Revisiting the Unit Root Hypothesis: A Historical and Empirical Study

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Abstract

This work presents empirical evidence supporting the Unit Root Hypothesis for Argentina real gross domestic product (GDP) between 1810 and 2004 (which is the longest series available). Particularly, six tests will be conducted, Augmented Dickey Fuller (ADF), Dickey Fuller Generalised Least Square (DFGLS), Phillip-Perron (PP), Kwiatkowski-Phillips-Schmidt-Shin (KPSS), Elliott-Rothenberg-Stock Point-Optimal (ERS) and Ng-Perron Test. The relevance of that hypothesis is linked with the long-run consequences of policy shocks, fiscal and monetary, as suggested by some Post-Keynesian models of growth where the principle of effective demand is incorporated in the long run and money is not neutral[1]. The main finding is that all tests applied favor the existence of a unit root in Argentine GDP when including the whole time series between 1810 and 2004.

I. Introduction

The analysis of the Unit Root Hypothesis in long run macroeconomic time series has produced, in the last decades, an enormous flow of empirical and theoretical papers to defend (or refute) the existence of unit roots in time series like Gross Domestic Product (GDP) and productivity, among others. The reason can be found in the consequences of this hypothesis for the economic theory, econometric modelling and policy makers. It claims that any random shock affecting a time series has a *permanent* effect on it.

The traditional point of view considers that macroeconomic variables are stationary series; therefore, random shocks would only have *temporary* effects and would not affect their long-run position. In contrast, under the Unit Root Hypothesis some variables such as GDP or productivity would not be stationary and random shocks would affect their long-run position.

In other words, to explain some features of a series we need to know whether or not it has a unit root. If a series does not have a unit root, it can be considered stationary and it will exhibit mean reversion (it will fluctuate around a constant mean in the long run). At the same time, unit root will have a constant and time independent variance (the behavior of the variance is essential for econometric forecasting). Consequently, the effects of shocks will dissipate or will disappear in the long run.

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1 See Braga, 2008.

On the other hand, if a series has a unit root, one will not observe a reversion to its long run mean. At the same time, and in contrast with stationary series, the variance will be dependent on time and it will go to infinite as time approaches infinity. As a result, the effect of shocks will not disappear in the long run.

As we can see, the unit root hypothesis is not only an important concern for econometricians but for economists and policy makers as well, since its implications are important to economic modelling and policies.

In this work we will evaluate the stochastic process governing the series of real GDP for Argentina between 1810-2004. Following a sequence of tests suggested by the econometric literature[2], we have run six tests, Augmented Dickey Fuller (ADF), Dickey Fuller Generalised Least Square (DFGLS), Phillip-Perron (PP), Kwiatkowski-Phillips-Schmidt-Shin (KPSS), Elliott-Rothenberg-Stock Point-Optimal (ERS) and Ng-Perron Test, for Argentina real GDP series from 1810 to 2004.

The results obtained here allow acceptance of the hypothesis of the existence of a unit root for the series. To put the argument in another way, one hundred ninety-four years of history are not enough to accept the idea of long-run mean reversion in this series. This reinforces other results obtained for Argentina's real GDP series by Sosa Escudero (1997), Carrera Feliz and Panigo (1999), Utrera (1999), Rabanal and Baronio (2010), and Gomez Aguirre (2012).

The rest of the paper is organized as follows. In section 2 we will present a brief review of the discussion surrounding the Unit Root Hypothesis, beginning formally in 1982 with Nelson and Plosser's work until the second decade of the twenty-first century. In section 3 we will introduce some basic econometric concepts that will help us to understand the following sections. In section 4 we will make six unit root tests, available in Eviews 7, to test the hypothesis on the existence of a unit root in Argentina real GDP between 1810 and 2004. In section 5 we will present the final conclusions.

II. Discussion Review: the origin of the controversy.

The study of the Unit Root Hypothesis was recently developed in Econometrics, but in 1926 Udny Yule had already detected problems when regressing two trending variables without any relation between them. According to Yule, one could find a positive or negative link between two variables

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2 See Stock, 1994.

even though they were not correlated. This problem is part of the famous "nonsense regressions". The finding was important at first but had been left behind for more than fifty years[3].

The problem of nonsense regressions was again brought up into discussion in a more formalized way with the seminal work of Nelson and Plosser (1982), "Times and Random Walk in Macroeconomics Time Series". The objective was to discover whether macroeconomic time series (even those having no trend[4]) were better characterized as a stationary or non-stationary process.

Nelson and Plosser found that the existence of a unit root can be accepted for thirteen out of the fourteen U.S. time series starting between 1860 and 1909 and ending in 1997, particularly: real gross national product (GNP), nominal GNP, real per capita GNP, industrial output, employment, nominal and real wages, the yield curve and prices of stocks, consumer price index, velocity of circulation of money, money supply and the implicit deflator of GNP.

The principal conclusion of Nelson and Plosser's work is that most empirical data is inconsistent with the null hypothesis that important macroeconomic series do not have a unit root.

Following this pioneering work, Campbell and Mankiw (1987) extended the analysis for quarterly postwar United States gross national product data, using a less restrictive model to the description of the GDP than that implemented by Nelson and Plosser (1982) and incorporating a non-parametric method proposed by Cochrane (1982). In the authors' former procedure, the null hypothesis is the series non-stationarity and the representation of the underlying data generating-process is changed to cover a more general case[5]. They conclude that the evidence found, supporting the existence of unit roots, is not only important for econometric reasons but also because it allows us to understand some economic analysis.

In a different way, John Cochrane (1988) argues that following a shock in the GNP, reversion occurs several years into the future and meanwhile the shock is very persistent. This short persistence can lead one to infer long-run persistence if one adjusts the long-run behavior to the short run. The problem is that tests for unit roots have low power. That is to say, it is difficult to distinguish a stationary process from a non-stationary process when the root is close to one. One

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3 Granger and Newbold (1974) and Hendry (1980) returned to the study of this concept.

4 The trend was an expression utilized to describe a growth or declining trend in the long run, even if it is not linear. Today it is called deterministic trend.

5 See Campbell and Mankiw, 1987.

can (erroneously) think that the process has a unit root when it is not the case. Afterwards, Cochrane showed that a time series with a unit root is equivalent to a stationary time series with a root close to one, finding little long-term persistence in GNP.

The second objection to Nelson and Plosser's work and the Unit Root Hypothesis comes from Phillip Perron, who in 1989 published: "The Great Crash, The Oil Price Shock, and The Unit Root Hypothesis" paper. He showed how the unit root standard tests cannot reject the existence of a unit root when the data contains a structural change. That is, if stochastic fluctuations exist around a trend function with a one–time break, then the test of the hypothesis cannot reject the hypothesis of the presence of a unit root, even if this does not exist. It was an attempt to refute Nelson and Plosser's work, like many others which followed made by Ren Stulz and Walter Wasserfallen (1985) and Wasserfallen (1986).

Perron holds that most macroeconomic time series do not have a unit root and fluctuations are stationary. His argument is that only two events in the twentieth century have had permanent effect on macroeconomic variables, the Great Crash in 1929 and the oil price shock of 1973.

He had to assume that these two shocks were exogenous, i.e. they were not a realization of the underlying data-generating mechanism (see e.g. Perron, 1989). Then the series remains trend-stationary if one allows a change in the intercept in 1929 and/or a change in the slope of the trend after 1973. Knowing the date when these "interventions" occur is the only requisite. In other words, the events have to be fixed exogenously and not stochastically.

In conclusion, Perron's finding showed that it is not possible to reject the hypothesis of the absence of a unit root in most macroeconomic series. The intuition behind these results is that the main economic factors which determine the trend function rarely change. That is, shocks do not have persistent effects, but vanish over the long run.

Continuing the discussion, for Christiano and Eichenbaum (1989) the problem is that the possibility of determining if real GNP is either stationary or not is extremely small. This is due to the fact that there is only one difference between these two types of processes. If the impact of a shock in real GNP is zero then the process is stationary, and on the contrary, if the impact is not zero then the process is not stationary. For the authors it is hard to believe that there exists enough evidence for one relevant experiment in finite samples.

Secondly, they argued that though permanent shocks may exist the agents would tend to respond more to temporary shocks than to permanent ones. They concluded that, with a finite data set, one could not distinguish between both types of processes. To identify the hypothesis under analysis, one would need infinite horizons, and the economic theory would not be conclusive about which shocks are considered important for the agents.

Another argument against the power of the unit root tests was raised by Cochrane in 1990. As was mentioned before, one of the problems is that the unit root tests could have low power against some similar alternatives in finite samples. For those reasons Cochrane concluded that when a unit root test is used, one has to be aware of their low power and the restrictions that are needed to be implemented in a finite sample, meaning that they can be applied but with care.

The 'low power argument' was reinforced by Stephen Blough in 1992 when he studied the relation between Power and Level in econometric tests. Blough showed that the maximum power (the power of a test is the likelihood of not accepting the null hypothesis when this is false) of a generic unit root test against any stationary alternatives is equal to the level of the test (the level of a test is the probability of rejecting the null hypothesis when this is true). In other words, if one selects a level (α) equal to 0.5, then the power of the test will be equal to 0.5.

Because any stationary process has a unit root process arbitrarily close, then no test can have high power against a stationary process without having, at the same time, a high probability of false rejection over nearby members of the unit root null. The corollary is that the power of a generic unit root test cannot exceed its level.

This result differs from the argument of Cochrane (1990) about the low power of a unit root test against alternatives with roots closer to unity. That is to say, Cochrane's argument is only possible when the root approaches one. In contrast, the corollary of Blough occurs over the entire alternative space, even with a root that is not close to one.

Katarina Juselius (1999) seeks to reconcile the economic theory, which assumes the stationarity of some macroeconomic variables, with the empirical evidence that contradicts it (existence of unit roots in them). This is because it would be contradictory to consider some variables stationary in some studies and non-stationary in others. Furthermore, most macroeconomic variables exhibit considerable inertia in the medium term. This is consistent with the existence of a unit root. Hence, in the absence of a structural interpretation (economic), such variables should be considered, within certain limits, non-stationary.

That is, for Juselius the non-stationarity of a variable is usually not an economic characteristic, but rather an appropriate statistical approach to distinguish between variations in the data of short, medium and long term. In other words, when one analyzes a variable in the short or medium term, it may be advisable to treat it as if it were non-stationary and assume that there are shocks with permanent effects, which lead the variables to diverge from its mean over a considerable period of time.

> "There are many arguments in favor of considering a unit root (a stochastic trend) as a convenient econometric approximation rather than as a deep structural parameter." (Juselius, 1999a, p. 8)

In sum, according to Juselius the strong evidence in favor of the non-stationarity of the series and/or structural breaks in the main macroeconomic variables should be incorporated into theoretical models.

Taking all these arguments into account, successive tests and methodologies to corroborate the hypothesis have been developed since the eighties. Recursive methods, rolling, panel data and endogenization of the selection of one or more structural breaks, led to a flood of empirical studies, many of which found evidence of non-stationarity[6].

As no particular test has more power than any of the others, one should run as many as possible. In other words, when one selects the size of the test (the probability of rejection when the null hypothesis is true) there is no test with the capability of increasing the probability of rejecting the null hypothesis when it is false for all possible values that the parameter could assume in the alternative hypothesis (see e.g. Stock, 1994).

III. Econometric Introduction to the Unit Root Issue

In this section we will present some econometric concepts under the unit root hypothesis, which will help us to understand the subsequent analysis.

The mathematical theory of stochastic processes asserts that the traditional definition of a stationary process includes a constant, finite mean and finite auto-covariances (Escudero, 2000). Thus, non-stationary processes include processes where any of those two features are absent. The latter includes variables with deterministic trends, random walks and random walks with drift. It should be noted that the time behavior of the first two moments of those three processes is not equal across them.

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6 See for example Cochrane (2002), Phillips y Xiao (1999), Maddala y Kim (1998), Harvey (1997), Stock (1994), McCallum (1993), Campbell y Perron (1991), Cochrane (1991a), Cochrane (1991b).

However, a major common feature of any non-stationary stochastic process is that, if any of them is fed by possible innovations (which may not be non-stationary necessarily) then such non-stationary process may turn the propagation of such innovations into a permanent phenomenon over time. This is important since some of those innovations may be policy shocks (monetary, fiscal or other). So, a non-stationary behavior for macroeconomic variables may imply that such policies have permanent effects on such variables.

Therefore, such diversity of types of non-stationary stochastic processes prevents from finding a unique general test of non-stationarity for a given time-series data. Instead, the time-series literature has more extensively developed tests about the presence of the so-called unit roots, that is, whether the time series behavior of an empirical variable is nearly a random walk, although some variants have been introduced to also test the presence of deterministic trends within random walks. This is the type of tests reviewed in section 4.

IIIB. Why do we have to test for Unit Roots?

There are two aspects to this question that are relevant for the discussion studied here. First, we have econometric reasons to test for unit roots; a unit root test can help us to detect the source of non-stationarity and, in consequence, the solution to restore stationarity will be different (Escudero, 2000). In other words, the way to restore stationarity depends on the features of the process under analysis.

Second, if one supposes that two series (Y_t and X_t) are two unit root processes, one can know that the regression between such series is very likely to be spurious. This means that one will probably obtain a high correlation coefficient (R^2 close to 1), and a significant t-statistics even when the series are completely unrelated[7], so the conclusion of the tests will be incorrect.

The third, and maybe the most important reason to test for a unit root is the impact or the effect of a shock at time *t* in the following period after it took place. The point is to know the effect of a shock in Y_t or X_t *s* periods ahead. When the processes are stationary the effect of the shock tends to zero when *s* tends to infinity, whereas in a non-stationary process its effect remains in the long run. Meaning that, the feature of the process determines whether shocks are transitory or permanent over time.

7 For example, Hendry. D. F (1993), found a correlation between the level of prices and the rain fall in United Kingdom.

Finally, we have economic reasons to test for Unit Roots. Traditional theories of Real Business Cycle hold two premises. First, fluctuations in output are driven by nominal factors, such as monetary or fiscal policies. Second, these nominal shocks are transitory and will not have effects in the long run because, over a long period, economy tends to return to a natural position (natural rate of growth or natural rate of unemployment are examples of gravitational centers in the long run) which is only driven by real factors, such as technological change which in turn is not related to demand (Libanio, 2009).

Nelson and Plosser (1982) argued that the first premise should be abandoned. In contrast, John Campbell and Gregory Mankiw (1987) claimed that it is possible to leave behind the second premise and assume that demand shocks can have permanent effects on the economy through some Keynesian channel.

Independently of the factors that explain the growth of the GDP in the long run, the point in discussion is whether any shock, from the output or demand side, which changes the level of product in time *t* can also change its level in time *t+s* (where s is the long run). If shocks generating output fluctuations are highly persistent, then both premises cannot hold, and furthermore, we will have a stronger relation between short and long run. This stronger relation will imply that the previous history of a series, for example the previous path of a macroeconomic series as GDP, is important to explain and understand the current and future movements of this series. This allows one to argue that the same factors which determine the effective product or its short-run path also drive the potential output or its long-run path. Thus, the distinction between trend and cycle would become futile and misleading.

This means that a discussion about what an economy has to do or what an economy can do when, for example, it is not at full-employment, (as is the current situation for most of the countries in the world) will lead to different and opposite outcomes. For that reason, the author considers that the study of the discussion initiated by Nelson and Plosser (1982) and continued in subsequent papers cannot be ignored.

IV. Empirical Analysis: a review for Argentina.

Ahumada (1994) only studied the behavior of nominal variables as the inflation rate, interest rate and devaluation rate with the methodology proposed by Johansen and Juselius (1990), which is more powerful than the standard tests of Unit Roots (as DF or ADF). She concluded that the only stationary variable detected was the devaluation rate, while the interest rate only was non-stationary until 1989, and the inflation rate was non-stationary throughout the entire period under analysis.

Sosa Escudero (1997) used different tests (including ADF and Phillip-Perron's, also performed in this paper) and found no rejection of the null hypothesis of unit root for series with annual data for the period 1900-1993. Another example of that literature is Carrera, Feliz and Panigo (1999). The latter, applying tests like Phillip-Perron's, Perron with a structural break, a test with an exogenous selection of trend break and another with an endogenous selection of trend break, to a quarterly series for the period 1-1980 to 4-1998, found that GDP can be considered integrated of order one (i.e., it has a unit root). In contrast, Utrera (1999), by using resampling techniques[8] and allowing multiple (endogenously selected) structural breaks in the alternative hypothesis of the trend-stationary process, rejected the hypothesis of a unit root for the sub-periods. He considered annual data for the period 1913-1999 and quarterly data for the period 1-1970 to 3-2000.

Using the same GDP series as in this paper (albeit for a shorter time period), Rabanal and Baronio (2010) and Gomez Aguirre (2012) also found no conclusive results. The first performed three tests for two sub-periods, one between 1880 and 1969 and the other between 1970 and 2009. They obtained a stationary GDP around a deterministic trend for the first sub-period, while a non-stationary GDP for the second sub-period.

Gomez Aguirre (2012) performed unit root tests for the period 1810-2010 using mostly the data from Ferreres (2010), as is the case here too[9]. The two tests performed there are the Augmented Dickey-Fuller and another by Enders and Ludlow (2002), which assume a set of time variant, periodically oscillating coefficients. In the non-stationary tests, in line with our findings, Gómez Aguirre (2012) detects the presence of a unit root in the Argentina GDP series for the above-mentioned period.

8 For re-sampling techniques in unit roots, co-integration and long memory see, e.g., Wu (1986), Park (2002), Chang, Park and Song (2005), Parker, Paparoditis and Politis (2006) and Andrews, Lieberman, and Marmer (2006), among others.

9 The goal of these tests is to determine the degree of integration of the GDP series. Having determined such degree, the paper proceeds to estimate a so-called smooth autoregressive transition model (see Chang and Tong, 1986).

First of all, in this work we only evaluate the hypothesis of the existence of unit root for Argentina Real GDP series using annual data from 1810 to 2004. In other words, we will not consider nominal variables and quarterly data.

The second and important difference between our work and the mentioned above is that we use a 194-year long series. This provides more power to evaluate the null hypothesis of non-stationarity than if we apply the same test in shorter series.

Third, to evaluate the null hypothesis we employ four tests not used until now. Particularly, the Dickey-Fuller GLS, Kwiatkowski-Phillips-Schmidt-Shin, Elliott-Rothenberg-Stock Point-Optimal and Ng-Perron tests, to show that the results obtained with classic procedures (ADF and Phillip-Perron) are robust when other tests specifications are used.

In summary, the power of our tests will be higher than any other presented in the literature and our results will enlarge those previously obtained by other authors.

IVB. Testing for Unit Roots in Argentina Real GDP (1810-2004)

In this section we will analyze the existence of a unit root in the real GDP for Argentina between 1810 and 2004[10]. We applied six unit roots tests, all available in Eviews 7, using annual data from Ferreres (2010).

Augmented Dickey Fuller (ADF) test[11]

The most popular test is the Augmented Dickey Fuller[12]. The form of the test is based on the following statistic:

$$\tau_{\alpha} = \frac{\hat{\alpha}}{\sigma_{\alpha}}$$

The numerator of the statistic is the ordinary least square (OLS) estimator of the following regression equation:

10 We did not expand the series from 2004 until 2013 to avoid the use of different series and sources of data.

11 This test is criticized in the literature for having low power. See Stock, 1994.

12 A more extended description can be found in Hayashi, 2000.

$$\Delta y_t = \alpha y_{t-1} + d_t'\delta + u_t$$

The null hypothesis is α=0 which corresponds to the presence of a unit root in the endogenous variable. It is possible to reject H_0 when |ADF|>Critical Value (CV) chosen for the test. The asymptotic distribution of a non-stationary series is shown not to be the t-student. For that reason the recommendation is to use critical values as proposed by MacKinnon (1996).

The selection of lags is relevant because it can alter the power of the test. One has to select a number of lags long enough to eliminate a possible serial correlation in the errors. This paper uses the criterion of Schwarz (Bayesian Information Criterion or BIC) as suggested by Stock (1994). Also, as proposed by Juselius (2009), we include a trend and an intercept in the test equation.

Dickey-Fuller GLS (DFGLS) test[13]

Basically, the DF-GLS is an Augmented Dickey-Fuller test except that the time series is transformed with a generalized least square regression before performing the test. The motivation of this test is to generate a test where the asymptotic distribution is not altered for the shape of d_t and its correct specification. The advantage, demonstrated by Elliot, Rothenberg, and Stock (1996), is that the test has more power than a Dickey-Fuller test when an unknown trend or mean is present.

When d_t is equal to zero, the asymptotic distribution of the t statistic, as the rejection criterion, is the same as in the ADF test (|ERS|>CV). When either d_t or its mean be different to zero, the asymptotic distribution changes and the critical values will be those tabulated by Elliot, Rothenberg and Stock (1996).

The information criterion used is BIC. Additionally, one can use the criterion suggested by Ng and Perron (2001) because in the presence of a large negative moving average component in the error process, the test will have low power. We also include a trend and an intercept in the trend equation.

13 A more extended description of the test can be found in Stock (1994).

Phillip-Perron Test[14]

Phillip-Perron test was constructed to eliminate asymptotic bias appearing in the original ADF test when serial correlation exists in the residuals (see e.g. Davidson and MacKinnon, 1993). To achieve the latter, it is necessary to modify the original τ statistic:

$$\Delta y_t = \alpha y_{t-1} + d_t'\delta + u_t$$

$$\tau^* = \frac{\sigma\tau}{\lambda} - \frac{T(\lambda^2 - \sigma^2)}{2\lambda y' M_X y}$$

In the last expression λ^2 is the long-run variance of the residual u_t; σ^2 is a consistent estimator of variance of errors and the matrix M_x equals I_T-P = $I_T - X(X'X)^{-1}X'$ where X is variance/covariance matrix of residuals.

The intuition of this modification is that, in the presence of serial autocorrelation, it is necessary to take into account not only the variance of residuals as their auto-covariances. The key point of this correction term is that it is a function of the difference between the estimated variance of u_t and the long-term variance u_t estimated. Theoretically, the variance of long term is the sum of the autocorrelations of the residuals. When there is no serial correlation, all auto-covariances are zero and the sum of auto-covariances will be u_t variance. Thus the correction term will be zero because $\lambda^2 = \sigma^2$. In other words, this correction term prevents the asymptotic distribution to be affected by the presence of a serial correlation.

However, the latter procedure requires an estimator for λ^2. Such an estimator should possess reasonable finite-sample properties. What may differentiate the estimators of λ^2 are the weights used for the auto-covariances adopted, and also the chosen q parameter, called bandwidth parameter. This last parameter is a function of sample size and number of auto-covariances used.

This work adopts the estimator indicated by the authors themselves (Phillip and Perron), which is the estimator covariance Kernel type Bartlett, (i.e. linearly declining weights). Finally, the bandwidth parameter was chosen by the method Newey-West. The critical values and rejection criterion used in the application here are the same as in ADF test (|PP|>CV). We also include a trend and an intercept in the test equation.

14 This tests is criticized in the literature for having large size distortions in finite samples.

Test of Kwiatkowski-Phillips-Schmidt-Shin (KPSS)

This test was designed to propound as null hypothesis the nonexistence of a unit root. In other words and unlike the other tests, the null hypothesis is that the process is stationary. The critical values are those tabulated by Kwiatkowski, Phillips, Schmidt and Shin (1992) according to the asymptotic results discovered by the authors. Thus, rejection of the null hypothesis occurs if KPSS >CV. The bandwidth parameter was chosen by the method Newey-West. Additionally, at this point, this test is also performed using the quadratic estimator spectral kernel as recommended by Stock (1994). This is due to the possible distortions of size as the Newey-West estimator may cause to the KPSS. We also include a trend and an intercept in the test equation.

Elliott-Rothenberg-Stock Point-Optimal (ERS-P)

This kind of test is an alternative proposed when the root is close to unity. In other words, it is a more efficient test and (in that case) has more power than ADF and PP tests. It is a type of likelihood ratio test adapted to the case when the variance-covariance matrix is unknown[15]. That is, it takes into account the possibility of existence of serial correlation in the errors. The critical values for the ERS-p statistic are computed by interpolating the simulations results provided by ERS (1996). We also include a trend and an intercept in the test equation.

Ng-Perron Test

This test is based on Monte Carlo simulations. The latter show that ignoring some dynamics in the residuals (the choice of the density estimator spectrum, the bandwidth parameter or lags of autoregressive components) can greatly influence the performance of the tests (see e.g. Stock, 1994). Ng and Perron (2001) built new information criteria from the observation that the information criteria normally used Akaike's Information Criterion (AIC), and Schwarz's Criterion (BIC) tended to select a small number of lags in the AR equations as ADF test. In short, the information criteria are considered as modifications to the traditional criteria. Among these, the authors suggest the use of the modified AIC criterion (MAIC). This criterion can also be used to select the bandwidth for the autoregressive spectral density estimator. We also include a trend and an intercept in the test equation.

15 See Elliot, Rothemberg and Stock, 1996.

IVC. Data description

Ideally, the tests summarized above may be applied to several macroeconomic endogenous variables of interest, including consumption, investment and unemployment. However, for the Argentine case at least, there is no available secular time series for such variables. National accounts officially started to report data on such variables only after 1970.

Applying the tests to such short series may partially incur the low-power criticism that comes from the debate in the literature mentioned above. The only secular time-series data corresponds to the annual estimates for Argentina's real GDP between 1810 and 2004 available from Ferreres (2010). This series has the particular feature that it is not an overlapping of different data sources but one original series constructed as a whole. The original series included data for the period 2004-2013. However the paper excludes such a period to avoid the use of different series and data sources. Given the time extension of the rest of the series, this absence does not seem to have too much influence on the empirical results.

IVD. Results

Table 1 below shows all the tests introduced above.

Table 1: Unit Root Tests from 1810 to 2004

	ADF (lag 0)	PP (BW 2)			DF-GLS (lag 0)	KPSS (BW 11)	ERS-P (lag 0)
			Statistics		-1.04	0.223	34.80
p-value Unit Root Test	0.91	0.91	**Critical Values**	1%	-3.47	0.216	4.06
P-value Constant	0.13	0.13		5%	-2.94	0.146	5.66
P-value Linear Trend	0.26	0.26		10%	-2.65	0.119	6.86
			P-value Constant			0.00	
			P-value Linear Trend			0.00	
			Ng-Perron (lag 0)				
				Mza	**MZt**	**MSB**	**MPT**
Statistics				-2.49	-1.03	0.41	33.32
Critical Values		1%		-23.80	-3.42	0.14	4.03
		5%		-17.30	-2.91	0.17	5.48
		10%		-14.20	-2.62	0.19	6.67

The upper left panel presents the results of the Augmented Dickey-Fuller and the Phillip and Perron tests with the number of lags and the bandwidth parameter (BW) selected, when applicable. Both statistics fall within the non-rejection region of the null hypothesis at the 10% confidence level, which corresponds to the presence of a unit root in the series.

The upper right panel presents the results for the GLS-based ADF, the KPSS and the ERS tests. The first of the three columns states that the null hypothesis cannot be rejected even for a relatively wide rejection region (i.e., 10%). Recall that the null hypothesis in the GLS-ADF is still the presence of a unit root, so the latter is not rejected from this test. The following two columns state that the null hypothesis is rejected even at 1% of confidence. In those other two tests, the null hypothesis is the absence of a unit root. Thus, these tests confirm the presence of a unit root. Finally, the low panel presents the different variants of the Ng and Perron test. Ng and Perron (2001) constructed four test statistics which are modified forms of Phillip and Perron statistics (namely Mza and MZt respectively), the Bhargava (1986) statistics (namely MSB) and the ERS Point Optimal statistic (namely MPT). For Mza and MZt statistics the rejection criterion is |Mza|>CV and |MZt|>CV. For MSB and MPT statistics the rejection criterion is MSB<CV and MPT<CV.

In summary, Table 1 states that all of the tests unanimously confirm the non-stationarity of annual GDP for the 1810-2004 period.

V. Final Remarks

Through this work we have reviewed the discussion about the existence of unit roots in principal macroeconomic time series, particularly the GDP. We have seen that there are econometric and economic differences among stationary and non-stationary processes. Particularly, the most important implication is the impact of a shock in the long run. In other words, a series with a unit root not only will suffer a variation in the short run after a shock, but, at the same time, its long-run path will be affected.

This led to a long and intricate discussion for more than three decades. The discussion initiated by the pioneer work of Nelson and Plosser in 1982 is not finished today. Currently, there is still conflict between those who argue that it is possible to test for the existence of a unit root and those who think that it is impossible. The latter group supports the idea that unit root tests have very low power against similar alternatives or in finite samples. As we noted, after the development of the Dickey-Fuller test, a lot of alternative tests were developed to analyze the existence of unit roots. So the argument about the lack of power becomes weak, or has an inverse relationship with the amount of statistical and econometric techniques available (many of them with more power than the first Dickey-Fuller test) to test stationarity. On the side of those who argue in favor of the existence of unit roots in macroeconomic series, the main argument is the enormous and diverse tests used to test this hypothesis. Because, in many countries and in different periods of time, a lot of them[16] have shown that one cannot reject the hypothesis of the existence of a unit root. One should consider this particularity in economic analysis.

Furthermore, the distinction between a series with a unit root or quasi unit root (coefficient of 0.99 for example) is trivial for two reasons. Firstly, since the behavior of the latter is not very different from the former. That is, the return to its mean of a quasi-stationary series is so slow and takes place in a future so distant, that it would make no sense to infer theoretical conclusions and policy implications assuming stationarity.

Second, it is also necessary that the period of return to its mean be neither too long or extremely short (the case of a coefficient clearly distinct from one and close to zero). In other words, following the argument of Juselius (1999), not only for econometric convenience but also for its theoretical relevance in the developing of macroeconomic policies, it would make no sense to consider a series with a high persistence of shocks in the short and medium term as stationary.

A third point against the unit root test comes from the difficulties in differentiating between series which have suffered a structural change from non-stationary series. Not only works with an endogenous approach for the detection of breaks (like the ones of Banerjee, Lumsdaine and Stock (1992) have continued finding evidence of the presence of unit roots, but, at the same time, have detected the existence of the hysteresis phenomenon which weakened this third argument. That is, the existence of hysteresis[17] in series such as output implies, among other things, that it is possible for structural changes in the economy to occur after the impact of a random shock.

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16 Different works about Unit Root in macroeconomics time series can be found in Fiorito, Amico and Hang (2010).

17 Hysteresis is a concept developed from the discipline of Physics by James Alfred Ewing in 1881, when he analyzed the magnetic properties of metals. The concept states that when a metal is magnetized, after removing the force used to do this, the level of magnetization does not return to zero but slowly fades over time. That is to say, there is a delay (permanence) in the change of the level of magnetization of a body after the magnetic intensity has been exposed.
This concept refers to a dependence of the final state of a system on the current environment but also on the conditions to which it was exposed in the past. On the other hand, in the field of Economics and following the definition provided by Setterfield (1997), hysteresis exists when the cumulative impact of a shock on the long-term outcome is different to zero.

Therefore, talking about structural changes that occur in a hysteric series is trivial, since the formers are an endogenous consequence of the latter.

Another postulate against non-stationarity in macroeconomic series comes from authors like Christiano and Eichenbaum (1989), who argued that not only one cannot tell when a series has a unit root or not (in other words, the technology to test the Unit Root Hypothesis does not exist), but also that it is not important or relevant. This last argument would be due to the lack of an economic theory that incorporates the idea of strong hysteresis in macroeconomic series. The Sraffian Supermultiplier model developed by Serrano (1995) refutes this last argument because it permits to include the phenomenon of strong hysteresis in a theory of economic growth. Clearly, the low power of the tests is not a sufficient reason for *not* assuming the non-return of the variable to its average in some macroeconomic variables.

In other words, not only because there is empirical evidence against the stationarity assumption of many macroeconomic series as we have seen, but also because there are theoretical postulates which allow the defense of the argument of the existence of unit roots, and therefore strong hysteresis. Both concepts are important for the construction of economic models.

Finally, in this work we have tested six tests, ADF, DFGLS, PP, KPSS, ERS and Ng-Perron, for Argentina real GDP series from 1810 to 2004. The results obtained allow us to accept the hypothesis of the existence of a unit root for the series. To put the argument in another way, one hundred ninety-four years of history are not enough to accept the idea of mean reversion in this series, even in the long run.

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