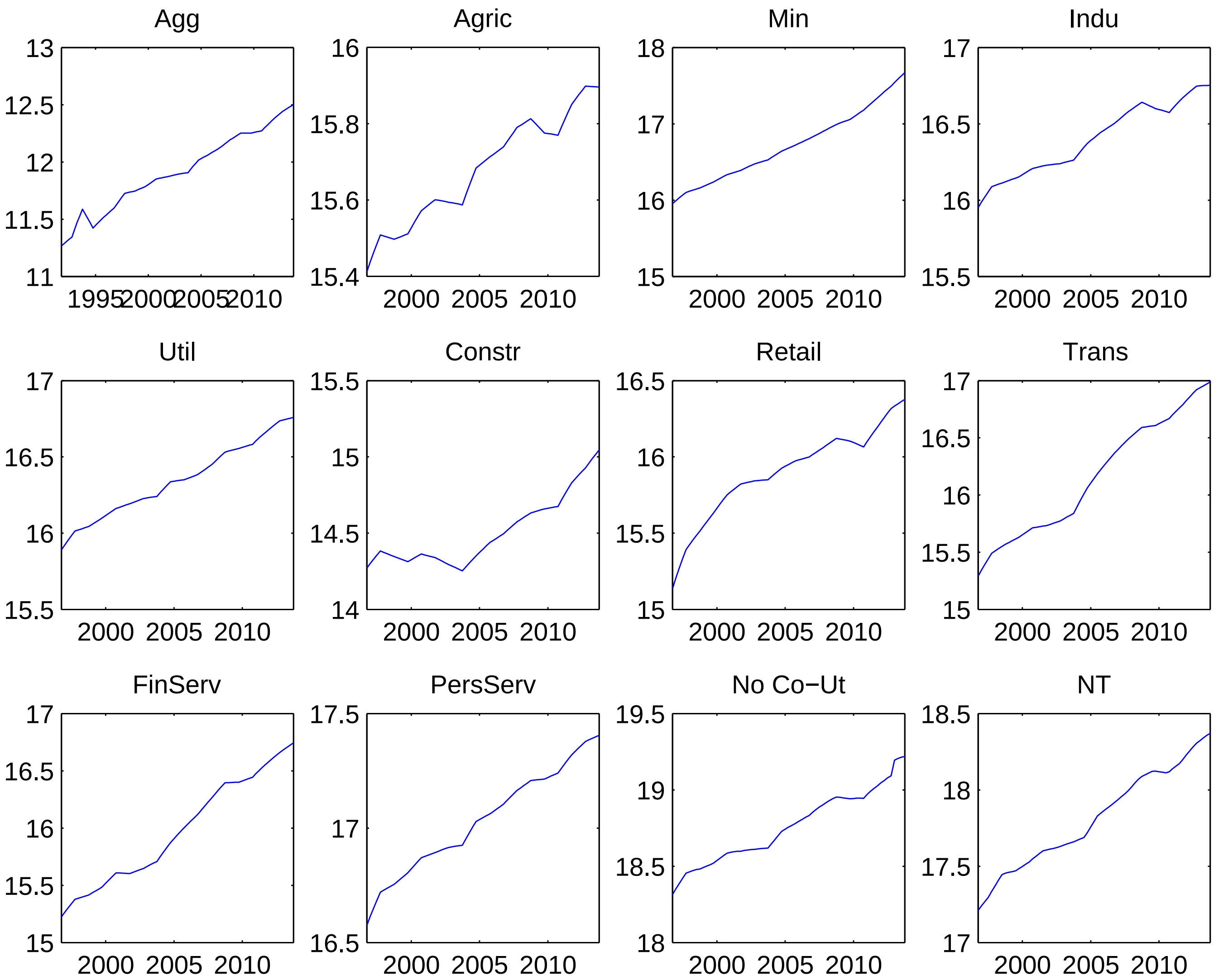
Note: The variables correspond to Aggregate, Agricultural, Mining, Industry, Utilities, Construction, Retail, Transportation, Financial Services, Personal Services, Aggregate excluding Mining and Utilities, and Non tradables (Construction, Retail, Transportation, Financial Services, and Personal Services).

Figure 2: Adjusted Labor.



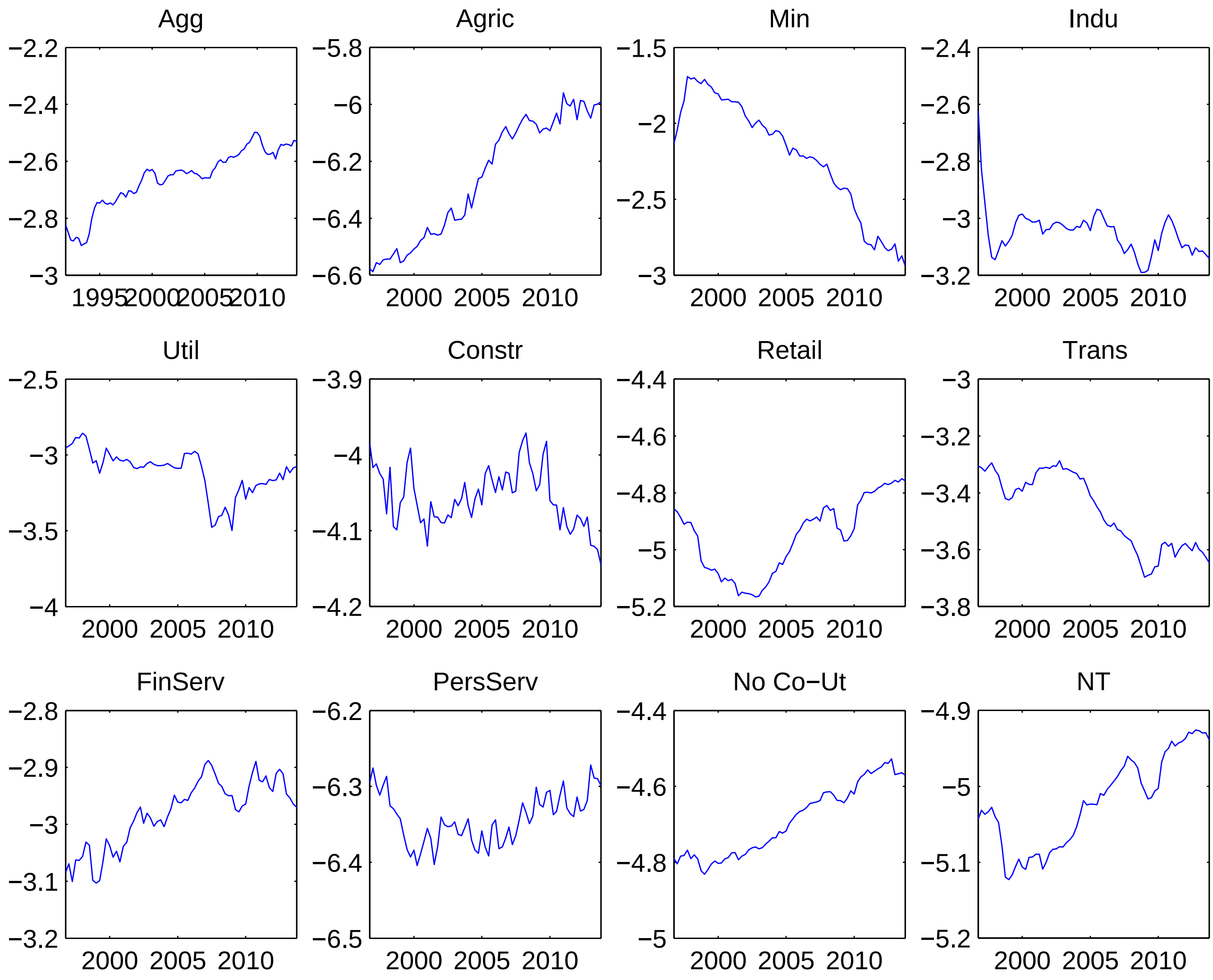
Note: The variables correspond to Aggregate, Agricultural, Mining, Industry, Utilities, Construction, Retail, Transportation, Financial Services, Personal Services, Aggregate excluding Mining and Utilities, and Non tradables (Construction, Retail, Transportation, Financial Services, and Personal Services).

Figure 3: Adjusted Capital stock.



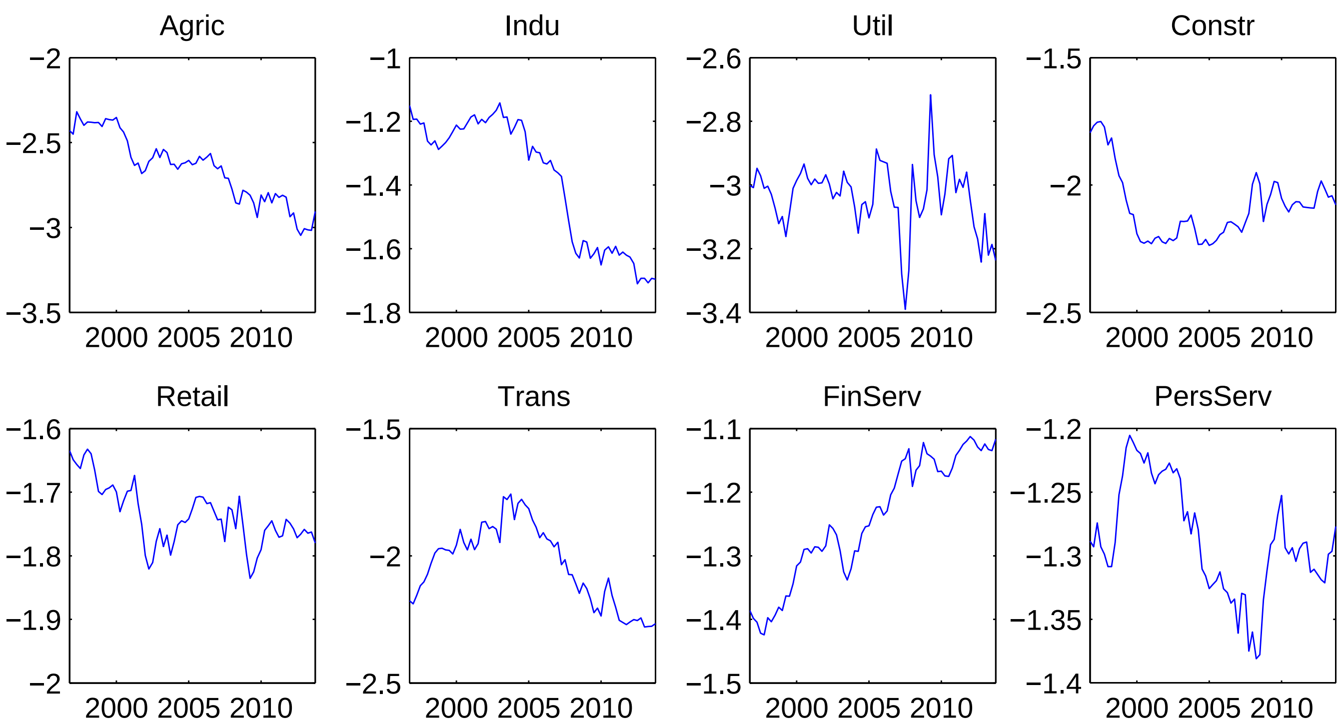
Note: The variables correspond to Aggregate, Agricultural, Mining, Industry, Utilities, Construction, Retail, Transportation, Financial Services, Personal Services, Aggregate excluding Mining and Utilities, and Non tradables (Construction, Retail, Transportation, Financial Services, and Personal Services).

Figure 4: Total Factor Productivity.



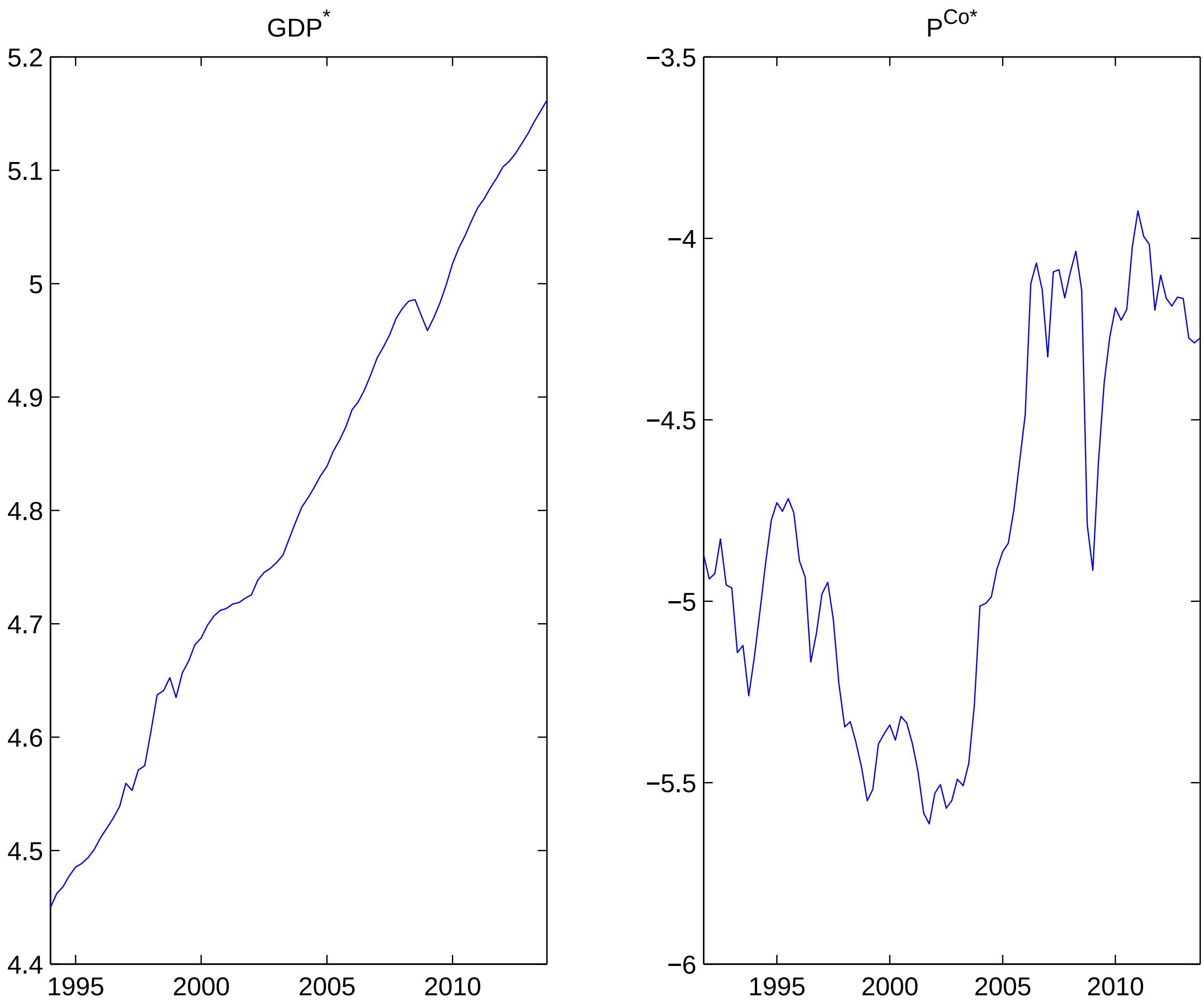
Note: The variables correspond to Aggregate, Agricultural, Mining, Industry, Utilities, Construction, Retail, Transportation, Financial Services, Personal Services, Aggregate excluding Mining and Utilities, and Non tradables (Construction, Retail, Transportation, Financial Services, and Personal Services).

Figure 5: Shares of nominal GDP (as a percentage of GDP excluding Mining and Utilities)



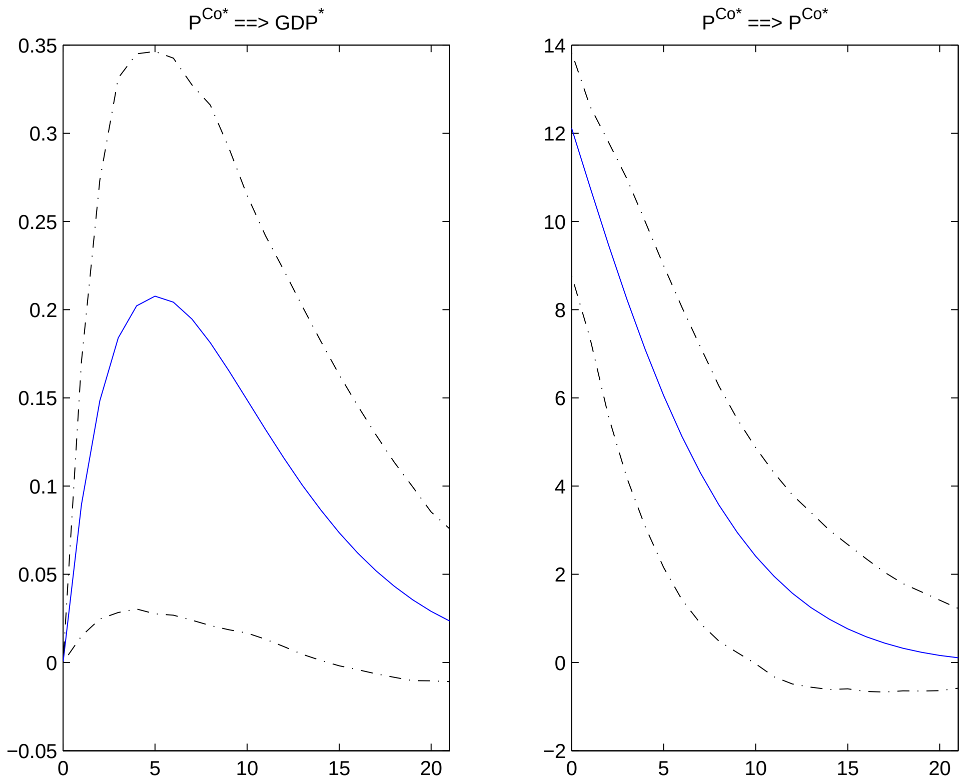
Note: The variables correspond to Agricultural, Industry, Construction, Retail, Transportation, Financial Services, Personal Services.

Figure 6: International variables



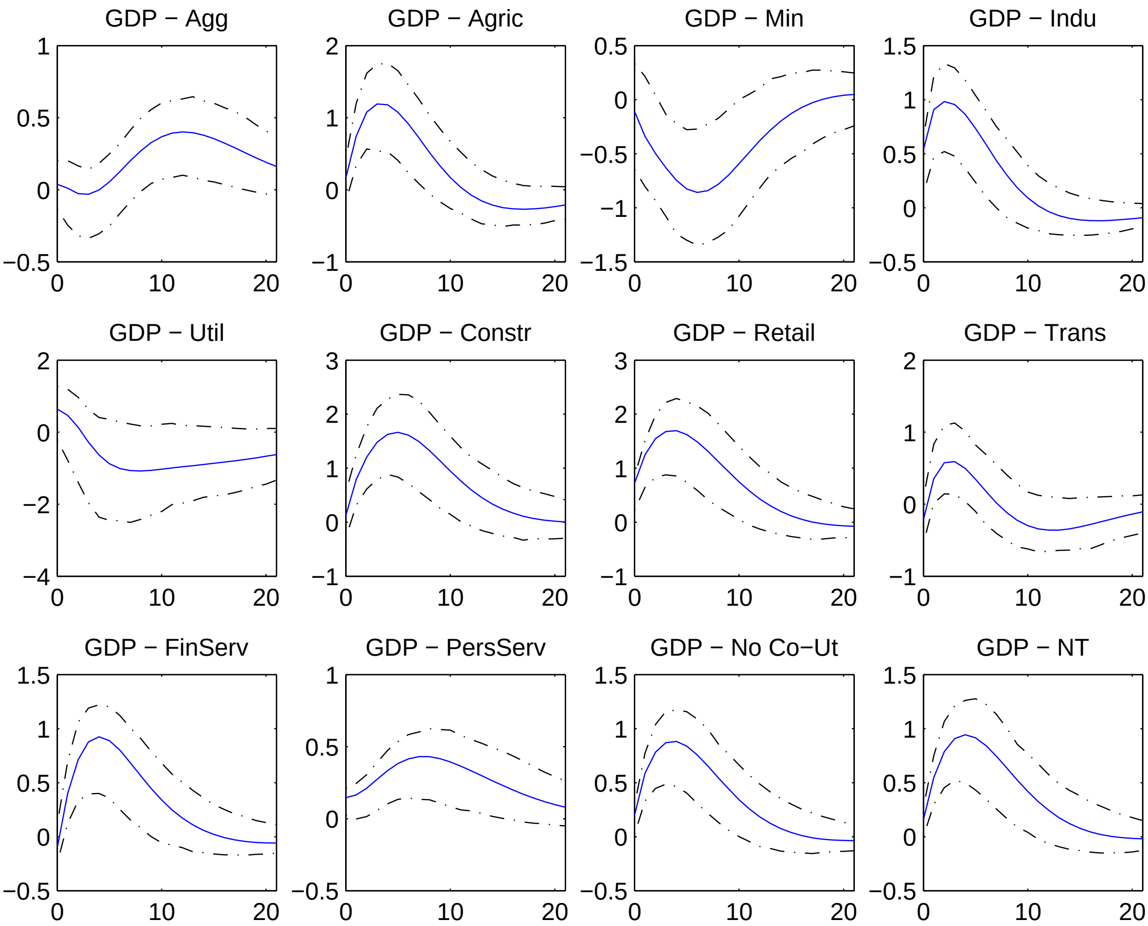
Note: The variables are, from left to right, GDP of Chile's comercial partners, and the international price of Copper.

Figure 7: Responses of international variables to a temporary commodity price shock.



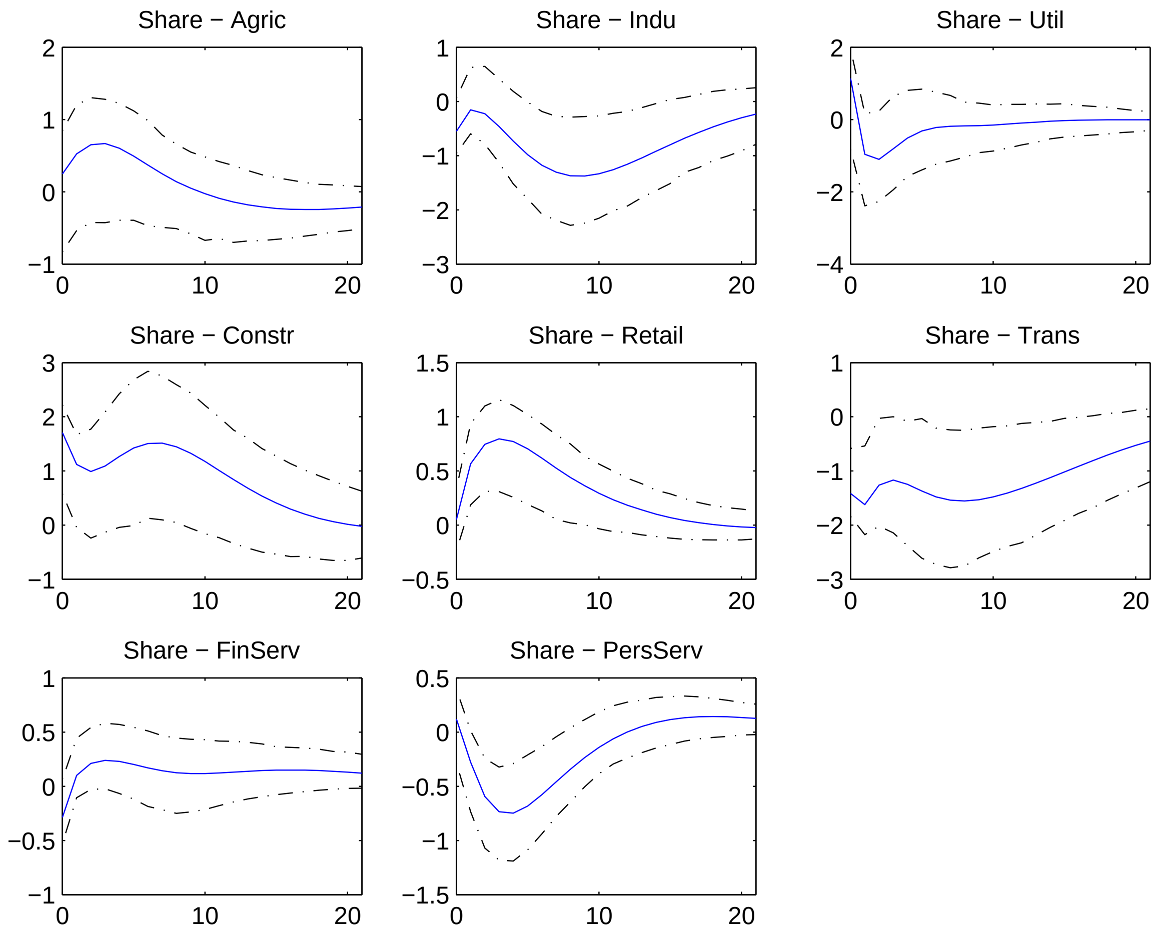
Note: The solid-blue lines are impulse responses obtained from the VAR, and the dashed-dotted black lines represent 95% confidence bands for the responses. Responses are in percentage. The variables are, from left to right, GDP of Chile's commercial partners, and the international price of Copper.

Figure 8: Responses of GDP to a temporary commodity price shock.



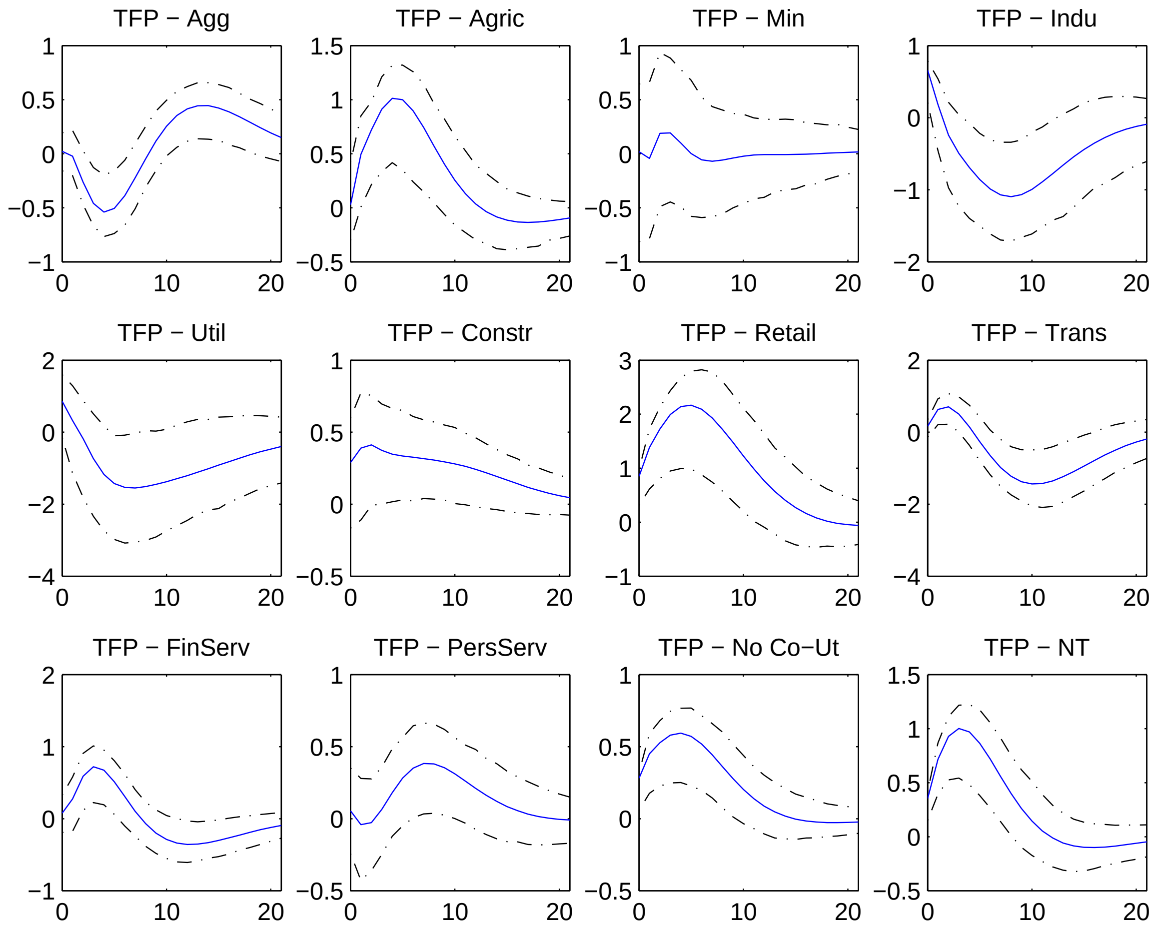
Note: The solid-blue lines are impulse responses obtained from the VAR, and the dashed-dotted black lines represent 95% confidence bands for the responses. Responses are in percentage. The variables correspond to, from left to right, Aggregate, Agricultural, Mining, Industry, Utilities, Construction, Retail, Transportation, Financial Services, Personal Services, Aggregate excluding Mining and Utilities, and Non tradables (Construction, Retail, Transportation, Financial Services, and Personal Services).

Figure 9: Responses of Nominal Shares (as a percentage of GDP excluding Commodities and Utilities) to a temporary commodity price shock.



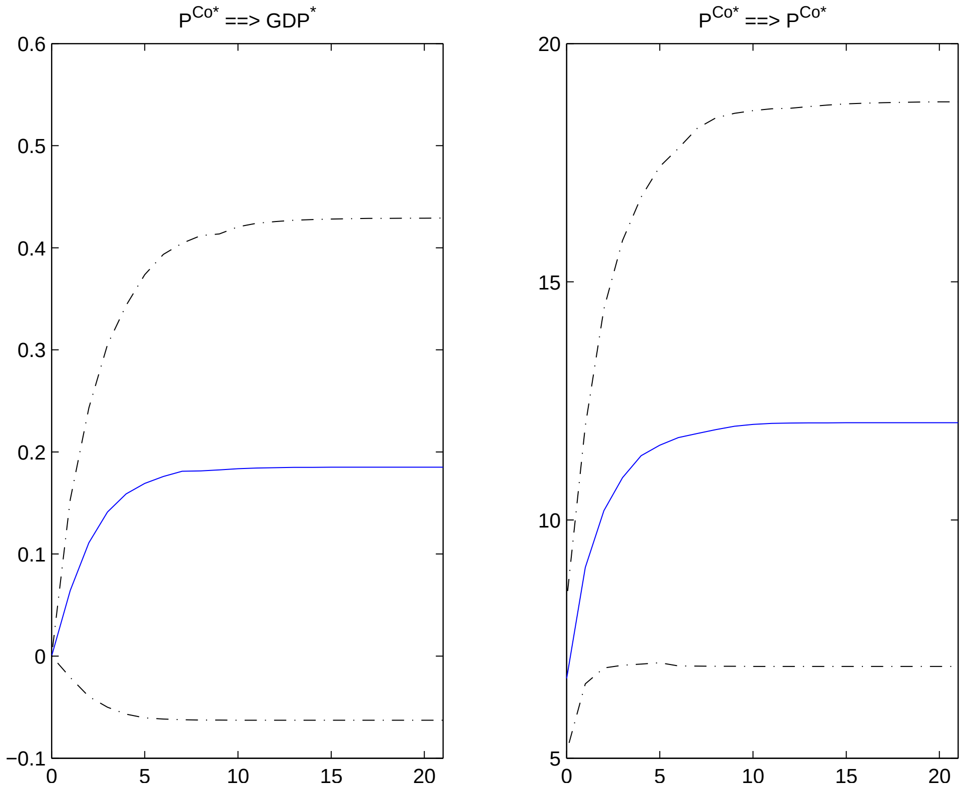
Note: The solid-blue lines are impulse responses obtained from the VAR, and the dashed-dotted black lines represent 95% confidence bands for the responses. Responses are in percentage. The variables correspond to, from left to right, Agricultural, Industry, Construction, Retail, Transportation, Financial Services, Personal Services.

Figure 10: Responses of TFP to a temporary commodity price shock.



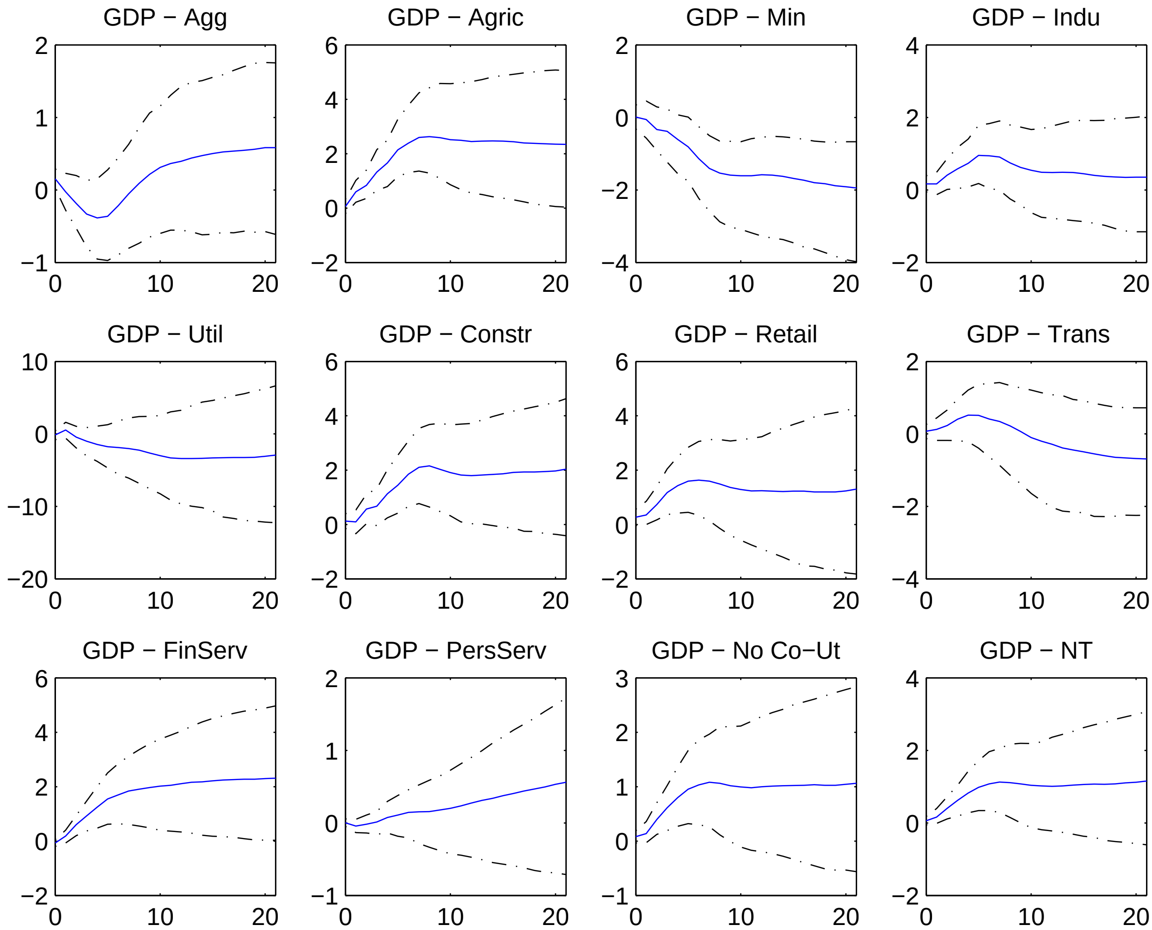
Note: The solid-blue lines are impulse responses obtained from the VAR, and the dashed-dotted black lines represent 95% confidence bands for the responses. Responses are in percentage. The variables correspond to, from left to right, Aggregate, Agricultural, Mining, Industry, Utilities, Construction, Retail, Transportation, Financial Services, Personal Services, Aggregate excluding Mining and Utilities, and Non tradables (Construction, Retail, Transportation, Financial Services, and Personal Services).

Figure 11: Responses of international variables to a permanent commodity price shock.



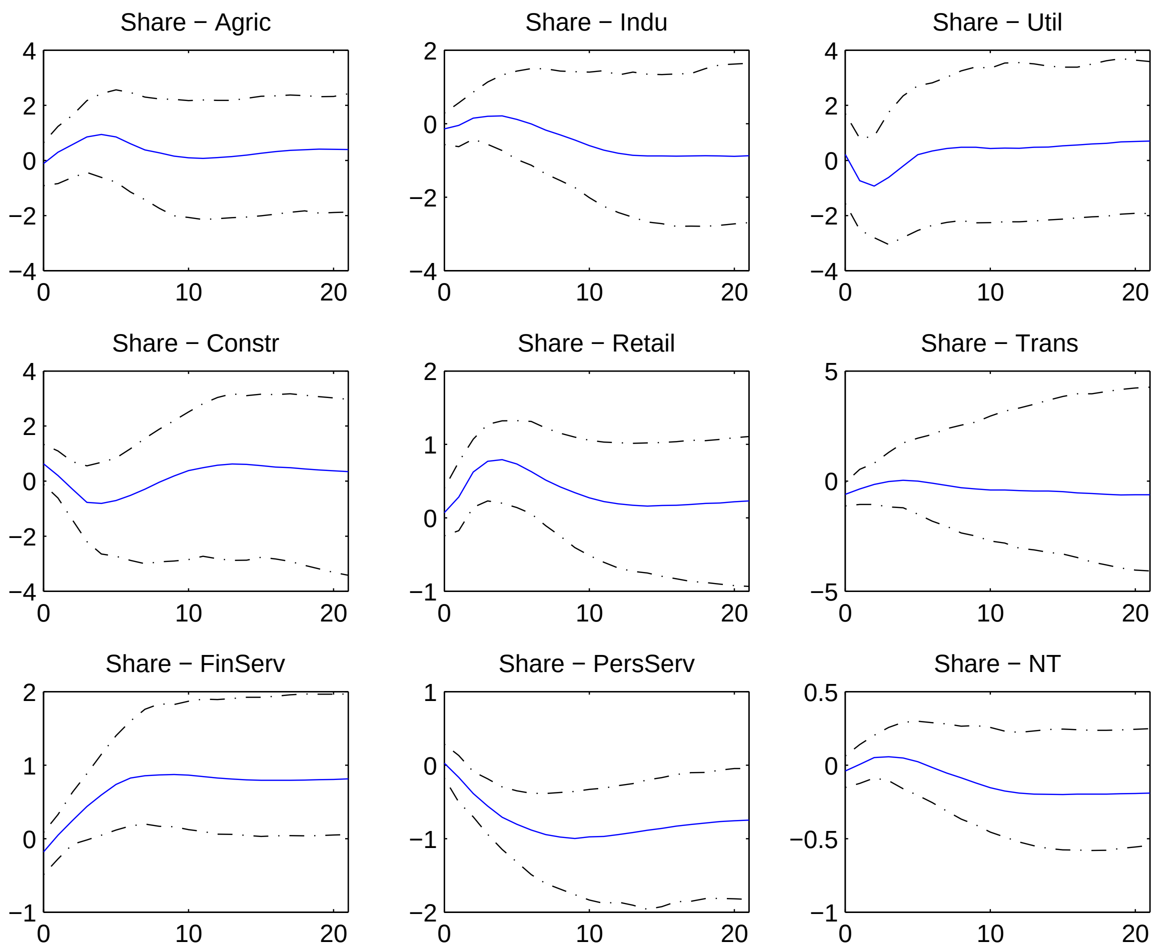
Note: The solid-blue lines are impulse responses obtained from the VEC, and the dashed-dotted black lines represent 95% confidence bands for the responses. Responses are in percentage. The variables are, from left to right, GDP of Chile's commercial partners, and the international price of Copper.

Figure 12: Responses of GDP to a permanent commodity price shock.



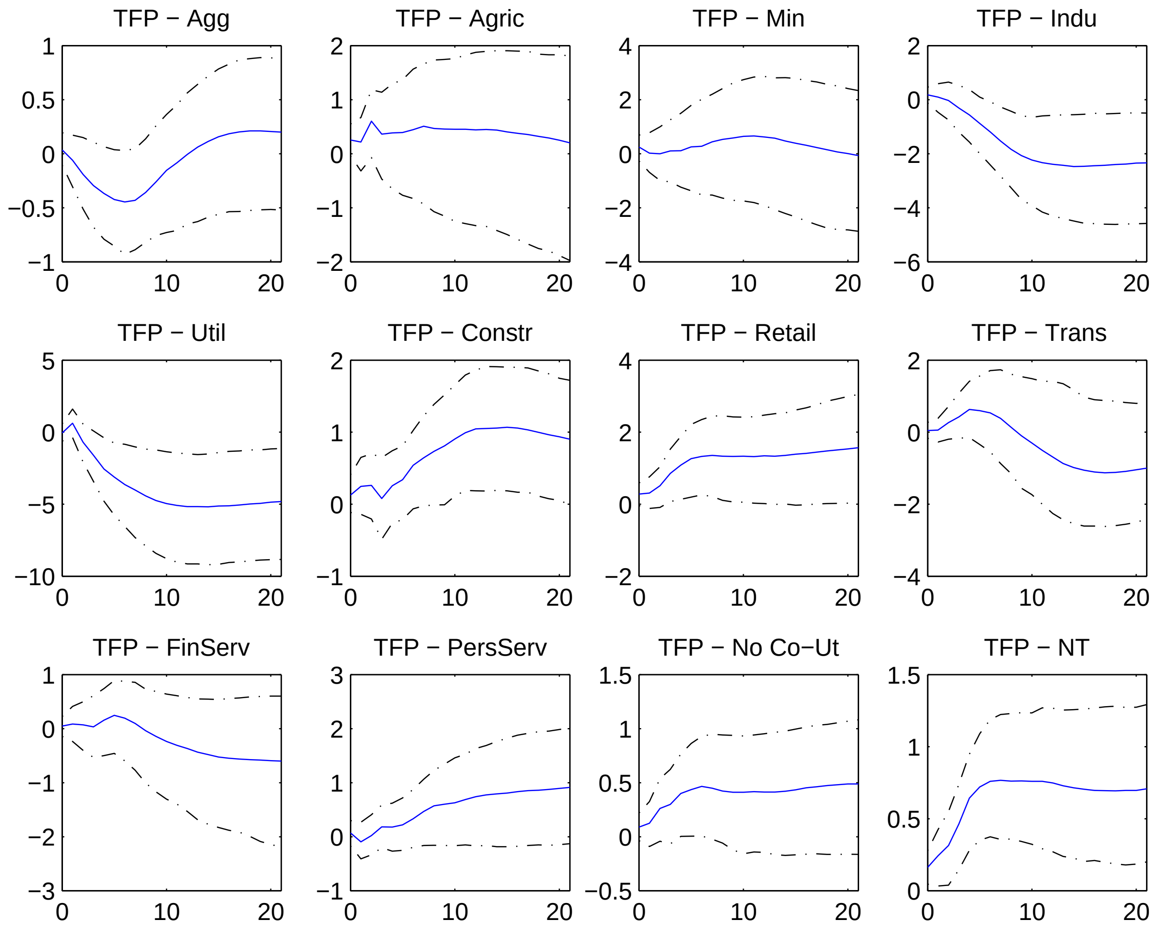
Note: The solid-blue lines are impulse responses obtained from the VEC, and the dashed-dotted black lines represent 95% confidence bands for the responses. Responses are in percentage. The variables correspond to, from left to right, Aggregate, Agricultural, Mining, Industry, Utilities, Construction, Retail, Transportation, Financial Services, Personal Services, Aggregate excluding Mining and Utilities, and Non tradables (Construction, Retail, Transportation, Financial Services, and Personal Services).

Figure 13: Responses of Nominal Shares (as a percentage of GDP excluding Commodities and Utilities) to a permanent commodity price shock.



Note: The solid-blue lines are impulse responses obtained from the VEC, and the dashed-dotted black lines represent 95% confidence bands for the responses. Responses are in percentage. The variables correspond to, from left to right, Agricultural, Industry, Construction, Retail, Transportation, Financial Services, Personal Services.

Figure 14: Responses of TFP to a permanent commodity price shock.



Note: The solid-blue lines are impulse responses obtained from the VEC, and the dashed-dotted black lines represent 95% confidence bands for the responses. Responses are in percentage. The variables correspond to, from left to right, Aggregate, Agricultural, Mining, Industry, Utilities, Construction, Retail, Transportation, Financial Services, Personal Services, Aggregate excluding Mining and Utilities, and Non tradables (Construction, Retail, Transportation, Financial Services, and Personal Services).

Appendix - Tables

Table 1: Labor income shares

Sector	Labor Income Share
Aggregate Economy	60.0
Agriculture	37.1
Mining	18.8
Manufacturing	30.2
Utilities	13.5
Construction	65.0
Retail	63.2
Transportation	35.1
Financial Services	45.3
Personal Services	71.3
No Co-Ut	60.0
NT	56.1

Source: Fuentes et al. (2006); Corbo and Gonzalez (2012).

Table 2: Unit Root Tests

Variable	DF GLS	ZA (trend & Intercept)	ZA (Intercept)
	Unit Root Tests		
TFP Aggregate	yes	yes	yes
TFP Agriculture	yes	yes	yes
TFP Mining	yes	no	no
TFP Industry	yes	no	no
TFP Utilities	yes	no	yes
TFP Construction	yes	no	yes
TFP Retail	yes	yes	yes
TFP Transport	yes	yes	yes
TFP Financial Services	yes	yes	yes
TFP Personal Services	yes	yes	yes
TFP No Co-Ut	yes	yes	yes
Copper Price	yes	yes	yes

Note: Each column reports the results of a different unit root test. The first one is the DF-GLS test, while the other two correspond to Zivot and Andrews test that controls for the presence of breaks (in both the trend and the intercept, as in the second column, or just on the intercept, as in the third column). A 'yes' means that the null of unit root cannot be rejected at 5%.

Table 3: Co-integration Tests

Variable	TFP Aggregate	Copper Price
	Co-integration With	
TFP Aggregate	—	no
TFP Agriculture	no	yes
TFP Mining	yes	no
TFP Industry	yes	yes
TFP Utilities	no	no
TFP Construction	yes	yes
TFP Retail	no	yes
TFP Transport	yes	no
TFP Financial Services	no	yes
TFP Personal Services	no	yes
TFP No Co-Ut	no	no

Note: For each posible combination we run three cointegration tests based in Johansen's methodoly: trace: maximum, and information criteria. A 'yes' means that the null of cointegration cannot be rejected at 5% for at least two of the tests.

Table 4: Decomposition of TFP effects for selected groups after a temporary shock

	Aggregate			No Co-Ut			NT		
Quarters	TFP only	Other	Sum	TFP only	Other	Sum	TFP only	Other	Sum
0	0.29	-0.27	0.02	0.28	0.31	0.60	0.25	0.04	0.28
4	0.35	-0.89	-0.54	0.60	0.44	1.04	0.69	-0.09	0.60
8	-0.03	-0.01	-0.05	0.36	0.02	0.39	0.27	0.09	0.36
12	-0.20	0.61	0.42	0.09	-0.19	-0.10	-0.06	0.14	0.09
16	-0.16	0.55	0.39	-0.02	-0.16	-0.18	-0.12	0.10	-0.02
20	-0.08	0.28	0.19	-0.03	-0.08	-0.11	-0.07	0.05	-0.03

Note: For each group of sectors (Aggregate, Aggregate excluding Mining and Utilities and Non-tradables) we compute the decomposition presented in the appendix. For each group, the Column labeled 'TFP only' reports the percentage growth of TFP in the group that is due to TFP changes within the group members (maintaining weights constant), while the column 'Other' is the percentage growth of TFP in the group that is due to either relocation of resources between sectors in the group or changes in relative prices. This is reported for different quarters after the shock. The sum of the two columns in each quarter equals the point estimate of the impulse response reported in the figures.

Table 5: Decomposition of TFP effects for selected groups after a permanent shock

	Aggregate			No Co-Ut			NT		
Quarters	TFP only	Other	Sum	TFP only	Other	Sum	TFP only	Other	Sum
0	0.13	-0.09	0.04	0.08	0.12	0.20	0.10	-0.01	0.08
4	0.12	-0.46	-0.34	0.40	0.22	0.62	0.40	0.00	0.40
8	-0.05	-0.27	-0.32	0.42	0.04	0.46	0.47	-0.05	0.42
12	-0.21	0.21	0.00	0.42	-0.14	0.28	0.38	0.04	0.42
16	-0.29	0.49	0.21	0.44	-0.19	0.25	0.33	0.11	0.44
20	-0.31	0.54	0.23	0.47	-0.17	0.30	0.34	0.13	0.47

Note: For each group of sectors (Aggregate, Aggregate excluding Mining and Utilities and Non-tradables) we compute the decomposition presented in the appendix. For each group, the Column labeled 'TFP only' reports the percentage growth of TFP in the group that is due to TFP changes within the group members (maintaining weights constant), while the column 'Other' is the percentage growth of TFP in the group that is due to either relocation of resources between sectors in the group or changes in relative prices. This is reported for different quarters after the shock. The sum of the two columns in each quarter equals the point estimate of the impulse response reported in the figures.