Stylized facts of the gross national product of Argentina: 1875 - 1999

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Abstract

The stylized facts of macroeconomic time series can be presented by fitting structural time series models. Within this framework, we study the behaviour of the gross national product of Argentina in the long run and provide a method for modelling this behaviour, which in turn is equivalent to establishing the stylized facts associated with these time series.

We analyse the annual data of the gross national product and the gross national product per capita of Argentina from 1875 to 1999. The study of these variables allows, among other things, to know the changes that have been taking place in the economy. The evolution of these variables in time tells us, roughly, if there was progress or not.

Keywords: Gross National Product; Outliers and Structural Breaks; State Space Form; Structural Time Series Models; Stylized Facts;

JEL classification: C3, C5.

1. Introduction

Establishing the "stylized facts" associated with a set of time series is widely considered a crucial step in macroeconomic research (see, e. g., Blanchard and Fischer, chapter 1, 1989). For such facts to be useful they should (i) be consistent with the stochastic properties of the data, and (ii) present meaningful information. However, many stylized facts reported in the literature do not fulfill these criteria. Particularly, if the information is based on mechanically detrended series it can easily give a spurious impression of cyclical behaviour. The analysis based on autoregressive-integrated-moving average (ARIMA) models can also be misleading if such models are chosen primarily on grounds of parsimony (for a treatment of these ideas see Harvey and Jaeger, 1993).

The aim of this paper is to study the behaviour of the gross national product of Argentina in the long run and to provide a method for modelling this behaviour, which in turn is equivalent to establishing the "stylized facts" associated with these time series.

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It is known that structural time series models provide the most useful framework within which to present stylized facts on time series. Structural time series models are explicitly based on the stochastic properties of the data. They provide meaningful information on the components of the series and further insight about them.

A form of measuring the economic activity of a county is by the analysis of its gross national product (GNPtotal) and its gross national product per capita (GNPpc). The study of these variables allows, among other things, to know the changes that have been taking place in the economy. The evolution of these variables in time tells us, roughly, if there was progress or not.

We analyse the annual data of the GNPtotal and the GNPpc of Argentina from 1875 to 1999.The data were obtained from Dornbusch and de Pablo (1988), Contés Conde (1997) and the “Economic Report” published quarterly by the Ministry of Economy and Public Work and Services of Argentina. We, specially the GNPpc, elaborated some of them. The GNPtotal is in thousands of pesos of 1993 and the GNPpc is pesos of this same year. Because of well known economic reasons, we work with the logarithm of both series.

The plan of the paper is as follows. Section 2 discusses an abridged history of the Argentinean economy. In section 3 we lay out the basic framework of structural time series modelling in this context, and in section 4 we define outliers and structural break and give techniques for testing and modelling them. Section 5 considers modelling and analyzing the series GNPtotal and GNPpc for the period under consideration. Section 6 draws the main conclusions.

2. More than a century of Argentinean economy

In the 1880’s a period of progress began in Argentina. Since then the government acted in a systematically and intentional way in order to reach the insertion of Argentina in the world economy. As a matter of fact, hundreds of ships bringing thousands of people, who were coming to work in the productive “pampeana” countryside, began to arrive in Buenos Aires. Together with people, goods and especially materials for the railroad construction arrived. On their way back ships took wool and leather, and a new product: cereal. With the implementation of this model of economic development, Argentina began a long period of progress. The first years of the XXth century were those of very high growth [see Figure 5 a) and b)]. In 1914, a renewed migratory impel made the population grow up to 8 millions of inhabitants, twice that of 1895. The area of cultivated land reached the record 24 millions hectares and Argentina became the first world producer of corn and linen, and one of the most important producers of wool, meat and wheat. Buenos Aires became the major Latin-American city. However, there were reasons of concern in the rhythm of economy. Despite the fact of general rising trend, there was a superposition of economic recession and expansion. Indeed, the 1890 crisis corresponds to one of those periods of economic contraction. There was also a crisis in 1897 nut by the end of the century the exportation of cereals started. The crises of 1907 and 1912, the last one motivated by the Balkans war, reminded of the vulnerability of the general growth of the trend. Between 1875 and 1914 the GNPtotal increased 1,053.63 % and 229.39 % the GNPpc.

The sensibility of the economy with the international crises appeared once again when World War I broke out, affecting exports, incoming capitals, labour, and the expansion of agriculture. Argentina was not economically prepared to face these contingencies. The problems risen by the war were difficult to solve. Among them, the disorganization of the trade and finance networks reduced the investments producing the rise in the price of subsistence and problems in many industries. Though, such activities as the exporting of canned meat for the belligerent profited from the situation. The period of economic expansion was followed by very difficult years between 1913 and 1917.

At the end of the war there was a time of recovery impelled by the necessity of feeding the European population unable to transform immediately the battlefields into productive lands. The demand pushed up the food price and led the producers to increase the area of cultivated fields and the number of livestock. We identify a structural change by the end of World War I. The demand lasted only a short time, since Europe recovered rapidly. After this short period of expansion that ended between 1919 and 1920, Argentina was affected by the international postwar conditions. Together with this fact, the new tendency of food self-provisioning which contributed to solve the shortage of food, but created oversupply leading to a fall in the agricultural prices with a negative consequence for the countries producers of primary goods. The war also brought about enormous fiscal deficits, great inflation, monetary instability, great volatility of capitals, scarcity and discrimination of trade and the beginning of the state's intervention in almost all the markets. The previous balance could never be regained in the post war period. Between 1914 and 1929 the total GNPtotal increased 94,37% and 32,39% the GNPpc.

The 1929 crisis in the United States had an immediate repercussion on Argentina and continued to influence negatively up to 1932 hitting hardly on what used to be an opened economy despite the changes of the previous decade. In fact, the GNPtotal fell 13.75% and the GNPpc 19.38%. During the 1930's the international economy was more and more disorganized. It was a different world that needed new and imaginative economic policies. In these policies the state assumed more important functions. It went from the simple regulation of the crisis to the definition of the general rules of the game, according to the theory of the British economist John Maynar Keynes that began to be applied all over the world. At the same time, the world economies closed progressively, with bounded zones of trade. It was still a new movement, impelled by occasional factors but it strengthened progressively and stimulated modifications that would make it irreversible.

Before the crisis broke out Argentina suspended the convertibility, policy taken by President Yrigoyen in August 1929. Once the crisis extended, the world demand on agricultural products fell as well as its prices. The fall of exports, the reduction of credit and the fall of the fiscal revenues due to the decrease of the imports stressed the recession. During 1931 the government adopted measures, among them it established the exchange control, through which the government centralized the purchase and sales of foreign currency. In front of the falling of the customs duties as a response to the decrease of imports, the income taxes were established. The public finances stopped depending exclusively on customs duties or external loans. In 1933 the government had balanced its budget thanks to the measures adopted and to the dramatic reduction of the public expenses. We identify a structural change by 1932.

In 1935 the Central Bank was created to have finance control. It had a stabilizing function, expanding the monetary offer in recessive periods and limiting the monetary growth in the expanding ones. At the end of the 1930's, the government began to find out the possibility of using the monetary instruments for the long term financing.

As a result of the falling of imports, of the increase in fares, the high exchange rate and the quantitative restrictions (i. e. the need of an authorization in advanced), an important part of demand of consumption goods, that provided from the interior of the country, was unsatisfied. At the same time there was a great industrial growth as a result of the growing domestic demand.

The changes in the farming and cattle-raising sector were less noticeable, especially in the "pampeana" region. Cattle raising become worse in relation to agriculture as in the 1920's. Corn exports grew in the central years of the decade, influencing the fiscal balance as well as the economic relative prosperity between 1934 and 1937, to such an extent that its effects stimulated industry and construction.

During the 1930's, the crisis and the responses of occasional nature had created a series of new conditions that make it difficult to return to the previous situation. The broke out of World War II changed the economic panorama. The imports fell dramatically, in spite of the war at sea, argentine exports continued to reach Great Britain that needed the food provided by Argentina. Industries had matured and supplied themselves with domestic products, e.g. textiles. Energy problems were serious, though the local oil supply got better. The state was not dependent on customs duties any more and had obtained new resources supplies. Investment was not based on the railway construction any more, because the state's investment on road construction was important. Despite the fact that the product fell in some years, the expansive wave reached the postwar period.

In June 1943 there was a coup d'etat that brought President Castillo down. The new military government that ruled up to 1946 was worried about the end of the war and the return to normality. They were worried that the experiences of the first post war period repeated when the renewal of trade led to the fall of the industrial activities born during the war, provoking the closing down of businesses, the dismissal of labour workers and profound social conflicts. Had these problems produced at this time they would have been worse because during the 1930's more than a million people had migrated from the interior of the country to the important cities. In front of this problem the objective of the government was clear, avoid conflicts what implied the closing of the economy to secure employment. J. D. Peron's government who takes the presidency in 1946 inherited these objectives and worries.

During the war, the belligerent countries kept restrictions in the capital and trade movements. At the same time the state intervened in the price mechanisms and in most of the economic activities.

With the Bretton Woods agreements in 1944 the Allies prepared the transition to a different peace from that of World War I, so the world did not live in the middle of the century the problems of the between wars period. The international agreements avoided compensatory devaluations and the commercial wars, and gave a great stability to the finance system and world trade.

It was not the same for Argentina. In order to avoid the shock of the return to normality, most of the restrictions and regulations of the crisis and the war were kept for more than a decade. While the world returned to normality, Argentina took a different way, isolating even more. The first decisions were taken on a wrong evaluation of future tendencies. It was a pessimistic vision of the evolution of the world trade based on the past experiences, but that did not correspond with the second postwar changes. The "bilateral thought" of the country had negative effects for the economy.

Securing full employment meant supporting no competitive activities. This was done through tariff measures, quantitative restrictions to imports; drop in local cost of work; overvaluing the "peso" to make food cheaper; capital formation with credit at a negative real interest rate; implicit tax on exports to keep high the real salaries. All this seemed possible to do thanks to the huge productivity of farming which could be taxed without affecting its output due to the believe that the land was a fixed resource and under the reasoning that its supply was not elastic. Though what they did not take into account was the alternative possible uses of the "pampeana" land, which in the case of unfavourable prices of agricultural exports could turn it into livestock or cattle raising (see Cortés Conde, 1998).

Taking into account what has been said and on the base of the analysis of available data we can see that from 1932 to 1947 the GNPpc grew 46.80% and 88.70% the GNPtotal. It is evident that during this period the country underwent an important economic growth. This process had a holdback in the period from 1947 and 1952 in which the GNPpc fell 13.61% and the GNPtotal 3.30%. We identify a negative structural change by 1947.

Since 1952 the economy began to give signs of recovery. That is why in 1955 there were not the economic factors that provoke Peron's fall. The revolutionary government produced changes in the economic policies, some of them very important, some others timid. During the period 1952-1958, both the GNPpc and the GNPtotal had a constant increase (21.10% for the former and 34.64% for the latter).

In the 1958 elections, A. Frondizi was elected president. This administration, defined itself as "developer", considered that the restrictions to the growth and the limits to the expansion of the industries were due to the incapacity of generating currency to import intermediate goods and capital. This in turn was due to the lack of competition of the domestic industries and the incapacity of farming to reach the adequate export levels to meet the import necessities of the industries. To overcome the gap between imports and exports it was necessary to deepen industrialization, which in turn needed a big capital effort, calling up in this case to foreign capital. In order to attract this capital it was necessary to show a stable setting, with a balance of fiscal accounts and the stability of the monetary sector and of the rate of exchange.

During Frondizi’s administration, there were important steps towards the modernization of the economy. The measures taken tended to eliminate controls, to free prices, to reduce expenses, to limit credit and the currency expansion and, finally, to allow a greater action to the market mechanisms. The effects of these and other measures produced a fall in demand and a recession, reflected in the decrease of a 6.45% of the GNPtotal an of a 7.90% of the GNPpc during 1959 and a great increase in prices at the same time. After the recession of almost a year there began a recovery in the last months and during 1960 and 1961. This recovery did not last long, production stopped and began to decline in 1962. Recession continued for the rest of the year and part of 1963 with a slight recovery at the end of that year. In some way these years of recession were a period of adjustment necessary for the following decade of growth.

In 1963 A. Illia became president. During his presidency the economic perspectives were better. After the two years of recession a recuperative phase began, allowing the implementation of expansive policies of government expenses without generating inflationary pressures. The most notable consequence was the increase in the production and the agricultural exports in 1964 and 1965. Besides, while the expansion previous to the crisis allowed the renewal of capital goods and the modernization of the industries, the crisis caused the disappearance of marginal businesses leaving a more competitive sector (see Gerchunoff and Llach, 1975).

In 1966 there was a coup d'etat. The Military Junta of Commanders designed J. C. Ongania to be in front of the government. Ongania’s government proposed to stabilize the economy without restricting demand in order to avoid the recessive effects of the stabilization plans of previous periods. From 1968 to 1970 there was stability due to the incoming capitals, the decrease in the nominal interest rate and the falling of inflation.

In June 1970, Ongania was brought down from power. In the same period, the endemic problems of the Argentine society began to appear. The longest period of continuous economic growth that began with Illia in 1963 and lasted up to 1974 finished, with an increase of 71.56% for the GNPtotal and of 45.80% for the GNPpc.

During the first months of 1974 the economy became worse, prices went up as well as the fiscal deficit, the external situation turned unfavourable and inflation grew up five times. General Peron died in July, having assumed the presidency the previous year. Vice-President Martinez de Peron took the presidency. The last months of the Peron´s administration ended with an enormous acceleration of inflation and fiscal deficit. In 1976 military forces took power by a coup d état again.

From 1974 to 1979 the economy, measured in terms of the GNPpc, was moving up and down. At the end of this period it could only reach the initial levels of 1974. Therefore, there was no improvement in the economic situation of the population.

Each of the attempts of stabilization programmed by the military governments that succeeded from 1976 to 1983 were frustrated not only for the inflation they left but also for the more serious problems they caused.

At the end of 1983 R. Alfonsín was elected President. Although the economic panorama was extremely difficult, the election victory not only open a new constitutional period but also gave to the government a wide margin of credibility that could have allowed it to make greater reforms, but this credibility was not adequately used. However there was a slight increase in the GNPtotal in 1984, annual inflation reached 600%. In 1985 there were new economic measures known as Austral Plan that were very successful at the beginning but they do not last much longer. In the middle of 1986 the economic panorama became complicated once more. From 1979 to 1986 the GNPpc decrease 15.12% while the GNPtotal fell 4.06%.

From 1986 inflation grew at an increasing rate of growth and in 1989 it reached hyperinflationary levels. As a consequence of this situation, there was a change of government, assuming C. S. Menem the presidency. After the first years of vacillations there were profound reforms that opened a new phase in which the inflation was lower to international levels, fiscal equilibrium was almost reached and the majority of the State owned companies were privatized. There was a major change in the role of the State resulting in a decade of grater growth in the XXth century. In fact, in this period the GNPtotal grew 47.17% while the GNPpc increased 29.08%. We identify a positive structural change by 1990.

3. The structural model

Structural time series models are set up explicitly in terms of components which have a direct interpretation (see Abril, 1999 and Harvey, 1989). In the present context we postulate the appropriate model to be

$$y_t = \mu_t + \psi_t + \mathbf{z}_t'\boldsymbol{\delta}_t + \varepsilon_t, \quad \varepsilon_t \sim \mathrm{NID}(0, \sigma_\varepsilon^2), \quad t = 1, \ldots, n, \tag{1}$$

where y_t is the observed series, μ_t is the trend, ψ_t is the cycle, ε_t is an irregular component serially independent, normally distributed with mean zero and constant variance, i. e. $\varepsilon_t \sim \mathrm{NID}(0, \sigma_\varepsilon^2)$, $\mathbf{z}_t$ is a $p \times 1$ vector of observed explanatory variables, some of them could be lagged values of the dependent variable as well as lagged values of exogenous variables, and $\boldsymbol{\delta}_t$ is a $p \times 1$ vector of unknown parameters. If the vector $\boldsymbol{\delta}_t$ does not depend on the time, then $\boldsymbol{\delta}_t = \boldsymbol{\delta}_{t-1}$. The trend is a local linear trend defined as

$$\begin{aligned} \mu_t &= \mu_{t-1} + \beta_{t-1} + \eta_t, & \eta_t &\sim \mathrm{NID}(0, \sigma_\eta^2), \\ \beta_t &= \beta_{t-1} + \zeta_t, & \zeta_t &\sim \mathrm{NID}(0, \sigma_\zeta^2), \end{aligned} \tag{2}$$

where β_t is the slope and the normal white noise disturbances, η_t and ζ_t, are independent of each other. A stochastic formulation of the trend as the one given in (2) allows the level μ_t and the slope β_t to evolve over time. The stochastic cycle is generated as

$$\begin{pmatrix} \psi_t \\ \psi_t^* \end{pmatrix} = \rho \begin{pmatrix} \cos\lambda_c & \mathrm{sen}\,\lambda_c \\ -\mathrm{sen}\,\lambda_c & \cos\lambda_c \end{pmatrix} \begin{pmatrix} \psi_{t-1} \\ \psi_{t-1}^* \end{pmatrix} + \begin{pmatrix} \kappa_t \\ \kappa_t^* \end{pmatrix}, \quad t = 1, \ldots, n, \tag{3}$$

where λ_c is the frequency of the cycle in radians within the interval $0 \le \lambda_c \le \pi$, κ_t and κ_t^* are two white noise mutually uncorrelated with mean zero and common variance σ_κ^2, and ρ is a smoothing factor such that $0 < \rho \le 1$. The period is $2\pi/\lambda_c$. The disturbances in (1), (2) and (3) are taken to be independent of each other.

The trend is equivalent to an ARIMA (0, 2, 1) process. However, if $\sigma_\varsigma^2 = 0$, it reduces to a random walk with drift. If, furthermore, $\sigma_\eta^2 = 0$ it becomes deterministic, that is $\mu_t = \mu_0 + \beta t$. When $\sigma_\eta^2 = 0$, but $\sigma_\varsigma^2 > 0$, the trend is still a process integrated of order two, abbreviated I(2), that is stationary in second differences. A trend component with this feature tends to be relatively smooth. An important issue is therefore whether or not the constraint $\sigma_\eta^2 = 0$ should be imposed at the outset. We argue that there are series where it is unreasonable to assume a smooth trend *a priori* and therefore the question whether or not σ_η^2 is set to zero is an empirical one.

The cyclical component, ψ_t, is stationary if ρ is strictly less than one. It is equivalent to an ARMA(2, 1) process in which both the MA and the AR parts are subject to restrictions (see Harvey, 1985, p. 219). The most important of these is that the AR parameters are constrained to lie within the region corresponding to complex roots. Since the purpose is to model the possible occurrence of stochastic cycles, imposing this constraint *a priori* is desirable.

The statistical treatment of the structural time series models is based on the state space form (SSF), the Kalman filter and the associated smoother.

All linear time series models have a state space representation. This representation relates the disturbance vector $\{\boldsymbol{\varepsilon}_t\}$ to the observation vector $\{\boldsymbol{y}_t\}$ via a Markov process $\{\boldsymbol{\alpha}_t\}$. A convenient expression of the state space form is

$$\begin{aligned} \boldsymbol{y}_t &= \boldsymbol{Z}_t\boldsymbol{\alpha}_t + \boldsymbol{\varepsilon}_t, & \boldsymbol{\varepsilon}_t &\sim N(\boldsymbol{0}, \boldsymbol{H}_t), \\ \boldsymbol{\alpha}_t &= \boldsymbol{T}_t\boldsymbol{\alpha}_{t-1} + \boldsymbol{R}_t\boldsymbol{\eta}_t^*, & \boldsymbol{\eta}_t^* &\sim N(\boldsymbol{0}, \boldsymbol{Q}_t), \end{aligned} \tag{4}$$

for $t = 1, \ldots, n$, where $\boldsymbol{y}_t$ is a $s \times 1$ vector of observations and $\boldsymbol{\alpha}_t$ is a $m \times 1$ unobservable vector called state vector. The matrices $\boldsymbol{Z}_t, \boldsymbol{T}_t, \boldsymbol{R}_t, \boldsymbol{H}_t$ and $\boldsymbol{Q}_t$ are initially assumed known and the error terms $\boldsymbol{\varepsilon}_t$ and $\boldsymbol{\eta}_t^*$ are assumed serially independent and independent among them at all time moments. The matrices $\boldsymbol{Z}_t$ and $\boldsymbol{T}_t$ may depend upon $\boldsymbol{y}_1, \boldsymbol{y}_2, \ldots, \boldsymbol{y}_{t-1}$. The first equation of (4) is usually called the measurement equation and the second one, the transition equation.

The structural model defined in equations (1), (2) and (3) has a state space representation like that given in (4). In this case, and assuming that the vector $\boldsymbol{\delta}_t$ does not depend on the time, y_t is 1×1, the $1 \times (p + 4)$ order matrix $\boldsymbol{Z}_t$ results to be

$$\boldsymbol{Z}_t = \begin{pmatrix}1 & 0 & 1 & 0 & \boldsymbol{z}_t'\end{pmatrix}, \tag{5}$$

where $\boldsymbol{z}_t'$ was defined in (1), the 1×1 matrix H_t turns out to be equal to σ_ε^2. The state vector of order $(p + 4) \times 1$ is

$$\boldsymbol{\alpha}_t = \begin{pmatrix}\mu_t & \beta_t & \psi_t & \psi_t^* & \boldsymbol{\delta}_t'\end{pmatrix}', \tag{6}$$

where $\boldsymbol{\delta}_t = \boldsymbol{\delta}$. In what follows, $\mathbf{0}$ is a $p \times 1$ null column vector, i. e. all its elements are equal to zero and $\boldsymbol{I}_p$ is a p-order identity matrix. Then, the (p + 4) $\times$ (p + 4) order matrix $\boldsymbol{T}_t$ and the (p + 4) $\times$ 4 order matrix $\boldsymbol{R}_t$ are given by

$$\boldsymbol{T}_t = \begin{pmatrix} 1 & 1 & 0 & 0 & \mathbf{0}' \\ 0 & 1 & 0 & 0 & \mathbf{0}' \\ 0 & 0 & \rho\cos\lambda_c & \rho\,\mathrm{sen}\,\lambda_c & \mathbf{0}' \\ 0 & 0 & -\rho\,\mathrm{sen}\,\lambda_c & \rho\cos\lambda_c & \mathbf{0}' \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} & \boldsymbol{I}_p \end{pmatrix}, \qquad \boldsymbol{R}_t = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \\ \mathbf{0} & \mathbf{0} & \mathbf{0} & \mathbf{0} \end{pmatrix}. \tag{7}$$

Finally, the 4×1 order column vector $\boldsymbol{\eta}_t^*$ and the 4×4 order matrix $\boldsymbol{Q}_t$ are

$$\boldsymbol{\eta}_t^* = \begin{pmatrix} \eta_t \\ \zeta_t \\ \kappa_t \\ \kappa_t^* \end{pmatrix}, \qquad \boldsymbol{Q}_t = \begin{pmatrix} \sigma_\eta^2 & 0 & 0 & 0 \\ 0 & \sigma_\zeta^2 & 0 & 0 \\ 0 & 0 & \sigma_\kappa^2 & 0 \\ 0 & 0 & 0 & \sigma_\kappa^2 \end{pmatrix}. \tag{8}$$

Estimation of the hyperparameters, $\left(\sigma_\eta^2, \sigma_\varsigma^2, \sigma_\kappa^2, \rho, \lambda_c, \sigma_\varepsilon^2\right)$, can be carried out by maximum likelihood either in the time domain or the frequency domain. Once this has been done, estimates of the trend, cyclical and irregular components as well as the coefficients of the explanatory variables are obtained from a smoothing algorithm. These calculations can be carried out very rapidly on a PC using the STAMP package (see Koopman, Harvey, Doornik and Shephard, 1995).

The model in (1) can be extended to deal with seasonal data. Thus there is no need to use data which has been distorted by a seasonal adjustment procedure. Furthermore, if we are interested in stylized facts relating to seasonal components, structural time series models provide a ready tool to determine these components without imposing a deterministic structure on the seasonal pattern.

4. Outliers and structural breaks

An outlier is an observation which is not consistent with a model which is thought to be appropriate for the overwhelming majority of the observations. It can be captured by a dummy explanatory variable in the measurement equation [equation (1)], known as an impulse intervention variable, which takes the value one at the time of the outlier and zero elsewhere.

A structural break occurs when the level of the series shifts up or down, usually because of some specific event. It is modelled by a step intervention variable in the measurement equation [equation (1)] which is zero before the event and one on the event and after. Alternatively, it can be modelled by a dummy explanatory variable in the corresponding transition equation [equation (2)] which takes the value one at the time of the structural break in the level and zero elsewhere.

A structural break in the slope can be modelled by a staircase intervention in the measurement equation [equation (1)] which is a trend variable taking the values, 1, 2, 3, …, starting in the period of the break. Alternatively, it can be modelled by a dummy explanatory variable in the corresponding transition equation [equation (3)] which takes the value one at the time of the structural break in the slope and zero elsewhere.

The concept of outliers and structural breaks apply quite generally. However, it is helpful for what follows to note that the level and slope breaks can be viewed in terms of impulse interventions applied to the level and slope equations of the model defined in (1), (2) and (3). The structural framework also suggests that it may sometimes be more natural to think of an outlier as an unusually large value for the irregular disturbance. This lead to the notion of a level shift arising from an unusually large value of the level disturbance while a slope break can be thought of as a large disturbance to the slope component. Thus interventions can be seen as fixed or random effects, however, the random effects approach is more flexible. For example, introducing an outlier intervention at $t = \tau$ is equivalent to regarding the irregular variance at this point as being infinity. By using a large finite variance, we can ensure that the observation y_τ is downweighted without being removed altogether.

Viewing intervention effects as random is consistent with the representation of a stochastic trend in the equations (1), (2) and (3). In this model the level and slope components are subject to random shocks at each point in time. When such movements are abnormally large, increasing the variance of the relevant disturbance or including an intervention variable may be appropriate.

Suppose that we want to test for an outlier at time $t = \tau$. It can be shown [see Abril (1997), de Jong (1989) and de Jong and Penzer (1997, 1998)] that the smoothing errors and their unconditional variances at $t = \tau$ constitute the basic elements for the construction of the tests. In fact, the standardization of the smoothing errors, called the *standardized smoothing errors*, constitute the test statistics for testing for an outlier at any point in the sample. Fortunately, the Kalman algorithm gives the values of these standardized smoothing errors for all time periods, so only one pass is needed to produce them. These are valid tests for cases in which the outliers are produced by both a fixed effect model as well as a random effect model. The STAMP (Koopman, Harvey, Doornik and Shephard, 1995) package computes routinely the values of these statistics. They are known there with the name *irregular auxiliary residuals*. This terminology was introduced by Harvey and Koopman (1992).

For the detection of structural breaks, de Jong and Penzer (1997) showed that all that is required is to have the model set up in state space form in such a way that the level shift can be introduced by a pulse intervention somewhere in the transition equation. As observed earlier, a structural time series model with a level or trend component is of such a form. Given such a setup, the Kalman filter and smoother produces directly the test statistic and its variance. The standardization then leads to the *level auxiliary residuals* which constitute the values of the tests used for detecting shifts in the level of a series.

As in the case of the level, the test statistics for changes in the slope are obtained from the appropriate component computed by the Kalman filter and smoother. Its variance is automatically available. The standardization then leads to the *slope auxiliary residuals* which constitute the values of the tests used for detecting changes in the slope of a series.

The auxiliary residuals are smoothed estimations of the irregular, level and slope disturbances. Although they are serially correlated and correlated among them, they play an important role in the sense that they split up portions of information which usually is mixed up in the innovations residuals. In particular, they are useful for detecting and distinguishing between outliers and structural changes. In order to make the relevant tests, it is possible to show that the statistics follow approximately a normal distribution [see, for example, Abril (1997) and Koopman, Harvey, Doornik and Shephard (1995)].

5. The statistical analysis of the data

A form of measuring the economic activity of a country is by its gross national product (GNPtotal) and by its gross national product per capita (GNPpc). Since our objective is to study the evolution of the Argentinean economy from 1875 to 1999, we analyse the annual data of the GNPtotal and the GNPpc for this period. We take the logarithm of the series and apply a structural time series model of the form given by equations (1), (2) and (3).

Initially, we estimated the basic structural model given in equations (1), (2) and (3) with no explanatory variables, written in the state space form given in (4) with the dependent variable y_t equals to the logarithm of the corresponding series. As a result of this first estimation and for both series, we identify and estimate a model with fixed level, i. e. $\sigma_\eta^2 = 0$, stochastic slope and cycle, with some structural changes in the slope and outliers. The estimation procedure was carried out by means of the Kalman filter and smoother and using the STAMP package (Koopman, Harvey, Doornik and Shephard, 1995).

5.1. Analysis for the gross national product (GNPtotal)

For the GNPtotal, the vectors $\boldsymbol{z}_t$ and $\boldsymbol{\delta}_t = \boldsymbol{\delta}$ are defined as

$$\boldsymbol{z}_t' = \begin{pmatrix} z_{1t} & z_{2t} & z_{3t} & z_{4t} & z_{5t} \end{pmatrix}, \quad \boldsymbol{\delta}' = \begin{pmatrix} \delta_1 & \delta_2 & \delta_3 & \delta_4 & \delta_5 \end{pmatrix}, \tag{9}$$

where

$$z_{1t} = \begin{cases} 1, & \text{for } t = 1891, \\ 0, & \text{otherwise,} \end{cases} \quad z_{2t} = \begin{cases} 1, & \text{for } t = 1899, \\ 0, & \text{otherwise,} \end{cases}$$

$$z_{3t} = \begin{cases} 0, & \text{for } t < 1881, \\ t - 1880, & \text{for } t \geq 1881, \end{cases} \quad z_{4t} = \begin{cases} 0, & \text{for } t < 1917, \\ t - 1916, & \text{for } t \geq 1917, \end{cases} \tag{10}$$

$$z_{5t} = \begin{cases} 0, & \text{for } t < 1990, \\ t - 1989, & \text{for } t \geq 1990, \end{cases}$$

It should be noted that the first two explanatory variables correspond to outliers and the rest correspond to structural breaks in the slope. They were detected by the tests explained in section 3 above.

Estimating model (1), (2) and (3) with the above given definitions for the vectors $\boldsymbol{z}_t$ and $\boldsymbol{\delta}_t = \boldsymbol{\delta}$ gives the following results:

$$\tilde{\sigma}_\varepsilon^2 = 0.000871, \quad \tilde{\sigma}_\zeta^2 = 0.000327, \quad \tilde{\sigma}_\kappa^2 = 0.000154, \tag{11}$$

$$\tilde{\rho} = 0.8751, \quad \tilde{\lambda}_c = 1.1198, \tag{12}$$

where $\tilde{x}$ means the smoothed estimate of x. The estimated value of the frequency, $\tilde{\lambda}_c$, correspond to a period of 5 years and 7 months approximately. The diagnostic and goodness of fit statistics are

$$H(41) = 0.4088, \quad DW = 1.945, \quad Q(10, 6) = 9.105, \quad N = 6.4271, \tag{13}$$

$$\tilde{\sigma}^2 = 0.00349, \quad R_D^2 = 0.2968, \quad R^2 = 0.9980, \tag{14}$$

where $H(m)$ is a basic non-parametric test for heteroscedasticity (unequal variances) formed as the ratio of the last m to the first m sums of squares of residuals and m is the closest integer to a third of the difference between the number of observations, n, minus the number d of non zero variances among $\left(\sigma_\eta^2, \sigma_\varsigma^2, \sigma_\kappa^2\right)$, DW is the well known Durbin-Watson test statistics, $Q(P,\ q)$ denotes de Box-Ljung test for serial correlation based on the first P residual autocorrelations and q is equal to P + 1 minus the number of hyperparameters, N is a test for normality originally given by Doornik and Hansen (1994), $\tilde{\sigma}^2$ is the estimated one-step-ahead prediction error variance, R_D^2 is a coefficient of determination defined as 1 minus the ratio of the estimated one-step-ahead prediction error variance to the variance of the first differences of the observations, and R^2 is the usual coefficient of determination. It should be noted that R_D^2 might be negative, indicating a worse fit than a simple random walk plus drift model. If the model is correctly specified, $H(m)$ is distributed approximately as an $F(m,\ m)$ distribution, DW is distributed approximately as $N(2, 4/n)$, and $Q(P,\ q)$ and N are approximately distributed as chi-square with q and two degrees of freedom respectively. The diagnostics indicate that the model is an appropriate one for the data.

In Table 1 we give the estimated coefficients of explanatory variables. There and elsewhere, R.m.s.e. means the square root of estimated mean square error of the corresponding estimated coefficient and t-value means the value of the corresponding t-statistic for testing the null hypothesis that the coefficient is zero.

Table 1. Estimated coefficient of explanatory variables for the GNPtotal

Variable	Estimated coefficient		R.m.s.e.	t-value
z_{1t}	$\tilde{\delta}_1$	-0.184621	0.0403853	-4.5715
z_{2t}	$\tilde{\delta}_2$	0.161802	0.0403840	4.0066
z_{3t}	$\tilde{\delta}_3$	0.107774	0.0363178	2.9675
z_{4t}	$\tilde{\delta}_4$	0.127911	0.0361111	3.5421
z_{5t}	$\tilde{\delta}_5$	0.078586	0.0361158	2.1759

The results in Table 1 indicate that the outliers and structural changes are significant. In fact, the first outlier associated with z_{1t} corresponds to an important financial crisis that occurred during 1890 but that showed its effects in 1891. The second outlier associated with z_{2t} corresponds to an important recovery of the economy, mainly due to the beginning of the exportation of cereals that occurred by the end of the XIXth Century.

Table 2. Estimated coefficient of final state vector for the GNPtotal

Variable	Estimated coefficient	R.m.s.e.	t-value
Lvl	19.46100	0.0302037	644.32
Slp	0.018291	0.0269341	0.679116
$\tilde{\psi}_n$	0.002590	0.0207061	

$\tilde{\Psi}_n^*$	-0.019808	0.0209459	

In GNPtotal, there are three important and positive changes in the slope. One in 1881 when a new economic model based on the development was introduced in the country. The second, in 1917, corresponded to the end of the World War I, and the third in 1990 captured the introduction of the so called “convertibility plan”.

In Table 2 we have the estimated coefficients of the state vector corresponding to the trend and cycle at the end of the period. There *Lvl* means level and *Slp* means slope. The growth rate of the trend at the end of the period under study is 1.83% per year.

Figure 1 shows the components of the GNPtotal according to the estimated model, i. e. it shows the estimated trend, the estimated stochastic slope of the trend and the estimated stochastic cycle. In Figure 2 we can see the residuals of the fitted model with its 95% confidence band, the correlogram also with its 95% confidence band, the periodogram, the estimated spectral density and the frequency distribution of these residuals. With the arguments given above and the observation of these figures we can conclude once more that the fitting is highly satisfactory.

In Figure 3 we have, for the GNPtotal, in parts (a) and (b) the irregular auxiliary residuals, its 95% confidence band and its frequency distribution, and in parts (c) and (d) the slope auxiliary residuals, its 95% confidence band and its frequency distribution. The value of the Doornik-Hansen tests for normality of the irregular auxiliary residuals is 0.6026 and of the slope auxiliary residuals is 2.5144. Since the large sample distribution of these tests is chi-square with two degrees of freedom, we accept the null hypothesis of normality, concluding once again that the model is appropriate for the data.

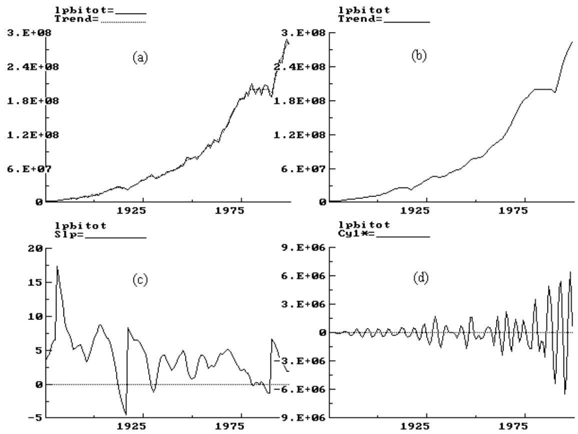

Figure 1. GNPtotal of Argentina 1875-1999 with trend [(a) and (b)], its slope (c) and its cycle (d)

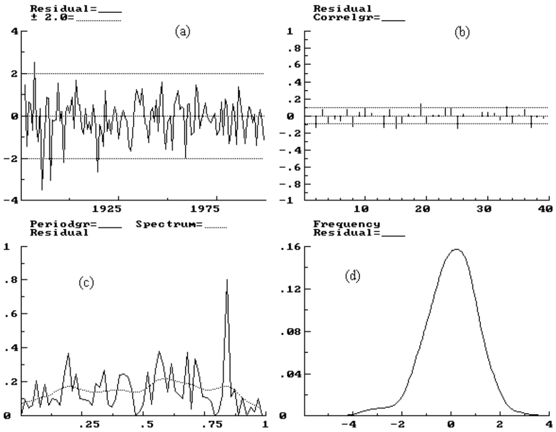

Figure 2. Residuals of the adjusted model for the GNPtotal of Argentina 1875-1999. Residuals with 95% confidence band (a), its correlogram with 95% confidence band (b), its periodogram (full line) and spectral density (dotted line) (c) and its frequency distribution (d)

In order to determine the ability of the fitted model to perform predictions, the last ten observations were predicted and some tests were carried out. The value of Chow's statistics within the sample period tern out to be 0.4645, which is significantly lower than the value of the $F(8, 113)$ distribution, pointing out that the model is well specified for prediction purposes. In Figure 4 we have the observed series y_t, in this case the logarithm of the GNPtotal, the predictions of its last ten values, the corresponding prediction residuals together with the 95% confidence bands for the predictions and for the prediction residuals. Clearly we see that the performance of the model seems to be satisfactory for making predictions.

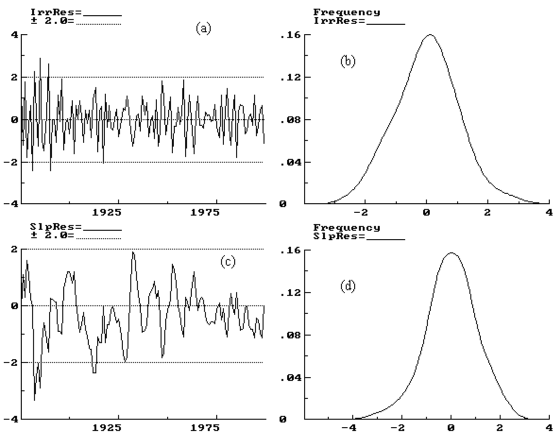

Figure 3. Auxiliary residuals. Irregular auxiliary residuals, its 95% confidence band (a) and its frequency distribution (b). Slope auxiliary residuals, its 95% confidence band (c) and its frequency distribution (d)

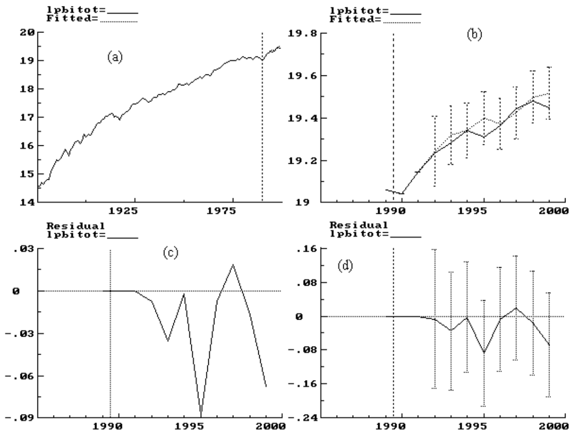

Figure 4. Log of the GNPtotal with predicted values (dotted line) (a), predicted values (dotted line) with 95% confidence band (b), prediction residuals (c) with 95% confidence band (d)

5.2. Analysis for the per capita gross national product (GNPpc)

Since the analysis is similar than the corresponding to the GNPtotal given before, we are going to present the most relevant results only. For the GNPpc, the vectors $\boldsymbol{z}_t$ and $\boldsymbol{\delta}_t = \boldsymbol{\delta}$ are defined as

$$\mathbf{z}_t' = \left(z_{1t} \quad z_{2t} \quad z_{3t} \quad z_{4t} \quad z_{5t} \quad z_{6t} \quad z_{7t}\right), \tag{15}$$

$$\boldsymbol{\delta}' = \left(\delta_1 \quad \delta_2 \quad \delta_3 \quad \delta_4 \quad \delta_5 \quad \delta_6 \quad \delta_7\right), \tag{16}$$

where

$$z_{1t} = \begin{cases} 1, & \text{for } t = 1891, \\ 0, & \text{otherwise,} \end{cases} \quad z_{2t} = \begin{cases} 1, & \text{for } t = 1899, \\ 0, & \text{otherwise,} \end{cases}$$

$$z_{3t} = \begin{cases} 0, & \text{for } t < 1881, \\ t - 1880, & \text{for } t \geq 1881, \end{cases} \quad z_{4t} = \begin{cases} 0, & \text{for } t < 1917, \\ t - 1916, & \text{for } t \geq 1917, \end{cases}$$

$$z_{5t} = \begin{cases} 0, & \text{for } t < 1931, \\ t - 1989, & \text{for } t \geq 1932, \end{cases} \quad z_{6t} = \begin{cases} 0, & \text{for } t < 1946, \\ t - 1989, & \text{for } t \geq 1947, \end{cases} \tag{17}$$

$$z_{7t} = \begin{cases} 0, & \text{for } t < 1990, \\ t - 1989, & \text{for } t \geq 1990, \end{cases}$$

It should be noted that the first two explanatory variables correspond to outliers and the rest correspond to structural breaks in the slope.

Estimating model (1), (2) and (3) with the above given definitions for the vectors $\mathbf{z}_t$ and $\boldsymbol{\delta}_t = \boldsymbol{\delta}$ gives the following results:

$$\tilde{\sigma}_{\varepsilon}^2 = 0.000940, \quad \tilde{\sigma}_{\zeta}^2 = 0.000309, \quad \tilde{\sigma}_{\kappa}^2 = 0.000069, \tag{18}$$

$$\tilde{\rho} = 0.9284, \quad \tilde{\lambda}_c = 1.1118. \tag{19}$$

The estimated value of the frequency, $\tilde{\lambda}_c$, correspond to a period of 5 years and 7 months approximately. The diagnostic and goodness of fit statistics are

$$H(41) = 0.4410, \quad DW = 1.973, \quad Q(10,6) = 9.426, \quad N = 6.441, \tag{20}$$

$$\tilde{\sigma}^2 = 0.00324, \quad R_D^2 = 0.3357, \quad R^2 = 0.9883. \tag{21}$$

The diagnostics indicate that the model is an appropriate one for the data.

In Table 3 we give the estimated coefficients of explanatory variables.

The results in Table 3 indicate that the outliers and structural changes are significant. The outliers, in this case, match in time with those of the GNPtotal. Three of the structural changes in the slope are coincident with those of the GNPtotal, but for the GNPpc we found two more. One positive in 1932 which could attributed to the end of the international crisis that occurred in 1929-30, and another negative in 1947 which corresponded with an important national crisis.

In Table 4 we have the estimated coefficients of the state vector corresponding to the trend and cycle at the end of the period. The growth rate of the trend at the end of the period under study is 0.49% per year.

Figure 5 shows the components of the GNPpc according to the estimated model. In Figure 6 we can see the residuals of the fitted model with its 95% confidence band, the correlogram also with its 95% confidence band, the periodogram, the estimated spectral density and the frequency distribution of these residuals.

Table 3. Estimated coefficient of explanatory variables for the GNPpc

Variable	Estimated coefficient		R.m.s.e.	t-value
z_{1t}	$\tilde{\delta}_1$	-0.188660	0.0397064	-4.7514
z_{2t}	$\tilde{\delta}_2$	0.159843	0.0397020	4.0261
z_{3t}	$\tilde{\delta}_3$	0.107512	0.0351001	3.0630
z_{4t}	$\tilde{\delta}_4$	0.133714	0.0348254	3.8396
z_{5t}	$\tilde{\delta}_5$	0.078046	0.0348261	2.2410
z_{6t}	$\tilde{\delta}_6$	-0.073836	0.0348251	-2.1202
z_{7t}	$\tilde{\delta}_7$	0.081493	0.0348572	2.3379

Table 4. Estimated coefficient of final state vector for the GNPpc

Variable	Estimated coefficient	R.m.s.e.	t-value
Lvl	8.952000	0.0289804	308.90
Slp	0.004898	0.0260842	0.187779
$\tilde{\psi}_n$	0.006714	0.0172526	
$\tilde{\psi}_n^*$	-0.018962	0.0173562	

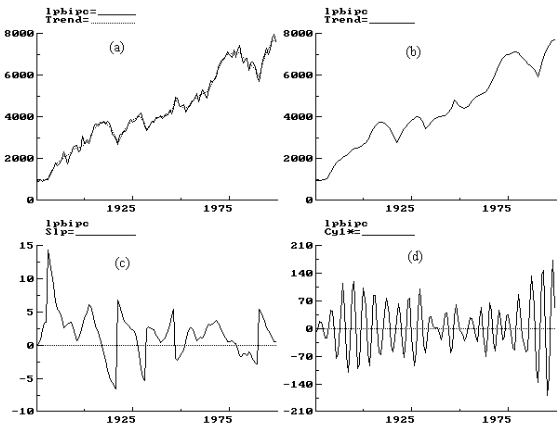

Figure 5. GNPpc of Argentina 1875-1999 with trend [(a) and (b)], its slope (c) and its cycle (d)

In Figure 7 we have, for the GNPpc, in parts (a) and (b) the irregular auxiliary residuals, its 95% confidence band and its frequency distribution, and in parts (c) and (d) the slope auxiliary residuals, its 95% confidence band and its frequency distribution. The value of the Doornik-Hansen tests for normality of the irregular auxiliary residuals is 0.5507 and of the slope auxiliary residuals is 1.2366.

From the analysis of the diagnostic and goodness of fit statistics and the observation of the figures we conclude that the proposed model is appropriate for the data.

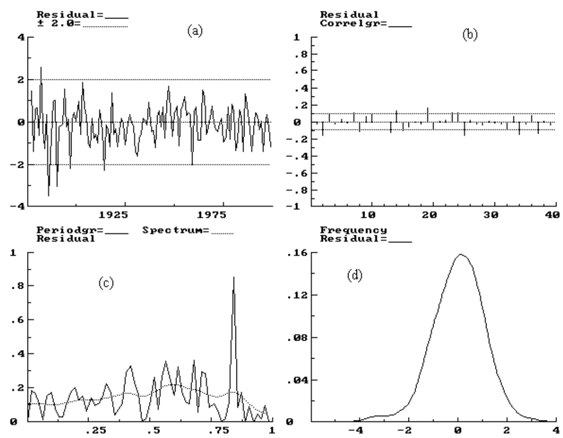

Figure 6. Residuals of the adjusted model for the GNPpc of Argentina 1875-1999. Residuals with 95% confidence band (a), its correlogram with 95% confidence band (b),

its periodogram (full line) and spectral density (dotted line) (c) and its frequency distribution (d)

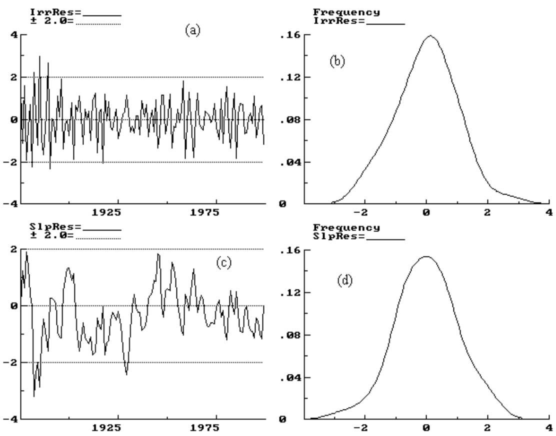

Figure 7. Auxiliary residuals. Irregular auxiliary residuals, its 95% confidence band (a) and its frequency distribution (b). Slope auxiliary residuals, its 95% confidence band (c) and its frequency distribution (d)

As before, in order to determine the ability of the fitted model to perform predictions, the last ten observations were predicted and some tests were carried out. The value of Chow's statistics within the sample period tern out to be 0.5047, which is significantly lower than the value of the $F(8,\ 113)$ distribution, pointing out that the model is well specified for prediction purposes. In Figure 8 we have the observed series y_t, in this case the logarithm of the GNPpc, the predictions of its last ten values, the corresponding prediction residuals together with the 95% confidence bands for the predictions and for the prediction residuals. Clearly we see that the performance of the model seems to be satisfactory for making predictions.

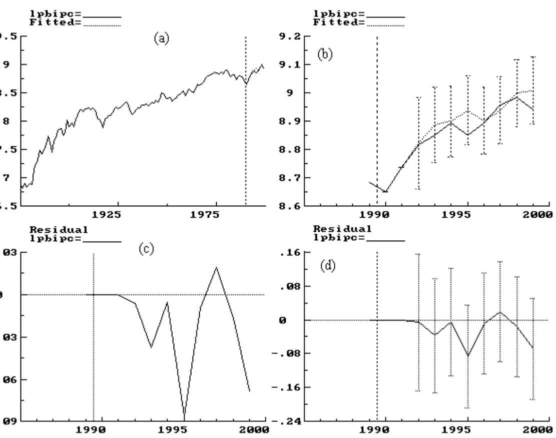

Figure 8. Log of the GNPpc with predicted values (dotted line) (a), predicted values (dotted line) with 95% confidence band (b), prediction residuals (c) with 95%

confidence band (d)

6. Conclusion

In the period under consideration and analysing the GNPpc there are five structural shifts corresponding to changes in the slope. The first one occurred in 1881 as a result of new economic policies implemented by the national government from 1880 and the increasing use of better technologies mainly in transport. The second one occurred in 1917, and it could be attributed to the consequences of the World War I. The third happened in 1932 and it was the result of the end of the world recession. The forth came about in 1947 and it corresponded with an important national crisis as a result of which economic reforms were introduced by the newly appointed government headed by J. D. Peron. Finally, the fifth occurred in 1990 and clearly it could be attributed it to the passage from an hyperinflationary period which reached its maximum in 1989 to a stabilisation period which started in 1991. For the GNPtotal the only changes in the slope that took effect where in 1881, 1917 and 1990.

The five structural changes occurring in the GNPpc determine six periods in the Argentinean economy associated with different political circumstances inside the country and with important international situations that affected Argentina.

Then, for both series it was possible to identify and estimate a cycle of 5 years and 7 months approximately. This could be associated with the duration of the presidential period which was of 6 years.

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