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Terms of trade cycles in extreme land abundant countries, 1870-2009. Spectral analysis

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TERMS OF TRADE CYCLES IN EXTREME LAND ABUNDANT COUNTRIES, 1870-2009. SPECTRAL ANALYSIS[1]

ABSTRACT

Spectral analysis is applied to the empirical identification of terms of trade cycles, in the secular evolution, 1870-2009, of a group of extreme-land-abundant countries: Argentina, Australia, Canada, New Zealand, and Uruguay. Estimates of the power density spectrum functions produce statistically significant spectral peaks associated with long-run cycle periods between 24 and 56 years, with a mode of about 28 years for all five countries, and the variance decomposition shows that these long-run cycles account for a very substantial fraction, between 68% and 83%, of the TOT total variance. These results are very robust to changes in the choice of truncation lag, as well as to the type of spectral window (Parzen and Bartlett) used in the estimations.

Key words: terms of trade; cycles; land abundance; policy; export specialization; volatility; spectral analysis; frequency domain; Argentina, Australia,Canada, New Zealand, Uruguay.
JEL: C22, F10, F11, F14, F44.

RESUMEN

Mediante aplicación del análisis espectral se descompone el ciclo empírico de los términos de intercambio en ciclos teóricos periódicos, para un grupo de países que denominamos "de extrema abundancia de tierra". Para Argentina, Australia, Canadá, Nueva Zelanda y Uruguay en el período 1870-2009 las funciones de densidad espectral identifican picos correspondientes a ciclos de largo plazo de sus términos de intercambio de entre 24 y 56 años, con una media de 28 años. La descomposición de la varianza indica que tales movimientos cíclicos de largo plazo explican una fracción sustancial de entre el 68% y el 83% de la varianza total. Los resultados estadísticos son robustos a la elección de los parámetros y del tipo de ventana espectral, Parzen o Bartlett, aplicada en las estimaciones. Implicancias de política apuntan a las restricciones que impone la abundancia de recursos idiosincrásica, al grado de diversificación de exportaciones, y la advertencia que al menos parte de los shocks de términos de intercambio debe ser ajustado.

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

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"The estimation of a spectrum has proved to be, for the statistician, one of the more interesting and difficult estimation problems so far encountered". Granger and Newbold (1997), p.60
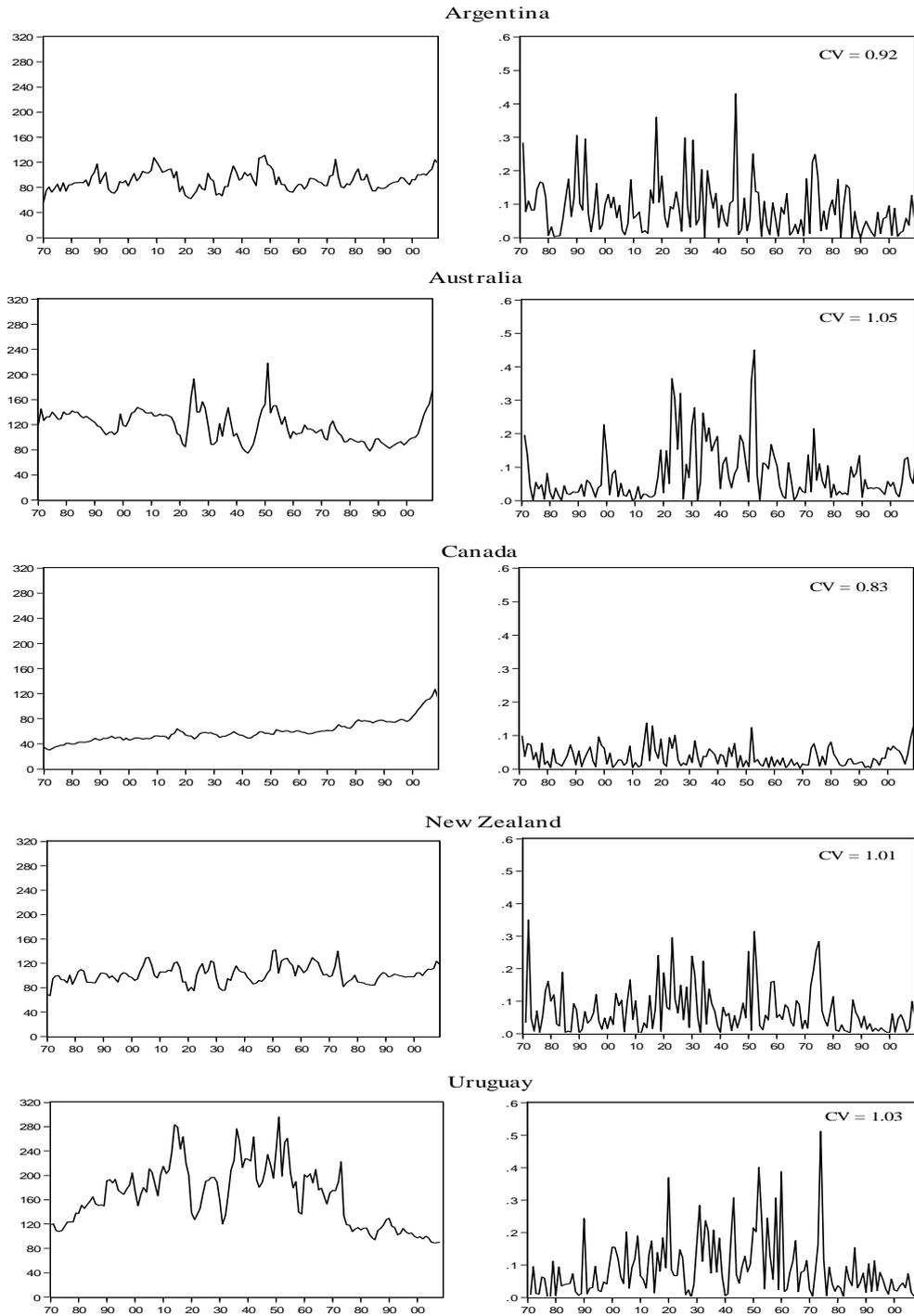
1. INTRODUCTION

This paper applies spectral analysis to the empirical identification of terms of trade cycles in the secular evolution of a group of extreme-land-abundant economies . The spectral analysis estimation allows us to capture, by decomposition of the terms of trade (TOT from now on) cycles, specific features of the high volatility of terms of trade which have been historically regarded as a source of external problems for commodity exporting countries.

In recent times new concerns are the boom in commodity prices, connected to social unrest and uprisings in developing countries; the rise in the price of oil, which produces disturbances in industrialized and oil importing economies; the increased demand for rare earths's raw materials, essential for the design of energy saving technologies, which could confer a significant market power to China and Russia bringing about a potentially significant change in the strategic balance of power in the globalized world. The development of international financial markets, the speculation, and the possibility of hedging against sharp movements in commodities prices are influencing the behavior of contemporaneous cyclical phenomena.

In particular, the pattern, causes and consequences of TOT fluctuations are attracting renewed interest in the literature due to the sharp cyclical movements and seemingly structural breaks in trends in the last decades. How do TOT behave? Does it matter? In the last half-century the behavior and consequences of TOT movements as described by trends, shocks and cycles, has been the subject of intense research both for industrial countries and for developing economies, with increasing attention being devoted to the identification of periodicities in the data, i.e. "cycles", and volatility .

Two stylized facts emerge from the historically observed TOT. The first one is that most TOT time series have been found not to have a clear long run trend, such that prices tend to rise and fall sometimes abruptly around a secular stable value. If this were really the case, long run trends would be less relevant for policy, and attention should be more usefully devoted to the characterization, effects, and policy implications, arising from the TOT cyclical behavior.

FIGURE 1.1

Land abundant countries, 1870-2009: Argentina, Australia, Canada, New Zealand, Uruguay.
Left: Terms of trade index 1951=100 (log scale). Right: TOT variability $|\Delta (\log TOT)_t|$

Argentina

CV = 0.92

Australia

CV = 1.05

Canada

CV = 0.83

New Zealand

CV = 1.01

Uruguay

CV = 1.03

Source: Own calculations. See data sources in the Appendix.

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The empirical approach in this paper tackles specifically the isolation of hidden periodicities in the data, by means of Power Density Spectrum (PDS) estimations, to analize the cycles of TOT in what we call extreme land-abundant countries: Argentina, Australia, Canada, New Zealand, and Uruguay. In Figure 1.1 we provide a bird´s eye view of the TOT and their variability. These widely fluctuating time series pose a significant challenge for researchers, that of uncovering whether there are any systematic components such as trends and trends breaks, cycles, or duration of shocks, which reveal the characteristics of these economies.

For the interpretation of the results we compare spectra of TOT in these countries, finding as an stylized fact that the movements of a country´s TOT appear to be similar on their statistical properties and behavior along time for this type of economy. Why should it happen? We argue that there is a role for "structural" characteristics, in the sense that do not change substantially in long periods, which in the first place explain the concentration of exports and TOT volatility thereof; and in the second place operate as a restriction for policies aimed to correct TOT volatility via export diversification.

This a priori reasoning is based on the assumptions that: a) the external barter TOT of open economies fluctuate; b) similar structures of trade flows of open economies are reflected in parallel TOT evolution along time; c) TOT shocks are exogenous to these countries. In consequence, similar types of countries are subject to similar type of international price shocks, and in consequence the TOT time series have common features which are determined by their idiosyncratic economic structure. A substantial fraction of their international trade is indeed of the type predicted by the Heckscher-Ohlin theory, with a low participation of manufactures on exports, rather than of the modern intra-industry type and specialization in stages of production. Table A.2.2 in the Appendix shows that the share of manufactures in total exports in the five countries of our sample range between 15% in Australia and 47% in Canada, in contrast with shares above 70% in land scarce industrial countries.

Our empirical findings suggest that the 5 countries in our sample are subject to similar exogenous TOT cycles. This accords with the presumption that on account of their extreme land-abundance in land, they have similar traditional sectoral specialization in agricultural commodities, both in production and exports.

A main policy implication of our results is that the extreme land abundant countries face typical policy problems to cope with TOT movements, which are fairly exogenous for these economies, both because they generally have low (though usually not null) power in the international markets for agricultural commodities, and because land abundance itself restricts the incentives to export a more diversified basket of goods.

Is sectoral diversification a possible solution? Maybe not because the underlying reason why there has been limited diversification is that the incentives to allocate resources to investment and production activities are associated with the high productivity of the natural resource. These economies remain sectorially specialized through time and consequently subject to the cycles of agricultural commodities prices.

Our intended contribution is to provide systematic evidence on TOT cycles by means of spectral analysis in the extreme land abundant economies, and to discuss the analytical and policy implications of the resource abundance, in spite of other substantial differences among these countries, such as geographic location, market access, size, institutions, or degree of development. We argue that this kind of empirical evidence opens a useful perspective regarding the role of the type of resource abundance on driving patterns of international trade specialization and in the design of development and macroeconomic policies. The relevance of an accurate determination of stylized facts is clear. More efficient policies can be designed starting from an accurate knowledge of the statistical processes of TOT, and with an understanding of the economic processes driving trends and cycles[2]. Knowledge of the TOT cycles of different frequency for each country, and the comparison of spectra, allows the researcher to understand systematic patterns which are related with characteristics of the economy[3].

The rest of this paper is organized as follows. Section 2 reviews the literature on the volatility and cycles of TOT, pointing out the relevance for policy making of knowing the typical size, duration and regularity, or lack thereof, of TOT shocks. Some metodological issues are addressed in Section 3, and we discuss how some econometric methods for the analysis of the statistical properties of economic time series in the time domain are related with the spectral analysis (frequency domain). Section 4 contains the empirical application of spectral methods to the five selected extreme land abundant countries. Section 5 offers a synthesis, policy implications and suggestions for further research.

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[2] A case in point is the Argentine default of 2001, analyzed in Díaz Cafferata and Fornero 2006: the overoptimism in the interpretation of a transitory for a permanent favourable TOT shock led to overborrowing in 1995-1998. In the opposite direction financial markets mistakingly overreacted to liquidity problems caused by a temporary TOT fall in 2000 and 2001 as if it were a permanent reduction in solvency, leading to the reversal of international capital flows.

[3] Since the focus is placed here on the TOT movements associated with endowments, no discussion is made of other influences such as the economic policy strategies, the degree of openness of trade policies, exchange rate regime, and the quality of institutions.

2. THE ISSUE OF TOT TRENDS, CYCLES AND SHOCKS. PROPERTIES OF TIME SERIES.

Trends and instability

In this section we provide empirical estimations in time domain. Two kinds of questions related with the evolution of TOT are, on the one hand, the possible existence of a secular trend and, on the other, the degree of instability of the TOT.

As regards the former, the identification of a secular TOT process has captured considerable attention since the hypothesis of a declining trend of developing countries TOT was advanced by Raúl Prebisch (1949) and Singer (1950); research, stimulated by the still alive controversy, has continued to our days. More recent contributions to this topic are enlargement and quality improvements in the data base, and the use of the *state-of the-art* econometric methods. One particular issue is that of testing the hypothesis of stable declining terms of trade, against the alternative of a once-and-for-all-shift in 1920-1921 as proposed by Cuddington and Urzúa (1989). Powell (1991) reviews this debate[4], and estimates that non-oil commodity prices and manufactured goods prices are cointegrated; the commodity TOT is stationary, with three breaks, in the twentieth century. But non-oil-exporting developing countries happen to face an even more serious problem than declining TOT, namely, infrequent booms and sharp negative TOT jumps, causing problems such as debt-servicing difficulties. He suggests that diversification, or else, the design of contracts that share commodity-related risks, may help.

The latter type of problems for developing countries derives from trade shocks and cycles. One strand of the literature has focused on TOT shocks: starting from the Harberger-Laursen-Metzler hypothesis of a terms of trade effect of a devaluation, research has moved on to understand the identification and differential effects of permanent and transitory shocks. This distinction brings new issues to the fore, such as the speed of return of the variable to the trends after a transitory shock, i.e. the degree of persistence. When shocks to TOT are classified as *permanent* or *transitory*, a natural question arises: do *transitory* shocks impinge on TOT for a mere two-year-period, say, or for an eight-year period? Or, are positive and negative transitory shocks symmetric? Given the fact that TOT shocks have differentiated effects, identifying which type of shock one has to deal with poses a key question, as well as difficult analytical and empirical challenges. Failure to achieve a proper identification leads to errors which may be very costly. Let us provide two examples. If a country raises its external debt when trying to adjust consumption to a negative shock, which is perceived as

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[4] Spraos (1980), Grilli and Young (1988), Cuddington and Urzúa (1989).

temporary, but is actually permanent, it will fall into solvency problems. Second example: if a shock to TOT that is perceived as permanent, is in fact merely transitory, the subsequent induced reallocation of resources will be inefficient.

New modern problems, from trends cycles and volatility

When approaching the dynamics of TOT, the emphasis is nowadays shifting from trends to *shocks* and cycles. The perception of recurrent dificulties caused by the peculiar characteristics TOT volatility exhibit in natural-resources abundant countries has deservedly received renewed attention due to the recent trends and fluctuations in the price of agricultural commodities, adding further difficulties to the prediction of future trends for the design of a development strategy and macro policies.

Some writers have advanced the perspective that the abundance of natural resources has been a negative mana. A strand of the literature following Sachs and Warner (2001) advanced the hypothesis of a "curse of natural resources" working through the windfall resources which may lead to a real exchange rate appreciation, among other channels. Van de Ploeg and Poelhekke (2008) provide an alternative interpretation arguing that it is volatility generated by the type of specialization, rather than natural resource abundance by itself, which has the potentially most harmful effects on less developed countries economic growth. These problems may be aggravated in some developing (as the Latin American) countries because their ability to cope with TOT volatility is to a significant degree jeopardized by institutional inefficiencies, such as the rule of law not being enforced, the reliability of policy announcements, or the weakness of their financial systems together with problems for integrating in the world´s financial markets[5]. Both further research on economic theory, as well as empirical evidence, are still needed to strengthen the basis for policy, and to contribute to private agents´ decisions.

An analytical problem in the research on TOT fluctuations is to provide appropriate representations of economic relevant processes, and to determine how they affect the decisions of private economic agents and the design of development, macroeconomic and trade policies.

The phenomenon of cycles such as those of population, activity, trade or prices through time has been of permanent interest for economists. Both aggregate growth and macroeconomic fluctuations evolve indeed in cycles along time, as well as prices.

We shall not try to review the history of how eminent economists have been allured by the idea of cycles and their efforts to define, to explain, and to measure cycles. We may here mention Jevons, Mitchell, Samuelson, Kaldor, Tinbergen, and Lucas, as some of the most

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[5] Caballero (2000).

conspicuous names. Let us just refer to the introduction of Mills (2003) and to Zarnowitz (1985) who provide a global picture of academic research on cycles.

Historically, "cycle" has been frequently used both to mean recurrent ups and downs of economic variables along time[6], and also to refer to a behavior that can be modelled by the proper use of a periodic function. In other words, thinking about volatility of the TOT is indeed related to their frequent and irregular positive and negative jumps which in time domain are associated with decomposition of the variance. Time series econometric models formulate the statistical properties of a variable across time with its movements decomposed into trend, seasonal, cyclical and an irregular component. The trend is frequently associated to long-run processes and factors such as GDP growth, technical change, fertility, education, while business cycles are related to the "wavelike motion of real economic activity" (Enders, 1995; p.2, 181). Spectral analysis, proceeds on the assumption that those fluctuations have a regular timing, that can be formally decomposed into cycles of different frequency.

We shall argue that the frequency domain approach (the shape of the power density spectrum function) provides an indication of whether the weight of the volatility of TOT is related to structural (medium and low frequency processes) economic phenomena, or is associated to macroeconomic fluctuations (high frequency). Are there theoretical bases to explain TOT cycles as an outcome of regular economic processes? Prices of commodities in international trade may shift for different reasons: climate, natural disasters, technical change. It remains an open question how the representation of regular cycles of different duration, as provided by spectral analysis, should be interpreted in relation with economic phenomena. At this point we can distinguish two different questions. The first one is about statistical facts: do TOT actually move in regular cycles which can be used as information useful for policy? The second question is whether there are analytical bases for expecting that regular "true" TOT cycles of different duration, are generated in economic activity through identifiable mechanisms, and picked up by the statistical cycles found through the analysis in the frequency domain. In this case the presumption that economic processes have driven in historical past the observed TOT cycles, symultaneous, of different duration becomes plausible. The information on the causes and statistical properties of these processes can be expected to improve the ability to make predictions which are useful for policy processes[7].

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[6] As an example, Prebisch (1950) discusses the presence of cycles of prosperity and depresion with asymmetric behavior of prices and salaries in the North industrial countries and the developing countries of the South, without giving these cycles a formal timing.

[7] For example the design of stabilization funds (León and Soto, 1995). Another practical application is the formulation of intertemporal fiscal budget.

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TOT volatility in land abundant countries: time domain.

Since theory does not provide a unique guidance for the identification of volatility in the data, diverse practical measures have been used in empirical research. Díaz Cafferata and Mattheus (2010) tackle TOT fluctuations in Argentina, Australia, and New Zealand, working in the time domain: "volatility" is associated to unexpected changes in TOT, as a *proxy* for uncertainty, in contrast with mere fluctuations of the variable named "variability". The authors point out that observed TOT contain a predictable and an unpredictable component. For example we would not interpret as "volatile" a variable with a strong but fixed seasonal pattern; in consequence measures of mere variability may be misleading[8].

On these bases, as a *proxy* for "volatility", the unexpected component of the TOT variability for informed agents, they estimate two alternative indicators[9], one using the HP filter and the other time series modeling

First, resorting to the Hodrick-Prescott (HP) filter breaks down the original series into a trend (the part which is explained) and a residual which captures cyclical components, as depicted in Figure 2.1[10]. The original series's total variance is decomposed into an *explained* component given by the variance of H-P trend, the *unexplained* variance, and an interaction term. Second, in the ARMA/GARCH models the explained component of the variance is the variance of the sum of a trend (with or without breaks) plus the ARMA/GARCH model. In this method, the *unexplained* variance is therefore the variance of the error term. We shall now sum up some of their results useful for comparison with our findigs in section 4.

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[8] Mansfield and Reinhardt (2008) point out that a weakness of measuring volatility as the variance within a time series for a given country over a long period is that unexpected shocks are not distinguished from predictable changes in terms of trade, and it does not allow for the possibility of varying volatility between sub-periods. Dehn (2000) distinguishes "variability" from "volatility", and suggests that one should leave aside the regular part to estimate volatility. Moreover, he observes that uncertainty may change across time. "Uncertainty" appears as a concept *ex ante* different from "variability", which reflects components that are predictable by producers. Following Ramey and Ramey (1995), these components may be modeled as a function of explanatory variables, taking the variance of the residuals as the component of "uncertainty".

[9] Díaz Cafferata and Mattheus (2010), Table 8 is reproduced for convenience in the Appendix, Table A.2.1.

[10] Ahumada and Garegnani (2000) analyze the conditions under which the HP filter performs a valid decomposition. Enders (1995), p.210 notes that "the benefit of the Hodrick-Prescott decomposition is that it can extract the same trend from a set of variables" in contrast with other methods.

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FIGURE 2.1

Argentina, Australia and New Zealand. 1870-2009. Terms of trade index 1951=100. Trend and cycle generated by HP filter $\lambda = 100$ (log scale)

Argentina ——— Australia ------ New Zealand
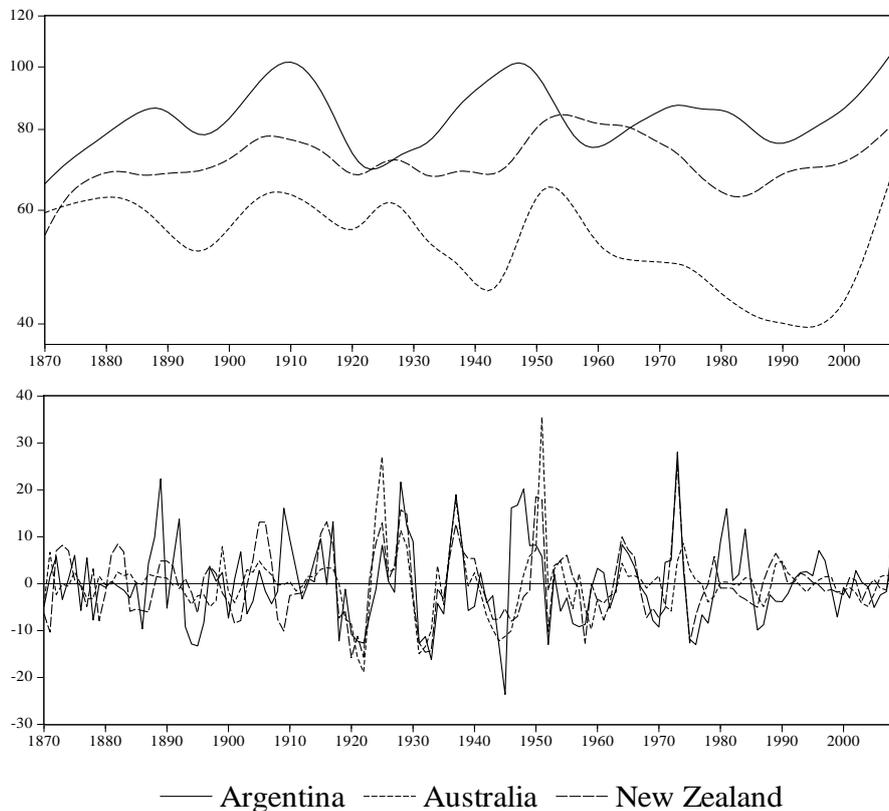
Source: Díaz Cafferata and Mattheus (2010)

i. First measure of volatility: dispersion of the cycle generated from Hodrick-Prescott filtering

The upper panel of Figure 2.1 shows the local trend, and the lower panel the residual or "cycle", which is generated by decomposing the Argentine, Australian and New Zealand series with the Hodrick and Prescott (1997) filter. On visual inspection, the local trend exhibits three peaks for all three countries. Roughly, TOT trend rises initially with a common local maximum around the beginning of WW1, followed by a "U" ending with another local maximum about 1950; and again, after a valley, the TOT rise in the last two decades until a third local maximum seems to appear in 2009, pointing out the likely presence of a common long term cycle, of about 30 years. Note that the generated HP cycle drawn in the lower panel has a zero mean by construction. Australia presents the largest difference between the maximum and the minimum, as well as the largest St. Dev. (0.11), while New Zealand and Argentina have the same difference and St. Dev. (0.10).

Further, significant estimated contemporaneous cross correlations of TOT deviations from the HP local trends among pairs of countries were found, which suggests the possible presence of similar influences and economic structures. The contemporaneous cross correlations are all high, and vary across time, between 0.66 and 0.85 in 1914-1955 (also the subperiod of highest volatility)[11]: For the period 1956-1975 cross correlations are low for AR-AU and AU-NZ (0.20 and 0.32 respectively) and extremely high (0.81) for AR-NZ. Finally, the TOT cycles do not seem to be coordinated in the periods of lower volatility 1870-1913, and 1976-2009, in which cross correlations are between 0.03 and 0.27.

A possible interpretation of the TOT evolution along the HP line, is that it describes the "long- run cycles" of the TOT, while, in contrast, the evolutions of the residuals (around zero by construction) are the "shorth- run cycles".

Another relevant feature is that TOT volatility, as captured by fluctuations of the residuals, for each of the three countries, appears to vary along time, an issue which is critical, both for the process of decision making of economic agents, and also for econometric estimation. The early period 1870-1913 of fast commodity-export-oriented growth is characterized by relatively low volatility, with standard deviations: AR 0.08; AU 0.05; NZ 0.09. The period 1914-1955 is the most volatile with standard deviations: AR 0.13; AU 0.19; NZ 0.13. After the mid fifties there follow years of medium TOT volatility (in 1956-1975 standard deviations are: AR 0.10; AU 0.08; NZ 0.11). The last sub-period 1976-2009 exhibits the historically lowest volatilities: 0.07; 0.05; 0.04 for AR, AU and NZ, respectively.

ii. A second measure of volatility: the conditional standard deviation.

The second volatility measure is obtained through time series modeling, following the intuition that rational agents form expectations based on the conditional distribution rather than the unconditional distribution. We find there are common sub periods on TOT volatility, with high conditional standard deviations in the years between the world wars for the three countries, as can be easily observed on the lower panel in Figure 2.1. "Volatility" has been considerably lower during the last decades for the three of them.

For the estimation of the ARCH type models, first stationarity and trends of the TOT are examined for the existence of trends and breaks in the trend, and subsequently detrended if necessary before carrying out the estimation of the ARCH models.

Volatility as the portion of variability which has not been modeled by HP filtering or ARMA/ARCH modeling, may be compared between pairs of

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[11] The contemporaneous cross correlations are 0.66 for AR-AU, 0.68 for AR-NZ, and 0.85 for AU-NZ.

countries. In Table A1 (see Appendix) figures for the decomposition of variance are portrayed. The main implications are the following.

Firstly, in most instances the explained fraction of the variance is substantial, ranging between 50% and 80%, the only two exceptions being Argentina and New Zealand under the HP detrending approach.

Secondly, comparing their relative degree of volatility, it is apparent from the table that Australian TOT are less volatile than those of Argentina and New Zealand. Under each of the three methods Australia has the highest explained fraction, always more than 50% and up to 82%. On the contrary, for Argentina and New Zealand the explained fraction is not only smaller than for Australia (36% to 70% for NZ, 46%-60% for AR), but also in which of both countries is higher depends on the estimation method. All in all, the explained fraction of the TOT variance is clearly higher for Australia. Let us emphasize at this point the difference betwen variability and volatility in the evolution of TOT through time: despite the fact that Australia exhibits the highest variability with both the HP filtering and the ARMA/ARCH, the decomposition shows that Australian TOT are however the least volatile.

3. TIME-SERIES ANALYSIS TECHNIQUES: TIME DOMAIN AND FREQUENCY DOMAIN. SPECTRAL ANALYSIS.

The time domain models of a time series are widely used[12]; let us only mention here the textbooks of Enders (1995) and Wei (1990) among a number of high quality textbooks as useful references. By way of contrast, spectral analysis allows the researcher to formally model the cyclical movements of the deviations from trend of an economic variable, by breaking down those movements in terms of cycles of different frequencies. Very good introductions are given by Bolch and Huang (1974), Gottman (1981) and Wei (1990). Some results for TOT using this approach have been shown in the previous section.

What new information, if any, can spectral analysis provide?

Do TOT move in cycles? If so, what specific characteristics do they have? These are the questions we shall answer by means of spectral analysis techniques, which provide a decomposition of the residual series total variance of TOT, using its sample autocorrelations.

We can think of the TOT evolutions along time as being made up of four basic components. A trend. Long-term cyclical movements. Short and

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[12] Such as the autoregressive (AR), moving average (MA), autoregressive moving average (ARMA) and in case a unit root is present the underlying time series is called an integrated autoregressive moving average (ARIMA) time series model. Regime switching models are ARCH or GARCH.

medium term cyclical fluctuations around them. Last, an unexplained residual. A detailed knowledge of these processes is a great boon.

Hence the key question that the spectral method can answer at our present concern is whether cycles of TOT for agricultural commodity exporters are present in historic data assessing the relative importance of the contributon of each of the frequencies (or its inverse, the period) to explain the total variance.

The raw periodogram and the application of spectral windows. Short, medium, and long run periods.

Very briefly. Take the case of a time series, which is the sum of just two periodic functions: a 5-year cycle, and a 22-year cycle. Consider now a graph where these periods are measured at points 5 and 22, on the horizontal axis, and the contribution of cycles to total variance on the vertical axis. In this extremely simple case, the contribution of each period to the total variance is measured by the height of a vertical line. This graph of the cycles is called a Fourier line spectrum or a *raw periodogram*.

A more elaborate tool, the *smoothed periodogram*, or *Power Density Spectrum* (PDS) function, on the other hand, goes beyond the exclusive presence of deterministic cycles, by allowing different bands of frequencies,or periods for that matter, to contribute to total variance.

Cunnyngham (1963) explains that the estimated PDS, a function of the frequency, arises from a finite Fourier transform of the autocorrelation functions (which belong to the time domain). The functional relationship which exists between the expected values of these "raw" spectral functions and the true spectral densities which they estimate, is known as the spectral "window". He shows there are at least 5 different window types: Parzen, Tukey and Hamming, Tukey and von Hann, Bartlett triangular window, Raw lag window. Wei (1990) presents a detailed, and more up to date, analysis of this topic. The problem associated with the design of spectral windows has been labelled "window carpentry" by John Tukey[13]. Bolch and Huang (1974) provide a careful comparison of the features of different types of spectral windows. In this paper we shall confine our attention to the use of the Parzen and the Bartlett windows which we will now discuss when carrying out PDS estimation.

Spectral windows in what follows are denoted by g(K). Specifically, the formula for the Parzen window is given by the following expression[14]:

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[13] See Bolch and Huang (1974), footnote 14, page 292.
[14] Bolch and Huang (1974), formula 8-31, page 292.

$$g(K) = \begin{cases} 1 - \dfrac{6K^2}{L^2}\left(1 - \dfrac{K}{L}\right), & 0 \le K \le \dfrac{L}{2} \\[3mm] 2\left(1 - \dfrac{K}{L}\right)^3, & \dfrac{L}{2} \le K \le L \end{cases}$$

(3.1)

Where K is an integer which denotes lag and L (also an integer) stands for the truncation point. An advantage stemming from the use of the Parzen window is that one may rest assured that no negative estimates of the PDS will ever occur.

In turn the formula for the Bartlett window is:

g(K)=1–K/L,   for K≤L;   and g(K)=0,   for K>L.   (3.2)

where all the symbols have the same meaning as before.

The literature suggests that the researcher should try different values for L to guard against the danger of missing significant hidden periodicities. So, for example, Gottman (1981, pages 224-226), warns of the dangers of using inappropriate values for L. He provides a striking example that convincingly shows how things can go wrong, by means of the estimated Power Density Spectrum as applied to artificially generated data. He shows that appropriate choices of the truncation point L can lead to a precise identification of the relevant periods. Improper selection of L, on the contrary, may give rise to the erroneous conclusion that a trend is present in the data.

The Power Density Spectrum (PDS) function evaluated at frequency (f_i*) is given by:

$$PDS\left(f_i^*\right) = 2\left\{1 + 2\sum_{K=1}^{L-1} g(K)r(K)\cdot\cos\left(\frac{\pi i K}{const\cdot L}\right)\right\}, \qquad i = 0,1,...,const.L \quad (3.3)$$

where g(K) is a spectral window (for our empirical estimations either Parzen or Bartlett window), and r(K) is the estimated, or sample, Kth autocorrelation. The following definitions are in order: P stands for period; f=1/P denotes frequency (such that the longer the periodicity, the lower the frequency 1/P); N is the number of observations; and L the truncation point. The scalar "const" which multiplies the truncation lag L must be chosen between 1 and 4, and (f_i*) refers to the particular frequency (inverse period) at which the estimation is made. Notice that since (i) in equation (4.3) ranges from zero to (const*L) the PDS function is estimated at (const*L+ 1) points. Thus, if L is 42, and const=2, a full set of 85 estimates is obtained.

Equation (3.3) is adapted from equation 8-33 in Bolch and Huang (1974), page 293, in which "const" is replaced by "2". They explain that the higher the value of "const", between 1 and 4, the smaller the bandwidth at which the PDS is estimated: "const"=4 provides four times as many different frequency points than those obtained when "const" is equal to 1. A natural impulse would be to deduce that, the higher the value of *const* the more numerous the frequency values at which the PDS is estimated; in consequence, more and more precision would be gained eventually in the process of uncovering "hidden periodicities".

This is not necessarily so however, because of leakages. "Because the lag window averages adjacent spectral estimates, if one estimate is large, it will tend to increase the estimates in its inmediate neighborhood. Thus a very slow cycle may impart power to, say, the zero frequency, leading us to believe that there is a trend in the series. This problem is called leakage through the window (italics in the original)". Bolch and Huang (1974), page 300.

Concerning the proper choice of the truncation point L, there is a trade-off: when L increases, the variance of the sample PDS also increases; but as L is reduced, the bias of the sample PDS increases as well. A usual procedure to circumvent this conflict is to compute spectral estimates trying different values of the truncation point L. One rule of thumb suggests the use of values ranging from 15 to 40 percent of N. "Estimation therefore requires considerable experience, and critics of spectral analysis are quick to point out that is hard pressed to know the meaning of a particular estimated spectral density function because it can be changed in appearance by changing L"[15]. Following this recommendation for our estimation exercises in the next section we use three values of L (42, 35, and 28), as shown in Table 4.2. In the case of our sample (1870-2009) N=140, and the 20% is L=28.The 25%, and 30%, provide L=35, and L=42, respectively, as can be seen in detail in Section 4. These are combined with two values of "const": 2, and 3.

It must also be said that the adequate interpretation of an economic data spectrum should be related to areas under the estimated PDS function, rather than too strict a reading of specific values of the PDS as implying that a "true" cycle of each frequency exists in the economic phenomenon. The reason why it is advisable to break down the contributions of different cycle lengths into intervals stems from the fact that the presence of leakages is likely to obscure the contributions that specific cycle lengths have.

Consequently we will adopt this more appropriate, safer, approach, considering the different cycle lengths' contributions according to intervals, yet to be defined. The choice should ensure the most useful interpretation of the specific phenomenon under analysis. By proceeding in this way we should be able to minimize, if not completely eliminate, an important source of potential error. So, for example, what appears as

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[15] Bolch and Huang (1974), page 291.

a major peak at the 30-year period, should be better conceived as occurring in a range around that value. In actual practice applied researchers would consider a band in the neighborhood of the observed peak, and to present the variance decomposition in terms of intervals.

Building confidence bands, interpretation, significance levels.

Once PDS has been estimated, one simple question arises: is a given value of PDS significantly different from what one should have obtained if the actual evolution of the economic variable were white noise? In this case, the values of the sample autocorrelations r(K) in equation (4.3) would fluctuate around zero (their population counterparts are strictly zero), such that the PDS function for white noise should be flat, with typical value around 2. Having this null hyphotesis in mind, the way to test whether a PDS estimated value is significantly different from 2 is to construct a $(1-\alpha)$ level confidence interval around 2. If the observed value for the estimated PDS fall inside this interval, the result is not significant at the alpha level. By way of contrast, if the observed value falls outside the interval's low and upper bound, the result should be judged significant at the said α level.

To be specific, taking $\alpha=0.05$ for a two tailed test, the lower and upper bounds of the 95% confidence intervals are computed as follows:

Lower bound: LB=2*EDF/ChiSquare(0.975, EDF);

Upper bound: UB=2*EDF/ChiSquare(0.025, EDF).

Where the *equivalent degrees of freedom* (EDF) in the numerator is calculated as follows using the Parzen and Bartlett windows:[16]

EDF-Parzen= [3.71*N /L] ; EDF-Bartlett = [3*N / L].

In these two expressions the use of square brackets means that the largest integer less than, or equal to, the expression inside the brackets shall be used.

To get a feel for magnitudes, suppose the sample size is, as in our data, N=140, and the truncation lag L=42. Straight application of the formulas give rise to EDF equal to 3.71*140/42 for the Parzen Window; and 3*140/42 for the Bartlett window EDF. For our example, the EDF are 12 and 10, for the Parzen and Bartlett windows, respectively.

In the denominator, ChiSquare (0.025, EDF) symbolizes the abscissa value of a central Chi-square distribution with EDF degrees of freedom, which leaves a cumulated probability of 0.025 to its left, and the remaining 0.975 to its right. In the same vein, Chi-square(0.975, EDF)

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[16] See Wei (1990),Table 12.4, page 283, who also provides EDF additional formulas for the rectangular, Tukey-Hamming, and Tukey-Hanning spectral windows.

stands for the particular abscissa value that cumulates 0.975 to its left and the remaining 0.025 to its right.

For the above numerical example ChiSquare(0.025, 12)=4.40, and ChiSquare(0.975, 12)=23.34. Bear in mind the meaning of these values: the integral between 0 and 4.40 under a central chi-square distribution, with 12 degrees of freedom, is equal to 0.025, and so is the value of the integral for the same underlying random variable, between 23.34 and infinity.

By substituting the values of EDF and ChiSquare(0.025,EDF) and ChiSquare(0.975,EDF), the lower and upper bounds for the 95% confidence interval, to test whether the PDS estimated for a particular frequency is different from what would be expected if the series under examination were white noise, are found to be equal to:

95% confidence interval,

> (i)Parzen window: Lower bound=1.03; Upper_bound=5.45

> (ii)Bartlett window: Lower bound=0.98; Upper_bound=6.16

But just how sensitive are these bounds to sample size N, given L and the level of confidence $1-\alpha= 0.95$? Two simple examples will suffice to illustrate the point that when observations are added or deleted the confidence band may change.

Read in Table 4.1 the confidence intervals for the case of 140 observations. The equivalent degrees of freedom are EDF=12 (not quoted in the table). The confidence interval for the Parzen window is: lower bound LB=1.03, and upper bound UB=5.45. When the estimation of the interval uses a Bartlett window, EDF=9, lower bound=0.98, and upper bound=6.16.

Now, consider the case when N=139, as it happens with Uruguay in our estimations (one fewer observation than for the other countries).[17]

Care should be taken of possible changes in the width of the confidence interval when the sample size varies. With N=140, the range of the confidence interval was (5.45-1.03)=4.42 (Parzen), and (6.16-0.98)=5.18 (Bartlett). Dropping a single observation (just 1 in 140) gives rise to confidence interval's ranges which remains unchanged when using the Parzen window. On the contrary a significant widening of the confidence band has been brought about, from 5.18 to (6.67-0.95)=5.72 when the Bartlett window is employed.

Since economic series are frequently not as long as desired, let us emphasize the fact that the width of the confidence interval depends on the sample size, take the case of a very large sample, say N=5000

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[17] To be discussed further in section 4.

(increasing sharply the equivalent degrees of freedom), while keeping L=42. The bounds are now:

Parzen window: EDF=441: LB=1.76; UB=2.29;

Bartlett window: EDF=357: LB=1.74; UB=2.33

These bounds are considerably tighter than those obtained for N=140. The range has shrunk from 4.42 to 0.53, and from 5.18 to 0.59 for the Parzen and Barlett windows, respectively. A dramatic drop in magnitude! These calculations are meant as an illustration on how the procedure works for the 95% confidence interval, and can be adapted easily to obtain the appropriate bounds for any other confidence level.

Last but not least, two specific periods, or frequencies, are of special relevance for testing the significance of the PDS estimated function. The first one is the origin (frequency equal to zero or period equal to infinity), to find indication of whether or not the series has been properly detrended[18]. The second one is that associated with the major peak.

Specific application of the technique is the subject of the next section.

4. POWER DENSITY SPECTRUM ESTIMATION

Our empirical analysis in this section includes the already mentioned land abundant countries, Argentina, Australia, Canada, New Zealand and Uruguay, selected with the aim of shedding light on the effects of natural resources abundance endowment on the TOT volatility. All of them share the experience of an early period of rapid export oriented growth in the second half of the nineteenth century based on an exceptionally high abundant, fertile, land. Regarding the pattern of trade historically they had, and still have, a low share of manufactures in exports. Also their exports of primary goods account for a large proportion of total exports. Both characteristics are in sharp contrast with countries on the other side of abundance, like Germany, the United Kingdom and Belgium, eventually serving as a suitable control group, for comparison, as European countries representative of land-scarce industrial economies.

Our selection of the five land abundant countries is not intended to provide basis for formal inductive generalization. Rather, the empirical estimation of spectra allow comparison of TOT behavior for selected cases. We shall not make further refinement of resource abundance and trade patterns here, because we are selecting the countries based on these broad characteristics seeking evidence of empirical regularities of

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[18] However this could also be due, at least in part, to "leakage" from low frequency cycles, as noted by Bolch and Huang (1974), footnote 15, page 293.

TOT, and will not attempt here to perform hypothesis testing based on these characteristics.

Even though the length of the series may often be a source of concern in applied work when dealing with the statistical properties of annual time series, our sample appears to be long enough since it covers a span of 140 years between 1870 to 2009[19], and therefore seems to provide a good starting point for our study. Its length should be adequate and allow us to test for the possible presence of roughly up to 5 cycles of 25 years each, or, alternatively 17 "business cycle" of average length of 8 years.

Regarding the quality of the data, the series are from official sources and were considered as reliable, with the usual warning about the difficulties in the construction of secular series. Details of the data are provided in Appendix II.

Estimation procedure: the power density spectrum (PDS) and interpretation of results

Knowledge of the statistical processes driving the TOT evolutions have direct implications for practical advice. As an example, one would be on the safe side by reacting to a negative transitory TOT shock by smoothing consumption; in other words typical TOT cycles which are of a short run nature (in the high frequency band), can be smoothed. For example, Cashin and Pattillo (2000) argue that for a group of African countries the typical half-life of TOT shocks is less that four years, providing scope for consumption smoothing. On the opposite side a negative TOT shock should be adjusted whenever the shock is permanent, meaning that in practice it belongs to a long run cycle. Intermediate duration of TOT shocks (or medium run TOT cycles) provide a much less clear-cut guidance, and it is up to the policy maker´s judgement and the use of whatever specific information he has available on the episode´s features to decide. Let us now move to the estimation process and implication of the TOT spectra.

By estimating the PDS we may assess what proportions of the residual series total variance is accounted for by different periods (or frequencies). The most important tasks to undertake are the following. One is to check the significance of the PDS at the origin. Second, check the significance of the abscissa at which the major peak is located (eventually, more than one peak might be of interest). Third, test whether or not they are significantly different from 2. Finally, the

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[19] The data for Uruguay are 1870-2008 (N=139). This is a small difference with the 140 data of the other four countries. As a short digresion, note that the shorter the ime series the lower theamplitude of the confidence bands for a given level of confidence; for example, when the L=42, constant=2, the lower bound LB and the upper bound UB at the 90% confidence level are in the Bartlett window. For Uruguay the EDF=12; LB=1.029 and UB=5.450. For Argentina the EDF=10, LB=1.093, UB=5.076.

fractions of the total variance which are accounted for by sets or bands of frequencies (or periods) are estimated. Levy and Dezhbakhsh (2003) in an interesting study of the growth rates of 58 countries, note that a peak in the spectrum suggests the existence of a predictable component because it indicates strong periodicity. They proceed to classify "spectral shapes" considering the frequency band where a peak is found, and the band where the spectral mass is concentrated.

For descriptive purposes, cycles in the present paper are called "long-run" when they are longer than 8 years (in the long run frequency band); "medium run" lengths are those longer than 3 years and up to 8 years; and "short run" cycles have lengths between 2 and 3 years in the short run frequency band[20]. The distinction is useful for policy purposes and the specific length may be adapted to the economic problem to tackle. These three bands may be interpreted as related to the degree of persistence of TOT shocks, short run shocks being assimilated to high frequency, long run shocks to low frequency instead.

As for the estimation procedure, the original series in logs were first detrended, by estimating a third-degree polynomial regression model with an intercept, a time trend (t), and its second and third powers[21]. The differences between the original series and the trend functions so obtained were computed for each of the five countries; the "residuals" series should be trend-free for the detrending method to be judged successful. Otherwise the PDS estimates would show significant contribution to total variance around the origin, a feature that would show up by an estimated PDS at the origin which breaks the boundaries of the relevant confidence bands.

Remember that the equivalent degrees of freedom EDF as defined in a previous section is given by the largest integer less or equal $EDF=[3.71*N/L]$ when using the Parzen window. For N=140 (annual data, 1870–2009), and with L (truncation lag) L=42, the equivalent degrees of freedom is EDF=12. Confidence intervals at 90%, 95% and 99% were calculated to test if the spectral density is consistent with a white noise data generating process once the trend has been removed. The band is wider the higher the level of confidence, since it makes it more difficult to reject the null that a given frequency (or period) is white noise.

To avoid cluttering the graph, the only bounds shown in Figure 4.1 are those which define the 95% confidence intervals.

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[20] Levy and Dezhbakhsh (2003) adopt these bands to measure activity cycles.
[21] No attempts have been made to test for the possible presence of structural breaks or changes in volatility.

FIGURE 4.1

Argentina, Australia, Canada, New Zealand, Uruguay. Annual data 1870-2009. TOT Power Density Spectrum (PDS) estimation. Parzen and Bartlett windows. 95% confidence bands. Upper bound = UB. Lower Bound = LB
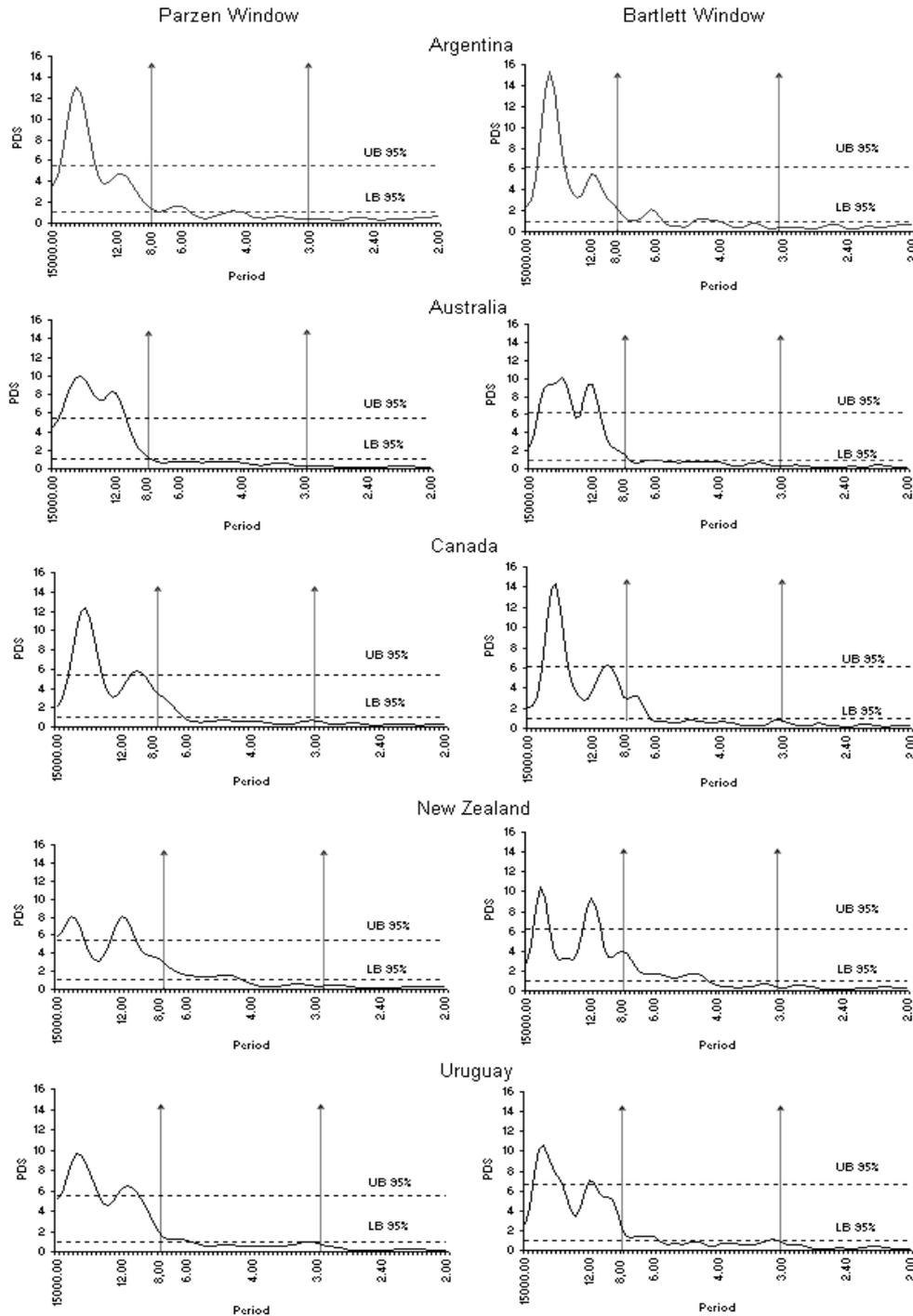
Source: Own calculations. See data sources in Appendix (A1)

TABLE 4.1
**Limits of the confidence intervals. Parzen and Bartlett windows.
L= 42;   const = 2, and N =140**

	Confidence intervals					
	90%		95%		99%	
	LB	UB	LB	UB	LB	UB
Parzen	1.14	4.59	1.03	5.45	0.85	7.81
Bartlett	1.09	5.08	0.98	6.16	0.79	9.28
Bartlett (URU)	*1.06*	*5.41*	*0.95*	*6.67*	*0.76*	*10.38*
Power density spectrum (PDS) at selected frequencies: origin (frequency zero), and major peak. Significance levels, *, **, *** at the 10, 5 and 1% level respectively						
	Infinite period or trend		Major peak. P=period in years.			
	Parzen	Bartlett	Parzen		Bartlett	
AR	3.62	2.46	13.04 ***; P = 33.6		15.33***; P = 33.6	
AU	4.56	2.50	9.91***; P = 28		10.13***; P = 24	
CAN	2.24	2.11	12.40***; P = 28		14.40***; P = 28	
NZ	5.93**	2.82	8.13***; P = 56		10.52***; P = 56	
URU	5.23*	2.62	9.60***; P = 42		10.60***; P = 42	

Source: Own calculations based on appropriate Chi-square critical values. N=140 (for Uruguay N=139); L=42. EDF=12 for the Parzen window. EDF=10 for the Bartlett window. In the case of Uruguay, the bounds for the Bartlett window estimates are those quoted in italics in the third row.

TABLE 4.2.
**Decomposition of TOT volatility, land abundant countries. In percentages.
Short run (2-3 years), intermediate run (3-8 years) and long run (more than
8 years) cycles. Parzen and Bartlett windows (+)**

	L = 42, const = 2		L = 35, const = 2		L = 28, const = 2		L = 42, const = 3	
	Parzen	Bartlett	Parzen	Bartlett	Parzen	Bartlett	Parzen	Bartlett
Argentina								
2-3 years	7.5	8.0	7.4	8.0	7.3	8.0	7.5	7.9
3 - 8 years	17.7	18.5	17.4	18.4	18.4	19.6	17.3	18.1
More than 8 years	74.8	73.5	75.2	73.6	74.3	72.4	75.2	74.0
Total	100	100	100	100	100	100	100	100
Australia								
2-3 years	3.7	4.2	3.7	4.2	3.6	4.3	3.7	4.2
3 - 8 years	13.3	14.6	13.0	14.4	14.1	15.7	13.0	14.2
More than 8 years	83.0	81.2	83.3	81.3	82.3	80.1	83.4	81.7
Total	100	100	100	100	100	100	100	100
Canada								
2-3 years	5.2	5.6	5.1	5.6	5.0	5.6	5.1	5.5
3 - 8 years	19.0	19.7	18.2	19.2	20.5	21.5	18.0	18.9
More than 8 years	75.7	74.7	76.7	75.2	74.6	72.9	76.9	75.6
Total	100	100	100%	100	100	100	100	100
New Zealand								
2-3 years	4.6	5.0	4.5	5.1	4.4	5.1	4.5	5.0
3 - 8 years	25.5	26.8	24.4	25.7	26.2	27.3	24.6	25.7
More than 8 years	70.0	68.2	71.1	69.3	69.4	67.6	70.9	69.3
Total	100	100	100	100	100	100	100	100
Uruguay								
2-3 years	4.5	4.9	4.4	4.9	4.2	4.8	4.4	4.8
3 - 8 years	17.7	18.4	17.3	18.2	19.3	20.1	17.0	17.8
More than 8 years	77.8	76.7	78.4	77.0	76.5	75.0	78.6	77.4
Total	100	100	100	100	100	100	100	100

(+) The sum may not add up to 100 due to rounding errors

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Empirical results: the PDS. peaks, confidence intervals and significance for each country

In Figure 4.1 the period of the underlying cycles is represented on the horizontal axis, with the period infinite in the origin, here approximated by a large number (15000), and the period of two years the shortest period (associated with the maximum frequency 1/2, usually referred to as the Nyquist frequency)[22]. The hump-shaped lines show the TOT power density spectrum (PDS) estimations with the Parzen and Bartlett windows. The countries appear vertically in alphabetical order Argentina, Australia, Canada, New Zealand, Uruguay in two columns for annual data 1870-2009. The two dashed horizontal lines are the 95% confidence bands, and the vertical lines at points 3 and 8 are the limits between the long, medium and short runs.

The five countries exhibit a striking main coincidence: under the two spectral windows estimations the spectrum is clearly skewed to the left, meaning that most of the variance is explained by long period cycles (low frequency bands). It may also be noticed that in the neighbourhood of the origin the line appears between the confidence bands, implying that detrending has in general been successful.

The most important results are summarized in Table 4.1 and Table 4.2. The former is devoted to checking whether detrending has been successful and also to the determination of the period length associated with the major peak. The latter table, in turn, provides the decomposition of TOT fluctuations into short, medium and long run frequency bands using alternative values of the truncation point and the constant.

The interpretation of the values in Table 4.1 is the following. The first three lines named Parzen, Bartlett and Bartlett (URU) provide the lower and upper bounds, labeled LB and UB, for the 90%, 95% and 99% confidence intervals, to test how significant the PDS for a cycle of a given period is. In the lower panel of the table, we provide in the two columns on the left the numerical estimated values for the PDS at the origin (infinite period or trend) with the two spectral windows. The following two columns test the significance of the major peak. They quote the PDS estimation of that peak and also indicate the length of the period (in years) associated with it.

As an example of the PDS estimate at the origin, for Argentina, using the Parzen window, the estimated value is 3.62, a number well within the bounds of the 90% confidence interval: LB=1.14; UB= 4.59. In consequence, the null hypothesis of white noise at the origin cannot be rejected at the 10% significance level, meaning that the detrending process has successfully removed the trend. Similar lack of significance at the 10% level applies for almost all the five countries, using both the

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[22] See Chatfield (1991) for a very intuitive characterization of this important concept.

Parzen and Bartlett windows. The only exceptions are New Zealand and Uruguay (Parzen window) which are significant at 5% and 10% levels respectively.

Turning our attention to the columns for the major peak, and starting once again with Argentina, the major PDS peak appears is associated with a period of 33.6 years with both windows. The corresponding PDS estimated values are equal to 13.04 (Parzen) and 15.33 (Bartlett) both significant at the 1% level, as they both are above the upper bound of 7.81 with Parzen and 9.28 with Bartlett at 99% level of confidence. Essentially similar results are obtained for the remaining countries, with peaks in the long run frequency bands, ranging from 24 to 56 years.

Table 4.2 shows the decomposition of TOT volatility for the 5 countries using different values for the truncation lag (L) and the constant (const). The main feature that stands out for the whole set of estimates is that the long-run contributions account for values that range between 68% and 83%, a very significant result. Remember that in section 3 we emphasized that spectral analysis practitioners strongly recommend that sensitivity analysis be carried out. It is reassuring that our results appear to be very robust with respect to the choices of different window types, truncation lag (L) and also the value of const.

5. SYNTHESIS, POLICY LESSONS AND SUGGESTIONS FOR FURTHER RESEARCH

If TOT cycles are estimated to be statistically significant. Moreover, they keep a regular pattern for decades (or centuries), this is an outstanding fact. We can think that this happens merely by chance and stop thinking. But we can suspect that this regularity may have an explanation, and in this case it would help to know why.

While the issue of TOT trends was the dominant interest since the early fifties after Prebisch (1950) and Singer (1950)[23], increasing attention is being payed to TOT fluctuations which is becoming crucial for policy making. Economies whose exports goods production, and exports flows are concentrated in commodities with volatile prices suffer from volatile terms of trade. Our interest was to study specifically the presence of TOT cycles for land-abundant "New Settlement" countries[24]. Our spectral

[23] More recent references are among others Grilli and Young (1988), León and Soto (1995).
[24] A research tradition has devoted attention to the comparison between the economic development of six land abundant countries, Argentina, Australia, Canada, New Zealand, Uruguay and the United States of America and in occasions South Africa. Several authors have been interested in comparisons between Argentina and Australia, namely Smithies (1965), Diéguez (1969), Dyster (1979), Di Tella (1987), Ferrer and Wheelwright (1966). Mundlak, Cavallo and Domenech (1989). Schedvin (1990) selects AR, AUS, CAN and NZ

analysis reveals that in fact the extreme land-abundant countries in our sample exhibit TOT similar temporal cyclical partterns. This has been documented in Figure 4.1, and strenghtened by results displayed in Table 4.1 and 4.2. However one would not in general expect a strict coincidence of temporal patterns, due to peculiarities such as the specific product specialization, wool for New Zealand, meat for Uruguay, grains for Argentina, which are presumed to generate the peculiar idiosyncratic fluctuations which differentiate them from each other within the group of extreme land-abundant countries.

Given that as a general policy rule, the effects of a temporary shock can be smoothed out and a permanent shock must be adjusted, knowledge of the duration of TOT shocks provide valuable information. The time domain approach provides an identification of the character of shocks, transitory or permanent (or the degreee of persistence thereof) related to the time it takes TOT to return to the trend after a shock.

No doubt the time domain approach has proved most helpful to understand the effects of shocks. However, it appears to be unable to provide a clear-cut guidance because it fails to tell how frequent those shocks are, or if they occur in regular patterns. It is precisely to answer this type of question that the frequency domain approach comes to help.

Spectral analysis provides a useful information for policy, in terms of expected behavior of TOT. Even when forecasting of the TOT at a particular point in future time may have a sizable error, the knowledge of the systematic characteristics of fluctuations of prices is useful for the formation of expectations and in consequence for the design of policy rules.

One interesting point is to understand the type of prediction spectral estimations may help perform. Good profits can be made by speculation on prices, but policy is rather concerned with expected behavior. If long run cycles carry substantial weight on TOT evolution, there will be a fraction of transitory movements that can be smoothed, and a component that shall be adjusted. As an example of the practical implications, if fluctuations of terms of trade have a main component of low frequency cycles, a sharp rise or fall in TOT is expected to be transitory to a substantial degree (in the absence of structural breaks). This constitutes a case for the advisability of a rule to adjust, at least partially. From a spectral analysis perspective, the "transitory" shocks are measured by the fraction of total variance which is related to short-run cycles, "permanent" shocks, on the other hand, are captured by the contributions stemming from long-run cycles. Therefore, shifting to the

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as those which "have most characteristics in common and which are closest to the ideal-typical region of recent settlement". However, he warns that despite their high growth in the past the structural characteristics of these countries may be inadequate for the modern conditions of the world economy: "Australia (with New Zealand and, to some extent Argentina) has been caught in a staple trap"; these economies have suffered adverse movements due to their "inability to move into high value-added production".

frequency domain, provides complementary information on the regularity of TOT shocks by estimating not only the frequency of cycles but the decomposition in cycles of different frequency.

Knowledge of historical patterns is a complement to specific information for the identification of the type of an innovation in TOT. As regards expectations about the future the following considerations are in order. Firstly, they are related to regular fluctuations as far as one believes that TOT will behave as in the historical experience. Secondly, allowance should be made for a possible structural break in *trends*[25]. Thirdly, the cycles which were identified may not be invariant in the future. Are there reasons to expect a structural change in the parameters of TOT *cycles*?

Now, as for our empirical findings. One particular fact, the TOT moving largely in long run cycles, poses a difficulty to the observers and policy makers alike, namely, that of identyfying whether in the available time frame a long run movement of the TOT is either sliding along a secular trend, or rather a moving along a low frequency cycle. A case of this sort is probably the reason for the new results regarding the Prebisch (1950) and Singer (1950) hypothesis; with the benefit of hindsight the alleged secular deterioration of terms of trade of developing countries appears now as being either the result of a structural fall or a partial perspective of the falling portion of long cycles.

In any case, the finding in our sample of significant peaks in the low frequency-cycle band, warns against an aprioristic assumption that typically TOT shocks can be taken as short run. In consequence, the natural temptation to resort to shock smoothing as a rule may be dangerous. If the future is like the past, 70% of the variance in TOT are long run related, but certainly, when facing a new shock, one wonders, is it like the past? There might be happening a structural break. Is it happening nowadays with the irruption of China? We will know tomorrow. The advise would point out that the type of shock should be carefully assessed in each episode, but certainly not taken for granted.

Errors in the prediction of the duration of a shock may be really costly: for example, mistaking a temporary for a permanent positive shock may lead to excess spending and overborrowing26. As an example, Cashin and Pattillo (2000) estimated that the reversion of TOT to their mean as

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[25] In a recent empirical study Keogh (2010) concludes that "the long-term downward trend in soft commodity prices which extended from the 1960s through to 2000 seems to have bottomed out, and a longer-term upward trend had emerged … Recent forecasts suggests that this trend will be maintained in the future".

[26] Díaz Cafferata and Fornero (2006) estimate, in a DSGEM for Argentina, the overborrowing arising from a mistaken evaluation of the duration of a fall in the TOT in the 1990s. And the default in 2001 was partly caused by a mistaken perception by creditors of insolvency due to low TOT just before a long decade of rising TOT contributed to a cycle of high growth in the first decade of the twenty first century.

measured by the shock´s half-life typically takes less than four years for 23 of 42 African countries, providing some scope for national consumption smoothing. They argue that policymakers can make use of two types of information, one is episode-specific such as the effect of weather, like an atypical drought or hurricane (causing large, short lived movements in supply), whereas the other one is the typical duration of TOT shocks. They point out that a useful complementary information is the variability of shock duration, because it determines the range of possible outcomes.

Reinhart and Wickham (1994) conclude that empirical regularities in commodity prices show variable downward trends in the relative prices of most commodities and even temporary shocks tend to persist over several years. They argue that in consequence structural policies that facilitate the diversification of the export base and rises productivity in the production of commodities are needed.

New ingredients have been suggested beyond the idea that export diversification may increase welfare by reducing the magnitude of aggregate TOT shocks (Kenen, 1969). This single strategy may in fact be associated in certain countries with rising costs of diversification in terms of the loss of benefits from trade when the economy moves away from comparative advantages.

We can think of policy recommendations such as: (a) devise policy schemes based on multiple instruments, rather than focusing only in export diversification; (b) contrive policies and institutions to manage volatility more efficiently; (c) implement instruments to smooth welfare effects of shocks, particularly of food prices with substantial weight in the consumption basket of workers; (d) move towards a strategy that may be focused on intra-sectoral rather than inter-sectoral diversification. As regards this last point, along the traditional "inter-sectorial" dichotomy there is still a role for improving efficiency in the natural-resource abundant sector. Also, even if TOT volatility remained unchanged, higher efficiency expands the production possibilities frontier, such that in the extreme case of no diversification and hence, no reduction of volatility, those fluctuations would however be at a higher welfare level.

Concerning possible extensions and suggestions for further research, in first place further understanding of the TOT behavior of land abundant economies may be reached by incorporating other large countries, like the USA, Brazil, Russia, and China, together with a detailed account of their relative factor abundance. Another promising direction is through the analysis of coherence and phase; the relationship between the behavior of TOT for pairs of countries can be handled enabling the researcher to discover the existence of lead-lag relationships. Two *a priori* interesting cases to consider are Argentina-Australia and Uruguay-New Zealand. Last, results obtained from cross spectral analysis could provide useful building blocks for the estimation of causal models in which extra variables are brought into the analysis to help explain the

effects of TOT shocks on important economic time series like investment, export performance, output or the government budget. So far, we have focused on estimations oriented by theoretical presumptions; and empirical findings on TOT fluctuations which in turn, raise further questions for theoretical research.

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APPENDIX

A1. Terms of trade of five land abundant countries. Data sources

TOT	Annual data
Argentina	1810-1985. Ferreres (2005). 1986-2009. Indec. http://www.indec.gov.ar/
Australia	1870-2004. Gillitzer and Kearns (2005), Reserve Bank of Australia 2005-2009. Australian Bureau of Statistics (number 5302.0)
Canada	1870-2001. Statistics Canada, merchandise imports and exports classified by commodity. 2002-2009. Statistics Canada, imports and exports balance of payments.
New Zealand	1861-1998. New Zealand's national statistical office: Statistics New Zealand. 1999-2009. New Zealand's national statistical office: Statistics New Zealand.
Uruguay	1870-1989. Baptista, B. & Bértola, L. 1990-2008. Cepal.

Argentina

(1810-1985) Ferreres (2005). Prices and quantities of goods exports and imports.

(1986-2009) Indec – www.indec.gov.ar. External sector, prices and quantities of goods exports and imports.

Australia

(1870-2004) Gillitzer and Kearns (2005). Terms of trade, goods.

(2005-2009) Australia Bureau of Statistics - http://www.abs.gov.au. Catalogue number 5302.0: Balance of Payments and International Investment Position, Australia. Table 6: terms of trade, goods.

Canada

Statistics Canada. - http://www.statcan.gc.ca/pub/11-516-x/11-516-x1983001-eng.htm

(1869-2001) non-Statistics Canada information. Table 176-0006 - Merchandise exports classified by commodity, Paasche Price Index (1992=100, seasonally adjusted), 1992 and current dollars (seasonally adjusted at annual rates), quarterly (table), CANSIM (database), Using E-STAT (distributor). Table 176-0007 - Merchandise imports classified by commodity, Paasche Price Index (1992=100, seasonally adjusted), 1992 and current dollars (seasonally adjusted at annual rates), quarterly (table), CANSIM (database). Using E-STAT (distributor).

(2002-2009) Imports and exports balance of payments and customs-based price and volume indexes for all countries; Canada; Customs; Price index; Paasche current weighted; Seasonally adjusted; Imports and exports (2002=100), total of all merchandise.

New Zealand

(1861-1998) Statistics New Zealand, Long-term data series - http://www.stats.govt.nz/browse_for_stats/economic_indicators/NationalAccounts/long-term-data-series/prices.aspx. Table G1: Merchandise terms of trade index.

(1999-2009) Statistics New Zealand, Long-term data series - http://www.stats.govt.nz/browse_for_stats/economic_indicators/NationalAccounts/long-term-data-series/prices.aspx. Table G4: Import price index. Table G5: Export price index.

Uruguay

(1870-1989) Baptista, B. & Bértola, L

(1989-2008) Cepal - http://websie.eclac.cl/infest/ajax/cepalstat.asp?carpeta=estadisticas. Cuaderno Nº 37: América Latina y el Caribe - Series históricas de estadísticas económicas 1950-2008. Cuadro 9.3.20: Uruguay índices de comercio exterior. (términos de intercambio de bienes y servicios).

A2. Methodological issues in spectral analysis and suggestions for reading

For illustration of the reader on some interesting caveats in the estimation of spectra, we quote Pope (1984) who emphasizes the following methodological issues. (**i**) "The statistical problem is not hard to spot. As other critics of long swings have noted, the results are highly sensitive to the method used to remove the trend and the "filter" (smoother) employed in taking out the shorter-run fluctuations and disturbances. Though not shown, moving averages of different length produce different patterns. Moreover, one can question whether any moving average - nine, three, or eleven years, is neutral in its representation of the unstransformed series. In 1937, of course, Eugen Slutsky demonstrated that the application of a moving average process to random numbers can generate cycles where none existed in the unaveraged series". Page 741. (**ii**) On Page 742. "The relatively high estimates of spectra are indeed concentrated at low frequencies. But there are some serious limitations to the statistical methodology which cloud the issue. First, the spectral density approach should only be applied to stationary random processes. A stationary time series is defined as trendless in mean and variance.However, the shape of the spectral density function generated by spectral methods is sensitive to the technique used to detrend the time series". (**iii**) Footnote 18, page 742. "Non-stationarity means that it is difficult to interpret the spectrum. It is to be noted that the power spectral estimates do not represent the contribution of each frequency component to the total variance of the series, because come true components will be closed out or overshadowed by the non-stationary elements". (**iv**) Page 745. "Spectral analysis requires long data series. One rule of thumb is that the method requires data of about seven times the length of the largest cycle one wishes to study for a proper determination. On this count Rostow's average cycle of 40 years could require not 110 but 300 data points to properly assess". Granger, C.W.J. (1966), "The Typical Spectrum Shape of an Economic Variable", Econometrica, Vol. 34, January, pp. 150-161. Granger and Hatanaka, Spectral Analysis: "The authors specifically mention the futility of measuring Kuznets cycles by spectral methods, concluding "to measure the reality of the uKuznets long wage, data of 140 years or so are required as a minimum. As reliable economic series are usually shorter than this it is seen that there is an insufficient amount of data available to make any such tests for such cycles".

TABLE A.2.1
Variance Decomposition in time domain.

(a) Hodrick-Prescott filter;
(b) ARMA/ARCH of TOT linearly detrended;
(c) ARMA/ARCH of TOT linearly detrended with breaks

(a) Hodrick-Prescott filter			
	Argentina	Australia	New Zealand
Trend component of variance: "Explained"	0,01162 (**46%**)	0,02189 (**54%**)	0,00696 (**36%**)
Variance H-P cycle	0,00988 (39%)	0,01276 (31%)	0,00989 (52%)
2 x Cov(,)	0,00386 (15%)	0,00606 (15%)	0,00222 (12%)
Total Variance	**0,02537** (100%)	**0,04076** (100%)	**0,01909** (100%)
(b) ARMA/ARCH of TOT linearly detrended			
	Argentina	Australia	New Zealand
Explained	0.013265 (**53%**)	0.03236 (**79%**)	0.01071 (**63%**)
Unexplained	0.011651 (47%)	0.01203 (29%)	0.00812 (48%)
2 x Cov(,)	-0.00006 (0%)	-0.00331 (-8%)	-0.000181 (-11%)
Total	**0.02486** (100%)	**0.04105** (100%)	**0.01701** (100%)
(c) ARMA/ARCH of TOT linearly detrended with breaks			
	Argentina	Australia	New Zealand
Explained	0,01481 (**60%**)	0,03380 (**82%**)	0,01224 (**70%**)
Unexplained	0,01026 (41%)	0,01061 (26%)	0,00603 (34%)
2 x Cov(,)	-0,00020 (-1%)	-0,00318 (-8%)	-0,00078 (-4%)
Total	**0,02486** (100%)	**0,04105** (100%)	**0,01748** (100%)

Source: Díaz Cafferata and Mattheus (2010).

TABLE A.2.2
Continuing sectorial export specialization.
Share of manufactures on exports (Xm) and imports (Mm) in 2008.

	Land-abundant countries						Scarce-land industrial countries						
	AR	AU	NZ	UY	CAN	USA	FRA	BEL	ESP	SWI	UK	DEU	JPN
Xm	31	15	25	26	47	75	78	77	73	89	71	86	89
Mm	83	71	68	59	76	65	70	70	65	80	68	71	45

Source: Statistic Database, Trade Profiles; Taken from Díaz Cafferata and Mattheus (2010),

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A.3. The resource abundance approach to comparative advantage

The Heckscher-Ohlin endowments approach to comparative advantages predicts that small economies with same land abundance and identical preferences would have high traditional North-South sectorial specialization, and similar trade patterns. Further, large natural endowment differences with the rest of the world shall drive the economy towards high sectorial specialization before factor price equalization is reached. Gandolfo (1994) notes that the farther apart the relative factor endowments are, the less likely the presence of a segment of equalization is. In the extreme case of identical specialization they would also face identical (exogenous) terms of trade fluctuations, a proposition that can undergo empirical testing. In the limit case of economies specialized out of the cone of imperfect specialization, resource allocation may be highly inelastic to TOT movements, and to trade policies, a phenomenon which we may describe as a "structural rigidity". In fact, the extreme difference of "first nature" endowments measured as population *per square* kilometer between the land abundant and selected European countries and Japan, remains almost unchanged since the twentieth Century until our days. Table A2.2 highlights that the direction of land abundant countries trade remains largely to our days of the "classical" type, with Argentine, Australian and New Zealand´s exports of manufactures in the range of 15% to 30%, while imports of manufactures are between 60% and 80%. This contrasts with the high participation of manufactures both on exports and imports of industrial countries, revealing the prevalence of intra-industry flows on North-North trade[27].

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[27] See Díaz Cafferata and Mattheus (2010).

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