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Assessing terms of trade volatility in Argentina, 1810-2010.

A Fourier approach to decycling.

Alberto M. Díaz Cafferata, José Luis Arrufat, M. Victoria Anauati, Santiago Gastelú*

ABSTRACT

The main thrust of the paper is to offer estimations of statistical volatility of the terms of trade (TOT) as a *proxy* for uncertainty. Volatility has been found costly for developing countries, but there is neither a unique measure, nor a canonical model to estimate a causal link between volatility and economic activity. There is also heterogeneity of findings in empirical research. We implement alternative definitions of volatility, going beyond frequently used methods based on the standard deviation (SD) of the TOT or of the detrended residual, by additionally modelling TOT cycles. Further, without agreed stylized facts regarded as conclusive of generalized behavior, country studies addressing the high volatility and heterogeneity of developing countries serve as a diagnostic device. We examine the case of Argentine, a prototype volatile land-abundant country, taking advantage of data availability for a fairly long span of two centuries between 1810 and 2010. To assess the volatility of TOT and GDP, the yearly series are first logged and subsequently detrended via two methods, cubic polynomial and Hodrick-Prescott; we then decompose the residuals in cycles using the Fourier technique. "Volatility" is computed as a five year rolling sample standard deviation of these residuals. This modeling is based on the theoretical presumption that people are able to perceive not only trends, but also the presence of cycles in economic variables. To get indication of the possible influence of the choice of definition in the association between TOT volatility and GDP volatility for Argentina, a VAR exercise was performed: higher TOT volatility appears positively but weakly, associated with higher GDP volatility in most of the alternative model specifications. We evaluate the empirical evidence and provide an economic interpretation in a historical perspective.

Keywords: Terms of trade. Volatility. Cycles. Argentina. Agricultural commodities.

JEL Classification: C22, F10, F11, F14, F44.

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* Instituto de Economía y Finanzas, Facultad de Ciencias Económicas. Universidad Nacional de Córdoba. Av. Valparaíso s/n. Ciudad Universitaria. 5000 Córdoba, Argentina. José Luis Arrufat JoseLuisArrufat@eco.uncor.edu; M. Victoria Anauati vickyanauati@hotmail.com; Alberto M. Díaz Cafferata diazcaf@eco.uncor.edu; Santiago Gastelú santigast@gmail.com TEL +54-351-4437300. FAX: +54-351-4334436. Previous versions were presented at the XIII Conference on International Economics AEEFI, U. of Granada 2012, the XXVI Congreso Internacional de Economía, U. Camilo José Cela, Madrid, 2012, and the XLVII Meeting of the Asociación Argentina de Economía Política. Sergio M. Buzzi provided assistance in the elaboration of Figure 1.1. Useful suggestions from Osvaldo Baccino, Sergio V. Barone and Gastón Utrera are gratefully acknowledged. The usual caveat applies.

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1. Introduction

1.1 Focusing on TOT volatility

The main thrust of the present paper is to estimate volatility by resorting firstly to a two-stage approach which consists of a sequential detrending and decycling of the time series data. Secondly, the standard deviation of these unexplained residuals provides a measure of volatility.

We deem this provides a flexible new approach which improves the usual one-stage detrending for the estimation of volatility. We also test whether there is a causal connection between terms of trade (henceforth TOT) volatility and GDP volatility in Argentina.

What is volatility? Our working definition of volatility, in line with the usual practice in the literature, follows the intuition that volatility is related to uncertainty, and can be proxied by the standard deviation of the residual obtained as the unexplained portion of time series representation. Our empirical approach contributes to the existing literature in three ways: modelling the identification of the explained portion by means of a time trend and Fourier regular cycles; comparing empirical volatility estimations under different assumptions; and providing a detailed examination of volatility, using a rolling sampling application, to a long-term data set to Argentina.

Whereas detrending is a routine procedure, the particular approach for the identification of the residuals via the additional removal of the cyclical influence, is a proposal that we emphasize to estimate the unexplained residual.

By so doing, we benefit from combining two lines of study of data along time: the time domain approach, to determine the residual and statistical fluctuations, and the frequency approach to model the cyclical component of the detrended series. Why shall decycling fit the analysis? The approach to learn about the TOT evolutions by decomposition combines two ideas.

One is that the econometric modelling of economic phenomena along time can be assumed to approximately replicate the "signals" as perceived and interpreted by economic agents. Recent literature points out (Dehn 2000; Wolf 2004) that it is advisable to distinguish "volatility" from the mere "variability" of data. While the latter is measured by statistical dispersion, volatility is instead associated with uncertainty which, after econometric modelling of the series, can be identified with the unexplained residuals.

The other one is that the movements along time of the economic variables can be appropriately modelled in terms of cycles, since their regularities are a fact of both natural phenomena and social life, and this perception is a usual way to see the world by men since the biblical seven years of plenty and seven years of scarcity. Certainly, the presence and explanation of cycles have a long tradition in economics. But, so far as we know, this strong interest has not been taken into account in the empirical estimation of volatility.

Following these two ideas, if the presence of cycles is arguably a natural representation of the knowledge of economic processes for the economic agent, "volatility" may be estimated by the part of the economic process that is not fully explained by trends and cycles. The usual estimation procedure of only detrending data by the Hodrick-Prescott or some alternative filter, might not provide a good proxy for volatility, and give rise to an overestimation. Certainly, events that could be easily explained by cycles, should not be considered volatility but rather should be included in only the measure of variability of the data.

As regards causality, the high volatility of developing countries´ GDP, coupled with the empirical evidence pointing that higher GDP volatility is normally associated with lower growth, has drawn attention to the sources of GDP volatility. A usual perspective to understand the fluctuations of developing open economies is to distinguish between internal and external forces. Examples of the former are government expenditure and economic policies. Examples of the latter, which are beyond the control of a small open economy policymakers, are the international rate of interest, and TOT, which are expected to be a major external variable influencing GDP volatility. This paper focuses specifically on TOT volatility, i.e. as related with the latter channel, with empirical application to Argentina. Studying the pattern of TOT evolution, its effects on activity, and the policy implications for coping with volatility of the TOT, are nowadays deservedly issues of great interest to policymakers. However, despite sustained efforts to shed light on the direction of causality, clear cut answers to this question and its policy implications are still needed.

Imperfect knowledge of the sources and channels of transmission of external shocks causes public and private agents to make forecasting errors. That´s why there is a lively debate about the design of a development strategy, and the policy responses in the presence of volatility, as well as the state of the art about the proper rules to apply in the presence of innovations. But even though knowledge is not accurate enough so as to provide precise policy advice, it is still undoubtedly useful to go deeper into the search for better guidelines that would enable policymakers to cope with TOT volatility.

In short, the relevance of understanding the effects of TOT evolutions in activity and the incentives to dig further on the issue remain alive, as a flourishing literature shows.

1.2 The Argentine experience

Figure 1.1 provides a synthetic view of the long-run history of Argentine growth. Panel (a) shows the GDP trend series, in millions of 1993 constant prices, represented in logarithmic scale[1]. To get a feel for the order of magnitudes, in the 1990´s the Argentine GDP was about 350 billion (convertible) pesos. On turn, panel (b) represents the first differences of the trend, what can be called the “trend growth” or “long-run growth” in percentages.

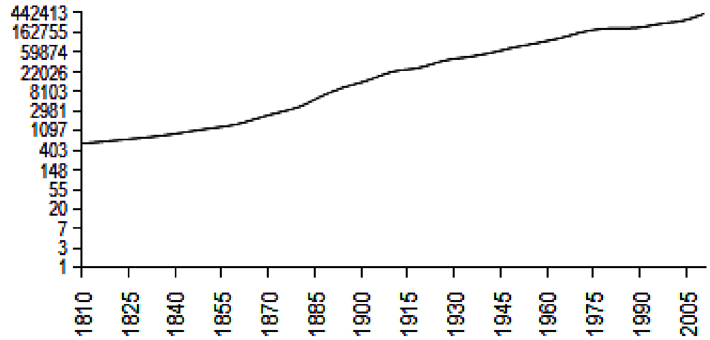
An outstanding peak appears in 1885, the year when the long-run growth reaches the historical maximum, as the culmination of seven decades of the export driven rising growth of the 19th Century, an experience shared with Australia, Canada, New Zealand and Uruguay. This group, which may include the United States of America, are the land abundant so called “regions of recent settlement” encompassing large open grasslands.

After the peak growth in 1885, the Argentine economy slips down in a long process of decelerating and highly irregular growth until 1983, where a change in trend growth insinuates. The figure provides also a first intuitive indication of relevant subperiods in the span of time we analyze, which shall qualify the channels of influence of TOT on activity: a first epoch of high and rising growth, a second one of deceleration, and a third one of recovery.

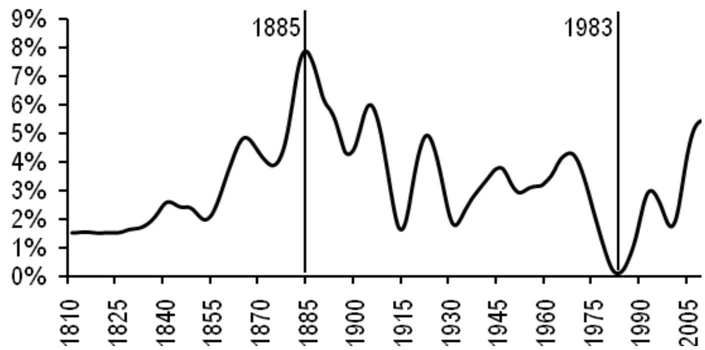
1 It was estimated by first logging GDP, and subsequently estimating the trend by Hodrick-Prescott (lambda=100); the trend values of GDP shown in the figure are the antilog.

Figure 1.1
Argentina, GDP in millions of 1993 constant prices, 1810 - 2010.

(a) Long run trend (HP, lambda=100).

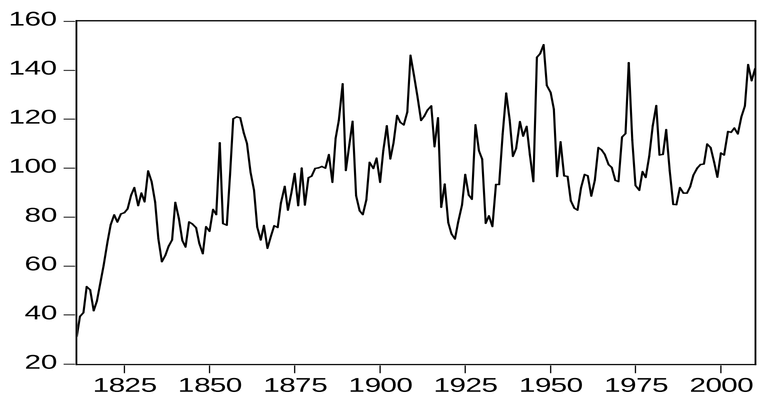


(b) Trend GDP annual percentage growth rate.

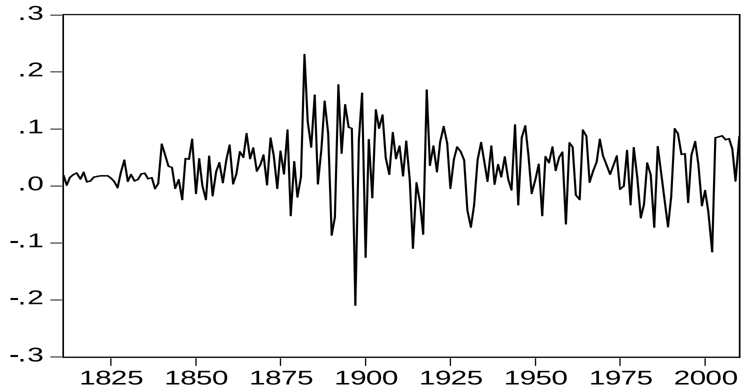


Figures 1.2 to 1.5 on turn provide a bird´s-eye-view of volatility in the Argentine economic history for our purposes. In Figure 1.2 we turn our attention towards the characteristics of fluctuations in TOT and GDP. The upper panel (a)shows the evolutions of Argentine TOT: they look highly irregular, exhibit a sinusoidal pattern and reach, from time to time, large peaks followed by sudden sharp drops. For an observer with a restricted window of data, a general decline between the beginning of the 20th Century and the 1940s might explain the perception that there was a deteriorating trend as stated in the Prebisch-Singer hypothesis.

Figure 1.2
TOT Index and GDP growth. Argentina 1810 – 2010.
(a) TOT Index



(b) GDP growth



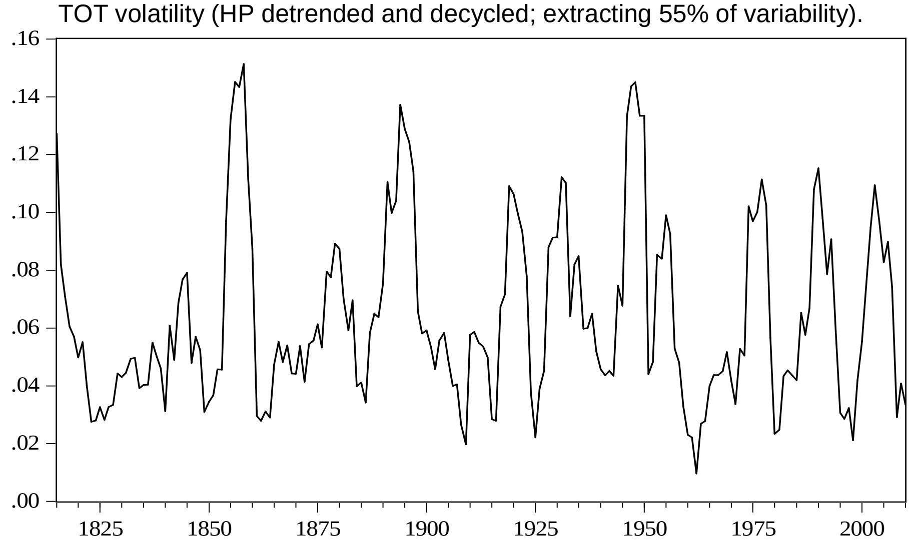
Panel (b) shows the also highly variable GDP growth rate. On visual inspection, growth rates are positive and rising gradually until the end of the 19th Century; subsequently large fluctuations with alternating positive and negative sign are outstanding. The alternation of sign throughout the rest of the century explains the long term growth decline shown in Figure 1.1, and lower and negative rates are more frequent in the last half century.

Figure 1.3 on turn provides a picture of TOT and GDP volatility, where a proxy to volatility is estimated by the 5-year SD of a series that was first detrended and subsequently decycled as will be explained in detail in the rest of this paper.

To close this brief historical summary, Figure 1.4, showing the scatter plot of the volatility of TOT against volatility of GDP growth, provides an intuition of the possible presence of an association. As a descriptive quantitative measure of this relationship, the contemporaneous correlation between TOT volatility and GDP volatility in 1816-2010 (some observations are lost in the rolling sample procedure) is 0.1443[2].

Figure 1.3
TOT and GDP volatility.

TOT volatility (HP detrended and decycled; extracting 55% of variability).



[2] The contemporaneous correlation between TOT volatility and GDP growth volatility almost doubles this number.

GDP volatility (HP detrending; extracting 80% of variability)

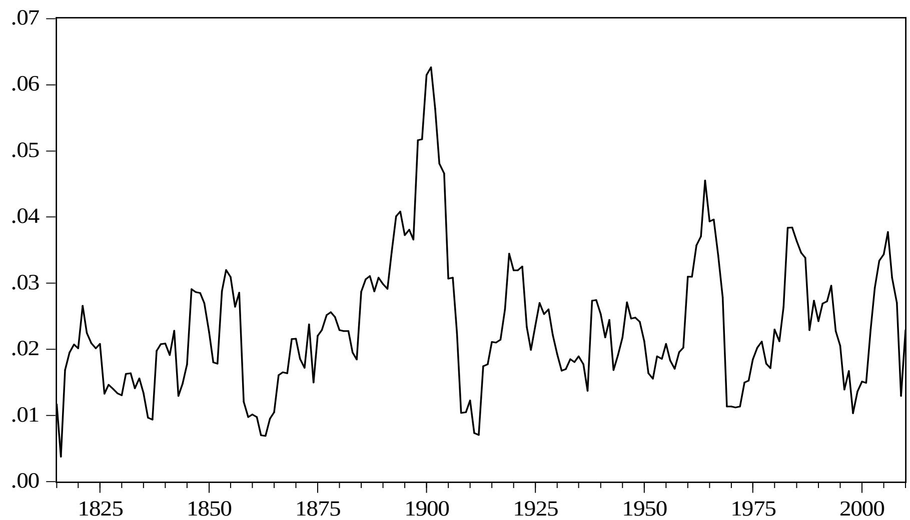
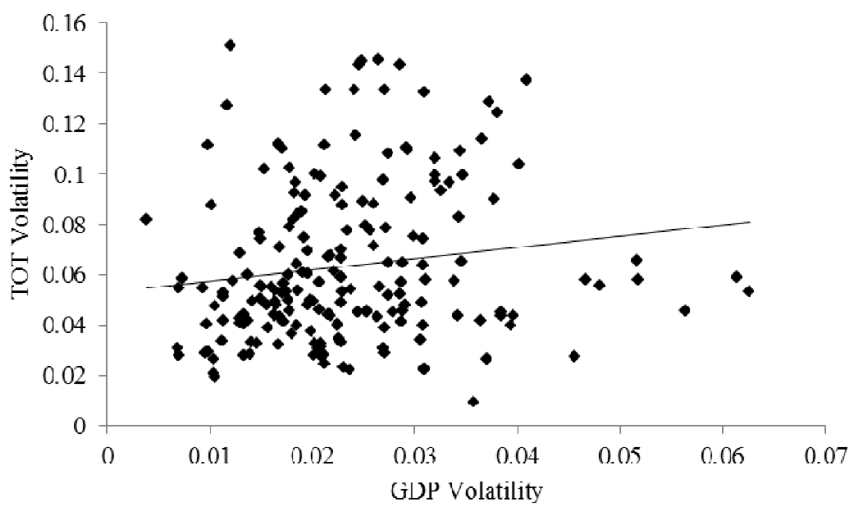


Figure 1.4
TOT volatility and GDP volatility. Argentina 1815 – 2010



1.3 Econometric methodology: estimating volatility by detrending and decycling

The issue of TOT cycles is usually handled in the empirical literature within the time-domain approach: an economic time series is decomposed into a trend, seasonal, cyclical, and an irregular component[3]. We are interested in the possible presence of cycles: it can be argued that the economic world (relevant phenomena of economic activity) moves indeed in cycles; and also, that those cycles can be perceived by economic agents. Hence, it seems to be a natural implication that this circumstance should be introduced in the representation of people´s knowledge, leaving other processes and stochastic behaviour as unexplained volatility.

This approach gives rise to particular questions. The first immediate one is of course whether there are economic processes along time which move in cycles. Further, is the statistical

[3] Cf. Enders (2004) for details.

data generating process stable, or instead structural breaks define historical subperiods? If so, when do they happen and with which consequences? Which is the appropriate econometric method to assess the presence of breaks? What is the type of influence of TOT on GDP, and how can the empirical method pick up this link?

Our estimates rest on finding volatility by extracting from the series the cyclical portions which are consistent with an adequate representation of regular movements of the variable.

Our approach poses a challenge for the analyst, because the unobservable theoretical cycles provided by the Fourier decomposition shall be interpreted in terms of economic phenomena. Since there is not a canonical framework to accommodate the features that seem relevant, there is a marked heterogeneity of theoretical presumptions about the channels from TOT to economic activity from alternative modelling, and similar heterogeneity regarding the presence and empirical relevance of the link has been found in empirical research.

By focusing in detail in a particular economy, this paper contributes to the active academic developments by addressing the question of the growth effects of terms of trade volatility in Argentina along two centuries. This long-term perspective, adding to the so far scant knowledge of Argentina, is a contribution to the understanding of these processes which shall help handling systematically the presence of volatility, rather than the pendular policies which are the immediate response to unexpected changes, without an intertemporal development strategy, an issue of general interest in the field of international economics.

In synthesis. Firstly, since the literature points out the heterogeneity of results in international comparisons, detailed analysis of Argentina as a prototypical member of the club of extreme comparative land endowment countries provides a useful reference for an understanding in comparative perspective of the TOT-growth link. Secondly, the research is of methodological interest, as the suggested estimation procedure can be applied to the comparative study of a larger set of countries. Thirdly, it poses the problem of the design of a development strategy in countries with natural resource abundance, in view of the recent seemingly global turn of the land intensive commodities prices.

There now appears to be contemporaneously an upward trend in the TOT for land abundant countries. Some people argue that the increasing importance of China and India is driving food and metal prices up. Consequently the proper design of a development strategy must be taken in consideration in the formulation of strategic scenarios.

In the rest of this paper, Section 2 reviews the literature and stylized facts from international country studies. Section 3 reports the experience of Argentina and a few other countries for comparison. Section 4 addresses the statistical properties of the TOT and GDP in Argentina for the period 1810-2010, examines the existence of unit roots and provides measures of volatility. Section 5 is a VAR exercise to evaluate the influence of choice definition. Section 6 provides a synthesis and interpretation of results.

2. Theoretical and empirical literature review

2.1 The shift in attention towards volatility

Only selected references will be discussed to provide a general picture of the issues and empirical approaches in the extensive literature on TOT volatility. To start, note that a distinction can be drawn between the issue of TOT volatility and the role of TOT in traditional international economic theory. The real price of trade flows has deservedly occupied the central stage in the economic analysis of open economies since the origins of our science. One critical question is whether the static gains from trade, which were the main concern until the mid 1960s, and the theoretical presumption that in a Small Open Economy (SOE) framework that once-and-for-all changes, with certainty, in TOT, drive the reallocation of resources to their best use, can be extended to an implication about trade and development. Hence attention shifted towards trade and external exposure, and more recent research in international economics is increasingly concerned with the new unstable conditions of the globalized economy. One major issue of the new agenda is the concern with “vulnerability” of the developing countries and also with the welfare implications, in particular distributive issues and the impact of fluctuations on low income families.

Research on the origin and transmission of international shocks finds that under some sets of market conditions and short-run price driven specialization, openness does not guarantee growth or maximizes welfare. We deal here with a fairly specific perspective of the relationships between trade and development, namely, that SOE are vulnerable to external shocks and volatility. This approach to development stresses that volatility causes deleterious effects on growth and distribution. Rodrik (1998) argues that this explains the higher government expenditure of more open economies. The modeling of uncertainty in the economic environment is discussed in Pomery (1984), and Baxter (1995) offers a framework to introduce the complexities created by the type of international transmission of fluctuations and the type of shocks (transitory or permanent, global or idiosyncratic).

The pattern and effects of TOT volatility for a particular economy are expected to be associated with their structural characteristics, such as the degree of openness, which is usually measured as the fraction of trade in GDP, but other sensible indicators are available, and the rankings based on them may deliver conflicting results, as shown by Pritchett (1991).

Other relevant characteristics of the open economy have been found to matter in empirical studies on the role of TOT in the open economy: the resource endowments, the composition and concentration of exports; the structure of domestic markets such as the degree of competitiveness; the exchange rate regime; the labor markets; or institutions. Caballero (2001) warns that the low efficiency of the financial sector is a critical weakness for Latin American countries. Another reason explaining the current focus in volatility is that decades of research on the thesis of a declining developing countries TOT trend, since the early formulation by Prebisch (1950) and Singer (1950), has produced inconclusive and all in all weak evidence of the presence of such phenomenon, and even an upward trend in the next decades seems likely.

There is a shift of attention and a more recent generation of studies is concerned with the problems created by volatility and cycles of the TOT, and the sudden and irregular jumps in prices[4]. Cashin & Mc Dermott (2001) argue that even when real commodity prices over the period 1862-1999 have declined about 1 per cent a year, price variability is large relative to trend, and those “movements of commodity prices present serious challenges for many developing countries, due to the large impacts on real output ... and because of the consequent difficult problems they pose for the conduct of monetary policy”.

2.2 Issues arising from the volatility of the TOT

Moving on to the discussion of TOT volatility, we shall distinguish two main branches of the literature. The first one asks which the appropriate concept of TOT volatility is; how it can be

4 It might be pointed out that the usual discussion about the TOT definition and behaviour is in terms of barter TOT, i.e. the ratio of the price of exports and the price of imports of developing countries. Different indexes related with the relative price of exports and imports may be computed, and have different interpretations. The income TOT, the gap between international or internal (distorted) TOT which domestic consumers and producers observe. The interest may be focused on the relative prices of particular aggregates (such as manufactures versus commodities), or the behaviour of prices which are critical for countries which have large share of exports in specific goods (such as copper for Chile, oil for Mexico or grains for Argentina). Last, the data may be annual, quarterly, or moving averages.

empirically measured; the causes of TOT fluctuations; and which statistical properties of the TOT are relevant for their effects on activity.

Price changes are large, frequent, and abrupt. But, what is “volatility”? A strand of the literature is concerned with finding an appropriate concept and a proper measurement of price fluctuations; Wolf (2004), distinguishes between predictable and unpredictable components of a variable. The latter carries *variability* and *uncertainty* as key connotations. In this line, Dehn (2000) distinguished variability from volatility, suggesting to leave aside the regular part to estimate volatility. Uncertainty is a concept *ex ante* different from “variability”, which reflects components that are predictable by producers. Baxter and Kouparitsas (2000) decompose TOT volatility in a component stemming from the composition of export and import basket and a country effect. Cuddington and Urzúa (1989) decompose commodity price movements into a secular and a cyclical component, asking to what extent commodity price shocks are cyclical. Let´s, at this point, remark that there is today consensus that “volatility” picks up the unexpected portion associated with uncertainty, i.e. the unpredictable component of the variability of TOT.

In relation to this issue, the choice of an appropriate time window to measure volatility is associated to heterogeneous methodology. Kim (2007) discusses the volatility of income, consumption and investment, as measured by the five-year SD of annual growth rates. In Wolf (2004) growth volatility is associated with the nine-year standard deviation[5]. The possible differential effects of unexpected sudden changes can vary as function of the degree of persistence of the shocks (permanent or transitory, and in case of transitory shocks of large or small median life); non linearities when the shocks are large or small; when jumps are positive or negative (the issue of symmetry).

A second strand of research is concerned with the association between TOT and economic activity in developing economies, given the structural feature of their export concentration on commodities. Is it the level, the trend, the cycles, the volatility, or some other statistical property of the TOT relevant? Do TOT affect the level, the volatility or some other characteristic of activity? Let´s go over some of them.

Several different effects of TOT volatility are possible. Firstly, on the level of GDPpc, which may be associated to a history of cumulated low growth in the past, or peculiarities of low income compared with high income countries. Secondly, associated with the rate of growth (ie the mean rate of growth) meaning that more volatile economies grow at a slower average rate. Thirdly, the main effect may be either on the “volatility of growth” (meaning an irregular rate of growth) or on the volatility of GDP level. It is also to be noted that also growth may be cyclical (rather than volatile), meaning that periods of high and low growth alternate regularly.

Bourguignon (2009 and 2011) remarks that TOT volatility is an exogenous force in developing countries, that it is necessary a more structural approach to understand the role of foreign-caused exogenous volatility, and mentions that the recent literature on growth and growth volatility concludes that volatility slows down growth. This seems to apply to low income countries but part of the correlation may be spurious. Decomposing volatility into exogenous and endogenous (policy caused) components, there is little evidence that GDP growth is affected by TOT volatility. More convincing is the evidence that GDP volatility is partly explained by TOT volatility.

Wolf (2004) points out that in the international experience the volatility of GDP (measured as the SD of the GDPpc growth) has a negative association with the mean growth rate of GDPpc. But the quantitative magnitudes vary for low-income, middle-income and high-income countries, and also for different periods. Further it may be useful to consider *normal*

5 The curse of natural resources is a possible related source of distress, associated in this case not with the specific pattern of evolution of commodity prices, but with the conflicts related with the use of the rent of abundant natural resources.

and *extreme* volatility; and also to differentiate between *equilibrium* and *excess* volatility, such that intuitively reducing volatility would improve welfare if volatility reflects some kind of market imperfection[6].

Ramey and Ramey (1995) argue that volatility is costly due to uncertainty-induced planning errors by firms, and also that there is an interaction between rigidities and uncertainty. They notice the conflicting empirical results regarding the effects of *business cycles volatility on growth* in the literature: Ramey and Ramey (1991) suggest a negative impact of volatility on growth through the effects on investment, but arguments for a positive sign have been found. In panel regressions with different specifications the relationship between *mean growth* on the *standard deviation of growth* has not a clear cut sign. They associate "volatility" to the notion of "uncertainty". Initial and lagged variables avoid the inclusion of "future information". The coefficient estimate on the innovation SD (i.e. the effect of "volatility") is -0.18 for 92 countries and -0.95 in the OECD sample. They conclude that the negative effect of volatility stems mainly from volatility of innovations to GDP growth, which reflects uncertainty. That the potential benefits of eliminating business-cycles volatility are underestimated if the impacts on growth are disregarded and, finally, that investment-based theories of the link volatility-growth do not seem to be verified.

A robust finding in the international experience is that high TOT volatility goes hand in hand with high GDP volatility, and also with less GDP growth. Take Mendoza (1995) who, after examining the relationships between TOT and business cycles using a general equilibrium model, concludes that TOT disturbances account for one half of the observed variability of GDP. Kose (2002) reaches results roughly in agreement. In a study of the link between TOT volatility and long-term growth in developing countries, Furth (2010) finds that differences in TOT volatility account for 25 per cent of the cross country variation in growth in the period 1980-2007. Vial (2002) mentions that three forces TOT and real exchange rate volatilities, along with economic volatility, have a negative effect on growth in Latin America[7].

Koren and Tenreyro (2007) define two main determinants of GDP growth volatility: one is a high degree of specialization or specialization in high-risk sectors; the second is domestic macroeconomic risk. They estimate that the specialization of poor countries in a few sectors which happen to have more volatile prices explains about 50% of the difference in volatility with rich countries.

Despite ample agreement about the relevance of the empirical effects of volatility, the specific influence of TOT has been difficult to pin down in international studies, due to the presence of many other domestic and external forces driving economic activity. Extracting the "ceteris paribus" signals of the TOT-GDP links has proven elusive. A prevalent feature of research findings for different countries and periods is indeed the heterogeneity of effects, associated with the varied degree of vulnerability of different economies.

The presence of multiple sources of GDP volatility is also emphasized by Bourguignon (2009) who argues that in the period 1980-1994 there was substantial impact of TOT volatility on growth but only a limited effect during 1995-2007. He adds an important reminder: correlation does not entail causation. This author summarizes the results obtained from a VAR analysis by Loayza and Raddatz (2007) as follows: a) the effect of a 10% TOT drop on GDP is between 0 and -1.5%. b) The degree of vulnerability is higher for more open countries. c) Little is known about the role of policies. d) This type of analysis faces important limits.

6 Wolf suggests a multi-measure approach and provides seven operational choices that a practitioner should make to assess the "volatility" of a particular variable: sample length, frequency, symmetry, expected or realized volatility, thresholds, persistence, and aggregation.

7 He mentions as a source an IADB study on Latin American countries, "Hacia una economía menos volátil. Progreso económico y social en América Latina. Informe 1995". The effect is particularly strong for Bolivia, Ecuador and Venezuela.

To understand the effect of openness on volatility, Kim (2007)[8] distinguishes between, on the one hand, the degree of openness (either trade, or gross private capital flows as a share of GDP) as the level of exposure of an economy to the international processes, and on the other hand, the external economic risk, which is related to the instability of conditions, and is captured by the TOT. The concept of TOT risk is measured by the SD of the first-differenced logs of the TOT multiplied by the trade share of GDP (like in Rodrik 1998)[9]. Independent variables are five-year averages and "economic volatility" is measured by the five-year standard deviations of annual growth rates.

Mendoza (1994) asks for the effects of TOT stressing the role of uncertainty on savings and consumption growth. The main empirical finding is evidence in support of large growth effects resulting from the variance of the TOT as an indicator of risk. And Mendoza (1997) builds a stochastic endogenous growth model where savings and growth are affected by TOT uncertainty. The model helps to explain the positive link between growth and the average rate of change of TOT.

In a study for Canada in the period 1877 to 1991[10], Henriques *et al*. (1996), address the direction of causality between exports and GDP: export-led growth; growth-driven exports; and the presence of feedbacks. Since the relationships between exports and growth are complex, the TOT are included as control variables. VAR and Granger estimations suggest that exports, GDP and TOT are integrated; that GDP growth may cause exports growth; and exports cause TOT suggesting that Canada may not in practice behave as an SOE due to its abundance of natural resources.

Raddatz (2007) points out that external shocks, such as TOT fluctuations and other international influences, are often blamed for the volatile performance of low-income countries. He quotes from UNCTAD (2002) to the fact that "the level and volatility of world commodity prices are an important influence on economic growth and the incidence of poverty in LDC". Raddatz quantifies the effect of external shocks on output volatility in low-income countries, using a panel vector auto-regression in which external shocks are assumed to be exogenous. The main sources of fluctuations are found to be internal, but the output effect of external shocks though small in absolute terms is considered significant relative to the historical performance.

Effects on growth of *ex-ante* commodity price uncertainty and *ex-post* shocks take into account the size of shocks (large vs. small, positive vs. negative). Positive shocks do not have an effect but negative ones have a negative impact on growth.

Kehoe and Ruhl (2007) find that correlation between changes in TOT and real GDP amounts to 0.30 for the US and to 0.73 for Mexico. Becker & Mauro (2005), in turn, argue that shocks to TOT are the most expensive ones.

Lutz (1999) finds evidence that there is a negative relationship between income TOT volatility and lower rates of output growth. A decomposition of TOT income reveals that fluctuations in real exports and in the relative price of tradable are of similar magnitude, and the volatility in the barter TOT is equally affected by variations in the price of exports and imports.

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8 Wolf´s discussion is concerned with the Rodrik (1998) hypothesis that in the face of externally generated volatility the public sector would expand to minimize total aggregate volatility because the public sector is relatively insulated from the international economy. Wolf argues that the hypothesis "rests on a dubious premise that openness brings about more volatility" (p 185). The theoretical presumption about the effect of openness in volatility is ambiguous. Openness can lead to more or less domestic volatility because trade can concentrate or diversify economic risk: a more specialized production may be more vulnerable to external shocks, but on the contrary the expansion of the market reduces volatility. Reflecting the theoretical ambiguity, empirical evidence of the link openness-GDP volatility is mixed (p. 185, 186).

9 Exchange-rate risk is defined in a similar way.

10 Two subperiods, 1877-1945, and 1946-1991 are taken into account for the estimations.

2.3 Summing up

The main picture that emerges from the literature emphasizes the prevalence of pervasive high volatility of the TOT for LDC's, and the difficult challenges this fact poses for the proper design of development policy.

Regarding applied research, volatility can be captured empirically by the residuals from time series modelling, and measured as the SD of logged and detrended series: several different empirical measures are found in the literature. There is evidence that volatility may not be homogeneous throughout time and that the evidence related to causality is very heterogeneous. More specifically, the effect of TOT volatility on the rate of growth is ambiguous both in relation to sign, and also with regard to magnitude. A more general finding is that a positive relationship between TOT volatility and GDP volatility seems to prevail. The heterogeneity of results between countries and periods may be explained by several influences, such as the degree of openness, the structure and concentration of exports and imports, the volatility of government expenditure and policies, the strength of institutions, the efficiency of the financial system, the frequency and magnitude of crises, risks and incentives to invest, and also incentives for particular types of investment (irreversibility vs flexibility and level of productivity in each case).

3. The argentine experience and other country studies

Lagos and Llach (2011) provide empirical evidence which in their view lends support to several alternative economic, sociological, and historical explanations of the decline of Argentina from 1870 to the present time. They conclude that the main factors have been the degree of openness, the volatility of GDP, the acceleration of inflation, and the two World Wars. They argue that chronic macroeconomic volatility has impaired growth because increased uncertainty reduces the incentives for investment. They approach the issue of the role of trade variables and the TOT looking for evidence that may support two possible links under the "dependency hypotheses" of an influence on GDP of the TOT and of the degree of openness as measured by the fraction of primary goods and manufactures of agricultural origin in total exports. They fail to find empirical evidence of an (apparently contemporaneous) positive correlation between either the level of TOT and GDPpc, or between the changes in the TOT and GDPpc, except in selected subperiods. Alternatively, they also fail to find evidence supporting the hypothesis that the differential growth of Argentine relative to other Latin American countries has been associated with the relative movements of their TOT[11].

Rabanal and Baronio (2010) distinguish permanent and transitory shocks in the Argentine GDP (1880-2009) to determine whether the trend should be modelled as deterministic (in case the shocks are transitory) or stochastic (in case of permanent shocks), and ask whether an interaction between trends and cycles is present in the data. They find two subperiods. In the first one, 1880-1969, the shocks are temporary and the polynomic model is the proper one to use. In the second subperiod, 1970-2009, the effect of shocks to GDP is permanent, therefor is best described by a model stationary in differences.

Artana, Bour, Bour, and Susmel (2011) estimated an aggregate production function which includes as arguments the industrial capacity utilization factor, total capital lagged one period, the total number of hours worked per occupied person times the total number of people in employment and, finally, a variable that captures the TOT. Their empirical finding points to a significant positive effect of TOT on GDP growth.

11 Lagos and Llach (2011) pages 130, 134, 241.

In a study of Mercosur countries, Barbosa-Filho (2004) concludes that the low correlation between the TOT shocks in Argentina and Brazil suggests that their bilateral real exchange rate should be allowed to fluctuate to accommodate differential shocks. A possible arrangement would be a joint and flexibly managed float of their currencies. Uruguay and Paraguay should accommodate to these events depending on whether a shock is more intense in Argentina or Brazil.

Bastourre, Carrera and Ibarlucia (2010) note that the dynamics of commodity prices is taking on new relevance in Latin American countries. They model commodity prices as driven by two forces, long-run fundamentals and financialization of commodities. The tensions between these forces are reflected in short-run price movements as commodity prices experience large and unpredictable fluctuations, related to the gap between observed prices and those that would obtain if fundamentals prevailed. Information on the nature of this volatility, such as the length and size of commodity-price cycles can be useful to policymakers.

Bucacos (2001) in a study of the Uruguay GDP cycle points out the usefulness of working with the commercial transmission channel of international cycles, with attention being paid to exports and import flows, and the TOT.

Lanteri (2011) reports that TOT shocks have a positive effect on GDP, and that the main source of GDP fluctuations are the aggregate supply shocks. Lanteri (2009) finds evidence that positive TOT shocks have positive and permanent effect on real GDP.

Broda and Tille (2003) note that “terms of trade matter so much” for developing countries because TOT fluctuations are twice as large as those in developed countries, which are more open and have little leverage over their export prices[12]. Moreover, note that large swings in the prices of the goods developing countries export contribute to increased volatility in GDP. They argue that a flexible exchange rate can help to insulate the economy against fluctuations in export and import prices. Argentina and Ecuador “show how forcefully changes in the terms of trade will drive economic activity when the buffer of a flexible exchange rate is absent”.

Grimes (2006) asks if TOT are able to explain “key growth outcomes”. He finds that “consistent with the international evidence” TOT explain “a considerable portion of New Zealand´s growth performance across a range of economic regimes”.

A general lesson from the literature is that international markets impulses are transmitted via TOT to economic activity through multiple channels. This gives rise to heterogeneous empirical responses, which are difficult to explain because there is not a comprehensive model. Empirical work in this case provides estimates of mechanisms suggested by the analytical framework. Further: TOT of developing countries are exogenous; TOT of developing countries (low and median-income) are more volatile; higher volatility of the TOT is associated with higher volatility of output; higher volatility of GDP (GDPpc) is associated with lower growth.

4. New estimates of volatility by decycling

4.1 Modeling and estimating uncertainty

4.1.1 **Representing ignorance**

Summarizing briefly the discussion on TOT volatility, the line of reasoning which has brought us to the present stage is the following: our starting point is the stylized fact that developing economies suffer from high volatility and also, tentatively, that volatility impairs growth.

Several measures of variability and volatility have been put forward in the literature, relying either on the original series, or on detrended versions thereof. A few additional ones model the detrended residuals either by removing the likely cyclical variation (as we do here), or some other feature. Each of these definitions may be analytically useful.

12 Cfr. Baxter and Kouparitsas (2000).

For analytical purposes a distinction is drawn between variability and volatility. The relevance of this latter concept is illustrated most forcefully by Dehn (2000) who argues as follows: economic agents face variable prices but not all the observed variability is a good measure for uncertainty. For example, when renting an apartment located near a beach, a rational agent will certainly be aware of the fact that he must pay, on average, more during the summer than during the winter. The opposite applies when renting a hut located near a ski resort. A rational agent must therefore be expected to base his expectations of rental prices by taking into account the seasonal patterns which: a) are discernible in his data base, and, b) he can reasonably judge that will still prevail in the future (Dehn 2000, Wolf, 2004).

To illustrate the issues at stake consider the TOT of two countries, say A and B, which we can decompose in terms of a trend, cyclical movements, and irregular components. Let us assume that they have the same SD; assume further that after removing the trend you again find that the SD are equal (but not the same pattern): still an important difference may occur; it may happen that in country A the identifiable cyclical movements of different duration account for disparate proportions that in country B; we would then be, under certain definitions, in the presence of different degree of "volatility".

Dehn (2000) suggests filtering out the regular part to estimate volatility. Volatility is costly because it is associated with uncertainty and risk (Kim 2007 uses "economic insecurity or volatility"). To estimate a *proxy* for uncertainty, it is necessary to distinguish in the variability measures a predictable and an unpredictable component, the latter being "volatility".

Economic agents may recognize TOT trend but would have more difficulties to predict each actual observation, because the former is more stable than the latter. Also, they might be aware of the fact that large shocks, such as the oil shock or the incorporation of China in the world economy, may be expected to affect trends. On the contrary, short term movements like the sharp upward movement in soy prices in 2008, are difficult to predict.

Without precise theoretical indication about how to perform empirical estimations, a sensible exercise is, in consequence, to model the evolutions of a variable along time, by whatever method the researcher judges fit to his purpose (such as a Hodrick-Prescott filtering, ARCH or GARCH models, or via Fourier decomposition). It is also useful to assess how robust the statistical measures of "volatility" are, as well as the difference with the variability of the original series. What are the implications from the causality point of view? In any case, one is dealing with proxies for volatility and therefore essentially non-observable variables have to be constructed. No wonder that there is a whole gamut of estimated responses among those variables given that different researchers resort to different approaches.

Hence, the empirical research problem is how the degree of ignorance of economic agents can be empirically identified. Or equivalently, how much people are assumed to know about the fluctuations of the TOT. A usual procedure in the literature is to assume that people usually perceive trends and, in consequence, to proxy empirically the degree of ignorance, resort to detrending. In this case, the explained portion is the trend. The detrended residual is the ignorance. In turn, the SD of the residual from detrending is a usual measure of "volatility". Let us now move into the empirical estimation of volatility.

4.1.2 **Methods of detrending and other measures of ignorance**

Our proposal rests on the argument that cycles perceived by economic agents should not be included in a measure of volatility. Consequently, a proper removal of those cycles ("decycling") should be performed. In empirical research, the choice of detrending and decycling method provides different measures of volatility. A few comments are in order.

First, the residual varies with the detrending method, a point emphasized by Canova (1998). Therefore, the estimated volatility is very likely to be sensitive to the choice of modeling of the time series. Bee Dagum and Giannerini (2006) warn about "the risk of using automatic detrending procedures in the preliminary analysis of a time series. The mis-specification of the trend can compromise the analysis as its effects reflect directly on the dependence structure of the process and this will preclude a correct identification and estimation of the model."

Second, in our approach people are assumed to base their decisions, on perceived trends and also on whatever information available regarding the presence of cyclical phenomena. If both trends and cycles are taken into account, all this is economic information that should be incorporated. However, cycles (as well as trends) are unobservable. Fourier decomposition provides an instrument for the identification of unobservable cycles in the data. Since Fourier decomposition is a purely statistical method, we must also engage in some discussion as to the proper economic interpretation of the theoretical cycles identified by this approach. For example, "anomalies" such as spikes may generate low frequency cycles; or the statistical cycle may not be regarded as a true underlying cycle for an economic agent at any point in time in Argentine history, such as our results for 202-year cycle. Or the exact statistical cycles of high frequency may be an arbitrary statistical decomposition of less regular processes.

To highlight the formal relationships among alternative measures commonly found we name the SD of the logged series "variability 1", "variability 2" to the SD deviation of the detrended series, as follows. Definition 1: The *variability* of a time series is computed as its SD when no corrections to the original series are introduced; we denote this SD by V1. Definition 2: The SD of the detrended (by whatever suitable method is used) version, is denoted V2. Definition 3: When, after detrending, a suitable algorithm is used additionally to model the residuals, this third measure is called V3(J), in which the J most important cycles have been sequentially used for decycling. Definition 4: Finally, note that the SD estimated in all three previous definitions is a single number but the researcher would be interested in having a time series to measure fluctuations of the residual. This measure is called V4.

The above measures for the Argentine TOT in 1810-2010, assume the following values. The SD of the logged TOT series V1 = 0.2539[13]. If now the logged TOT are detrended using a cubic polynomial, the resulting SD of the residual is V2=0.1717. Notice it is a very significant reduction compared with V1. In other words, it mimics the fact that if economic agents perceive the trend, this additional knowledge of the behaviour of the TOT reduces their ignorance. It becomes important for empirical estimations of the magnitude, and influence, of TOT volatility, to devise a correct *proxy* of this economic process.

Hence, the natural question is: which of the above best captures empirically the underlying uncertainty about the TOT that economic agents face when devising their consumption, production and investment plans? Certainly V1 does not. Under our conjecture that people plausibly are aware of medium-run and long-term processes, a more relevant measure of uncertainty should also take into account the contributions of local or global trends, such that V2 would be a better choice. Further when cyclical influences are expected to be operative, the appropriate measure would be V3(j). The underlying idea is that an economic agent is more likely to perceive the most important cycles. In this case, how many cycles do agents take into account? When does an agent stop incorporating information?

13 Given the mean value of the logged TOT equal to 4.540656, the CV is equal to 5.570570E-02.

Since the first two measures are common use of the SD, let us now explain the procedure for estimating the movements of the variable under definitions V3 and V4. When we remove the cycle C1, the one which carries the highest explanatory power, the SD of the filtered series is denoted by V3(1) -and provides a particular measure of variability. If we additionally remove the second most important cycle C2, the ensuing SD is labelled V3(2). In like vein, we continued by sequentially removing the information contained in the third, fourth, fifth and sixth, most important cycles. The measures of variability so obtained will be labelled V3(3), V3(4), ...,V3(J) up to a maximum J=102.

To get a feel, V3(1)=0.146 and V3(2)= 0.137. Both measures of volatility are smaller than V1 and V2.

The representation of perceived cycles cannot assume that all cycles are known by people. In our empirical procedure that means that a criterion is necessary to set an upper bound for the number of cycles to be considered. To this end, the estimation of the detrended and decycled residuals can be oriented both on statistical and economic grounds.

On the economic side there is a point of the ability and the costs of gathering information. For our purposes it is enough to say that in any case information is incomplete if it is costly, which means to assume that in our method only some of the cycles would be "bought" by people. Only the most valuable can be assumed to be perceived. Is there an objective statistical method to define which cycles are to be taken into account for decycling? Only the most important ones. But, which are they? A related question is whether the different methods of estimating volatility are rank-preserving[14]. Since much of the research on volatility is devoted to comparisons between countries which exhibit different degree of volatility, a related question is how sensitive this ranking of volatility is to the choice of method.

4.2 Decomposition of TOT and GDP series

For all the empirical applications we use the following sources: for period 1810-1985, Ferreres (2005) and for period 1986-2010 INDEC (www.indec.gov.ar).

4.2.1 **The identification algorithm**

The empirical estimation of periodicities in time series may be carried out following two strands of the literature. The first one, the Box-Jenkins time domain approach based on ARMA or ARIMA modeling, posits the presence of stochastic processes as its starting point. Although periodicities are taken into account, no breakdown of the individual contributions of specific regular cycles is provided. The second one, the Fourier decomposition frequency domain approach, provides a breakdown of a given series into cosines and sines which capture the relative importance of cycles of different periodicities or frequencies.

We have adopted this latter approach in order to estimate cyclical components. We must first introduce some notational conventions.

$$Y_{1t} = Log\left(TOT_t\right) \qquad (4.1)$$

This is the series that we take as our starting point in the modeling process. We next apply ordinary least squares (OLS) to regress Y_{1t} on an intercept, time trend (t), t squared, and t cubed. The residual of this regression labeled Z1t is therefore the detrended value of log TOT at time t.

$$Z_{1t} = Y_{1t} - \hat{Y}_{1t} \qquad (4.2)$$

The standard deviation of Z_{1t} over the whole period 1810-2010 which amounts to 0.172 provides a measure of TOT "variability".

14 As an illustration of the issue, Pritchett (1991) argues that regarding the question of the outward orientation of developing countries, alternative definitions of openness generate different rankings.

We next follow Bolch and Huang (1974) to decompose this $Z_{\mathbf{1t}}$ series into its periodic components, which allows us to highlight the role of cycles, using:

$$Z_{1t} = \sum_{i=0}^{101} \alpha_i \cos\left(2\pi i \, t/T\right) + \sum_{i=0}^{101} \beta_i \sin\left(2\pi i \, t/T\right) \qquad (4.3)$$

A new variable R_{1t} is defined as:

$$R_{1t} = Z_{1t} - Cyclical\ Correction(k)_t \qquad (4.4)$$

Where the second term on the right-hand side denotes the combined contributions of k different cycles. Consequently, R_{1t} stands for the detrended, and k-decycled, residuals, whose SD measures TOT volatility in a given span of time.

Formula (4.3) looks like an ordinary regression equation but for the fact that no error term is present, the reason being that a complete breakdown into cycles is accomplished by the Fourier approach. The cosine, $\cos(2\pi i \, t/T)$, and the sine, $\sin(2\pi i \, t/T)$ regressors, capture the contribution of each cycle i associated to period (T/i). The value of t in the formula ranges from 1 to 202[15]. In a general setting, 101, the upper limit of the summations for **i**, should be replaced by the largest integer less than or equal to the ratio [T/2].

The values of the estimated coefficients $\hat{\alpha}_i$ and $\hat{\beta}_i$ are associated with the cosine and the sine terms respectively. Our estimation procedure is akin to an ordinary least squares regression, the only unusual feature being that the resulting residual sum of squared is equal to zero, since the estimated cycles account exhaustively for the $Z_{\mathbf{1t}}$ series[16].

4.2.2 **Cyclical patterns of TOT**

The first two columns of Table 4.1 report the value of i and its associated period span of the cycles in years (rounded to two decimals) T/i. Columns three and four, in turn, report the relative contribution to the explained sum of squares in decreasing order of importance.

Notice that if you multiply out the figures in the two first columns you obtain T=202. The reason is that the second column indicates the period of each specific cycle isolated by the technique; the first column on turn represents the number of complete cycles of this particular period that can be observed when you have 202 yearly data points.

When i=zero, not shown, the corresponding period is equal to infinity (the zero frequency).

If i=1, a potential cycle whose period is P=T/i=202/1=202 (years) is captured, if in fact such a 202-year cycle exists in the data. Obviously, this cycle can be observed only once in 202 years from 1810 to 2011.

At the other end of the range, when i=101, the period is P=T/i=202/101=2 (years), associated with the so-called Nyquist frequency.

15 The time index t goes from 1 to 202, to account for the yearly data spanning the period 1810-2011, such that T=202, and i is an integer ranging from zero to 101. The only reason why 2011 was included in this exercise is that the data point of the year 2010 was repeated for 2011, because the computer algorithm we use must operate with an even number of observations, and the data for 2011 is not yet available.

16 For practical reasons, the use of this algorithm is not advisable when T is very large. A second alternative estimation procedure is available. See Bolch and Huang (1974, page 278).

By the same token, it is apparent that this 2-year cycle would be observed 101 times in the 202 years span of time under study.

Since most of those estimated cycles explain a very small fraction of the total variance, only selected periods were reported in Table 4.1, showing those few whose contribution are relatively most important for the logged TOT until a cumulative explanatory power of 71.38 percent is reached.

It is readily apparent that for i equal to 7, the cycle period is 28.86 years, and the relative contribution of this particular cycle is 26.52%, significantly greater than that contributed by the following 40.40-year cycle which only amounts to 8.08%. The last line of Table 4.1 reports the values associated with the 9.62-year cycle which only accounts for a mere 1.95% of the total sum of squares.

Table 4.1
Estimates of cyclical patterns of log TOT: Argentina 1810-2010.
Values of i range from 0 to 101.

i	Period (T/i)	$\hat{\alpha}_i$	$\hat{\beta}_i$	Contribution to TSS (in percentage)	
				Relative	Cumulative
7	28.86	-0.074277	-0.100609	26.52	26.52
5	40.40	-0.048533	0.049061	8.08	34.59
3	67.33	-0.011200	0.060851	6.49	41.09
8	25.25	0.032471	-0.048437	5.77	46.85
15	13.47	0.001766	-0.053962	4.94	51.8
11	18.36	-0.028542	-0.037448	3.76	55.56
17	11.88	0.019214	-0.039233	3.24	58.79
32	6.31	0.033478	-0.027366	3.17	61.96
12	16.83	0.039866	-0.004198	2.72	64.69
2	101.00	0.011674	0.036616	2.5	67.19
10	20.20	0.019372	-0.030821	2.25	69.44
21	9.62	-0.015295	0.030226	1.95	71.38

Note: TSS stands for Total Sum of Squares.
Data Source: Ferreres (2005) and INDEC web page. Own calculations base on Bolch and Huang (1974), Chapter 8, Section 8.2 The Fourier series and the correlogram, pp. 275 – 283.

4.2.2.1 Cyclical patterns of GDP

Using the same procedure as with the TOT series, the logged GDP and the detrended are defined as:

$$Y_{2t} = \log(GDP_t) \qquad (4.1')$$

$$Z_{2t} = Y_{2t} - \hat{Y}_{2t} \qquad (4.2')$$

As before, applying OLS, Y2t was regressed on an intercept, a time trend (t), t squared, and t cubed. The residual of this regression, labeled Z2t, is the detrended value of log GDP at time t.

As already stated the standard deviation of Z2t over the period 1810-2010 which amounts to 0.1520 provides our measure of GDP variability. We next follow Bolch and Huang (1974) to decompose this detrended Z_{2t} series into its periodic components, which allows us to highlight the role of cycles, using:

$$Z_{2t} = \sum_{i=0}^{101} \alpha_i \cos\left(2\pi i \, t/T\right) + \sum_{i=0}^{101} \beta_i \sin\left(2\pi i \, t/T\right) \qquad \textbf{(4.3´)}$$

All the symbols used in the preceding formula have been defined before.

Table 4.2 displays the relevant information for GDP cycles.

Table 4.2
Estimates of cyclical patterns of log GDP: Argentina 1810-2011.
Values of i range from 0 to 101.

i	Period (T/i)	$\hat{\alpha}_i$	$\hat{\beta}_i$	Contribution to TSS (in percentage)	
				Relative	Cumulative
2	101.00	0.166078	0.007773	57.70	57.70
3	67.33	-0.033491	0.047847	7.12	64.82
10	20.20	0.045337	-0.007748	4.42	69.24
5	40.40	0.041753	0.006052	3.72	72.95
1	202.00	-0.035759	-0.002552	2.68	75.63
12	16.83	0.031626	-0.011927	2.38	78.02
4	50.50	0.030783	-0.001724	1.98	80.00
6	33.67	0.022053	-0.021532	1.98	81.99
14	14.43	0.026946	-0.003827	1.55	83.53
7	28.86	0.019666	-0.018753	1.54	85.07
16	12.63	0.023526	-0.010475	1.38	86.46
23	8.78	0.000847	-0.023375	1.14	87.60

Note: TSS stands for Total Sum of Squares.
Data Source: Ferreres (2005) and INDEC web page. Own calculations base on Bolch and Huang (1974), Chapter 8, Section 8.2 The Fourier series and the correlogram, pp. 275 – 283.

The following comments are in order.

The most important cycle, a long 101-year cycle, which can be observed only twice, accounts for 57.70 percent of the total sum of squares. Another very long 202-year cycle is statistically picked up by the estimation, but both cycles should not be taken mechanically since their economic relevance has not a clear interpretation. For example, is it meaningful to assume that the 202-year super-cycle exists as a long run process of GDP? From the statistical point of view, in turn, this particular cycle is observed only once; we cannot assume that it is a true underlying cycle that will repeat itself regularly in the course of the next centuries.

The contributions of the remaining cycles are much smaller, but also may make more economic sense, as far as it is more plausible that they can be observed in the period of time relevant for people.

4.3 Economic interpretation of the cycles of different frequency

4.3.1 How to choose the theoretical Fourier cycles to be computed

The next step is to determine a suitable selection of cycles which could conceivably be relevant pieces of information, taken into account by economic agents such that the unexplained portion of the world represents the degree of uncertainty regarding consumption, saving, and investment decisions. We argue that a sensible approach to go about the degree of ignorance is to determine criteria to define the residual detrended and decycled series which provides the measure of the remaining uncertainty, the variability of which would represent the volatility of the variable.

A choice has to be made about how many of the theoretical cycles are to be removed from the detrended series. Without a theoretical model to determine how agents collect and process information, a possible exercise is to sequentially estimate the volatility with gradually accumulating the explanatory power of successive cycles.

At this point we made a choice by extracting the first six most important cycles in the TOT series and the first seven in the GDP series. Even though these end points were first selected somewhat arbitrarily, by assuming that economic agents are aware of approximately 55% of TOT variability and 80% of GDP variability, the results have proven to be robust to different choices of end points.

A complementary perspective of the relative contribution of cycles of different frequency is to break down the total variance in brackets typically associated to three different kinds of phenomena. In line with an usual convention in the literature, two to three-year cycles belong to the realm of short-run or macroeconomic processes; those between more than three and eight years are called “business cycles”; and periods longer than eight years are interpreted as long-term. This type of aggregation can be also obtained from the Fourier decomposition: 79.20% for cycles longer than 8 years, 15.74% for those between 3 and 8 years, and, finally, 5.06% for cycles between 2 and three years.

The following comments are in order. Firstly, the cycles estimations are in line with previous findings in Arrufat, Díaz Cafferata and Viceconte (2011) performed for Argentina for the period 1870-2009 via power density spectrum estimations (using the Parzen and Bartlett windows and alternative values of the truncation lag). Roughly, periods between 2 and three years, between 3 and 8 years, and cycles longer than 8 years, accounted for 7.5%, 18.5% and 74% of the total detrended log TOT variance pointing to the need to go deeper into the study of the economic presence and economic meaning of possible long cycles[17]. In particular, this sort of estimation technique is not risk-free, since the finding of particular cycles might be unduly influenced by extraordinary surges and drops caused by few singular events, such as the two World Wars, rather than the outcome of a cyclical economic phenomenon. Nowadays, there does not seem to be a widespread consensus concerning the existence and economic relevance of very long cycles such as Kondratieff’s. See Appendix for more elaboration on these important issues.

4.4 How to remove one or several specific cycles. The residuals of TOT

4.4.1 **Estimating TOT and GDP volatility**

Once the cycles of different frequency have been estimated, the “decycled” series are obtained by subtracting from the original (logged) time series, one or more cycles, as deemed appropriate in line with the analytical purposes at hand.

For instance, given the information contained in Table 4.1, it is natural to remove first the most important cycle found in the TOT series (which period is 28.86 years).

It must be stressed that the particular cycle which we intend to remove is associated with $i=7$, and that the values of $\hat{\alpha}_7 = -0.074277$ and $\hat{\beta}_7 = -0.100609$ are both negative. Consequently the decycled TOT_t series at this stage is computed as follows:

[17] Similar estimations of TOT power density spectrum for Australia, Canada, New Zealand in 1870-2009 and for Uruguay in 1870-2008 are provided in that paper.

$$DecycledTOT(1)_t = Z_{1t} + 0.074277\cos\left(2\cdot\pi\cdot7\cdot {}^{t}\!/_{202}\right) + 0.100609\sin\left(2\cdot\pi\cdot7\cdot {}^{t}\!/_{202}\right)$$

Hence, each and every yearly value of the "DecycledTOT(1)$_t$" is the residual where the value for year **t** of this 28.86 cycle has been removed.

In the same vein, we may additionally remove the second most important cycle, the one associated with the 40.40-year period (i.e. with i = 5). The calculation is:

$$DecycledTOT(2)_t = DecycledTOT(1)_t + 0.048533\cos\left(2\cdot\pi\cdot5\cdot {}^{t}\!/_{202}\right) - 0.049061\sin\left(2\cdot\pi\cdot5\cdot {}^{t}\!/_{202}\right)$$

Note that the "DecycledTOT(2)" is the residual obtained when the trend and the 28.86 and the 40.40-year cycles have been removed. The two previous examples have proceeded in a sequential fashion. But obviously, exactly the same result may be obtained in a single step calculation[18].

If we were to routinely apply this procedure until all the cycles were extracted exhaustively, we would end up with a series made up of zeros for each point in time, since the Fourier approach produces a complete breakdown with cycles of different periods measured in years, as i goes from zero to 101. The estimation identifies the whole set of all cycles present in the data, and their relative contribution of each of them to the total sum of squares of the variable Y_t. A natural question arises. If we proceed via cumulative decycling, where is the cut-off point; is there an optimal number for cycles to be removed?

Summarizing, the detrended and decycled residuals of a variable are calculated, for a given choice of the cycles which are postulated as representative of the cycles perceived by economic agents.

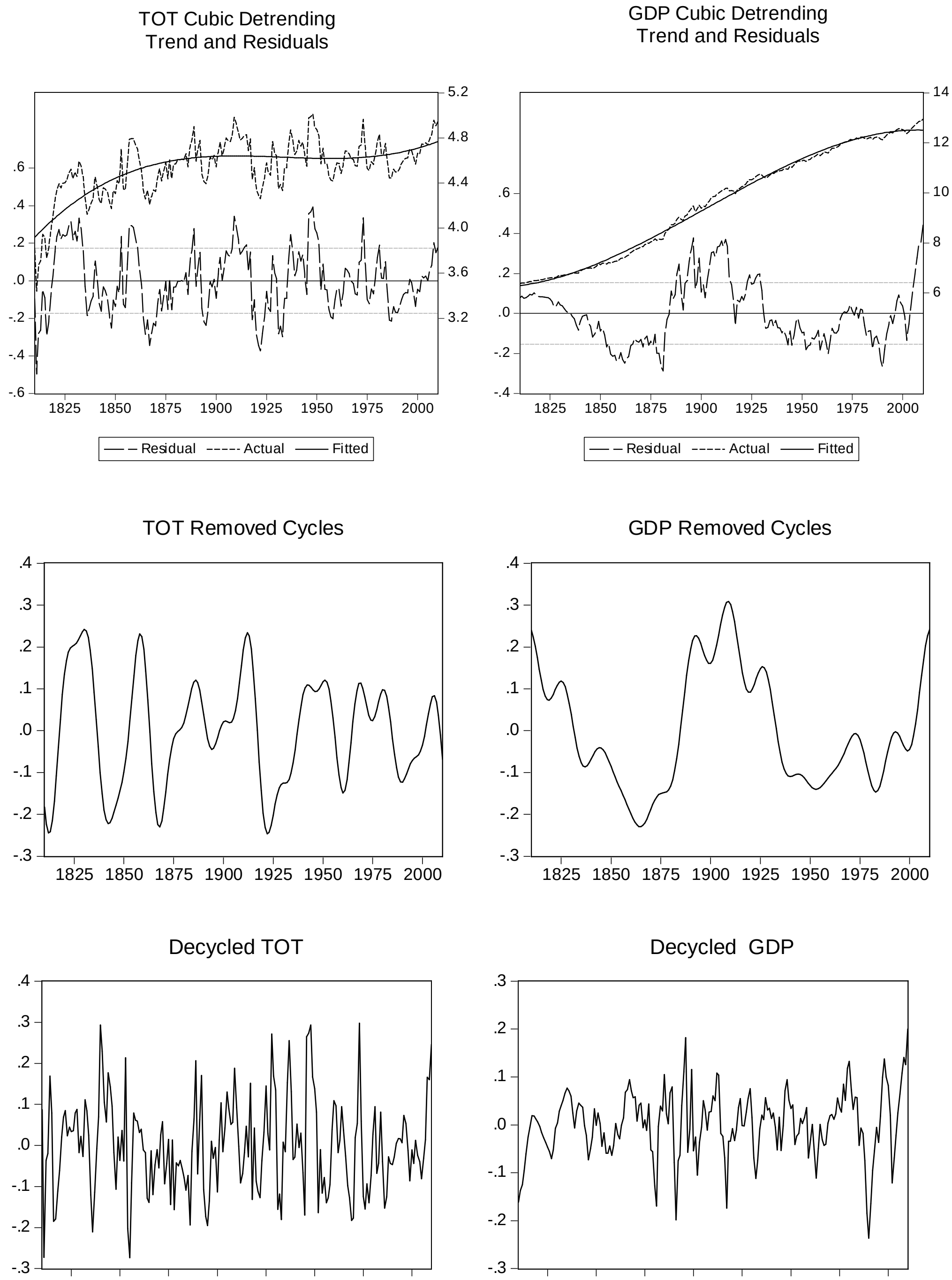
$$R_{1t} = Y_{1t} - \hat{Y}_{1t} - Cycle_{1t} \qquad (4.4)$$

A positive value of R1t, at any time, means that this particular year the unexplained portion of the TOT movements has risen, i.e. a positive "surprise" for the economy.

[18] One simply would have to proceed as follows:

$$DecycledTOT(2)_t = Z_{1t} + 0.074277\cos\left(2\cdot\pi\cdot7\cdot {}^{t}\!/_{202}\right) + 0.100609\sin\left(2\cdot\pi\cdot7\cdot {}^{t}\!/_{202}\right) + 0.048533\cos\left(2\cdot\pi\cdot5\cdot {}^{t}\!/_{202}\right) - 0.049061\sin\left(2\cdot\pi\cdot5\cdot {}^{t}\!/_{202}\right)$$

Figure 4.1
Logged, cubic detrending, and decycling, of TOT and GDP.
Argentina 1810-2010.



The whole procedure can be visualized in Figure 4.1. The left column refers to TOT, and the right one to GDP, each with three panels.

The first two upper panels display the logged values of TOT and GDP; the cubic trend, and the detrended residuals. The next two middle panels, plot the “removed cycles” i.e. the combined contributions of the most important estimated cycles, 6 and 7, respectively for TOT and GDP. This could be regarded as the part of the evolution of the variables along time that belongs in people´s information set. This is what results from the particular exercise we perform**:** part of the evolution of TOT and GDP is represented as explained by the trend and part by the perception of the presence of cycles.

In the two lower panels we plot the decycled TOT and GDP series, once the trend and the selected cycles were removed, which stand for a proxy of the remaining ignorance. From these residuals we estimate volatility as follows. Not formal estimation of a model, but one that is useful to provide objective alternative measures of the "volatility" variable for quantitative research.

Table 4.3 shows estimates of the variability and volatility of both the TOT and GDP detrended series.

The proxy for variability is the standard deviation of the detrended residual series; while a more refined measure of volatility is estimated by the SD of the decycled residual series. According to definitions already presented V1 is based on Z_{1t}, for log TOT (at t) and Z_{2t} for GDP, also at time t.

As can be seen in the table, when more knowledge on the nature of cycles is attributed to the economic agents, the measure of volatility drops monotonically. For example, supposing that agents only recognize the 50% most important cycles of TOT (associated with *i*=15), volatility would be 0.118, whereas if agents could extract 60% of those cycles (corresponding to *i*=32), then volatility would drop to 0.104.

The final step is to determine the volatility of a variable at every point in time **t** by calculating the standard deviations in a five-year rolling sample using the decycled series estimated in the previous section. It is possible to identify two sub periods of higher TOT volatility occurring in (1837-1958) and (1949-1980). While the GDP shows a first period of relative more volatility between 1890 and 1900 and a second at the end of the sample.

Table 4.3

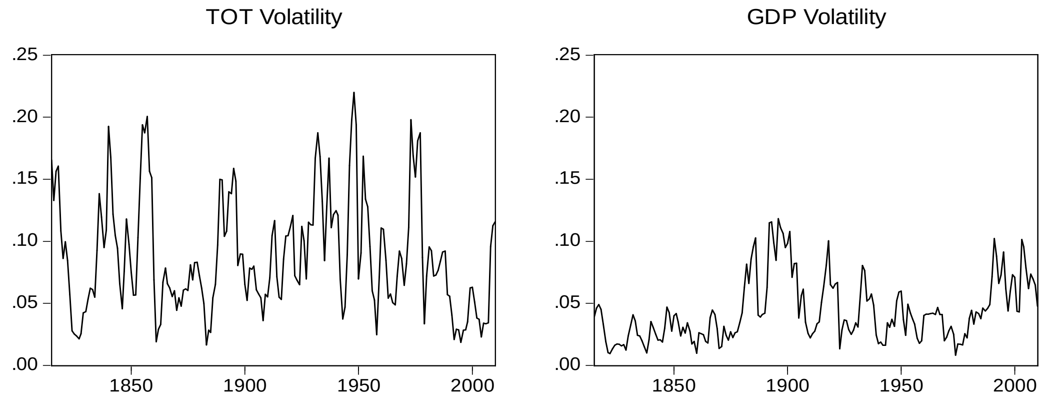
Measures of volatility (V3) for TOT and GDP based on cubic polynomial detrending**.**

Number of cycles removed	TOT				GDP			
	i	Period (T/i)	SD	TSS	i	Period (T/i)	SD	TSS
0	-	-	0.172	5.925	-	-	0.152	4.643
1	7	28.86	0.146	4.313	2	101.00	0.099	1.970
2	5	40.40	0.137	3.805	3	67.33	0.089	1.606
3	3	67.33	0.130	3.411	10	20.20	0.084	1.419
4	8	25.25	0.124	3.087	5	40.40	0.079	1.259
5	15	13.47	0.118	2.794	1	202.00	0.074	1.112
6	11	18.36	0.112	2.553	12	16.83	0.071	1.012
7	17	11.88	0.108	2.372	4	50.50	0.068	0.929
8	32	6.31	0.104	2.201	6	33.67	0.065	0.841
9	12	16.83	0.101	2.058	14	14.43	0.062	0.775
10	2	101.00	0.097	1.913	7	28.86	0.059	0.706
11	10	20.20	0.094	1.787	16	12.63	0.056	0.644
12	21	9.62	0.091	1.665	23	8.78	0.054	0.589
13	13	15.54	0.088	1.571	17	11.88	0.051	0.535
14	33	6.12	0.085	1.471	15	13.47	0.049	0.487

Note: SD and TSS stands for standard deviation and total sum of squares respectively.
Source of data: Own estimations

Figure 4.2

TOT and GDP Volatility (5-year rolling sample): Argentina 1815-2010.



4.4.2 **Order of integration of TOT and GDP volatility**

Measures of variability based on HP detrending:

A fairly customary procedure frequently employed in the macroeconomics literature is to detrend a series by using the Hodrick-Prescott procedure using lambda equal to 100 in the case of annual data. Needless to say, it is to be expected that this approach, as opposed to cubic detrending, follows more closely the movements of the variable, and consequently, focuses attention on the detection of shorter-period cycles.

In keeping with the procedure outlined for cubic detrending, once the HP detrended residuals have to be computed, use is made of the Fourier algorithm to break down those residuals in terms of cosines and sines and estimate what proportion of the total sum of squares is contributed by cycles of different periods. Once the, say, 14 most important cycles have been estimated we are in a position to compute the SD as a measure of variability (or volatility) when the first most important cycle has been removed, when the first two most important ones have been removed, etc.

Table 4.4
Measures of volatility (V3) for TOT and GDP based on HP filter detrending.

Number of cycles removed	TOT				GDP			
	i	Period (T/i)	SD	TSS	i	Period (T/i)	SD	TSS
0	-	-	0.172	2.150	-	-	0.152	0.548
1	20.9979	9.62	0.1	1.991	2	20.2	0.051	0.513
2	32.0127	6.31	0.096	1.846	3	14.43	0.049	0.480
3	14.9963	13.47	0.093	1.723	10	8.78	0.047	0.449
4	17.0034	11.88	0.09	1.632	5	16.83	0.046	0.418
5	18.0036	11.22	0.088	1.547	1	12.63	0.044	0.387
6	46.0137	4.39	0.085	1.465	12	18.36	0.042	0.358
7	19.0028	10.63	0.083	1.387	4	5.77	0.04	0.329
8	12.9987	15.54	0.081	1.313	6	10.1	0.039	0.303
9	33.0065	6.12	0.079	1.242	14	11.88	0.037	0.278
10	12.0024	16.83	0.076	1.173	7	9.18	0.036	0.262
11	51.0101	3.96	0.075	1.121	16	11.22	0.035	0.247
12	22.0044	9.18	0.073	1.070	23	3.26	0.034	0.233
13	11.0022	18.36	0.071	1.026	17	13.47	0.033	0.218
14	23.0068	8.78	0.07	0.982	15	6.52	0.032	0.205

Note: SD and TSS stands for standard deviation and total sum of squares respectively.
Source of data: Own estimations

Detrending was carried out by the use of the Hodrick-Prescott filter and subsequent decycling by the Fourier approach. Notice that in the first line only the first most important cycle has been removed. In the second one, the first two most important ones have. And so on. In each successive line the following most important cycle is additionally removed. It is straightforward to notice that as we move down the fourth or seventh column in that table, the measure of ignorance is becoming smaller because one additional cycle has been removed. An important point to notice is that the newly estimated cycle decomposition has periods which are significantly shorter than was the case with decycling based on cubic polynomial detrending. For example, in Table 4.4, the four most important cycles are associated with 9.62, 6.31, 13.47, and 11.88-year periods for TOT. Their counterparts in Table 4.3 amount to 28.86, 40.40, 67.33, and 25.25. It is readily concluded that the latter figures are between two to six time larger than the former. Analogous results apply to GDP periods. These differences in orders of magnitude should not come as a surprise. HP detrending relies on local trends whereas, by its nature, cubic detrending emphasizes global trends. This is compounded by the very substantial length of the time period under study. Consequently detrended residuals obtained by each of these approaches are liable to exhibit starkly different cyclical variation. From the decision maker’s point of view, we should stress that the HP approach has one important advantage: it is more plausible for the measurement of uncertainty, and therefore volatility, to be estimated on the basis of short-length cycles which can be observed with greater frequency and can mimic the data more closely.

4.5 Testing for unit roots

Finally, we address the stationarity of both TOT and GDP volatility series. We applied the Augmented Dickey-Fuller (1981) and the Phillips-Perron (1988) unit root test. When implementing the ADF regression, should one include only an intercept, an intercept and a trend, or neither? The literature suggests that it might seem reasonable to start with the less restrictive of the plausible models (which includes intercept and trend). Unit root tests have low power to reject the null hypothesis; hence, if the null hypothesis of a unit root is rejected, there is no need to proceed any further (Enders 2004).The results of the ADF and Phillips-Perron tests for both series are shown in Table 4.5. As testing results may vary depending on the criterion used to select the number of lags, we used the Bayes Information criterion (BIC), and the Akaike information criterion (AIC). With BIC and AIC, the unit root null hypothesis is rejected at the 1% level of significance for the TOT volatility series, and at the 5% level of significance for the case of GDP volatility. The outcomes of the Philips-Perron tests are in line with these results; the null hypothesis of a unit root is rejected, for both series, at the 1% significance level.

Table 4. 5

Unit Root Tests: Augmented Dickey-Fuller and Phillips Perron.

Volatility measures based con cubic detrending

Unit Root Tests: Intercept and trend

Null Hypothesis: the variable has a unit root

	Volatility TOT p value	Volatility GDP p value
ADF (AIC)	0.000	0.015
ADF (BIC)	0.000	0.043
Phillips Perron	0.001	0.003

Note: ADF stands for Augmented Dickey Fuller test; AIC and BIC are Akaike and Schwarz information criteria respectively.

Very similar results were obtained when testing for unit roots with volatility measures based on HP-detrended residuals and therefore we will not show them for the sake of brevity.

5. Association between TOT volatility and GDP volatility

In the previous section we presented a detailed account of the TOT and GDP volatility under different empirical approximations. It may prove useful to employ the estimated series of volatility to get a hint as to how relevant the choice of alternative definitions may be for the estimation of causality.

Hence, does the choice of a particular detrending and decycling method make a difference for the identification of volatility? To answer this question we compare VAR estimations. Alternative measures of volatility, obtained by detrending and decycling, are statistically appropriate, and also bear plausible economic interpretation. Hence, it is advisable to know how the choice of method for estimating the residuals may affect causality. As seen in sections 2 and 3 empirical research, across countries and time periods, has repeatedly found that internal and external factors bring about very heterogeneous effects on GDP volatility. Some external variables that play a role are the TOT, the price of exports, the degree of openness, the international rate of interest and the risk premium, whether the international assets' position is positive, or negative; the degree of openness; or the fixed or flexible exchange rate regime.

We carry out an exercise to get a feel for whether the estimations of the link between the volatility of TOT and GDP are robust to alternative empirical measures of volatility. Without an economic model pointing out a specific causality to be analyzed, different possible behavior reflecting the presumption that the volatility of TOT may influence the volatility of GDP may be tested. This can be usefully done using different empirical econometric models, and including different control or additional variables. The state of the art is less than fully satisfactory, and there is not a canonical model including variable definitions or functional relationship to handle country cases. All in all, the empirical estimations are useful to contribute to a growing body of knowledge.

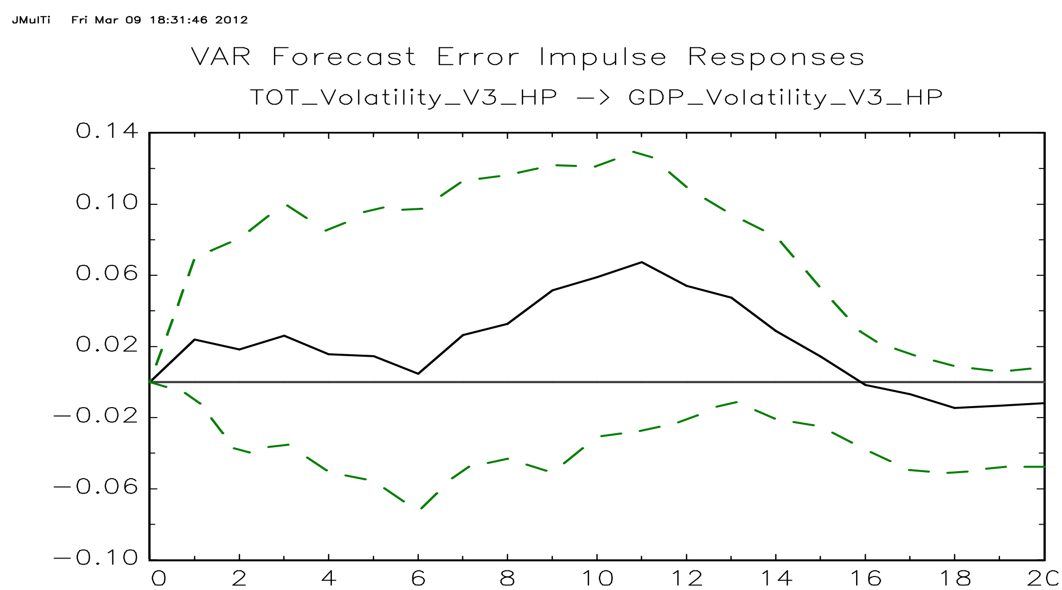
We resorted to tackle a standard case. Note that with HP and cubic detrending of two variables, TOT and GDP, there are four possible different combinations of volatility, as defined by what we call "variability two" (V2), i.e. the one based on detrended residuals. There are in like vein four different V3 combinations.

We have been very parsimonious with regard to the model specification. Just two control variables and a few dummies were included because our interest is to explore the role of definitions rather than pinning down the full complexity of the effects at work. As a benchmark, a simple VAR model with TOT and GDP volatilities was estimated. We employed the programme JMulti[19]. We resorted to the usual BIC or AIC to select the appropriate number of lags for the estimations. Each equation is allowed to have an intercept. No exogenous variables were included. As to the ordering of the variables we adopted the standard small open economy assumption of exogenous terms of trade, placing TOT volatility first.

Figure 5.1 displays the forecast error impulse response function arising from of a once-and-for-all 1-standard deviation shock to TOT volatility on output volatility. We show that impact over a span of twenty years. The full line shows the impacts themselves whereas the upper and lower dotted lines provide their 95% confidence intervals.

Figure 5.1

VAR estimations: TOT and GDP volatility. Argentina 1810 - 2010



VAR specification: Included variables: TOT_Volatility_V3(ncr=14)_HP

GDP_Volatility_V3(ncr=27)_HP

where ncr is the number of cycles removed.

As seen in the figure, most of the impacts are positive, a result in line with our presumptions. However the 95% confidence intervals, shown as the upper and lower broken lines contain zero, that is, impact values, although mostly positive, are not significantly different from zero at the 5% level of significance.

To assess how sensitive the results may be to alternative measures of volatility we estimated the VAR model replacing the definition of volatility. We employed alternatively the volatility measures stemming from using the cubic detrending approach, instead of HP, followed by

19 See Lütkepohl and Krätzig (2004).

the sequential removal of the 6, and 7, most important cycles, for TOT, and GDP, respectively. Namely, the definition changes either because of the choice of the detrending method, or the decycling, or both.

With a few minor exceptions, our overall findings generate impact responses which are mostly positive, with heterogeneous quantitatively values. In all cases, the pertinent 95% confidence intervals revealed that they were not significantly different from zero: this could arise either because the true relationship is indeed weak, a feature commonly reported in the literature, or because we have adopted very parsimonious specifications.

A few considerations at this stage are the following:

i. The TOT used in this paper are the barter external TOT. In Argentina there has been historically a gap of variable size between internal and external TOT. Trade policy may alter the economic incentives by levying export taxes, for example. Berlinski (2003) showed that in the 1920’s domestic terms of trade doubled the foreign prices, whereas at the beginning of the 1950’s the opposite was true.

ii. When sudden surges in TOT take place, severe distributive conflicts arise because Argentina is an important exporter of wage goods. A sudden and significant improvement in TOT usually calls for the design and implementation of compensating measures.

iii. The relationship between TOT and GDP volatility may be subject to threshold effects, which by its very nature, cannot be properly tackled within a linear framework.

iv. Wolf (2004) argued that the uncertainty proxied by SD might be better measured by resorting to a weighting procedure. Instead SD is computed by assuming symmetry.

v. Our measures of volatility are based on yearly data. It could be the case that measurements based on, say, quarterly data, might provide better estimations.

vi. There is a very stringent limit on the availability of control variables like the degree of openness. If only the exports to GDP ratio are taken as the relevant variable, the estimations may be carried out for the whole period 1810 – 2010. If, on the other hand, exports plus imports were used to measure the degree of openness, data availability limitations would restrict the sample period to 1854-2010.

vii. Similar considerations apply when ones tries to introduce investment as a control variable.

viii. So far our analysis has been carried out on the basis of the full sample. Further research might point to the convenience of segmenting our sample. Testing of structural breaks might point out the existence of sub periods.

6. Synthesis and concluding remarks

In this paper we highlight the fact that alternative definitions of volatility may be used to measure the degree of uncertainty in the evolution of an economic variable. In empirical research, to quantify uncertainty of a time series variable, the literature resorts to associate knowledge of people with the predictions forthcoming from econometric modeling of the time series. And the degree of ignorance remaining about how the variable evolves is associated with that part of the time series that has not been explained by the model, i.e. the residuals. This general idea, despite its intuitive appeal, is subject to several qualifications.

The first one is that the concept does not provide a unique admissible objective measure. In consequence, there is a priori to be expected that the choice of a specific method might impinge on the magnitude, and other statistical properties of the volatility of a variable. Some subjectivity in the portrayal of the stylized facts, as well as on the determination of causality thereof, may creep in. Other qualifications found in the literature warn us about paying due attention to particular circumstances such as the possible asymmetry for upward or downward movements, the existence of nonlinearities, interactions between variables, or the disparate responses to extraordinary large fluctuations. Another methodological issue is related with the approaches to time series. The usual representation in the time domain views the evolution of a variable in terms of trends and cycles; the stationarity of the series in turn gives rise to the distinction between permanent or transitory shocks. The behavior and impact of volatility has been addressed in the literature as a line of analysis distinguished from the degree of persistence (permanent or transitory) of shocks.

By its nature the volatility of a variable is a recurring fact, and in this perspective belongs to phenomena that cannot be described with the distinction between permanent or transitory shocks, but rather in the context of cycles. The appropriate approach is, in this case, the frequency domain we use in this paper. Namely, to empirically identify the volatility of the Argentine TOT, the series were logged, detrended, and decycled, mimicking the perception of people about the movements of the variable. The whole historical period of two centuries (1810-2010) was considered for the estimations: this procedure carries the implicit assumption that there are relevant permanent features of the Argentine economy, associated with its land abundance and concentration of exports on agricultural commodities, which are operating throughout the complete sample. Further research will address formally the possible presence of structural breaks identifying specific sub-periods if need be.

As regards the possible causality from TOT volatility to GDP volatility, VAR estimations for the whole 1810-2010 period show weak, but still consistent, evidence that the volatility of TOT raises the volatility of GDP. Again, a natural extension is to identify relevant sub-periods. Firstly, identification of statistical breaks in TOT volatility. Secondly, a presumption of asymmetry, such that positive shifts in TOT have higher impact on GDP growth in periods of long run growth, associated with stimuli to invest is possible. Finally, further modeling with regard to control variables should be a natural extension.

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