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TESTING FOR UNIT-ROOTS AND TREND-BREAKS IN ARGENTINE REAL GDP

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1. Introduction

A major topic in the applied macroeconomics literature during the last 15 years was the analysis of the 'Unit-Root Hypothesis' as a valid characterization of most macroeconomic long run time-series and its consequences on economic theorizing. The main consequence of the Unit Root characterization is central for macroeconomic analysis: under this hypothesis macroeconomic time-series should be modeled as difference stationary processes in which any random shock has a permanent effect on the economy. The traditional view that macroeconomic variables can be characterized as stationary fluctuations around a deterministic trend -and therefore, that random shocks have temporary effects- would be inappropriate.

The seminal work by Nelson and Plosser (1982) presents statistical evidence that most macroeconomic variables for the US can be represented under the unit-root hypothesis. Since then, the economic literature has witnessed an enormous amount of applied and theoretical research on the subject. Perron, in his 1989 paper, challenged this view by arguing (and providing empirical evidence) that a more appropriate characterization is provided by a model with stationary fluctuations around a deterministic trend that presents 'structural breaks' caused by exogenous shocks. Some recent work on the topic cast some doubt on the inference procedures used by Perron, weakening the strength of his conclusions.

Surprisingly, there is not available in the literature a set of results for the Argentine case. The purpose of this paper is to provide some basic results

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for the argentine real GDP so as to have a starting point for future research[1].

The structure of the paper is the following. In the first part we present a brief summary on the relevance of the unit-root debate in econometric and macroeconomic terms, and the theoretical framework guiding the statistical procedures used in the paper. The second part presents the statistical methods utilized. Then we present our empirical results. The last part contains some concluding remarks and directions for future research on the topic.

2. Unit-roots, trends and breaks

The traditional view[2] of the economic cycle proposes the following type of model for a typical macroeconomic time series y_t:

$$y_t = a + bt + e_t \qquad (1)$$

Under this setup the variable y_t is characterized as a stationary fluctuation e_t around the time trend $a+bt$. Though y_t is obviously non-stationary (due to the presence of t), stationarity is easily achieved by 'removing the trend', that is, regressing y_t on t. In this context 'stationary fluctuation' means that once the trend is removed we are left with a stationary disturbance term that explains deviations from this trend. Hence, this process is described in the literature as being *trend stationary (TS)*.

A competing non-stationary model is the following:

$$y_t = a + y_{t-1} + e_t \qquad (2)$$

Here y_t is modeled as its own past value plus a deterministic value a (the 'drift') and a random stationary shock e_t . This process is the well known *random walk with drift*. Note that the first difference of the series $y_t - y_{t-1}$ is

[1] Ahumada (1992) presents recursive Dickey-Fuller results for several nominal variables as part of a study on cointegration relationships among these variables.

[2] See, for example, Farmer (1993) for a comparison between these models from a macro perspective.

equal to $a + e_t$, a stationary process. The fact that in this process stationarity is achieved through differencing justifies labeling it as *difference stationary (DS)*. This model represents the 'unit-root hypothesis'.

A quick comparison[3] between these two models yields the following results:

1. As noted above, in the TS model stationarity is achieved by subtracting the trend term while in the DS model the correct procedure is to take the difference of the series.

2. If e_t is assumed to be a zero-mean stationary ARMA process, the linear forecast s periods ahead made at moment t of the TS model converges (in mean square) to the time trend $a + bt$ as the forecast horizon s grows large. The forecast for the DS process can be shown to be equal to $y_t + bs$. The main difference is the following: under both specifications the forecast converges to a line with slope b, but in the TS case the intercept is always a while in the DS case the intercept (y_t) changes with the value y takes at the moment at which we forecast is made.

3. The mean square error of the forecast of the TS model converges to the unconditional variance of e_t as the forecast horizon grows large. For the DS representation, the MSE of the forecast error grows linearly with the forecast horizon.

4. For the TS model, the effect of a shock at time t on y_{t+s} tends to zero as s grows large while the same shock has a permanent effect on y_{t+s} for the case of the DS representation. This is the idea of 'persistence of innovations' in the unit-root model.

In this context, testing for unit-roots means discerning which of the

[3] Hamilton (1994) Ch.15 provides a detailed analysis of the statistical features of both models.

two competing models explains better the nonstationary character of macroeconomic time series. From an econometric point of view the question is whether nonstationarity arises from the presence of a deterministic time trend or a unit-root in the autorregresive polynomial. From a macroeconomic point of view, the main point here is to be able to determine whether a shock in a macroeconomic variable will have a permanent or a transitory effect in its future values.

A model nesting both hypothesis is provided by:

$$y_t = a + bt + uy_{t-1} + e_t \qquad (3)$$

The null hypothesis that the process is characterized by (1) can be evaluated testing $b=0$ and $u=1$ in the OLS estimation of (3), using the Dickey Fuller procedure. Nelson and Plosser's results using this test do not provide statistical evidence to reject the null, suggesting that the nonstationarity in most macroeconomic US macroeconomic time series seems to be better characterized by a unit-root process.

In his 1989 paper, Perron challenged this view suggesting that a more appropriate model is provided by:

$$y_t = a + d_t + bt + e_t$$

where:

$$d_t = \begin{cases} \text{a) } 1 & \text{if } t > k, \text{ 0 otherwise} \\ \text{b) t-k} & \text{if } t > k, \text{ 0 otherwise} \end{cases}$$

This is a trend-stationary model in which the variable d_t allows for a deterministic change in the trend at moment k. Case (a) allows for a change in the intercept of the trend (*shift in mean*) while case (b) allows for a change in the slope of the trend without any sudden change in the moment of the break (*shift in trend*). According to this specification, all innovations have temporary effect except for the one that changes the trend at time k, and it turns out to be the only shock in the process that has a permanent effect.

If the presence of this type of break is ignored when testing for a unit-root, the process mimics the DS specification. Perron shows with a Montecarlo experiment that as the magnitude of the break increases, the distribution of the autorregressive coefficient of y_{t-1} in (3) becomes concentrated at a value closer to 1. This suggests that if the shift is significant one could hardly reject the unit-root hypothesis, even if the series is a trend with i.i.d. disturbances. Using transformed versions of the Dickey-Fuller and Perron's non-parametric procedure he concludes that the null of a unit-root can be rejected in most cases in the Nelson Plosser data.

Some recent results[4] cast some doubts on Perron's conclusion. The central point of this criticism is that the moment of the break (k) is claimed to be determined exogenously in Perron's analysis. As many authors show, if this exogenous determination of the break point is influenced by observation of the data, it introduces a *pre-test bias* that favors rejecting the no-break null hypothesis. The intuition is that the choice of a breakpoint based on prior observation of the data is inconsistent with a testing procedure based on a distribution that is claimed to be data independent.

Hence, an appropriate procedure should involve the specification of a data-dependent algorithm to find the break-point (if there is one) and then to evaluate the unit-root hypothesis using distributional results that take into account this data-dependence to avoid the pre-test bias.

It is important to remark, as in Zivot and Andrews (1992), that in this type of analysis our interest in structural breaks is in testing the presence of a unit-root against the alternative of a stationary process with a break at some point, and not structural breaks *per se*. To clarify this point, it is not our purpose to build a conditional (or unconditional) model for the real GDP series allowing for a time-break, but to consider different alternatives to model the inherent non-stationarity of GDP in the light of the DS, TS or time-break models considered above.

In this paper we implement some traditional tests to evaluate the unit-root hypothesis for the Argentine real GDP. We also apply a family of statistics introduced by Banerjee, et.al (1992), Christiano (1992), and Zivot and Andrews (1992) to evaluate the possibility of a trend-break process.

[4] See the special issue of the Journal of Business and Economic Statistics, Vol, No, (1992)

3. Testing for Unit-Roots and Trend-Breaks

We computed the Dickey-Fuller (DF) and the Phillips-Perron statistic to evaluate the null hypothesis of the presence of a unit-root. We started by estimating the following augmented Dickey-Fuller regression for our annual information:

$$y_t = a + bt + u\, y_{t-1} + \beta(L)\, \Delta y_{t-1} + e_t$$

where $\beta(L)$ is a lag polynomial of order p. These statistics are analyzed in detail in Hamilton (1994).

To consider the possibility of a deterministic change in the log GDP process we considered a family of statistics proposed by Banerjee, et.al. (1992):

1. *Recursive tests*: they are obtained using a recursive estimation of the DF t statistic evaluating $u=1$ in (5). These statistics are computed recursively with subsamples $t=1,\ldots,k$ where $k = k_o, k_o+1, \ldots, T$. k_0 is the starting value of the recursive estimation and T is the size of the full sample. From this sequence of DF statistics we will evaluate the maximum and minimum DF test.

2. *Rolling tests:* these statistics are computed using a subsample of fixed size T_s, rolling through the sample. Again, the statistics of interest are the maximum and minimum Dickey-Fuller t coefficients.

3. *Sequential tests:* Here we estimate the following equation using the full sample but allowing for a possible single shift or break at every point in the sample:

$$y_t = a + bt + c\, d_t + u\, y_{t-1} + e_t \qquad (4)$$

where:

$$d_t = \begin{cases} \text{a) } 1 & \text{if } t > k,\ 0 \text{ otherwise} \\ \text{b) } t-k & \text{if } t > k,\ 0 \text{ otherwise} \end{cases}$$

The statistics considered are:

- Maximum F-statistic evaluating $c=0$ in (6).
- DF statistic evaluated at the period in which the F-statistic evaluating $c=0$ is maximum.
- Minimum DF statistic evaluating $u=1$ in (6)

Two sets of sequential statistics are evaluated, one allowing for a change in mean (case (a)) and another allowing for a change in the slope of the trend (case (b)).

The other sequential statistic we considered is the *Quandt likelihood-ratio* statistic testing for a change in at least one coefficient in (6) at every possible time in the sample. The procedure consists in estimating separate regressions of type (3) for a break point at period k, one using observations 1, ... , k and the other using observations $k+1$, ... ,T and evaluating the likelihood ratio:

$$\lambda(k) = -2\ln\frac{\sigma_{1,k}^{k}\sigma_{k+1,T}^{T-k}}{\sigma_{1,t}^{T}}$$

where $\sigma_{i,j}^{2}$ is the maximum likelihood estimator of the OLS variance of the error term of each regression. The Quandt statistic is the maximum $\lambda(k)$ of the sequence of statistics computed for every possible k in the sample.

4. Empirical Results

The variable analyzed in this work is the real GDP for Argentina. We implemented the empirical work using annual and quarterly data. The main sources used to construct long-term series of the GDP were:

- 'National Accounts of the Argentine Republic', Central Bank of the Argentine Republic, Historic Series, Vol III, 1976. (Cuentas Nacionales de la República Argentina, Series Históricas, Vol. III, 1976, in Spanish).

• 'Quarterly Estimations of Global Supply and Demand', Central Bank of the Argentine Republic, several issues. (Estimaciones Trimestrales de Oferta y Demanda Global, in Spanish).

For the annual case, though there is information available starting in 1900 to the present, there is not an official continuous series that covers the period 1900-1993, mainly due to differences in the sources and in base years on which real valuations are made. The series used in this work is a simple "chain", linking the series available by its implied growth rates, always using the latest information available. The same procedure was adopted for quarterly data for which the same problems arise.

We started by estimating (5) with $p = 5$, and following a 'general-to-specific' procedure we concluded that $p = 0$ is appropriate for our annual data, according to the Akaike and Schwartz information criteria, as suggested in Hall (1994). The values of both Dickey-Fuller and Perron statistics do not allow us to reject the null of a unit-root at the 10% level. The Dickey-Fuller coefficient is equal to -2.8339 and the Phillips-Perron coefficient is equal to -2.9132 both greater than -3.15 the 10% critical values reported in Hamilton (1994, pp. 763).

A summary of the statistical results for annual data is presented in Table 1. Figure 1 shows the recursive and rolling DF statistics, together with the log GDP series. The recursive DF was estimated with an initial sample size of 35 observations. The rolling DF was estimated with a fixed sample of 40 observations, moving the initial point starting at the first observation.

TABLE 1: Summary of Statistics. Annual Data (1900-1993)

	Statistic	Period	Crit.Val (10%)
Full Sample Statistics			
-DF	-2.8339		-3.15
-Phillips-Perron	-2.9132		-3.15
Recursive			
-Min DF	-3.6293	1980	-4.00
-Max DF	-1.9619	1934	-1.73
Rolling			
-Min DF	-4.3392	1964	-4.71
-Max DF	-0.3382	1989	-1.31
Quandt test	14.3100	1917	23.86
Trend-Shift			
-Max F	11.0637	1981	16.20
-DF at F max	-4.3984		-4.52
-Min DF	-4.3984	1981	-4.54
Mean Shift			
-Max F	6.8685	1975	13.64
-DF at F max	-3.9269		-4.19
-Min DF	-3.9269	1975	-4.20

The minimum and maximum *recursive* DF statistics are -3.6293 and -1.9619 and they occur at 1980 and 1934 respectively. The same measures for the *rolling* DF statistics are -4.3392 and -0.3382 at periods 1964 and 1989 respectively. Banerjee, et.al. (1992) provides tables with critical values for these statistics. In both cases the minimum DF are greater than the 10% critical value for a sample of 100 observations, hence, we cannot reject the unit-root null.

Figure 2 shows the first set of *sequential statistics*. First we constructed sequential statistics allowing for a change in the intercept of the trend (case (a)). The F-statistic shown in the graph evaluates sequentially $c=0$ in equation (6) and using the case (a) dummy. The maximum F is observed in 1981, with value 11.0637, lower than the critical value reported by Banerjee, et.al (1992). Hence, we do not reject the null of no change in the intercept of the trend.

The Figure also shows the sequential DF tests computed under case (a). The minimum DF test gives a value of -4.3984, greater than the critical value in Banerjee, et.al. (-4.52) suggesting not rejecting the null hypothesis of a unit-root. This minimum DF test is observed at the same period in which the F statistic achieves its maximum value.

Figure 3 presents the second set of sequential statistics, but in this case allowing for a change in the slope of the trend (case (b)). The maximal F statistic is observed in 1975 and is lower than the corresponding 10% critical value, again suggesting that the null of no change in the slope should not be rejected. The minimum DF test is observed at the same period in which F achieves its maximum value, and also in this case it does not allow us to reject the unit-root null.

We also report the Quandt likelihood-ratio test commented above (figure 4). The corresponding statistic (the maximum likelihood ratio) is equal to 14.31, lower than the critical value reported by Banerjee, et. al.(1992), indicating that the null of no change in the coefficients cannot be rejected.

From the analysis of annual data we can make the following comments:

1. Using full-sample, recursive and rolling tests we cannot reject the unit-root null in the real GDP process.

2. We do not find evidence of changes in the coefficients (evaluating the F and Quandt tests), and the null of a unit-root cannot be rejected with a size of 10% according to the sequential DF statistics. It is important to remark that the F-statistic used has very low power against the alternative hypothesis in the extremes of the sample, as Christiano (1992) shows.

3. Perron (1989) provides critical values for Dickey-Fuller statistics obtained using model (6) but for the case in which the break period k is determined

exogenously. If we treat the break periods 1975 and 1981 as determined exogenously for cases (a) and (b), then our DF statistics are both lower than Perron's critical values at 10% (-3.46 for case (a) and -3.50 for case (b), see Perron (1989), pp. 1376-1377 Tables IV and V), suggesting that the unit-root hypothesis should be rejected. But as argued above, Perron's result are subject to a "pre-test bias" if the break-point is not data-independent. Then, our results are consistent with some recent findings (See the special issue of the Journal of Business and Economic Statistics, 1992) in the sense that after we eliminate the pre-test bias using distributional results consistent with a data-dependent time break the unit-root hypothesis cannot be rejected.

4. Zivot and Andrews (1992) also provide critical values for minimum DF statistics estimated sequentially. For a size 10% they report a critical value equal to -4.58 for case (a) and -4.11 for case (b). Again, using these distributional results we cannot reject the null of a unit-root in both cases.

We repeated the same analysis using quarterly data from the first quarter of 1970 to the second quarter of 1994. The series analyzed in this case are the residuals of a regression of the original series on a set of seasonal dummies to remove the seasonal effect. For this data, the appropriate order of the lag polynomial was 5 periods, according to Akaike and Schwartz information criteria applied to equation (5). A summary of statistical results for quarterly data is presented in Table 2 and recursive, rolling and sequential statistics are shown graphically in Figures 4, 5 and 6.

TABLE 2: Summary of Statistics. Quarterly Data (I-1974,II-1994)

	Statistic	Period
Full Sample Statistics		
-DF	-1.8096	
-Phillips-Perron	2.3256	
Recursive		
-Min DF	-3.3322	IV-80
-Max DF	-1.3671	II-82
Rolling		
-Min DF	-3.3511	I-81
-Max DF	-0.9582	II-94
Quandt test	**34.2413**	**I-88**
Trend-Shift		
-Max F	9.2628	I-91
-DF at F max	-1.8581	
-Min DF	-2.6088	I-92
Mean Shift		
-Max F	9.0938	II-90
-DF at F max	-2.6076	
-Min DF	-2.8343	II-91

It is important to remark, as in Shiller and Perron (1985) that we should expect an implicit loss in power of tests of a unit-root against a stationary alternative when using a smaller span sampled more frequently as is the case with our quarterly information.

The same results as in the annual case hold here, except that the Quandt test now is higher than the 10% critical value, suggesting that the null hypothesis of no change in coefficients should be rejected, according to the value obtained for the 1st quarter of 1988. In all cases the unit-root null cannot be rejected with size 10%.

5. Discussion and directions for future research

The following comments arise from our analysis:

1. As in Perron (1989), we consider it important to highlight that this type of analysis does not intend to propose an unconditional stochastic model of the real GDP. This type of analysis tries to evaluate some characteristics an appropriate model for the business cycle must take into account.

2. In the annual case, though none of our results allows us to detect changes in the coefficients according to our F and Quandt tests, one should be very cautious when interpreting these results. The observation of the sequentially computed statistics and the inspection of the time plot of the series seem to suggest that if there was a structural change one should expect it to be at the extremes of the sample considered. This is consistent with some historical facts about the Argentine economy, but as noted above our statistical procedures are not powerful at the extremes of the sample. Then, non-rejections are not very informative about the null.

3. For the quarterly case, two comments hold. First, as mentioned above, since our goal was to characterize the long-run behavior of the real GDP series, the use of quarterly data led us to restrict our analysis to the last 25 years whereas with annual data we considered nearly a century of information. Then, even though we had more data points for quarterly data, annual data provides a better characterization of the long-run behavior. This is consistent with the well-known fact that the stochastic properties of GDP series are better characterized by processes with high explanatory power at low frequencies. Then, one obvious direction for further research is to re-elaborate the analysis reconsidering longer quarterly time series. Though there are not available for Argentina quarterly GDP series before the late sixties some information could be extracted from related series like privately computed indexes of industrial production.

Second, the use of quarterly information introduces the problem of considering the seasonal structure of the process. In this paper we adopted a naive approach removing seasonality using a regression on a set of dummies, but new results can be explored using better seasonal techniques.

4. Throughout this work we set our 'trimming parameters' for the sequential, rolling and sequential analysis so as our data cannot provide information about possible changes occurring at the beginning of the period analyzed. Though some statistics used are not powerful at any extreme of the sample, rolling and recursive statistics can be accommodated to provide information of the beginning of the sample, using a 'backward recursion'. This possibility was not explored in this paper.

5. One obvious extension of these type of analysis is to match empirical findings with a historical analysis of the Argentine economy. Again, one should be very cautious with the interaction between historical analysis and econometric implementation to avoid "pre-test biases" induced by data exploration mechanisms not taken into account in the statistical procedures used to make inferences.

The Argentine economy presents several episodes that are natural candidates for breaks, but the implementation of an econometric procedure to take into account these changes is in general data dependent and must be handled very carefully. One important result of this work is that using annual data we do not find evidence of a structural change in the characterization of the non-stationarity of the GDP series. This does not mean that there were not significative structural changes in the real GDP in general. A formal statistical model for the GDP (conditional or unconditional) should be built to address that question. But such a model should incorporate information from the unit-root testing procedure presented in this work, say, the fact that the unit-root hypothesis could not be rejected.

6. Conclusion

The original purpose of this work was to obtain a set of empirical results to characterize the stochastic process governing the series of real GDP for Argentina. According to our results, the null hypothesis of the presence of a unit-root in the stochastic process governing argentine real GDP cannot be rejected using a conservative size of 10%. To evaluate this possibility, we implemented a battery of full-sample, recursive, rolling and sequential test using annual and quarterly data. In all cases we considered the possibility of a break in the deterministic trend as a possible characterization.

Though statistical considerations do not allow us to accept the null when we do not reject it, we are tempted to comment that the results of this paper suggest that any shock suffered by the Argentine economy had and will have a permanent effect and that a model for the real GDP should take into account this important characteristic.

Fig.1. Recursive and Rolling DF test

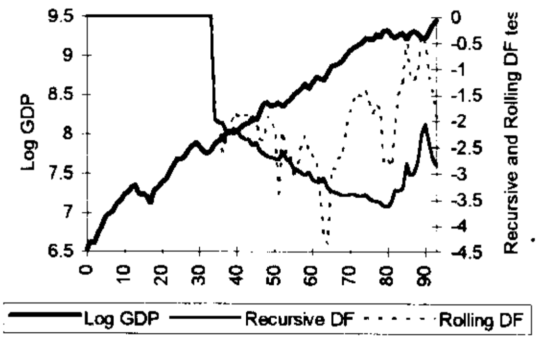


Fig.2. Sequential tests
Change in mean

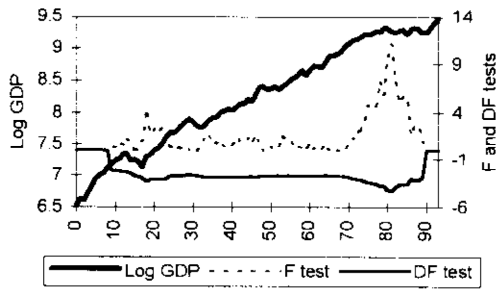


Fig.3. Sequential tests
Change in slope

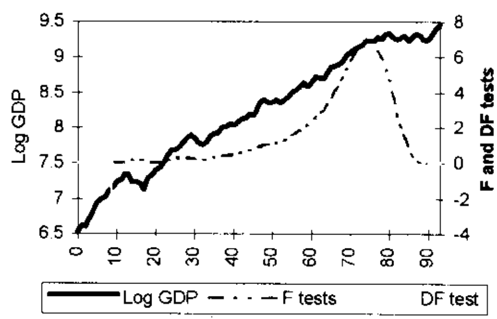


Fig.4 Recursive and Rolling DF Test

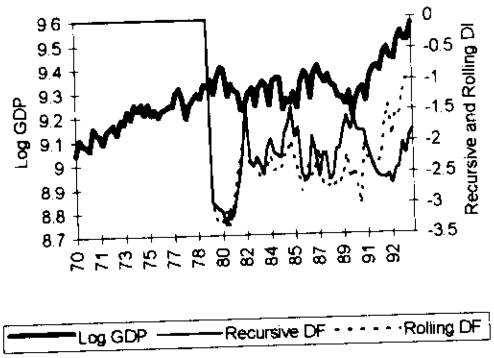


Fig.5 Sequential Tests
Change in mean

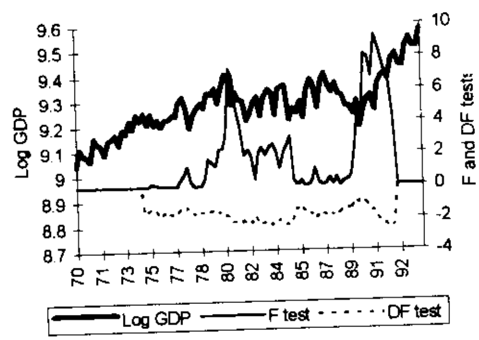
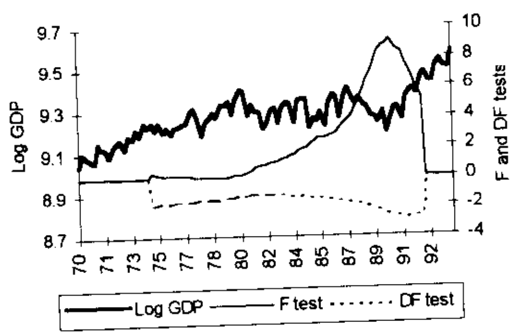


Fig.6 Sequential Tests
Change in slope



REFERENCES

AHUMADA, H. (1992): "Propiedades Temporales y Relaciones de Cointegración de Variables Nominales en Argentina", (Time Properties and Cointegration Relationships in Nominal Variables in Argentina, in spanish), Central Bank of The Argentine Republic, mimeo.

BANERJEE, ANINDYA, LUMSDAINE, ROBIN, STOCK, JAMES (1992): "Recursive and Sequential Tests of the Unit-Root and Trend-Break Hypothesis: Theory and International Evidence", Journal of Business and Economic Sstatistics, July 1992, Vol.10, No.3.

CHRISTIANO, L. (1992): "Searching for a Break in GNP", Journal of Business and Economic Statistics, July 1992, Vol.10, No.3.

FARMER, R. (1993): "The Macroeconomic of Self-Fulfilling Prophecies", The MIT Press, Cambridge, MA.

HALL, A. (1994): "Testing for a Unit-Root in Time Series With Pretest Data-Based Model Selection", Journal of Business and Economic Statistics, October 1994, Vol.12, No.4

HAMILTON, J. (1994): "Time Series Analysis", Princeton University Press, Princeton, NJ.

NELSON, C. R., PLOSSER, C. I. (1982): "Trends and Random Walks in Macro-Economic Time Series: Some Evidence and Implications", Journal of Monetary Economics, 10, 139-162.

PERRON, P. (1989): "The Great Crash, the Oil Price Shock and the Unit Root Hypothesis", Econométrica, 57, 1361-1401.

SHILLER, R., PERRON, P. (1985): "Testing the Random Walk Hypothesis: Power Versus Frequency of Observations", Economic Letters, 18, 381-386.

ZIVOT, E., ANDREWS, D. (1992): "Further Evidence on the Great Crash, the Oil-Price Shock, and the Unit-Root Hypothesis", Journal of Business and Economic Statistics, July 1992, Vol.10, No.3.

TESTING FOR UNIT-ROOTS AND TREND-BREAKS IN ARGENTINE REAL GDP

SUMMARY

The purpose of this paper is to provide some first empirical results for the case of the argentine real GDP on the unit-root hypothesis. Full sample statistics and some recent iterative techniques are used to evaluate the presence of a unit root and the possibility of a trend-break process. Our empirical results do not allow us to reject the null unit-root in the real GDP process for Argentina, even when the statistical method used allows for the presence of a broken trend.

TESTEO DE RAICES UNITARIAS Y CORTES ESTRUCTURALES DE TENDENCIAS EN EL PBI REAL DE ARGENTINA

RESUMEN

El objetivo de este trabajo es presentar un primer conjunto de resultados empíricos acerca de la hipótesis de raíz unitaria en el PBI argentino. Se utilizan técnicas de muestra completa y métodos iterativos recientes para evaluar la presencia de raíces unitarias y la posibilidad de existencia de procesos caracterizados por tendencias con cortes estructurales. Los resultados obtenidos no nos permiten rechazar la hipótesis de raíz unitaria en el PBI argentino, aun cuando los métodos estadísticos utilizados permiten la presencia de un proceso con cortes estructurales.