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GDP FORECASTING BIAS DUE TO AGGREGATION INACCURACY IN A CHAIN-LINKING FRAMEWORK*

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Abstract

When evaluating the economy's performance, Gross Domestic Product (GDP) is the most often used indicator and it is therefore also one of the most often forecasted. Due to the shortcomings of the traditional fixed-base methods, many countries have adopted chain-linking to avoid price structure obsolescence. This has meant that GDP's well-known accounting identities hold only approximately raising challenges for those reading the numbers, but also for forecasters that follow approaches that rely on these accounting properties. Oddly enough, the issue of aggregation is hardly mentioned in forecasting. This omission could be the result of everybody adopting the chain-linking methodology with ease and considering it unnecessary to make a point out of it, but it could also originate from ignoring the issue altogether. Whatever the reason for this omission, it could lead practitioners that are unfamiliar with the method to make unnecessary mistakes. This document presents explicitly the role of prices in a bottom-up forecasting framework and, based on it, argues that they should be taken into account when generating aggregate forecasts based on the accounting identities. Also, something that should be taken into consideration by practitioners is that discrepancies due to aggregation inaccuracy are not necessarily negligible.

Resumen

El Producto Interno Bruto (PIB) es uno de los indicadores más utilizados para evaluar el desempeño de una economía y, por lo tanto, uno de los que más suele proyectarse. Debido a las debilidades que presenta el enfoque tradicional de base fija, muchos países han adoptado la metodología de encadenamiento para evitar la obsolescencia de la estructura de precios del agregado. Esto ha significado que las conocidas identidades contables del PIB solo se cumplan aproximadamente, resultando en nuevos desafíos tanto para aquellos que interpretan las cifras, como para los que basan sus proyecciones en modelos que dependen de estas identidades. Es de extrañar que, en este contexto, el tema de la agregación rara vez sea mencionado en la literatura de proyección. Dicha omisión podría ser el resultado de la correcta adopción de la metodología de encadenamiento por parte de todos y por lo tanto considerar redundante referirse al punto, pero también podría deberse a ignorar el tema por completo. Independiente de la razón de dicha omisión, ésta podría llevar a analistas no familiarizados con la metodología a cometer errores innecesarios. Este documento presenta explícitamente el rol de los precios en un marco de proyecciones desagregado y basado en ello argumenta que debieran tenerse en consideración al utilizarse las identidades contables para generar proyecciones agregadas. También, algo que deberían tener presente los analistas, es que no

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necesariamente son despreciables las discrepancias que se generan debido a la agregación utilizando las identidades aproximadas.

1. Introduction

Macroeconomic analysis devotes a fair amount of effort to the economy's real variables, thus generating a need for aggregate measurements of volumes and quantities. When evaluating the economy's performance, Gross Domestic Product (GDP) is the most often used indicator and it is therefore also one of the most often forecasted. The new releases of GDP figures have important effects on market perceptions and, in this context, GDP forecasting by the different agents is taken seriously, and accuracy is valued greatly.

Regarding the forecasting methods, a large amount of literature is available and covers a broad scope of models and methods that vary in levels of sophistication. The spectrum of techniques may be grouped in to those that forecast aggregate GDP directly (direct approach), even if they include disaggregate information, and those that generate an aggregate forecast from the forecasts of its components (indirect or bottom-up approach). The merits of each approach have been discussed extensively without finding an overall winner, but the second approach has an undeniable advantage over the first in that it provides a background story for the aggregate movement. For a policy maker, for example, this is highly desirable as the reasoning behind their decisions may be built upon a broader picture of the economy.

In this context, the way in which GDP is measured is crucial to the forecasting framework and, in particular, the way in which the different components are aggregated to obtain the total measure. Traditionally GDP had been measured using the fixed-base-year method, where the complete series is valued at a given year's prices; however, in the last decades, its shortcomings became too relevant to be ignored (Steindel, 1995) and many countries moved to a chain-linked method based on the annual update of the price structure. This move has not been trouble-free. Probably the most notorious inconvenience for practitioners has been that an aggregate is not the direct sum of its components (loss of additivity) and therefore aggregate performance cannot be easily broken down into its component's performance. To alleviate this specific problem, the entities in charge of publishing GDP have accompanied the aggregate with the corresponding component's contributions to aggregate growth, that do add up to the total. In forecasting literature, however, the issue of aggregation is seldom mentioned and therefore gives the impression that it is being ignored. Even if this is not true, the omission could lead practitioners that are unfamiliar with the method to make unnecessary mistakes.

This document has the objective of raising awareness regarding the role of prices in the construction of GDP with the chain-linking methodology and, based on it, argues that they should be taken into consideration when generating aggregate forecasts based on the bottom-up approach. Section 2 provides an explanation to the chain-linking method for measuring GDP, particularly the annual overlap method. Section 3 provides a brief recount of literature that deals with forecasting GDP from its components and their allusion to the aggregation method. Section 4 provides the empirical framework to explain the potential bias that could appear in the forecasts if price evolution is ignored. Section 5 contains the concluding remarks.

2. Measuring GDP[1]

GDP is by far, the most common indicator to measure economic performance. It summarizes in one number the production of a country's households, firms, government and NGOs over a period

[1] OCDE (2006) presents a detailed but accessible explanation of national accounts.

of time. However, something that tends to be neglected is taking into account that constructing this indicator is far from trivial. Given the spectrum of goods and services, it is fairly obvious that they cannot be summed up directly to generate the aggregate measure. A reasonable approach is to express them in the same units by weighting them by their respective prices; this reflects their relative importance to consumers and compensates for differences in qualities. However, prices evolve over time and this blurs the real performance. The challenge then, consists in removing these price changes from the measure.

The traditional fixed-base method relies on measuring GDP using the prices of a specific period.[2] From its construction, this method removes the evolution of prices, but depends fundamentally on the base year's price distribution. This fixed price structure may become obsolete and therefore reduce dramatically the economic relevance of the aggregate measure. The extent of the obsolescence will become obvious with the updating of the base year when the complete series is revised due to the new price structure. This equates to economic performance being determined and re-written by administrative decisions.

The shortcomings of the fixed-base method may be highlighted with the simple example presented in Table 1. Here we observe how the price of A grows at an annual rate of 30% while its quantity remains unaltered and, on the contrary, B's quantity grows 4% annually while its price remains fixed. This rapid and persistent change in prices translates in approximately a 0.6 pp. reduction in yearly aggregate growth, for the whole series, when the base year is changed from 2003 to 2008. This significant revision comes from the fact that the prices of 2003 are a poor approximation to the price structure in 2008 (the weights in 2003 are 0.33 for A and 0.67 for B, while in 2008 they are approximately 0.5 each).

Table 1: Growth bias due to base year selection with the fixed-base methodology

						constant prices of:			
Year	***Quantities***		***Prices***		***Total at***	***2003***		***2008***	
	A	***B***	***A***	***B***	***current prices***	***Level***	***YoY***	***Level***	***YoY***
2003	100	100	2.00	4.00	600	600		802	
2004	100	104	2.30	4.00	646	616	***2.7%***	818	***2.0%***
2005	100	108	2.65	4.00	697	633	***2.7%***	835	***2.0%***
2006	100	112	3.04	4.00	754	650	***2.7%***	852	***2.1%***
2007	100	117	3.50	4.00	818	668	***2.8%***	870	***2.1%***
2008	100	122	4.02	4.00	889	687	***2.8%***	889	***2.2%***
2009	100	127	4.63	4.00	969	706	***2.8%***	908	***2.2%***

To prevent this from happening, the solution has come in the form of frequently and periodically updating the price structure and generating a consistent time series through the linking of short constant price indices that overlap. According to OECD (2013) most of its members have adopted a method in which the price structure is updated annually. Of the different options the most common is the annual overlap method using Laspeyres indices and therefore the rest of the document will unfold with this method in mind.[3]

[2] Steindel (1995) provides an excellent exposition of the pitfalls of fixed-base measures in the context of the revision of the way in which the BEA calculated GDP and its shift to the chain-weighted method of computing aggregate growth.

[3] For extensive information on the annual overlap methods and its alternatives see IMF (2001). According to OECD (2013) the annual overlap method is the most common implementation within its members. It is worth noting that Australia, Canada, Japan, United Kingdom and United States use Quarter Overlap.

The annual overlap technique involves calculating the variation between the current and previous years, both valued at the previous year's prices and building a time series from the variation between them. Table 2 illustrates the procedure, using the same basic information from Table 1. As mentioned, it uses a series of overlapping fixed-base links to provide the annual growth rate to generate the aggregate chain-linked series. As it can be appreciated, the aggregate growth of 2004 coincides with that of the 2003 fixed-base method of table 1 and gradually converges to the growth rate calculated for 2009 using the 2008 fixed-base method also in table 1.

Table 2: Annual overlap chain-linking methodology

	prices of:													***Aggregate***	
	2003				***2004***					***2007***		***2008***		*(reference 2003)*	
Year	***A***	***B***	***Sum***	***YoY***	***A***	***B***	***Sum***	***YoY***		***Sum***	***YoY***	***Sum***	***YoY***	***YoY***	***Index***
2003	200	400	**600**												600
2004	200	416	**616**	***2.7%***	230	416	**646**							***2.7%***	616
2005					230	433	**663**	***2.6%***						***2.6%***	632
2006									. . .					***2.5%***	648
2007										818				***2.4%***	663
2008										836	***2.3%***	889		***2.3%***	678
2009												908	***2.2%***	***2.2%***	693

This procedure reduces significantly the problem of price structure obsolescence but generates loss of additivity (the aggregate is not the direct/weighted sum of its components). This phenomenon occurs because the aggregate composition depends not only on the evolution of quantities, but also on the relative price changes of the components. To see this, it is necessary to develop an expression for the chain-linking weights.

Let us have J components that make up an aggregate Q. The chain-linked aggregate for year *t*, that is Q_t, is defined as:

$$Q_t = Q_{t-1} \cdot \frac{\sum_{j=1}^{J}\left(p_{t-1}^{j} \cdot q_{t}^{j}\right)}{\sum_{j=1}^{J}\left(p_{t-1}^{j} \cdot q_{t-1}^{j}\right)} \tag{1}$$

where, p^{j}_{t-1} : is the price of component *j* in year *t-1* (for purposes of GDP the deflator)
q^{j}_{t} : is the quantity of component *j* in year *t*

For the reference year *t0* we have that $Q_{t0} = \sum_{j=1}^{J}\left(p_{t0}^{j} \cdot q_{t0}^{j}\right)$

Then by reorganizing (1) we have:

$$Q_t = \sum_{j=1}^{J}\left(\frac{Q_{t-1}}{\sum_{j=1}^{J}\left(p_{t-1}^{j} \cdot q_{t-1}^{j}\right)} \cdot p_{t-1}^{j} \cdot q_{t}^{j}\right) \tag{2}$$

By noting that $\sum_{j=1}^{J}\left(p_{t-1}^{j} \cdot q_{t-1}^{j}\right)$ is the aggregate at current prices at time *t-1* the aggregate's price deflator for *t-1* may be written as:

$$P_{t-1} = \frac{\sum_{j=1}^{J}\left(p_{t-1}^{j} \cdot q_{t-1}^{j}\right)}{Q_{t-1}}$$

and then the chain-linked weight for component *j* in period *t* may be written as:

$$\omega_t^j = \frac{p_{t-1}^j}{P_{t-1}} \qquad (3)$$

From this expression it is obvious that the weights are prone to be time-varying given that this will happen every time that a component's price evolves, at a different rate than the aggregate deflator.

The textbook identities, like that of the expenditure approach $GDP_t=C_t+I_t+G_t+NX_t$, rely on all variables being expressed in prices of the base year. That means standardizing the component's quantities based on their prices in the base year so that the corresponding fixed-base weights are all equal to one. In the above nomenclature this is:

$$Q_t^{p0} = \sum_{j=1}^{J} p_0^j \cdot q_t^j = \sum_{j=1}^{J} q_t^{j,p0} \qquad (4)$$

where, Q^{p0} : is the fixed-base aggregate based on year 0
$q^{j,p0}$: is the quantity index of component *j* times its price in year 0

This simply means that the components have been rescaled by a constant and, therefore, their growth rates remain unaltered. However, as shown before, the chain-linked weights evolve over time, meaning the components cannot be rescaled to add up to the total and still maintain their properties. To construct the chain-linked aggregate from the quantities valued at prices of year 0 the weights get rescaled but continue to be time varying as it can be seen from introducing the quantities rescaled to the reference year 0 in expression (2):

$$Q_t = \sum_{j=1}^{J}\left(\frac{p_{t-1}^j}{P_{t-1}} \cdot q_t^j\right) = \sum_{j=1}^{J}\left(\frac{p_{t-1}^j}{P_{t-1}} \cdot \frac{1}{p_0^j} \cdot q_t^{j,p0}\right) \qquad (5)$$

Only by chance or under the very particular case where $(p^j_{t-1}/P_{t-1})\cdot(1/p^j_0)$ is equal to one will the components, referenced to prices of any given year, add up to the total.

Having found the chain-linked weights, we can use the data from the previous example to see how the actual weights vary over time. In this example, by 2009 the weights are significantly different from one.

Table 3: Time varying weights as the source of discrepancy between the chain-linked aggregate and the sum of components

Year	*Constant prices of 2003* A	B	***Fixed-Base Total (sum)***	**Chain-linked *Total*** *(reference 2003)*	*Chain-linked minus Fixed-Base*	*Chain-link weights* A	B
2003	200	400	600	600	0.0	1.00	1.00
2004	200	416	616	616	0.0	1.00	1.00
2005	200	433	633	632	-0.8	1.10	0.95
2006	200	450	650	648	-2.4	1.20	0.91
2007	200	468	668	663	-4.9	1.31	0.86
2008	200	487	687	678	-8.5	1.42	0.81
2009	200	506	706	693	-13.1	1.53	0.76

The loss of additivity generates some practical issues but, more importantly, it reflects the fact that the well-known accounting identities of GDP hold only approximately for the levels of the series.[4] To alleviate the inconveniences produced by the lack of additivity, the publishing bodies have started accompanying the aggregate with the corresponding component's contributions to aggregate growth. These are defined as the percentage points of aggregate growth that are attributable to each component and by definition do add up to the total.[5] OECD (2006), for example, raises the question of whether it is not better to publish only component's contributions and forget about levels. In practice, however, practitioners typically use totals, sub-totals or differences to make economic models and therefore eliminating them seems socially undesirable. The use of levels, though, requires considering the implications of the potential inadequacy of the fixed-base accounting identities.

3. Forecasting GDP using an indirect or bottom-up approach

Given the importance of GDP for public and private decisions, it is not surprising that there is abundant literature on forecasting it. There are many methods and approaches, both theoretical and atheoretical, and just as many forecasting accuracy comparisons. A special niche has been comparing the accuracy of direct methods relative to indirect methods, and through the years, many refinements have been introduced to both. Nevertheless, the question of which method provides the most accurate forecasts remains open and depends on the problem at hand (Hendry and Hubrich, 2011).

Even when both simple and more sophisticated aggregate methods have proved to be powerful, models based on the components of GDP continue to appeal to those who need to provide an economic story for their forecasts. Central Banks and other policy makers typically require, at least for some applications, that aggregate forecasts be rooted in the movements of the relevant components, both from the expenditure and production perspective. Then, in this forecasting framework, a consistent GDP forecast will be generated through the aggregation of the forecasts of its component.

Once the convenience of providing some background for the aggregate forecast is acknowledged, the question that remains is how to forecast the components. Nowadays, strictly univariate methods and VARs seem to have fallen out of grace, at least as standalone methods, but probably continue to be used as benchmarks. However, more recent general approaches have also found their way into disaggregate applications. Examples are Soares Esteves (2011) that use a dynamic factor model to build an indirect GDP forecast from the expenditure approach.[6] Also centring on expenditure, Perevalov and Maier (2010) and Drechsel and Scheufele (2012) explore the benefits of combining mixed frequency data. Hahn and Skudelny (2008) and Burriel (2012), on the other hand, use Bridge Models to forecast the production components.

Regardless of the forecasting method, little is said in terms of the procedure employed to generate the aggregate forecast, which is odd given that it is something that is at the core of GDP.

[4] The accounting identities hold perfectly for the fixed-base links.

[5] Under the annual overlap method calculating annual contributions is straightforward, see Robjohns (2007), but calculating quarterly contributions is not. The difficulty consists in finding the right quarterly weights that permit the contributions to sum up to the total. For more on this refer to Cobb (2013).

[6] Interestingly they also exploit the required consistency and dependency that should exist between the different expenditure component forecasts.

Exceptions to this are Cuevas *et. al.* (2011) who, in the context of regional and national forecast consistency, go in to a fair amount of detail to explain the aggregation of the regional series; or Girardi et. al. (2013) who, in a framework for forecasting GDP in a data rich environment, question whether the move from fixed to chain-linked bases asks for a further extensions of the disaggregate information set to include prices.[7]

The lack of reference to the issue could be the result of everybody adopting the chain-linking methodology with ease and considering it unnecessary to make a point out of it, but in this case one would expect to see prices included in the models or at least some discussion regarding their future path. However, this does not seem to be the case and therefore suggests that the issue is being overlooked to some extent. This could be due to unawareness on the issue or to practitioners assuming a negligible impact due to aggregation inaccuracy when compared to the total forecasting error. The latter is the assumption found in Drechsel and Scheufele (2012) for example. In certain cases ignoring the issue could have no visible effects; however, there is no way to be sure if the determining conditions are unknown and not checked.

4. Acknowledging changes in aggregate composition in a forecasting framework

4.1. GDP growth as a function of components quantities and prices

The accounting properties of GDP are at the core of its construction and, therefore, it is likely that many types of models rely on them to work; for example, the popular DSGE models of Smets and Wouters (2003) use the expenditure identity as the market equilibrium condition.[8] However, with the adoption of chain-linked series, the textbook identity of GDP as the sum of investment, consumption, government expenditure and net exports does not hold perfectly anymore (the same is true with the supply side approach). This is due to the fact that the composition of the aggregate depends not only on the evolution of quantities but also on the changes in relative value of the components. To maintain familiarity, national accounts agencies publish GDP accompanied by contributions to aggregate growth, however, it is hard to find reference to the methodological change in papers dealing with macroeconomic modeling. In this context, it seems relevant to examine whether using the approximate accounting identities is safe in a forecasting framework.

A first step to tackle a potential bias is to compare the outcome of using the approximate identities to construct a measure of output with actual GDP (chain-linked). To calculate a measure consistent with the accounting identities we start from expression (4) and normalize the components so all prices of the reference period (the same as the base year) are equal to one. Then we define a constant price measure of aggregate output as:

$$Q_t^{CPM} = \sum_{j=1}^{J} p_0^j \cdot q_t^j = \sum_{j=1}^{J} q_t^j \qquad (6)$$

where, as before, there are J components that make up the aggregate.

[7] They do not explicitly refer to the aggregation method, but acknowledge the fact that the component's weights depend on the evolution of prices and that, therefore, the aggregate is directly affected by them.
[8] There is a large amount of literature that builds on the approach of Smets and Wouters (2003) and it is quite probable that most of it also use this condition.

For GDP it may make more sense to compare the resulting growth rates. Then, aggregate growth for this constant price measure is:

$$\frac{\Delta Q_t^{CPM}}{Q_{t-1}^{CPM}} = \frac{\sum_{j=1}^{J} p_0^j \cdot q_t^j}{\sum_{j=1}^{J} p_0^j \cdot q_{t-1}^j} - 1 = \frac{\sum_{j=1}^{J} q_t^j}{\sum_{j=1}^{J} q_{t-1}^j} - 1 \quad (7)$$

For the growth of GDP (chain-linked), we turn to expression (1) and reorder:

$$\frac{\Delta Q_t}{Q_{t-1}} = \frac{Q_t}{Q_{t-1}} - 1 = \frac{\sum_{j=1}^{J}\left(p_{t-1}^j \cdot q_t^j\right)}{\sum_{j=1}^{J}\left(p_{t-1}^j \cdot q_{t-1}^j\right)} - 1 \quad (8)$$

and the difference between them is straightforward:

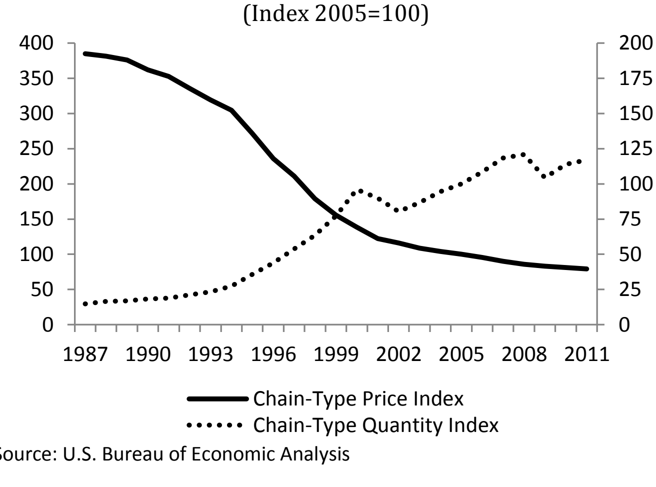
$$\frac{\Delta Q_t^{CPM}}{Q_{t-1}^{CPM}} - \frac{\Delta Q_t}{Q_{t-1}} = \frac{\sum_{j=1}^{J} q_t^j}{\sum_{j=1}^{J} q_{t-1}^j} - \frac{\sum_{j=1}^{J}\left(p_{t-1}^j \cdot q_t^j\right)}{\sum_{j=1}^{J}\left(p_{t-1}^j \cdot q_{t-1}^j\right)} \quad (9)$$

As one would expect, due to the fact that GDP is built from a series of two year fixed-base links, GDP growth at any given time is a function of the components quantities and the deflators of the previous year. This means that ignoring the chain-link properties of the aggregate is equivalent to assuming that the economy's price structure has not changed since the reference year. The discrepancies that arise between GDP and a constant price measure of output then, depend on the particular evolution of the components and the difference between the relevant prices and those of the reference year. The individual discrepancies may cancel out, but there is no way of knowing beforehand.

In this context, a reasonable question to ask is whether the magnitude of the price changes is sufficiently important to justify doing something about it. As explained by Steindel (1995) when presenting the U.S. Bureau of Economic Analysis (BEA) change in method of measuring the growth of the U.S. economy, the dramatic and recurring reduction in prices exhibited by computers in the mid 80's and 90's introduced a considerable upward bias in the fixed-base aggregate. As shown in Chart 1, the price deflator, as currently measured by BEA, has continued to fall during the following decade.[9]

Chart 1: Computer and Electronic Products Gross Output

(Index 2005=100)



Source: U.S. Bureau of Economic Analysis

[9] He presents the deflator for producers' durable office, computing, and accounting machinery spending.

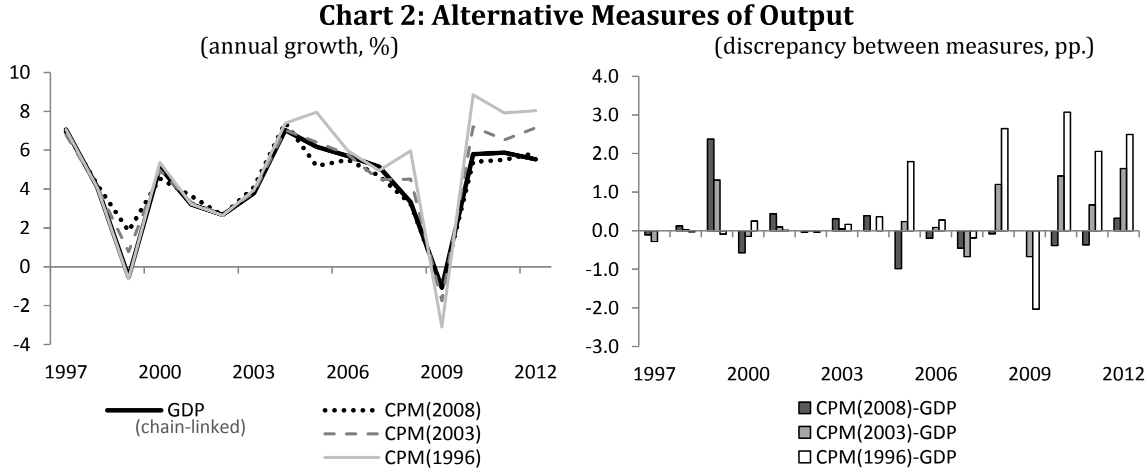
At least in the U.S. the problem was significant enough to justify changing the way of measuring GDP. However, the extent to which changes in prices affect the composition of the aggregate depend on the particular circumstances of each economy and, therefore, need to be examined on a case-to-case basis. In a real-world forecasting setting, the problem of ignoring the price changes may be summarized in whether the discrepancies generated by the price changes are significant and how do they compare to the forecasting error. To examine both questions we conducted an exercise using Chilean data.

Chile adopted chain-linking for its accounts in 2012 and implemented the annual overlap method for Laspeyres indices using 2008 as the reference year (Guerrero et. al., 2012). For the purpose of this exercise we used annual expenditure data spanning from 1996 to 2012.[10] To have a feel for the magnitudes of the discrepancies we compared actual GDP growth rates with the growth rates of constant price measures. Then, to measure them up to the forecasting errors, we conducted a simple forecasting exercise to compare the discrepancies with the actual forecasting error.

4.2. Discrepancies in the measurement of GDP due to price changes

As it was mentioned, Chile currently uses 2008 as the reference year for chain-linking and, therefore, a constant price measure (CPM) using this data directly would be equivalent to using 2008 as its base year. In the case of the chain-linked series, the growth rate does not suffer modifications due to the selection of a different reference year; the CPM, however, does.[11] Given that the differences between the relevant prices and those of the reference year have a direct impact on the discrepancies, we illustrate the impact of moving further away from the reference year by constructing additional CPMs using previous years as a base, specifically 1996 and 2003. Chart 2 shows the growth rate of GDP, that of the three CPMs and the difference between them for the whole sample.

Chart 2: Alternative Measures of Output



Source: Own calculation with data from the Central Bank of Chile

[10] The level of disaggregation was the following; Construction and Infrastructure, Machinery and Equipment, Durable Goods, Non-durable Goods, Services, Government Expenditure, Exports, Imports and Inventory Change. The last two were grouped due to the fact that Inventory Change cannot be chain-linked.

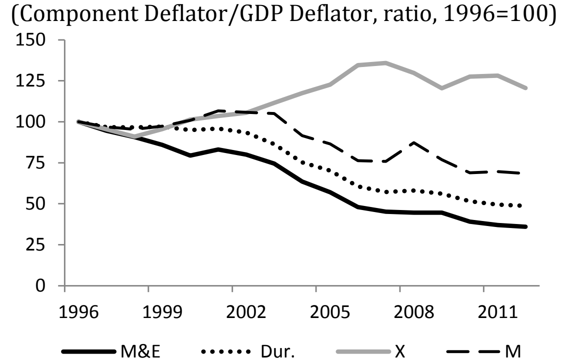
[11] The growth rate of chain-linked series is independent of the reference year due to the fact that it is, by definition, the growth rate of a two-year fixed-base link and this link is unique. Growth of a chain-link aggregate is given by expression (8) that only depends on variables of the current and previous years as opposed to growth of a constant price measure, given by expression (7), which also depends on the prices of the base year.

One thing that becomes obvious is that the further from the base year the larger the discrepancies. This should not come as a surprise as it allows for larger price changes. However, from comparing the growth rates of CPM(2003) and CPM(2008), one observes that significant differences may arise even when both base years are not very far apart. Regarding the significance of the discrepancies, the relevance of their size is debatable, but in 1999, for example, the difference between GDP and CPM(2008) it is over 2 pp., The magnitude of the discrepancy is quite striking in itself, but more important, it makes the difference between a contraction and a slowdown only a matter of differing aggregation. All of the above suggests that ignoring price changes completely is unadvisable given that it may, under certain circumstances, lead to relevant mistakes.

To venture into explaining the differences found in the previous comparison, Chart 3 shows the evolution of the chain-linked weights of Machinery and Equipment, Durable Goods, Exports and Imports (the components deflator standardized to the aggregate deflator). Here it becomes clear how the components prices have evolved consistently at a different pace. This highlights the fact that relevant price structure has changed significantly over the years.

Chart 3: GDP component's chain-linked weights

(Component Deflator/GDP Deflator, ratio, 1996=100)



Source: Own calculation with data from the Central Bank of Chile

In this particular case, the value of exports increased considerably faster than the rest of the economy in the 1998-2007 period, even when real growth did not, affecting therefore the composition of GDP considerably. This change in composition is mostly responsible for the differences that arise between GDP and the CPMs 1996 and 2003. In this case, the shifts in relative value of the components clearly affected the aggregate in a way that is not negligible. However, the outcome also suggests that the problem is not so serious when staying close to the reference year. Then, the question that follows is how the discrepancies measure up in a forecasting setting.

4.3. Aggregation inaccuracy relative to forecasting error

There is an array of methods available to forecast GDP and its components, but given that the objective is providing insight on the impact of aggregation inaccuracy on the aggregate forecast, rather than on the forecasts themselves, we will not resort to sophisticated methods but rely on a univariate ARIMA modelling approach.

For the forecasting exercise we use current seasonally adjusted quarterly data spanning from 1996 to 2012, and perform a yearly recursive forecasting exercise starting in 2002.[12] That is, to forecast

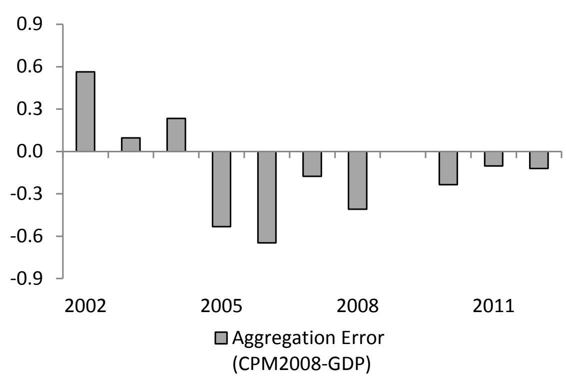
[12] Seasonally adjusted GDP is constructed following the methodology of Cobb and Jara, 2013.

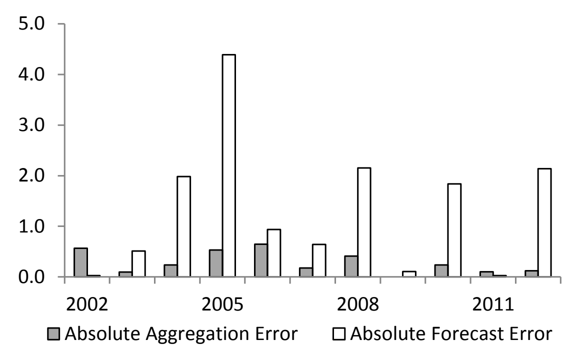
annual growth of 2002, we take the sample of data spanning from 1996.I to 2001.IV and for every component select the most appropriate ARIMA model using the TRAMO program (Gómez and Maravall, 1997).[13] Then we forecast four quarters into the future and add them up to have the annual forecast. After obtaining the forecasts for all the components we calculate the forecasted annual growths for 2002 using expressions (7) and (8) and the respective aggregation error using expression (9). Then, we proceed to forecast the following years by extending the sample and using the same procedure one year at a time.

It is worth mentioning that by restricting forecasts only to one year, it is not necessary to forecast prices (the chain-linked forecast is generated using the prices of the most recent year). However, if longer forecasts were needed one would also require price forecasts. The same is true if forecasting from one year to the next with the most recent observation being other than the fourth quarter.[14]

The results of the exercise are shown in Chart 4. The left side shows the error due to aggregation inaccuracy. As it can be seen, the larger discrepancies are in the vicinity of 0.5 pp., that in the context of the importance that is given to revisions of such a magnitude, suggest that they are at the least not negligible. Also, the signs of the discrepancies suggest that the aggregation inaccuracy introduces a systematic bias into the forecast. The right side of Chart 4, on the other hand, shows the absolute aggregation error compared to the absolute forecasting error.[15] Contrary to the notion of the relative unimportance of the aggregation error, in some periods it is considerable when compared to the total forecasting error. Just as an example, in 2002 the GDP forecast error is nearly zero, but the aggregation error is just under -0.6 pp.; while in 2006, the aggregation error is nearly as large as the forecasting error. Of course, the quality of the component's forecasts is debatable and a more involved approach would probably result in more accuracy, but a fact remains. The outcome suggests that the size of the aggregation error is not necessarily proportional to the magnitude of forecasting error.

Chart 4: Discrepancies in a One-Year-Ahead GDP Forecasting Exercise
(reference year = base year = 2008, percentage points)





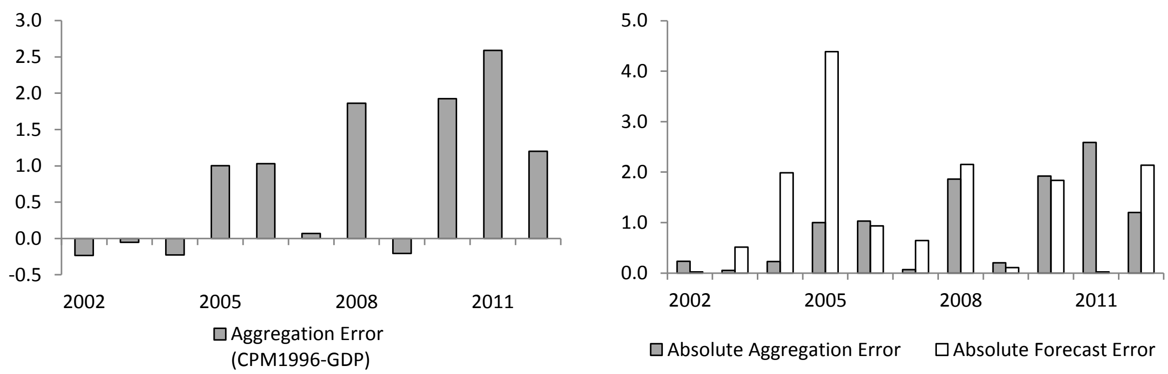
Source: Own calculation with data from the Central Bank of Chile

[13] The TRAMO program selects the most appropriate ARIMA model based on a routine based on parametric unit-root tests and lag-length selection according to the Bayesian Information Criterion.
[14] The problem in this case is that the prices of the most recent year are still unknown, because the year has not ended, and therefore are not available to chain-link the forecasts of the following year.
[15] Forecast error is calculated as forecasted annual growth (expression 8) minus actual GDP annual growth.

The previous example, although informative, is unrealistic due to the fact that it consists of forecasting series over a period that predates the base/reference year, therefore, assuring small/inexistent differences in prices for a portion of the relevant period within the forecasting exercise. The fact is that national accounts data is released a number of years after the reference period and, therefore, a realistic forecasting exercise, starting in 2002, should rely on data based on a year well before that.

With this in mind, we redo the exercise using 1996 as the base year. It is worth noting that as the growth of the chain-linked series is not affected by the selection of base year, only the aggregation error suffers changes not the actual forecast error. Chart 5 shows how the aggregation errors are considerably larger due to the fact that the implicit price structure of the constant price measures is so outdated. In particular, the price structure of 1996 pre-dates the surge in commodity prices that affects notoriously the deflator of exports and the decline in the prices of imports,[16] both of which can be seen in Graph 3. This translates into a significant and persistent upward bias in the CPM forecast. Also, given the particular evolution of prices, the size of the aggregation errors are comparable to those of the forecasting errors strongly suggesting that assuming that aggregation errors are always small relative to the forecast error may lead to unnecessary, and possibly large, mistakes.

Chart 5: Discrepancies in a One-Year-Ahead GDP Forecasting Exercise
(reference year = base year = 1996, percentage points)



Source: Own calculation with data from the Central Bank of Chile

The previous case may only be a particular example and by no means intends to represent more than that, but it does make a point regarding the need to consider the effects of prices in a forecasting framework that relies on the accounting identities. Forecasters following the bottom-up approach should check on a case-to-case basis whether, in their specific setting, the evolution of prices validates ignoring the chain-linked nature of the aggregate. In this scenario, if the forecasting framework allows for a straightforward chain-linking of forecasts, it seems sounder to incorporate it explicitly and avoid the checking process. In fact, even if the aggregation error were guaranteed to be small, at least for the one-year-horizon proper aggregation would completely eliminate this source of uncertainty. On the contrary, if the incorporation were unfeasible then provisions should be taken to account for it. One relatively simple way of potentially reducing aggregation error dramatically would be to rebase the series to the most recent year.

[16] The decline of import prices also affects machinery and equipment and durable goods.

5. Concluding remarks

This document tackles the issue of a potential bias due to forecasting chain-linked GDP relying on the approximate accounting identities. To do this, first we provide the analytical framework that shows the differences that arise from generating forecasts using the common fixed-base accounting identities instead of chain-linking them and then provide an empirical exercise to have some evidence on the magnitude of potential aggregation errors.

The results show that, in a bottom up approach, both actual measurement and forecasts depend crucially on the relevant price structure and, therefore, the degree of inaccuracy in aggregation due to the use of the fixed-base accounting identities will be directly affected by how the prevailing price structure differs from that of the reference year. This is especially relevant in a context where, given that growth of the chain-linked series does not suffer revisions due to rebasing, one could envisage agencies ceasing to update the reference year. In particular, the errors stemming from the use of the identities may be significant and by no means are necessarily negligible when compared to total forecasting errors. This strongly suggests taking the issue into consideration when generating aggregate forecasts based on the accounting identities. A simple procedure that could potentially reduce the problem significantly is rebasing the relevant series to the most recent year.

This document, however, has covered only the most direct way in which aggregation inaccuracy could affect forecasting precision and in a particularly simple way. A topic for further research would be to explore the effects of chain-linking on other models and more complex forecasting frameworks.[17] These could also suffer from other derived problems like parameter instability due to the shifting weights.[18] Moreover, incorporating chain-linking in to these settings could require significant work and that these and other difficulties could need addressing during the estimation procedure (allowing for time varying parameters could alleviate the problem). Also, for longer horizons, the need for forecasted prices appears, adding more parameters and uncertainty to any setting.

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[17] Duran and Licandro (2013) explore the effects of chain-linking on GDP as a welfare measure.

[18] This might affect forecasting models that do not necessarily rely on the accounting identities directly but include disaggregate components.

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