OPEN ACCESS

Journal of Advanced Research in Social Sciences
ISSN 2538-919X

Argentine Chaotic Term Length Series in an American Historical Context
Part II: Complex System Analysis

Felice, C.J.* and Ruiz, G.A.

Laboratorio de Medios e Interfases, Departamento de Bioingeniería, FACET-UNT and INSIBIO-CONICET, Argentina

ARTICLE INFO

Keywords:
chaos theory,
fractals,
Spanish,
British,
Amerindian,
conqueror

ABSTRACT

The political stability of a government system is crucial for achieving social, economic, and cultural growth of a people. Among other things, political stability depends on the norms that come from a state of rights. Several metrics have been proposed to measure political stability, such as the weighted sum of the number of revolutions or the index defined by the World Bank comprising 72 variables, which include subjective concepts, numerical parameters, and other variables. Therefore, it must be applied carefully to individual countries or to compare countries. No definitions in the related literature directly consider cultural factors and are limited to quantifying their practical effects, such as numbers of strikes or manifestations against a government. Concepts such as *contempt for authority* have not been directly quantified. In this part, we present two more indicators that account for the *contempt for authority* and permit a rapid quantitative and visual analysis of the political stability of a country or province throughout its history. They are, the *social stability index* that allows the general quantification of the social stability level at a historical moment, and the *phase planes* that graphically show the predominant chaotic system. These tools manifest the behavior patterns that affect the political stability of a country or province. Finally, we perform an in-depth analysis of the indicators for the Republic of Argentina between the 16th and 21st centuries, with the historical context of the more important Spanish and British colonization of the American continent.

The results indicate 1) the permanence of socially toxic behavior patterns in Argentina and other Latin American countries, 2) inherited cultural causes could explain the high political instability in Argentina over the last 500 years and 3) a succession of singles term length by rulers during decades could be used to stabilize a country.

*Corresponding author E-mail address: cfelice@herrera.unt.edu.ar

Cite this article as:
Felice, C.J. & Ruiz, G.A. (2023). Argentine Chaotic Term Length Series in an American Historical Context– Part II: Complex System Analysis. *Journal of Advanced Research in Social Sciences, 6*(3): 1-34. https://doi.org/10.33422/jarss.v6i3.937

1. Introduction

In the first part of this study, we present the analysis of political instability in Latin America and particularly in Argentina, using the time series of time in office (TIO) of american rulers. Wide time frame from America discovered to the present day is used, and time series of TIO of rulers are quantitatively and qualitatively analyzed. This framework allows us to become independent from any ideology or form of government. In that part we perform a time domain analysis and present stepped graphs as tools for visual analysis of historical processes.

In this second part we present an analysis in the domain of complex systems, using time series data from the point of view of chaos theory and fractals. We also present a new algorithm for signal processing, the moving average filter, as a tool with strong social implications. The filter takes into account social customs and how they persist over time. This information allows us to understand how good or bad social behaviors persist and how easy or difficult it is to change them. It is often very difficult to model a social system like political stability. Our analysis from the theory of chaos and fractals will allow us to model social systems and generate predictions that help improve social behaviors.

In this work we use the phase diagram construction methodology to detect different types of strange attractors, which serve as indicators of certain social behaviors.
Fractal behaviors are ubiquitous in nature and we can find many papers about them in the bibliography. In social systems the situation is different, because is apparently more difficult to demonstrate fractal behaviors.

In this opportunity we demonstrate the presence of fractal behaviors in political systems. Our findings show that in the analyzed series there are moments with marked fractality and others with quasi-periodic signals that indicate different types of social behavior.

As a case analysis, we collected and performed in-depth analysis of the indicator for the Republic of Argentina between the 16th and 21st centuries, with the historical context of the more important Spanish and British colonization of the American continent. From the analysis of the results, we propose the possible cultural causes that can explain the high political instability in Argentina over the past 500 years.

2. Materials and Methods

2.1. Quantitative Indicators of Contempt for Authority

The *contempt for authority* is the devaluation of power that an individual manifests with respect to who governs or exercises command. In practice, it comprises removing the *de facto* authority from whom it was granted to, with or without prior formal agreement, or indirectly acting against the authority by failing to comply with the laws or regulations dictated by the authority. The degree of contempt for the authority of a society is directly related to the political instability of a country.

In this second part, contempt for authority is quantified using two indicators based on the analysis of the time interval between mandates of the rulers of a given country, state, or province.

The analyzed time range includes the date of discovery or foundation of the country, state, or province until the year 2020. The territory governed by the rulers can vary over time while maintaining its historical denomination. For example, the Argentinian province of Tucumán first belonged to the Viceroyalty of Peru and included a territory of more than 700,000 km^2. It then became a part of the Viceroyalty of the Río de la Plata with a smaller territory and is now a 22,525 km^2 province of the Argentine Republic. When counting the office terms, the leaders are called Governors of Tucumán, as they are referred to in historical books and publications (Zinny, 1879; Olivieri, 2018; Astrada, 1987, Lascano, 1992). To avoid confusion, the person who rules will be called *ruler* in all cases, which includes the governor, president, interim president, interim governor, chairman of government boards, military governor, civil controller, military controller, commander-in-chief, and other similar titles used by countries to refer to their rulers at certain historical times.

The length of the term of a ruler depends on several factors. Particularly, when the term in office (TIO) is shorter than agreed, there may be many reasons to justify it. However, if this behavior is repetitive, it ceases to be an exception and becomes the norm, thereby making the government system unstable. History provides different reasons in different cultures to justify these exceptions, e.g., military reasons during the conquest of a territory, or internal political reasons in a defined and independent country.

To avoid the complexity of justifying the particular reasons in each case, a hypothesis is raised, which is that there exist a set of graphic and numerical indicators that reflect the cultural habit of contempt for authority at the country or province level, and they can be obtained from the TIO analysis of the rulers.

The proposed indicators are: 1) social stability index (SSI) to quantify the stability degree of the predominant social behaviors and 2) phase plane to identify the type of predominant chaotic system. These indicators refer to social behaviors and their evolution over time, and also to human systems that can change over time both in behavior and number of people involved.

2.2. Social Stability Index

The SSI is defined as the output value of a filter of progressive averages applied to the temporal series of TIOs of a determined country, province, or state. The temporal series is obtained through two steps: first, the TIO series of the political governor in a determined geographic territory is generated. Second, the series under analysis is generated by measuring the deviation of the permanence times with respect to a reference value.

The reference value is the last term length formally assigned by a given country to a ruler. In the year 2020, the term length for the presidential post of 172 countries fluctuated between four and seven years, out of which 56% had a maximum term length of five years. In 81% of these countries, the rulers could remain in office for only two periods that could or could not be consecutive (CIA World Factbook, 2021). The predominant values of the term duration during a period, or the maximum number of times they can govern, are the result of historical learning across centuries accumulated by humanity, which can be considered as a learning of *trial and error* in all the cultures, and a motif by which we adopt the last value defined as reference.

2.3. Temporal Series of TIO

The temporal series is generated by incorporating a pair of data [*date of assumption; term in office]* of all the rulers of a territory in the interval of time between the discovery or foundation of a country, province, or territory and the year 2021. The time in office is denoted by TP(t) in Equation (1) and the analyzed series are expressed in years.

2.4. Temporal Progressive Average Filter (TPAF)

The TPAF is defined as the average of the TP(t) values between the origin and the moment in time to which the filter is applied. Each value obtained at the filter output considers the entire history of the territory or country; thus, it includes a huge set of situations, customs, behaviors, and contexts that are typical of the culture being analyzed. From the signal processing point of view, the filter is non-recursive because it only considers past data from the point in time to which it is applied.

$$(TPAF)_t = \frac{1}{t}\sum_{j=1}^{t}(TP)_j \quad (1)$$

It is stated that the filter considers the history of the territory or country because the output is the average of all previous values from the day of the discovery or foundation of a country or province (j = 1) until the moment at which the calculation is performed. For example, we may consider the temporal series of the first six Premiers of Ontario, Canada, since the creation of the Canadian Confederation in 1867 (Table 1) until 2021.

To clearly understand the working of the filter, it can be interpreted or visualized as an operator that changes the arithmetic average of TP(t) from t = 0 up to the instant of the time of analysis.

As an example, Figure 1 shows a black continuous line that indicates the series of deviations in the permanence time with respect to the value of reference (4 years = 1460 days). The first Premier of Ontario, John Sandfield Macdonald, was in charge for 1681 days; therefore, the difference between the number of days and the reference value (1460) is 158. This is the first value of the series indicated by the black solid line (ordinate axis).

Table 1.
TIO of Ontario

	Name	**Term in office**		**Days ruling**
		Start	**End**	
1	John Sandfield Macdonald	16/07/1867	20/12/1871	1618
2	Edward Blake	20/12/1871	25/10/1872	310
3	Oliver Mowat	25/10/1872	21/07/1876	1365
4	Arthur Sturgis Hardy	21/07/1896	21/10/1899	1187
5	George William Ross	21/10/1899	08/02/1905	1936
6	James Whitney	08/02/1905	25/09/1914	3516

Note. Temporal series of the first six Premiers of Ontario, Canada.

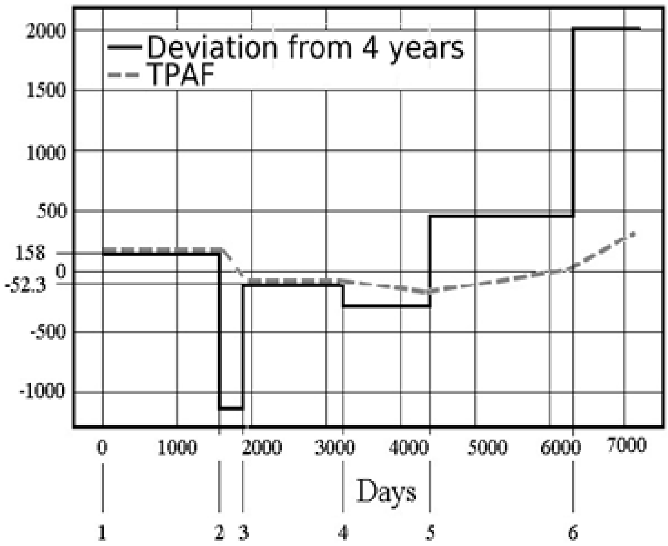

Figure 1. TIO of Ontario
Note. Temporal series under analysis (black continuous line) that shows the functioning of the filter. The gray dashed line is the result of applying the filter to the temporal progressive averages (TPAF). The numbers on the horizontal axis correspond to the names of the Premiers of Ontario (Table 1). These are found at the beginning of your terms.

If the filter of the temporal progressive averages is applied to the temporal series of the example, we obtain the gray dashed line shown in Figure 1. For the first 1618 days, the output TPAF of the filter is constant and its value coincides with that of the series. This can be appreciated by taking any value for t in the interval (for example, taking t = 1000) in Equation (1).

$$(TPAF)_{1000} = \frac{1}{1000}\sum_{j=1}^{1000}(TIO)_j = \frac{1}{1000}\sum_{j=1}^{1000}(158) = \frac{158 * 1000}{1000} = 158$$

Although Edward Blake assumed power after Macdonald, he remained in office for only 310 days. This makes the answer of the filter decay progressively until the end of his rule:

$$(TPAF)_{1928} = \frac{1}{1928}\sum_{j=1}^{1928}(TIO)_j = \frac{1}{1928}\left(\sum_{j=1}^{1618}(158) + \sum_{j=1619}^{1928}(-1150)\right) = -52.3$$

2.5. Interpretation of the SSI

The SSI has the following characteristics:

- To obtain a positive value, it requires a TIO sequence with equal durations and superior reference value.
- To obtain a negative value, the TIO or its absence must be lower than the reference value.
- To obtain a null value, the TIO must be the same as the reference value. A sequence alternating between the negative and positive values of the same value also generates a null value, but it is very improbable that this would happen.
- When a sequence is negative, positive, or null, and keeps in time, changing its value in any direction is very difficult.

These characteristics make the SSI an indicator of the grade of temporal persistence of social behaviors related to *contempt for authority*. The cultural interpretation of the sign and numeric values of the temporal evolution of the index for a determined country or province is obtained through the analysis of the corresponding stepped graph and phase plane. Stepped diagrams were introduced and thoroughly discussed in the first part of this paper. A stepped graph of TIO shows the number of years, months, or days that the rulers of a country or province/state remained in office for a given period.

2.6. Political Chaotic Attractor

One of the primary goals of social sciences is to predict the behavior of political systems. Several mathematical models (Uddin, 2017; Jia, 2021) use different grades of success based on their specific application. For example, the political stability of China and India could be forecasted (Shi, 2020) using the fractional order accumulation grey number model (Wu, 2013), or the degree of political instability can be used to predict the fraction of government revenue derived from seigniorage (Cukierman, 1990).

In the context of this study, the deterministic chaotic model is introduced as a tool to analyze the political stability of a country or province. An attractor is a set of numeric values towards which a system tends to evolve owing to a wide variety of initial conditions. For a set to be an attractor, the trajectories of the analyzed variables must remain in proximity, although they may be slightly disturbed. The attractors are typical of chaotic systems, which are complex, multifactor, and their future behavior is extremely sensitive to the initial conditions and may induce significant changes or evolve over time. In these systems, small fluctuations may induce significant changes, which is different to linear systems wherein the behavior of the variables is predictable. The chaotic systems are non-linear with answers that do not respond to the principle of superposition; they can be affected by past states, and are unpredictable without being completely random. In a complex system, knowing how the parts work is not sufficient; therefore, knowing how the entire system works is necessary because it is not possible to deduce the whole from the characteristics of its parts.

The natural and social systems can be considered complex because they can be modelled more adequately using non-linear dynamics. Some examples of these systems are the human body, government types, ecosystems, stock markets, weather, and the election of a new president or governor (Mennin, 2010). Quantitative analyses of chaotic political systems are generally not available, which limits a qualitative description of apparently complex systems in terms of the theory of Chaos (Banerjee, 2014).

In this study, we obtained political chaotic attractors (PCA) by constructing phase planes of the temporal series of TIOs. For a PCA to appear in a phase plane, specific social behaviors must be repeated, such as attempts at rulers finishing their periods, or on the contrary, actively attempting that they do not finish. Both cases would have different justifications. These behaviors or social customs are not constant, but appear as near trajectories inside the phase plane and shape towards a chaotic attractor.

Each phase plane is obtained in the following way:

1. From the *temporal series of times in office,* we define the *series of the first differences* (FD).
2. The FD is defined as the difference between two successive TIOs.
3. A graph of a FD vs TIO phase plane is created.

The phase plane of the TIO series allows for the identification of PCA in a single figure, which can be interpreted as a *set of social behaviors that are repeated* in cultural terms.

It is possible to establish a clear bond between the phase diagram and the stepped graph. Figure 2 shows a diagram of phases that has been rotated 90° left to show the bond.

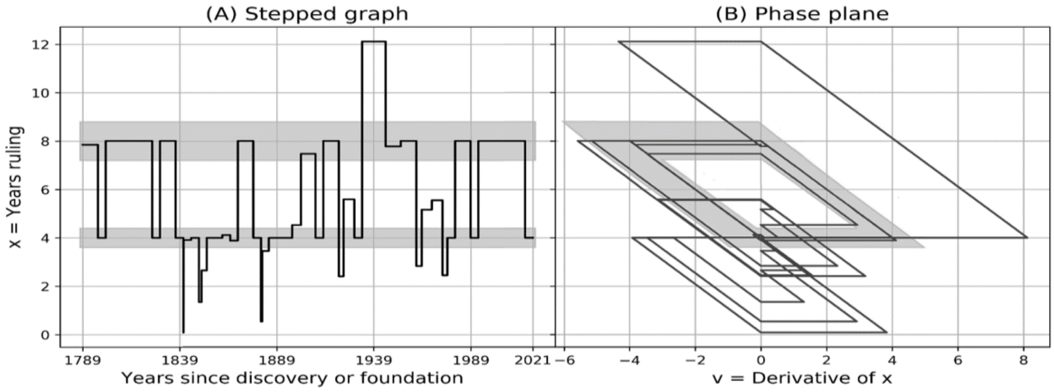

Figure 2. Relationship between the stepped graph and the phase plane
Note. (a) the stepped graph and (b) phase plane. Both have a 10% tolerance band.

From Figure 2, It is evident that the bonds of the phase diagram are directly related to the amplitudes of the stepped graph; hence, the components can be easily identified from every part of the diagram. The stronger bonds are associated with a longer period of government, which is approximately 12 years (4380 days) in the figure. The intermediate bonds are bonded with governments that lasted eight years and the inferior bonds with those that lasted less than four years (1460 days).

Likewise, from Figure 2(a) it is evident that the bands of 10% tolerance are associated with the standard deviations around the X values of 1460 and 2920 days (4 and 8 years, respectively), which are indicated in grey. In Figure 2(b), also in grey, it can also be appreciated a PCA. In this scheme, it can then be assumed that the strange attractors are trajectories in the space of phases to the ones that tend to the normal trajectories.

Figure 2(b) also shows the dynamic behavior of the government system at two points in time. All the bonds in the 10% bands can be considered as equivalent, which means that the system tends to return to the attractor when the trajectory is diverted. In the case of a negative PCA, the positive behaviors do not last long and the trajectory of the phase plane tends to return to the negative PCA; for example, when a government is intervened through constitutional means or by the armed forces. On the contrary, if there exist positive behavior attractors (e.g., highly periodic elections), a diversion in a negative way (e.g., trying to interrupt the government) makes the system go back to the trajectory of the positive attractor; for example, making a governor end his period but avoiding his re-election.

2.7. Sensitivity to Initial Conditions

Another characteristic that categorizes a system as chaotic is its sensitivity to the initial conditions. In analytical systems, various initial conditions can be simulated. Thereafter, visualize that their trajectories converge on one attractor. This is not possible in our temporal series because they are characterized such that they are irreversible because history has only one direction in time, which makes it impossible to change the initial conditions similar to the dynamic systems studied in physics or chemistry. However, different initial conditions departing from different moments in time can be similarly simulated. The Wolf paper describes how to discover suitable points in the time series to use as “initial conditions“ and how the Lyapunov exponent can be calculated from the separation of these points in time (Wolf, 1985).

2.8. Lyapunov Exponent

Identifying if a system is chaotic deterministic may allow for short term predictions in economy, finances, or climatology (Guegan, 2009; Selvam, 2017). When applied to social sciences and politics in particular, it may be used to predict or identify the dynamics of large social systems, such as the "Arab Spring," and how they could be the starting points of regime changes (Filipe, 2013).

To verify that the systems being analyzed are chaotic, the Lyapunov exponent of the temporal series was used, which enables quantification of the system sensitivities to the initial conditions as the rate of exponential divergence from the perturbed initial conditions. The maximal Lyapunov exponent (MLE) is often used to quantify the system changes owing to small perturbations, wherein a positive MLE is usually indicates that the system is chaotic (Bishop, 2017).

When the initial conditions are slightly changed in an analytical system, two points in the state space that are separated by a small distance will diverge exponentially as the system evolves. In mathematical terms, if x(n) is from our temporal series and the initial condition is given by x(0), the system represents a chaotic dynamic when the initial condition is changed by an infinitesimal quantity $\delta x(0)$. Furthermore, the trajectories diverge with time and lose their correlation. This implies the following:

$$\lambda = \lim_{t\to\infty}\left(\frac{1}{t}\ln\left|\frac{\delta x(t)}{\delta x(0)}\right|\right) > 0 \qquad (2)$$

Where,

λ: Lyapunov exponent
t: time

The study of temporal series differs from the case wherein the differential equations that rule the system dynamics are known. Wolf et al. (Wolf, 1985) developed a method to estimate the Lyapunov exponent by rebuilding the attractor from the data of only one variable in a temporal series.

2.9. Attractor Reconstruction

To place the data of one variable (temporal series) in a space or multidimensional phase planes, the delay coordinates method (Takens, 1981) can be used, or the time series and its successive derivative can be used as coordinates (Packard, 1980). To generate the phase space using the delay coordinate method, the optimal delay and embedding dimensions must be known. The delay is obtained by self-correlating the temporal series and locating the first minimum on the curve, and the embedding dimensions are calculated using the *false nearest neighbor* method. From a preliminary analysis of the available temporal series data of the times in office, excessively high value delays were discovered with respect to the total available data in each series (e.g. min = 20, N = 68). This results in loss of information when the plane phases are generated; therefore, this method was discarded.

In the second case, the phase space coordinates are generated using the derivatives of successive order for each new coordinate. This method has as a disadvantage in that it is sensitive to noise, that is, the information unrelated to time in office, which are only the historical imprecise dates in our case. This means that the precise dates on which the historical events occurred are doubtful, particularly the oldest ones. The difference between two consecutive values of the temporal series is considered a discrete derivative because it minimizes information loss. Therefore, this method was used to generate the phase planes.

If only N data are available for a single scalar variable x(n), the geometric structure of the phase space can be reconstructed from the scalar time series by using the following equation (Parlitz, 1998):

$$y(n) = [x(n), \Delta^1 x(n), \Delta^2 x(n), \ldots, \Delta^{D-1} x(n)] \quad (3)$$

Where

y(n): D-dimensional vector
x(n): time series

$$\Delta^1 x(n) = x(n) - x(n-1)$$
$$\Delta^2 \mathrm{x(n)} = \Delta^1 \mathrm{x(n)} - \Delta^1 \mathrm{x(n-1)}$$

After obtaining the phase plane, the Lyapunov exponent is calculated using the basic algorithm of Alan Wolf, which allows for the estimation of the non-negative exponents of a temporal experimental series (Wolf, 1985).

The algorithm considers two proximal points in the system (D0+1)-dimensional designated as $y^i(n)$ and $y^j(n)$, and then investigates if these two sequences diverge as the system evolves. The divergence is quantified by calculating the distance d(n) between them, which is given by the square root of ${R_D}^2(n)$ in Equation (4):

$$\mathrm{d(n)} = \sqrt{{\mathrm{R}_{D0+1}}^2(\mathrm{n})} \quad (4)$$

Where D = (D0 + 1).

If the system is chaotic, *d(n)* will initially increase exponentially with *n*. The slope of the graph *ln[d(n)] vs n* will be an estimation of the Lyapunov exponent, where *ln* represents a natural or Napierian logarithm. The derived values here belong only to a pair of initial states, and the Lyapunov exponent is an average of this divergence over all nearby initial pairs. Therefore, we identify all "j" points such that the distance $y^i(0)$ is less than some small fixed value. The distances are calculated and averaged, and the natural logarithm of this average distance versus n is graphed. The slope of the initial linear range represents the estimated value of the MLE, which is the parameter that indicates if the system is chaotic. In this case, a positive sign indicates that the system is chaotic.

2.10. Fractality in the Temporal Series of TIO

The fractality of the TIO is the most important quality that allows for the classification of a set of trajectories in the phase plane as an attractor. The characteristics of a fractal are: (a) It has a fine structure at arbitrarily small scales, (b) it is too irregular to be easily described in traditional Euclidean geometric language, (c) it is self-similar (at least approximately or stochastically), (d) it has a Hausdorff dimension greater than its topological dimension, and (e) it has a simple and recursive definition. The Hurst exponent (Hurst, 1951) and the Mandelbrot fractal dimension (Mandelbrot, 1982) are used to find out if TIO are fractal and have memory.

The Hurst exponent (H) is a measure of the long term memory of the temporal series and quantifies the relative tendency of a times series to return to a mean value or group in a cluster, thereby measuring its persistence. H varies between zero and one, and has been demonstrated to be of great importance in identifying whether a process is persistent. This value can be interpreted as:

0 < H < 0.5 → not persistent (*anti persistent*)
0.5 < H < 1 → persistent and has memory
H = 0.5 → random

The best-known method for calculating H is the *rescaled range analysis* (Mandelbrot, 1969), which satisfies the following potency law:

$$E\big(R(\tau)/S(\tau)\big) = c\,\tau^{H} \tag{5}$$

where $R(\tau)/S(\tau)$ is the *rescaled range*, E is the expected value or mathematical expectation, τ represents the number of observations, c is a constant, and H is the exponent or Hurst index. To obtain the Hurst index of a temporal series of N data, windows of data having equispaced in a logarithmic scale lengths between 10 and N are created.

Let $X = H_1, H_2, \ldots\ H_\tau$ be a data window of arbitrary length τ. For each window, the following are calculated:

1. The arithmetic average: $\underline{X} = \frac{1}{\tau}.\sum_{i=1}^{\tau} X_i$
2. A series of deviations Y with respect to arithmetic average: $Y_i = X_i - \underline{X}$

   with $i = 1,2, \ldots, \tau$
3. A series of accumulated deviations Z: $Z_t = \sum_{i=1}^{t} Y_i$
4. The range R of the Z series: $R = \max(Z_1, Z_2, \ldots\ Z_\tau) - \min(Z_1, Z_2, \ldots\ Z_\tau)$
5. The standard deviation S of the data windows: $S = \sqrt{\frac{1}{t-1}.\sum_{i=1}^{\tau}\big(X_i - \underline{X}\big)^2}$
6. The R/S ratio for the data windows.

Figure 3 shows a hypothetical situation, wherein the phase plane and the H calculation were obtained using the proposed stepped graph.

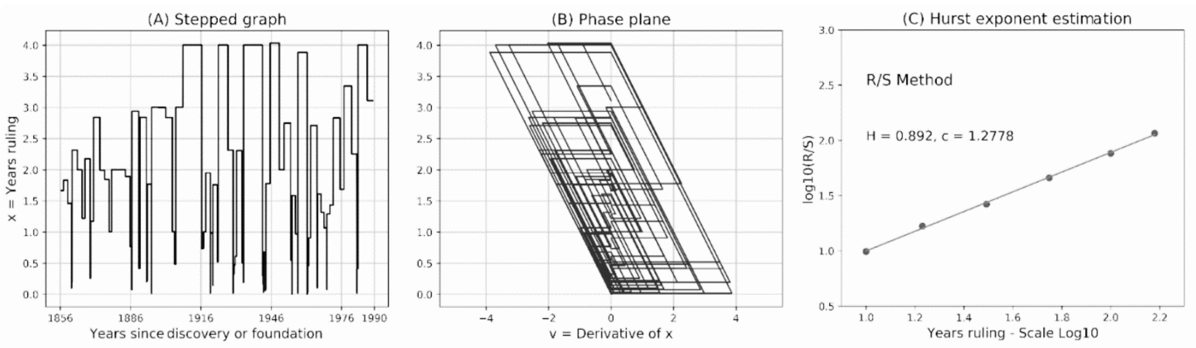

Figure 3. Analysis of the Tucumán time series
Note. (a) Stepped graph, (b) phase plane, and (c) Hurst exponent estimation.

In the Figure 3(c), the horizontal axis representing the lengths of the different data windows are equispaced on a logarithmic scale. Likewise, H evaluated using the *rescaled range analysis* method has a value in the interval 0.5 < H < 1.

The H and fractal dimension (fractional dimension) of a series are related as follows:

$$D = 2 - H \tag{6}$$

2.11. Analyzed Countries

In this study, we analyzed the time in office of rulers of the Republic of Argentina at the country and province levels. The analysis was performed considering the geographical context of the American continent, including countries that were conquered and colonized by the Spanish and British empires between the 16th and 21st centuries. The analyzed countries with a predominant Spanish influence were Mexico, Colombia, and Argentina, which include 40% of the Spanish-speaking population from the 33 countries in America. The analyzed countries with Anglo-Saxon influence are the USA and Chile, with Chile being a special case wherein there was simultaneous British and Spanish influence. Chile is the Latin American country with maximum British ascendancy who still influence the way of living in Chile (Zimmerman, 1977; Bernal-Meza, 2013).

The histories of other Latin American countries such as Peru, Venezuela, Paraguay, Bolivia, and Panama show a pattern of political stability similar to the previously mentioned countries. Therefore, they were not included in this study.

For the local analysis of Argentina, the province of Tucuman was considered because it has the oldest chronological records. The ephemeral city of “El Barco” was founded in Tucuman in 1550 (Medina, 1896), and it was the first city in the future territory of the Republic of Argentina. After the juridical act of foundation, it was certified by a notary with a royal license; thus, this new territory was incorporated into the crown of Castilla (Medina, 1896; Palacios, 2012). In the analysis, we also included the province of Buenos Aires because it contains the capital city of Argentina. Furthermore, it has the largest population and greatest political, cultural, and economic influence on Argentina. The behavior of other provinces such as Santa Fe, Córdoba, Mendoza, Entre Ríos, Salta, Misiones, and Chaco, which all had more than a million inhabitants each in 2020, show similar sequences up to the end of the 20th century. These provinces will be analyzed in a future work.

For a province-level comparison between the British and Spanish influences, we included the state of New York, which was first colonized by the Dutch, and then by the British; the state of Virginia because it is the oldest American colony and a model of pure British influence; the states of California and Florida because they were conquered and colonized by the Spanish, Mexican, and British.

The selected territories allow us to visualize the historical influence of the British and Spanish cultures on the political stability of an American country. The sources consulted for each date of the time in office series are listed in the spreadsheet that contains the analyzed data.

The analyzed countries and provinces are listed in Table 2, including their independence dates, and the formal TIO duration of their governors and presidents in the year 2021. The formal duration is used as the reference value in our analysis.

Table 2.
Reference values of countries and provinces

Place	Level	Independence	Reference (in 2021)	Time range	Years from independence
Argentina	Country	09/07/1816	4	1777–2019	203
Buenos Aires	Province	09/07/1816	4	1534–2019	203
California	Province	14/06/1846	4	1767–2019	173
Chile	Country	12/02/1818	4	1539–2018	200
Colombia	Country	20/07/1810	4	1538–2018	208
Florida	Province	04/07/1776	4	1565–2019	243
México	Country	16/09/1810	6	1521–2018	208
New York	Province	04/07/1776	4	1624–2021	245
Tucumán	Province	09/07/1816	4	1543–2019	203
United States	Country	04/07/1776	4	1607–2021	245
Virginia	Province	04/07/1776	4	1607–2020	244

To interpret the results, it is important to know that the countries under Spanish rule had centralized governments prior to their independence; however, this was not the case in the USA under British rule. Argentina had two Spanish colonial governments, the first one under the rule of the Viceroy of Peru, and in a lesser way through the Captaincy General of Chile; and the second under the Viceroyalty of the Rio de la Plata when it was created. Chile, Colombia, and Mexico also had centralized governments; for example, Viceroys in Mexico and Colombia, and governors in Chile. In the USA, they did not have centralized governments for the colonies, and each colony negotiated directly with Great Britain.

3. Results

3.1. Social Stability Index (SSI)

In the context of this study, the stability of the SSI value must be interpreted as the permanence of a determined set of social habits with respect to the *contempt for authority*. This is because by cumulatively averaging the data, the longer the habits remain negative or positive, the longer the SSI remains stable.

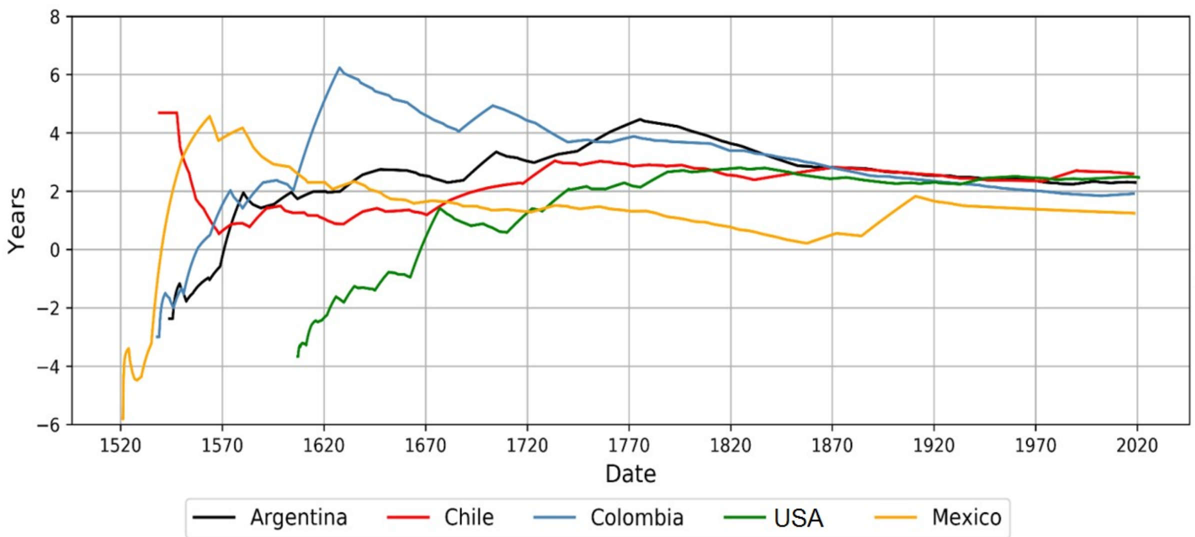

Figure 4. SSI of analyzed countries
Note. Social stability index (SSI) of all countries since their independence.

Figure 4 shows that in the last 200 years, except in Mexico, the social habits tend to stabilize. In Mexico, there is a positive jump in the SSI in 1884, and in Chile there are jumps in 1831 and 1973; however, there is a general tendency of SSI decreasing in both cases. The USA shows an exponential answer tending to a constant value.

In Figure 5, Tucuman shows a stable index since 1890, similar to that of the state of Virginia. But when its phase planes of the same period are analyzed, Tucuman shows a strange attractor with low TIO values and Virginia maintains a point attractor for 145 years.

In Buenos Aires, there is a positive jump in 1835 before a decrease, and a tendency to stabilize with a positive SSI value. Between 1900 and 2020, Buenos Aires and Florida show similar tendencies, but they differ in their behavior in the phase planes. While Buenos Aires shows a strange attractor from its independence up to almost the end of the 20th century, Florida shows a point attractor between 1877 and 1950, which is then transformed into a quasiperiodic signal that remains till now.

New York shows a behavior similar to the other countries and provinces up to 1933, after which there is a change in the slope that tends to stabilize at SSI = 4. The SSI curves of California and Florida initially contain opposing signs and tendencies, but it is astonishing that the trajectories join in 1980, and keep the parity up to the present.

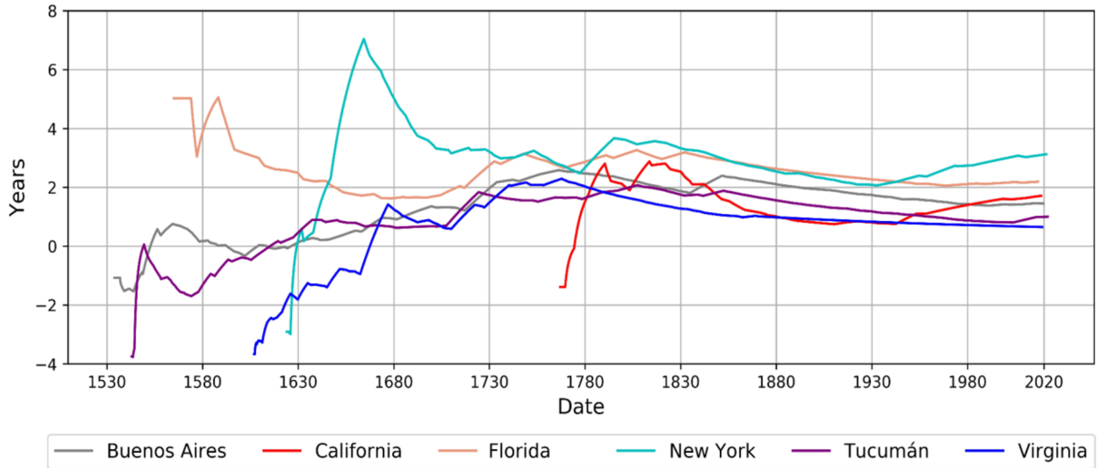

Figure 5. SSI of provinces and states
Note. Social stability index (SSI) of all provinces and states since their independence.

3.2. Phase Plane and Chaos Attractors

3.2.1. Country Level

In addition to the behavior of Argentina, the behavior of Mexico is presented since it is an example of a punctual attractor. The behaviors of the United States, Chile and Colombia were also studied but these are presented in the supplementary material.

In Figure 6(a), we can observe that before the pro-independence process of Argentina that began in 1810, the trajectories show an attractor at 5< TIO <6 and another more diffused attractor at TIO < 3. Post-independence (Figure 6(b)), most trajectories are concentrated at an attractor at TIO < 3, indicating an increased negative stability of the system.

Argentina: time evolution in stages

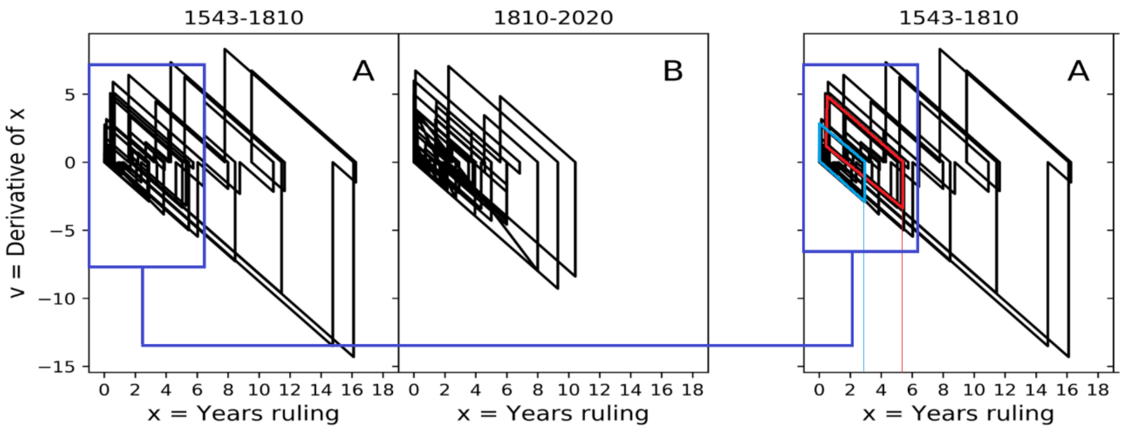

*Figure 6.*A rgentina timeline phase plane by stages
Note. Argentina phase plane stages: (a) 1543–1810 and (b) 1810–2020. Red: 5< TIO <6; Sky blue: TIO < 3.

Argentina: time evolution

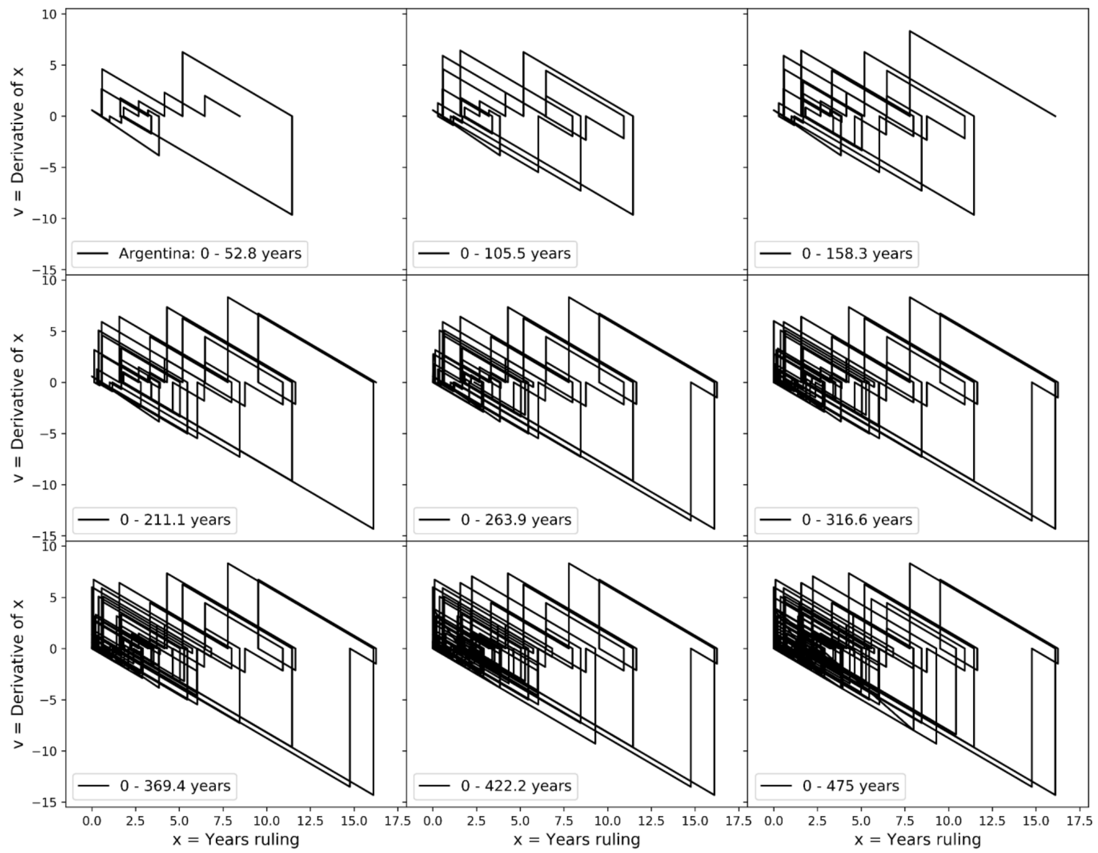

Figure 7. Argentina timeline phase plane
Note. Phase plan of the temporal evolution of Argentina in the range of 1544–2020.

The temporal evolution shown in Figure 7 confirms that after 1810, there was a significant concentration of trajectories in TIOs < 3 years, which formed a strange attractor.

Mexico: time evolution by stage

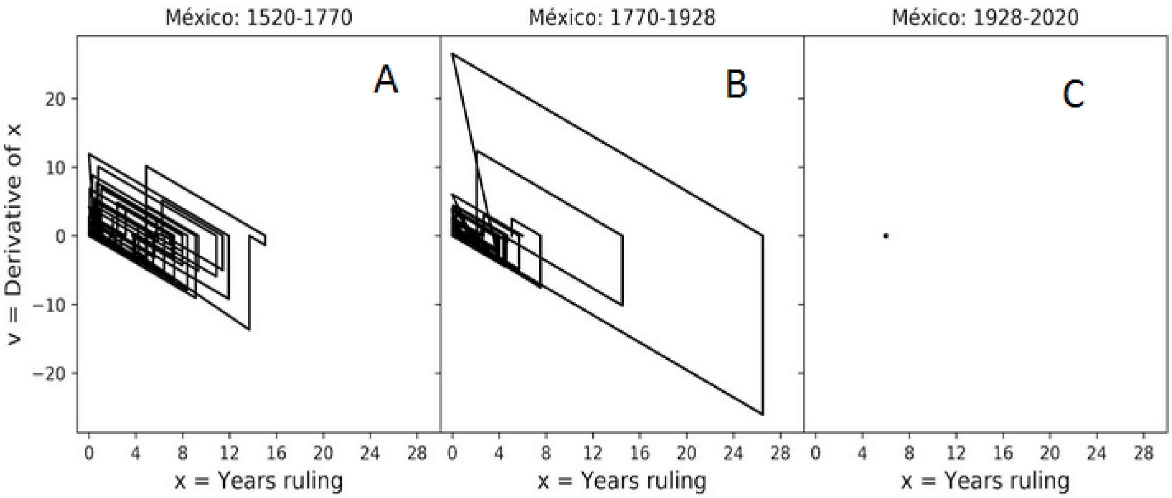

Figure 8. Mexico timeline phase plane by stages
Note. Time evolution of Mexico phase plane from 1520 to 2020. The figure is divided into three intervals to enhance periods of (a) positive and (b) negative stability, and (c) a point attractor. Reference value of TIO for Mexico is 6 years.

Figure 8 shows three different patterns of social behavior in Mexico over time. In Figure 8(a), positive durations of TIOS with significant variations are predominant. In Figure 8(b), TIO durations of less than six years are predominant, with two exceptions of longer durations. In Figure 8(c), we can observe a period of more than 92 years wherein the rulers succeed uninterruptedly, each ruling for only one period.

3.2.2. Province Level

In a similar way to the country level, this section presents the behavior of Tucumán and Buenos Aires, leaving the cases of Florida and Virginia as examples of point attractors. The supplementary material presents the other case studies: New York and California.

The phase plane of Tucuman (Figure 9) shows a very dense strange attractor at TIOs of less than four years. The remaining trajectories are distributed in the range of TIO = 4 to 17 years, showing a significant TIO diversity in the entire range of the analyzed time.

Tucumán

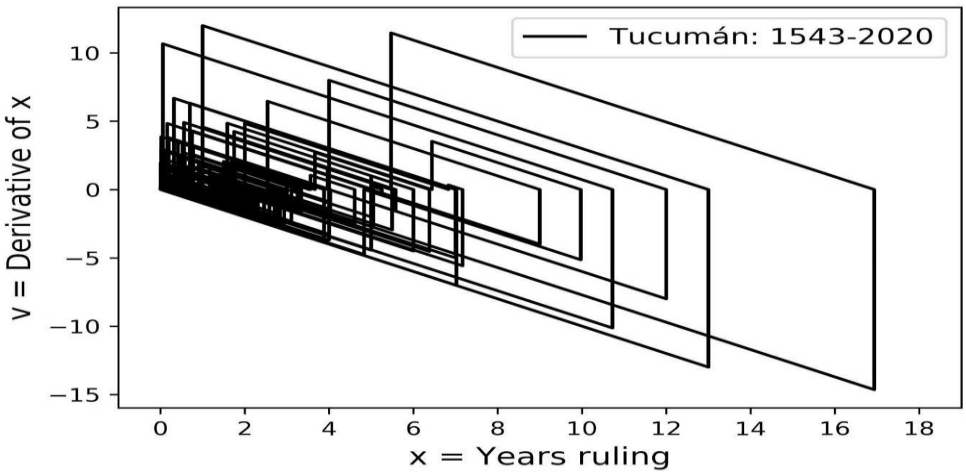

Figure 9. Tucumán timeline phase plane
Note. Phase plane of Tucumán between 1543 and 2020.

Tucumán: time evolution by stages

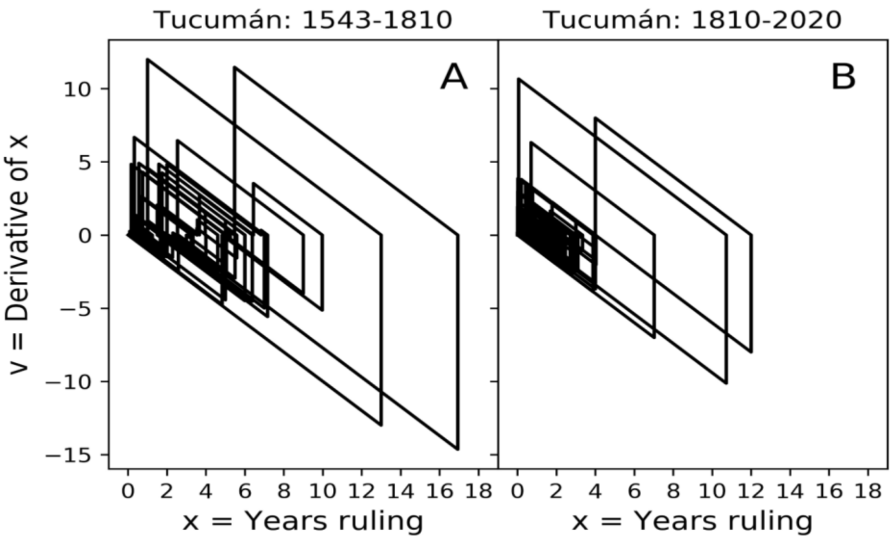

Figure 10. Tucumán timeline phase plane by stages
Note. Time evolution of Tucumán phase plane between 1543 and 2020. The figure is divided into two stages: (a) Pre- and (b) post-independence process beginning in 1810.

In Figure 10, the phase plane of Tucuman shows the existence of only one predominant attractor during the 477 years analyzed. To better understand the temporal evolution of the trajectories, the phase plane is divided into two parts: before and after 1810. This allows us to better visualize the behavior before and after Argentina's independence.

The phase planes in Figure 10 show that the political instability in Tucuman increases from May 1810, the year in which the Argentinean state began to define itself in a process that ended in 1816, with a formal break of the political bonds of the Provincias Unidas del Rio de La Plata with the Spanish Monarchy. The increase in instability is shown at the appearance of a strange attractor concentrated on the trajectories of less than three years (Figure 10(b)), which remains until the year 2020 with a few exceptions.

Buenos Aires

Figure 11. Buenos Aires timeline phase plane
Note. Phase plane of Buenos Aires between 1534 and 2020.

In Figure 11, which shows the phase plane of Buenos Aires, a strange attractor can be observed at TIO values of less than four years. Thereafter, a dispersion of TIO values fluctuating between days to more than 16 years can be observed. A limitation of visualizing data in this way is that they do not highlight the trajectories that are very close, which is prominent in the stepped diagram of Buenos Aires for the period of 1770–1980 (Figure. 16).

Florida: time evolution by stages

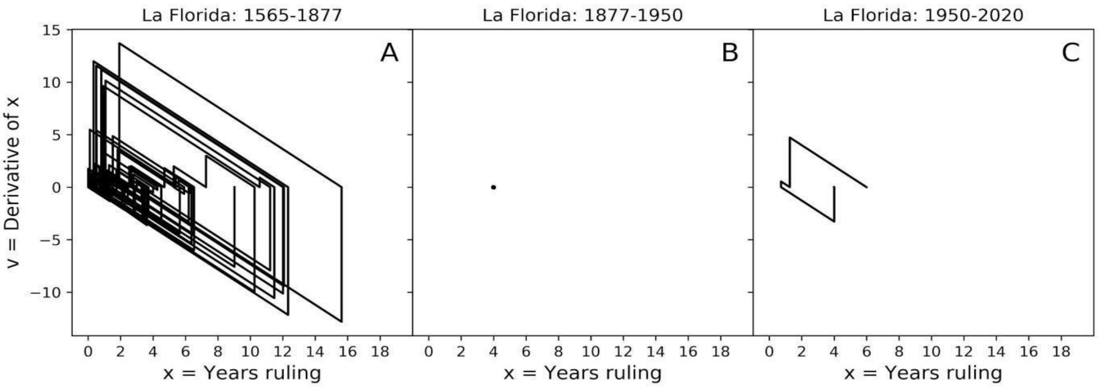

Figure 12. Florida timeline phase plane by stages
Note. Time evolution of Florida phase plane by stages between 1565 and 2020. Time intervals are (a) 312 , (b) 73, and (c) 70 years.

The temporal division of the phase planes in Figure 12 is based on the observations from the stepped diagram of Florida in Figure 17. To isolate social behavior, we considered the criteria before and after the period in which the rulers stayed in their posts for only four years between 1877 and 1950. In Figure 12(a), three strange attractors in 4, 6, and 12 years are prevalent and temporal trajectories fluctuate among them, as observed in the stepped diagram in Figure 23. Figure 12(b) shows the complete transformation of the trajectories in a point attractor that lasted 73 years, which transform into a quasiperiodic signal over the following 70 years in Figure 12(c).

Virginia: time evolution by stages

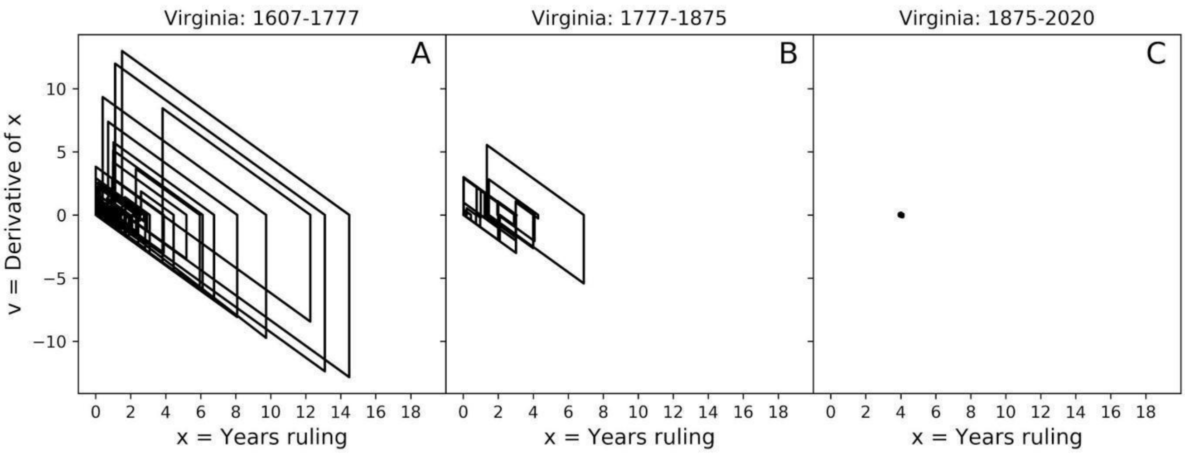

Figure 13. Virginia timeline phase plane by stages
Note. Time evolution of the phase plane of Virginia in stages entre 1607 y 2020. Time intervals are (a) 170 years, (b) 98 years and (c) 145 years.

The phase plane of Virginia (Figure 13) was divided into three stages based on the following criteria. The first stage of 170 years begins from the foundation of Virginia up to the independence of the US. In Figure 13 (a), we can observe an attractor with TIO values of three years or less and significant TIO variations of more than four years. The second stage, shown in Figure 13(b), includes a period of 98 years from independence up to the end of the secession war in the US, wherein short durations of TIOs are predominant. The third and more intriguing is the one shown in Figure 13(b), which shows a single point attractor for 145 years that lasts up to now.

3.3. Fractal Dimension, and Hurst (H) and Lyapunov Exponents of Time Series

To confirm that the temporal series of TIO are fractals and chaotic, the fractal dimension and the H and Lyapunov exponents of each series were calculated. The results are listed in Table 3.

Table 3 lists the fractality and chaos levels in the provinces and countries analyzed in the entire available temporal range. When the parameters are generalized in time, the listed values do not allow for a differentiation in the changes owing to historical situations, but they verify that all the systems are fractals and chaotic. In Table 3, the analyzed temporal series are all fractals in all cases of $0.5 < H < 1$ with a fractal dimension >1 and <2, thereby indicating a fractional geometry, which means that the series indicate a *persistence*, that is, a period of growth is continued by a similar one. One persistent series is characterized as having a long term memory, and all changes that occur in the present are correlated and will consequently affect future changes.

Table 3.
Fractal features

Governors	**Time range**	**H**	**D**	**Lyapunov**
Tucumán	1543–2020	0,869	1,131	1,742
New York	1624–2020	0,859	1,141	1,708
Buenos Aires	1534–2020	0,922	1,078	1,575
Florida	1565–2020	0,659	1,341	1,508
California	1767–2020	0,845	1,155	1,467
Virginia	1607–2020	0,712	1,288	0,483
Presidents				
Chile	1539–2018	0,936	1,064	1,817
Argentina	1543–2020	0,877	1,123	1,634
EEUU	1777–2020	0,984	1,016	1,633
México	1520–2020	0,866	1,134	1,633
Colombia	1538–2020	0,837	1,163	1,525

Note. Hurst exponent (H), fractal dimension (D), and Lyapunov exponent of time series

These characteristics expressed in cultural terms indicate that the habits related to the *contempt of authority* persist over time, that is, they are difficult to change.

The last column of Table 3 lists the maximum Lyapunov exponent values for each analyzed series. The Lyapunov exponents measure the sensibility of the initial conditions and provide information on the rate at which the orbits converge or diverge. Particularly, the maximum value is more interesting because it contains information about the maximum rate at which the orbits are separated. The maximum values of the Lyapunov exponents are positive for all analyzed cases, which means that the distance between close orbits will increase exponentially over time and the system will be sensitive to the initial conditions. In cultural terms, the Lyapunov exponent values indicate that the social behaviors are repeated with differences that can be small but affect the permanence time of a ruler.

Social behavior refers to the actions of a person or group of people that result in the premature end of the period of a ruler. The reasons that justify this action can include expressions such as *they do not manage the economy well, they are not ideal for the post, they are stealing, it is a government with left (or right) tendencies, it is difficult to believe in* *this government, all the people in the government steal money, infant mortality rate has increased excessively, they abuse their power, they are ruining the country, they have indebted the country, they do not provide security, they perform nepotism,* and other similar reasons that may be true or false.

On the contrary, when the permanence in the post is excessive and is not a multiple of the reference value, the reasons originate from the ruler or from a small group of people and can include *I have a divine mandate, we require a hard hand, the people do not understand what is better for them, we are the only ones who can change the way, we are at war, we have to rebuild the country,* and other similar reasons. These reasons result in concrete actions of social control, which allow for the indefinite permanence of the ruler through physical or psychological ways.

4. Discussion

4.1. Comments on the SSI

The SSI accounts for the cultural patterns rooted in a society that cannot be changed in the short or medium term. The SSI accumulates the cultural history because it considers a determined time in history and the entire historical past of the country or province being analyzed. The irregularities in the output SSI value are more noticeable at the beginning of the analyzed temporal range owing to the characteristics that are typical of a filter. This means in a longer time frame, the temporal variations are smoothed by the effects of the average. Technically speaking, the SSI is a non-recursive moving average filter with a cut-off frequency that decreases with time. Based on the observed results, we can state that the *SSI is a general indicator of the level of social stability of a country in a determined moment of history***.** From the results and simultaneously considering the stepped diagrams, plane phases, and SSIs, we can deduce that the sign and numeric value of the SSI may be interpreted as listed in Table 4**.**

Table 4.
Cultural interpretation of the SSI sign

SSI	Interpretation
= 0	Forced political stability with a point attractor (typical) or symmetrical fluctuations around the reference value (very uncommon)
> 0	Perdurable political stability or authoritative governments of long duration with strange attractors or quasiperiodic systems
< 0	Negative political stability and unstable governments with several rulers in a short period

The numeric value of the SSI indicates the intensity of social stability. The farther it is from the reference value of the TIO in any direction, the lower the social stability. A null value may indicate a significant variation in both directions such as in Argentina, Colombia, or Tucuman, or in an interrupted TIO of only one government such as in Virginia. The interpretation is identified by simply observing the step diagram. It is unclear whether a point attractor or SSI = 0 belongs to a system that is politically stable in the medium or long term. To clarify this, we believe it necessary to analyze more countries and cultures. The interpretation of the SSI in cultural terms indicates that the longer a pattern of behavior persists, the more difficult it is to change. The persistence is easily observable in the permanence of the different attractors in the phase planes in long time periods.

Next, we analyze Argentina and the two provinces considered as examples: Tucuman and Buenos Aires.

4.2. Argentina

In Figure 14, the time evolution of the stepped graph and SSI of Argentina are shown between 1543 and 2020.

In more than 450 years, social behavior is distributed between positive irregular behavior up to the end of the 18th century and negative irregular behavior up to the 21st century. The transition coincides with the independence of Argentina and marks a point of inflection, from which a significant decrease in TIO occurred that lasted until the end of the 20th century.

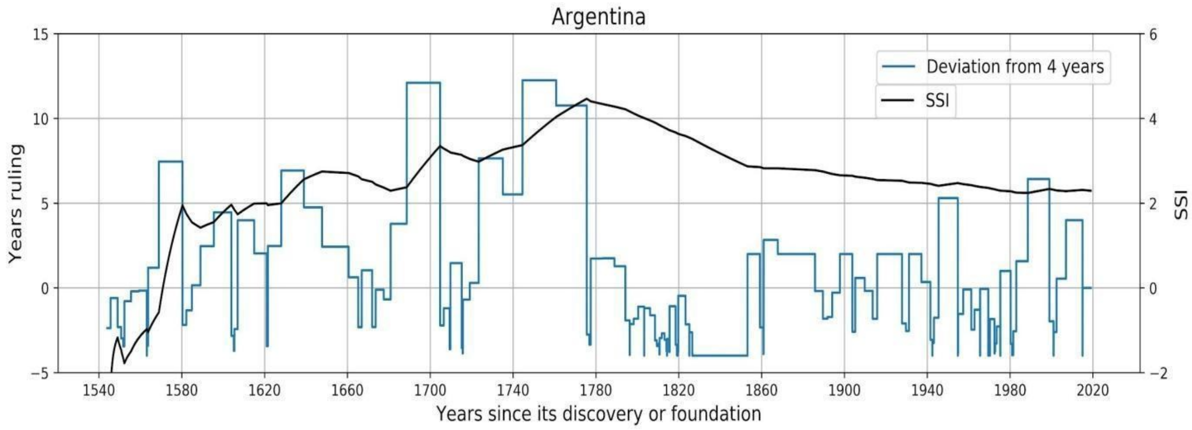

Figure 14. Stepped graph and SSI of Argentina
Note. Stepped graph and SSI of Argentina from 1544 to 2020.

The history shows that the algid point was the interregnum of 27 years between 1827 and 1845, wherein the social custom of contempt for authority was manifested in its highest expression, which prevented treaties and having a common president. The irregularities still exist in the 21st century, and there is no solution proposed to this challenge.

The curve of the SSI can be interpreted as "will to change but with insufficient force" because an ordered sequence of periods multiples x1 or x2 of reference value is not achieved.

4.3. Tucumán

Figure 21 shows the stepped graph and SSI of Tucuman.

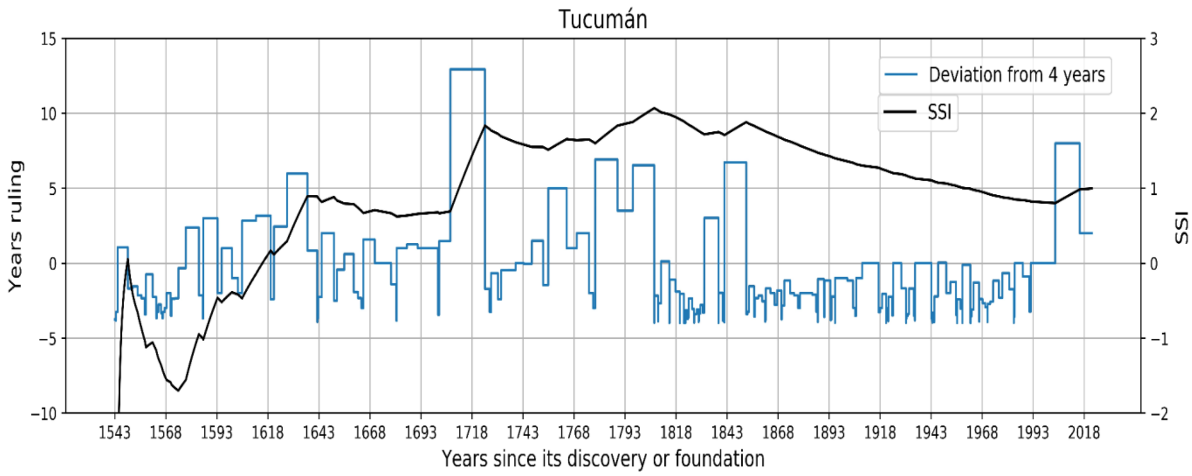

Figure 15. Stepped graph and SSI of Tucumán
Note. Stepped graph and SSI of Tucumán from 1543 to 2020

As expected, a pattern of behavior similar to that of Argentina can be seen in Tucuman, but with unchanged negative irregularities remaining until the beginning of the 21st century. In cultural terms, these characteristics indicate deeper issues regarding the *contempt for authority*. In the possible causes section, two negative effects are added in Tucuman, the *contempt for authority of* the *king* and the *contempt for the law of the white*, which can partially explain the persistence of negative social behavior.

For the SSI to stabilize closer to the reference values, the sequence of TIO multiples of x1 and x2 must remain stable for several decades.

4.4. Buenos Aires

In Figure 16, we can observe that Buenos Aires shows a behavior similar to that of Tucuman, with a predominance of positive irregularities up to 1810, and then a monotonous drop to negative SSI values. Both Buenos Aires and Tucuman have little evidence of positive TIOs since the end of the 20th century.

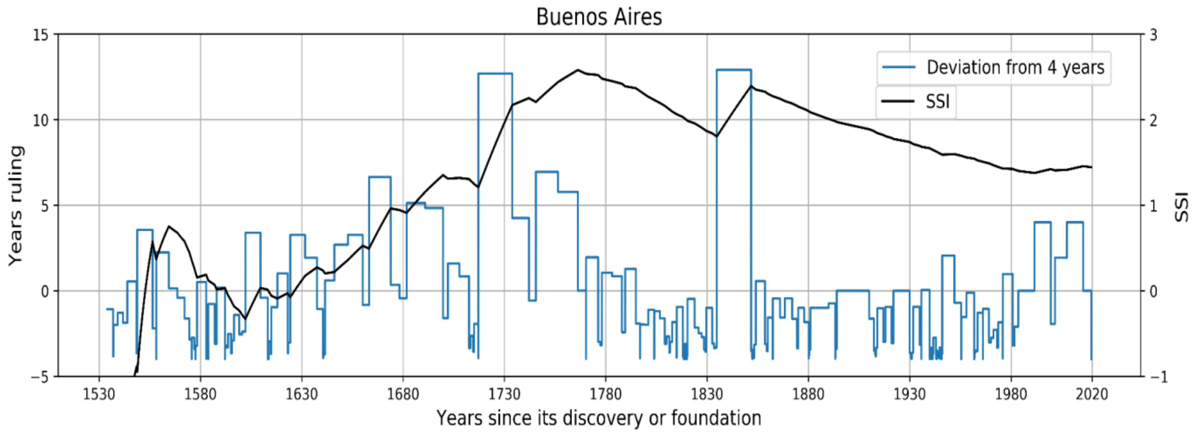

Figure 16. Stepped graph and SSI of Buenos Aires
Note. Stepped graph and SSI of Buenos Aires from 1534 to 2020

4.5. Florida as an Example of Social Change

In Figure 17, as an example of a desirable transition of social behavior, we can observe a transition between the attractors in the state of Florida in 1877.

In Figure 17, the change begins in the 1830s and manifests as a gradual decrease of the SSI for a period of negative instability that ends with the appearance of a point attractor in 1877. The SSI stabilizes as a quasiperiodic attractor in 1953 and since then, there is a time sequence of TIO multiples x1 and x2 of the reference value.

In cultural terms, we can deduce that there was a collective decision, conscious or unconscious, of maintaining only one period of government per ruler for more than 75 years. *The reasons for when and why to reelect a ruler are individual to each country and culture,* and apparently in Florida they were appropriate because its SSI stability is notable until 2020.

Similar instances of maintaining only one period of government per ruler have been occuring in Mexico since 1934, with no end in sight. Additionally, in the State of Virginia, only governors of one period are uninterruptedly succeeded since 1875. This may also be the case in Chile since 2006, but it would be premature to confirm this. Although the results of these social essays have an open ending, they may be applicable.

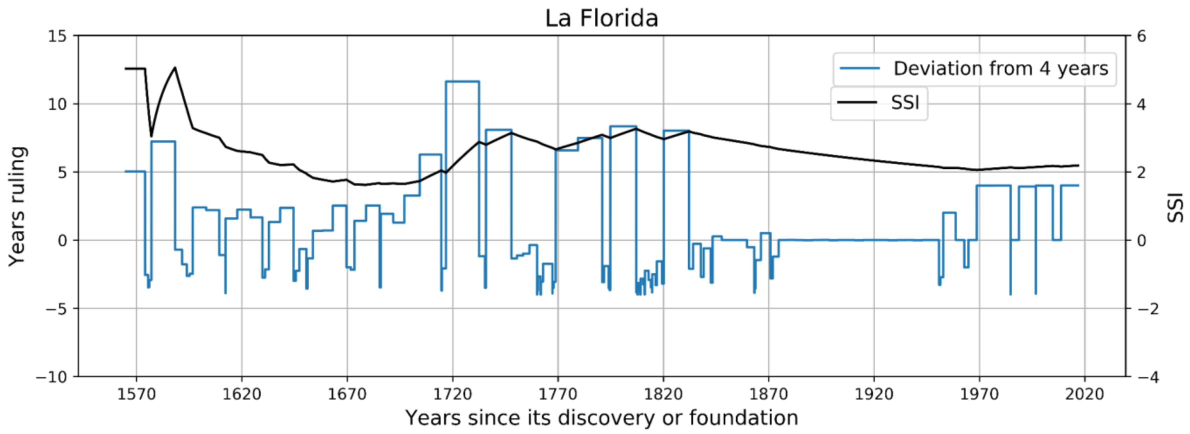

Figure 17. Stepped graph and SSI of Florida
Note. Stepped graph and SSI of Florida from 1565 to 2020

4.6. Global Analysis of the SSIs of Tucuman, Buenos Aires, and Argentina

We can observe that the social behaviors in Tucuman, Buenos Aires, and Argentina are similar. The three SSI curves show the same temporal profile, indicating the common cause as the *contempt for authority*, which is justified owing to them sharing the same governors, customs, norms, and laws inherited from Spain.

The pattern of SSI behavior appears to be valid by entire Latin America, because the Argentinian social behavior reflected in the SSI is similar to that of Colombia and Mexico. Basically, the curves indicate that under Spanish control there was TIO of long lasting, its disappear when the countries became independent, and next never more the countries achieve perdurable stability over time.

Chile appears to be an exception in that it still demonstrates permanence of long TIOs; however, since the year 2005, we can observe an apparent point attractor with periods of strictly four years that remain unchanged in 2022.

SSI is criticized in that with the passage of time, the effect of the same changes on the output decreases. This means that what happened before affects every time more than what happens now. Identifying the number of terms that must be averaged and the fundamentals exceed our study; therefore, we can only state that in the SSI analyzed for 500 years, the results indicate that it may be useful to compare or analyze the political stability of a society.

4.7. Chaotic Attractors

The results obtained from a single graph of the phase planes of the TIO temporal series show that these series have characteristics of chaotic systems, such as those expressed by the fractal dimension and the Hurst and Lyapunov exponents listed in Table 3. Fractality appears when time series are graphically analyzed and the properties of a chaotic system appear when the Lyapunov exponent is calculated and the strange attractors, point attractors, and quasiperiodic orbits are plotted in the phase planes.

4.8. Fractality in the Stepped Graphs

In the systems analyzed in this study, the stepped graphs of nearly all graphs show significant similarities with the fractal models of rough surfaces, such as the Canto-bar from Samuel Liu (Liu, 1985) or the self-similar capacitance distribution function proposed by Pajkossy and Nyikos (Pajkossy, 1992). In the first work, the roughness of the surface is modelled with metal channels that are sub-divided into two branches and repeating this operation for each new subdivision. Each branch is similar to the original when the factor ”a” is augmented, where a > 2. To randomize the number of subdivisions, the scale factor does not alter the fractal quality of the model (Kaplan, 1985).

In the second work, the authors generated a rough surface by imagining the outline of an electrode as a square wave, which repeats the same self-similar structure when the amplification scale is augmented. This structure is electrically interpreted as a distribution of scale-invariant capacities, which allows for the calculation of the impedance interface of the electrode (Pajkossy, 1992).

Similarly, the stepped graphs of the political systems have the aspect of a fractal structure generated by a square wave. We add randomness of the signal amplitude as well as the period, thereby making them similar to the fractal structures of Pajkossy and Liu, as shown in Figure 18.

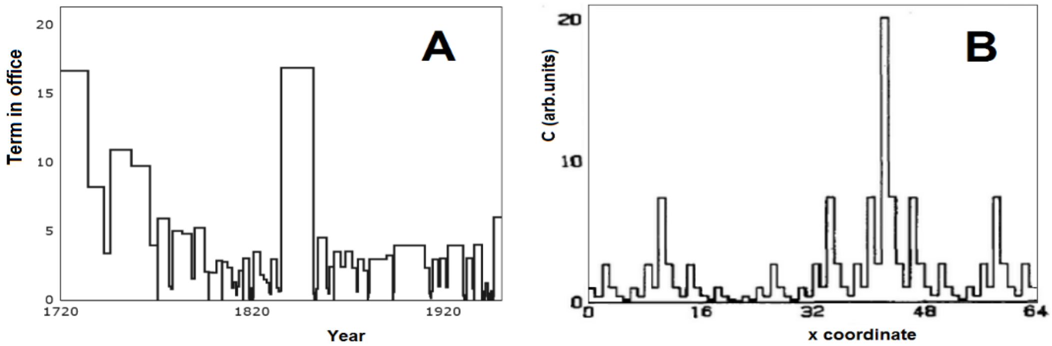

Figure 18. Similarity between the TIO of Buenos Aires and the fractal structure of Pajkossy and Liu
Note. (a) Example of Term in office vs Year of Buenos Aires; (b) Capacitance distribution vs distance (Pajkossy, 1992).

In our temporal series, a clear example of self-similarity can be seen in the stepped graph of Tucuman (Figure 15), which is re-scaled in Figure 19.

4.9. Attractors in the Phase Planes

In the phase planes of the temporal series, three basic types of attractors can be observed: a) ones that converge to equilibrium, b) periodic ones, and c) chaotic ones with oscillatory irregular processes. As an example of a case in political systems, one may find the geographic limitation of a country, where the limits of the country and the national sentiments converge to an equilibrium, such as countries with more or less cyclic elections and those that oscillate between anarchism, civil war, authoritarianism, and democracy (Peled, 2000).

With concrete numerical data, our results confirm the presence of three types of chaotic systems in the temporal TIO series of the analyzed countries. Those that converge to equilibrium with point attractors, quasiperiodics with terms that are more or less cyclic multiples of the reference value, and strange attractors with irregular oscillatory processes.

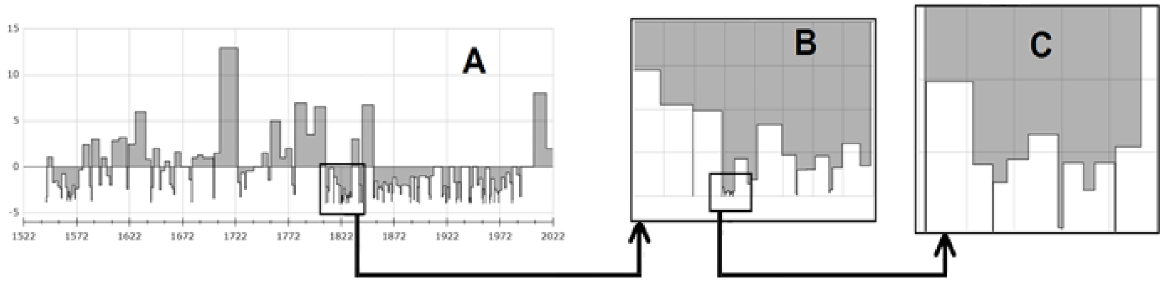

Figure 19. Self-similarity in stepped graph of Tucumán

Figure 19 is similar to the Liu model of a fractal with two levels of bifurcation in temporal scales of (a) decades, (b) years, and (c) months. This can be confirmed from the spreadsheet that contains the analyzed data.

Based on these results, the interpretations of the three types of attractors from a cultural point of view are:

1. The strange attractors indicate persistent social behaviors of contempt for authority that maintain political instability.
2. The point attractors function as stabilizers of unstable political systems.
3. The quasiperiodic orbits belong to stable political systems with periodical uninterrupted elections.

4.10. General Comments on the Phase Planes of Argentina, Buenos Aires, and Tucuman

The phase planes of Argentina, Buenos Aires, and Tucuman show a tendency to concentrate the trajectories in one attractor for values of TIO < 4 years. The interpretation is the same for the SSI curves, that is, the social behavior patterns regarding the contempt for authority show time persistence in Argentina; they appear during the colonial period and intensify after independence.

The phase plane of Tucuman can be considered as a reference of social behavior for all of Argentina. It coherently shows that the social behavior of *contempt for authority* was maintained during the 267 years before 1810 and reinforced in the 210 years after. This persistence can be considered as proof of cultural transmission of toxic social habits throughout time.

This historical process is remarkable in that it appears to be independent of the number of individuals involved in the system. It existed both in the small group of first conquerors of Tucuman and in the million people that chose a governor in the complex social network of the 21st century.

It can be considered that the *personality* of a country is formed in its *childhood*, which is the moment when the traits of its *maturity* are defined.

5. Conclusions

The *contempt for authority* has its origin in the non-compliance of royal laws by the Spanish authorities in America (Teran, 1927; Luna, 1993) and it is an obstacle in the development of Latin-American (Araujo, 2009; Puit, 1995; Holland, 2017). The stepped graphs show that the social behavior of contempt for authority originated during the Spanish conquest and colonization, and was inherited by the countries after their independence. They are rooted in the culture and manifested in the persistent instability in the posts of governors in Latin

America. In the cases of Argentina, Buenos Aires, and Tucuman, the contempt for authority is observed from the significant instability of the TIO values, the permanence of negative strange attractors in the phase planes, and the negligible evolution of the temporal SSI over the last 200 years. Thus, it can be deduced that the social conduct of *contempt for authority* was transmitted through generations, from the times of conquest and colonization up to present day.

During the historical analysis of the governors, an enormous amount of evidence appeared in different publications when identifying the dates on which they assumed office and ceased their rule. Several Spanish historians and *probanzas the meritos y servicios* indicate that there is a second deep cause of political instability in Latin America: *the indigenous contempt for the white man's law*, which is considered as a *post-hoc* hypothesis.

5.1. Post-Hoc Hypothesis Foundation

We defined it as *the contempt of the pure Amerindian people and their descendants by the Spanish authorities and their descendants*. In *descendants of Amerindians,* we include all people with genetic admixtures of Amerindians with Europeans and Africans, and in *descendants of Spaniards* we include *criollos* or children of Spaniards born in America and those with genetic mixtures of Spaniards with Amerindians and Africans.

The complexity of the definition is understood when the causes and historical evolution of this *contempt for authority* is known, which we believe explains a large part of the Argentine social behavior.

This contempt originated owing to the extensive historical maltreatment of the Amerindian People over the centuries. They were enslaved, humiliated, tortured, denaturalized, and uprooted for hundreds of years (García Hamilton, 1984; Clendinnen, 1982; de las Casas, 1552; Montes, 1998; Farberman, 2006; de Albornoz, 1990).

The deep hate developed by the Amerindian people for the conqueror and their descendants was passed down the generations over centuries, and in Latin America it is reflected by the non-compliance of laws and regulations as a practical effect of the *indigenous contempt for the white man's law,* which is a factor for the permanent instability of Latin America proposed as the hypothesis *post-hoc* in this study. It will be further developed in a future study. Thus, we can state that the political instability of Latin America originated from two fundamental causes: the *contempt for authority* inherited from the Spanish, and the *indigenous contempt for the white man's law* inherited from the Amerindian people. These factors form a negative synergy that hinders the development of countries.

Freezing the TIO could be a part of the solution, that is, *allowing for only one period of government* per ruler. This has been in effect in Virginia for 145 years, in Mexico for 92 years, very recently in Chile for 16 years, and in Florida it was stopped in 1950 after 73 years to allow for the stabilization of the system. Of course, more data is require to confirm this affirmation through an analysis that includes more countries, states, and provinces.

All the cases require a redefinition that includes a right to equal basis for all people regardless of their genetic mixture, and incorporating the Amerindian, African, and European cultures as an integral part of each nation.

In any case, the results of this study can serve to change the future using knowledge of the past, because observing behaviors can help in changing them. This concept, which is known and applied in psychology, is called Heisenberg's uncertainty principle in physics (Stamm, 1985).

5.2. Policy Suggestions

The results of this work may provide an overview of the social behavior of a country, and allow us to step back from everyday affairs and plan actions that have a deeper effect. During the planning of concrete policies, scientists of different areas must participate, including Political Sciences, Sociology, History, and Statistics, to identify intentional cultural changes that can benefit citizens.

5.3. Research Limitations

- There could be a polarization of the authors in the points of temporal division or *stages* used for data analysis.
- In some cases, there was insufficient data available. For example, it is difficult to identify whether an attractor exists when relatively few data are available because there are insufficient trajectories in an area of the phase diagram that can distinguish an attractor.
- Because the study involves working on vastly different areas of knowledge, there may have been a loss of objectivity in some points. The authors have tried to eliminate such problems.
- Although the dates of the events can be controversial, in all the cases the mistakes in dates are low and do not significantly affect the general tendencies of fractality, phase diagrams, or percentages.
- The point attractors may not be a general solution, and may only be adequate for some cultures.
- The analysis of chaotic systems in the current form is not applicable to monarchies or authoritative governments of extremely long durations.

Acknowledgements

This work was supported by grant from Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), and institutional funds from the Instituto Superior de Investigaciones Biológicas (INSIBIO-UNT/CONICET).

Appendix

COMPLEMENTARY MATERIAL: Other countries

Phase plane and chaos attractors

A. Country level

United States: time evolution

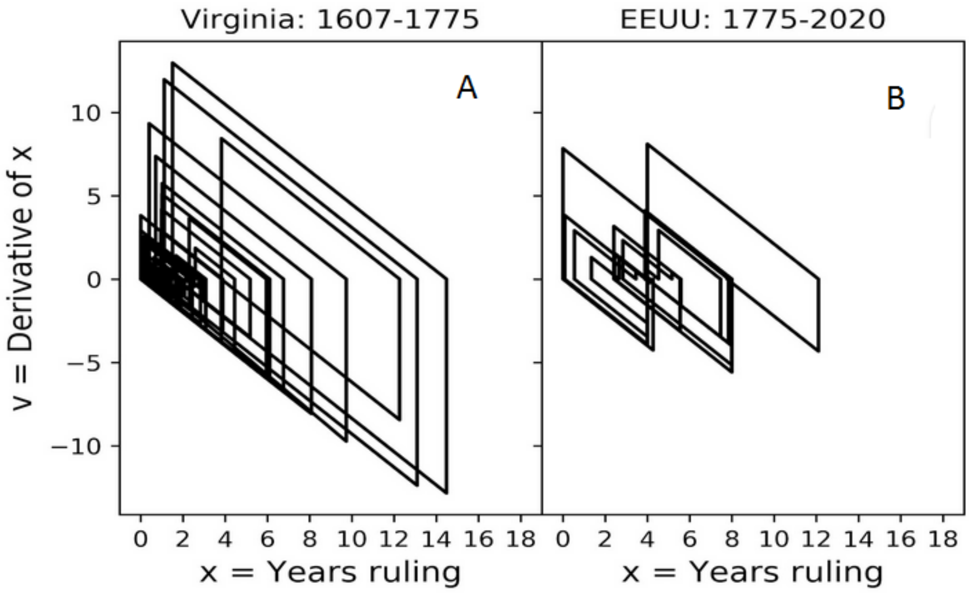

Figure A1. US timeline phase plane
Note. Time evolution of the US phase plane between 1607 and 2020: (a) Virginia state was added as an example of social behavior in the colonies before independence of the (b) United States.

The temporal evolution in Figure A1(a) shows Virginia with a strange attractor at TIO = 3 and other less defined attractors at TIO = 6 years. Post-independence, the USA shows only quasiperiodic orbits at TIO = 4 and 8 years and no attractors can be observed (Figure A1(b)).

Chile

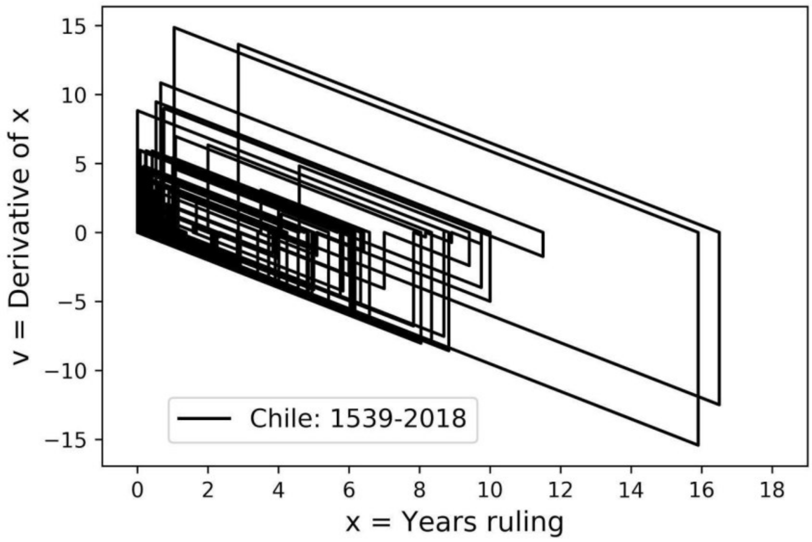

Figure A2. Chile timeline phase plane
Note. Phase plane of Chile between 1539 and 2018.

In Figure A2, we can clearly distinguish three attractors for TIOs of four, five, and six years, and one attractor at TIO < 1. We can also highlight two trajectories of TIO = 16 years.

Colombia: time evolution by stage

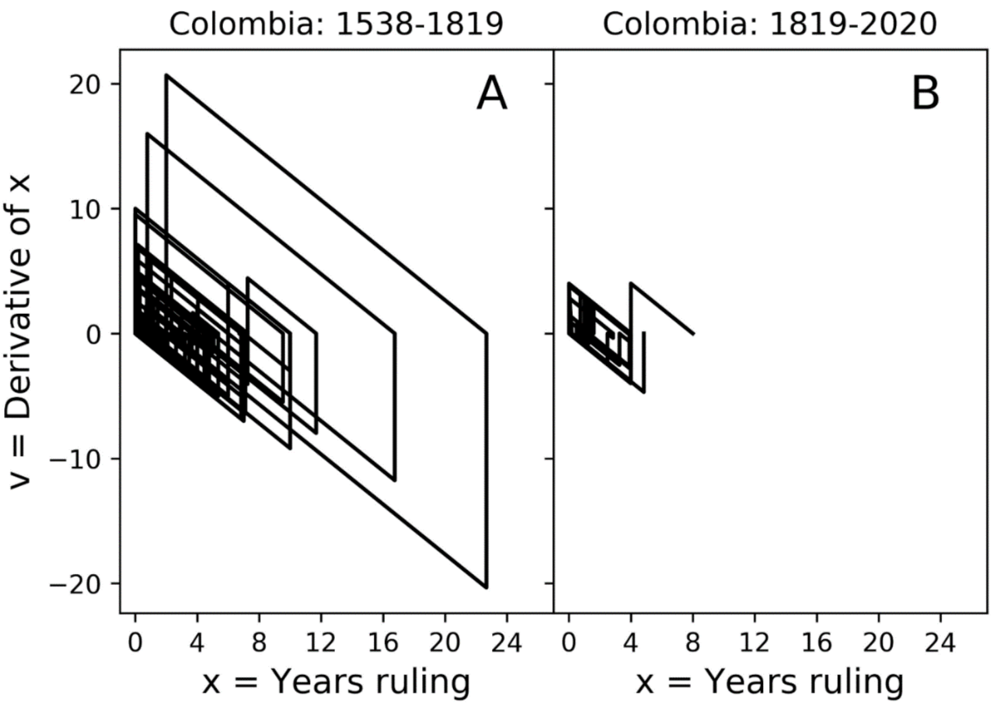

Figure A3. Colombia timeline phase plane by stages
Note. Phase plane of Colombia between 1538 and 2020. The Figure is divided into two intervals: (a) Pre- and (b) post-independence from the Spanish Empire in 1819.

In Figure A3(a), we can observe a strange attractor of TIO = 6 years in Colombia. In the following 170 years, only one unique strange attractor appears that is highly concentrated at TIO = 2 years and remains until the end of the 1980s. Since then it appears to transform into a quasiperiodic sequence of X1 and X2 multiples of the reference value.

B. Province level

New York: time evolution by stages

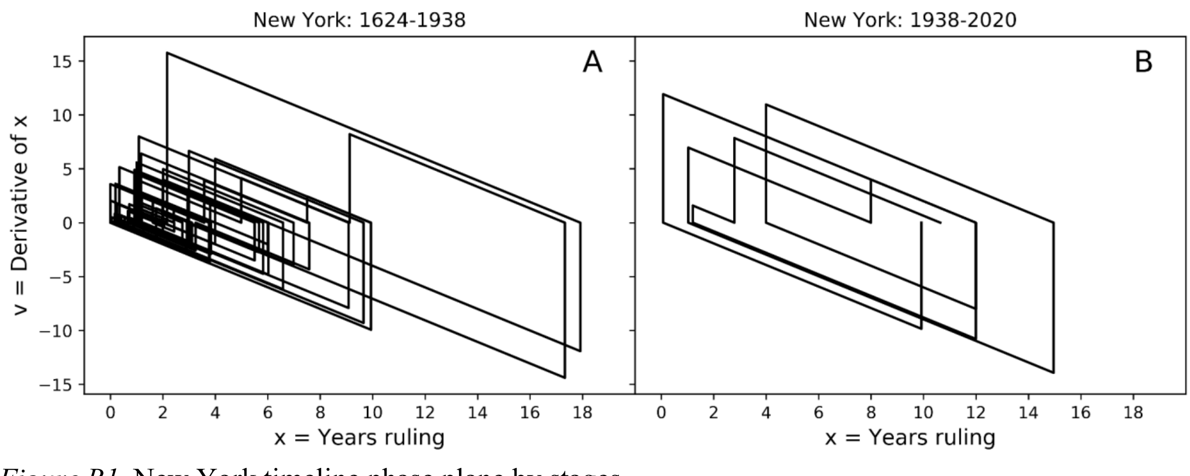

Figure B1. New York timeline phase plane by stages
Note. Time evolution of the phase plane of New York by stages between 1624 and 1938. Time intervals are (a) 314 and (b) 82 years.

To better understand the temporal evolution of New York, the phase plane was divided into two stages: before and after allowing the indefinite reelection of the rulers. In Figure B1(b), the small values of TIO that are typical in Figure B1(a) disappear, and there is a very meaningful increase in the TIO duration.

California

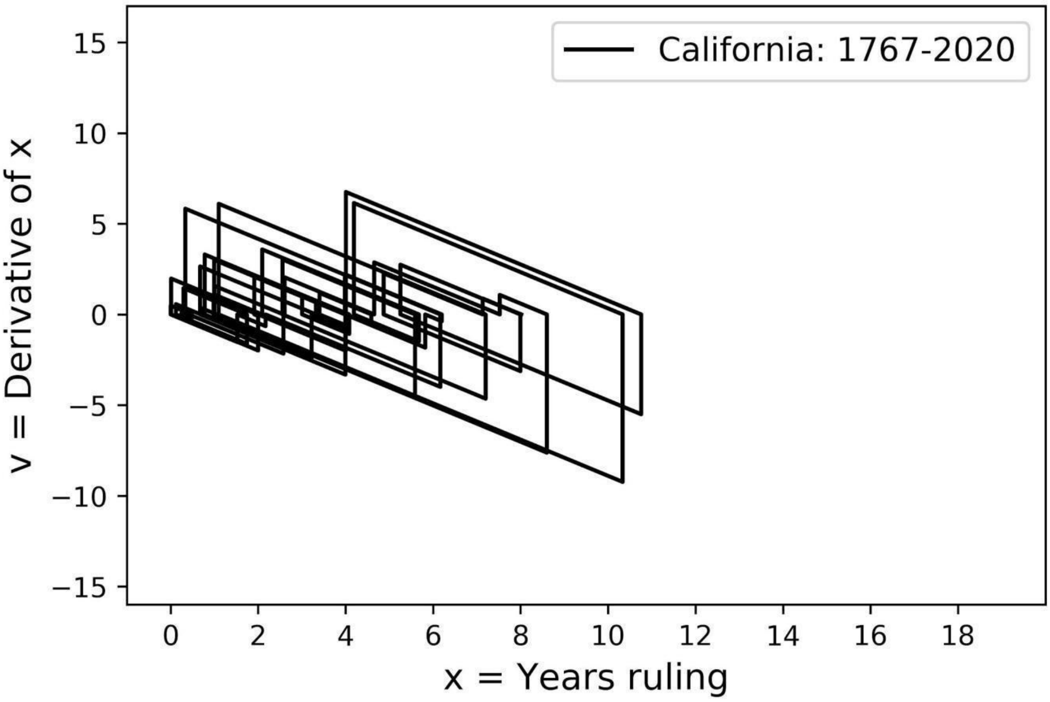

Figure B2. California timeline phase plane
Note. Phase plane of California between 1767 and 2020.

In Figure B2, an attractor is difficult to distinguish because several different TIOs can be observed and none are predominant with a particular trajectory. To extract some useful information, the phase plane was divided in stages according to who was in-charge of the government, as shown in Figure B3.

California: time evolution by stages

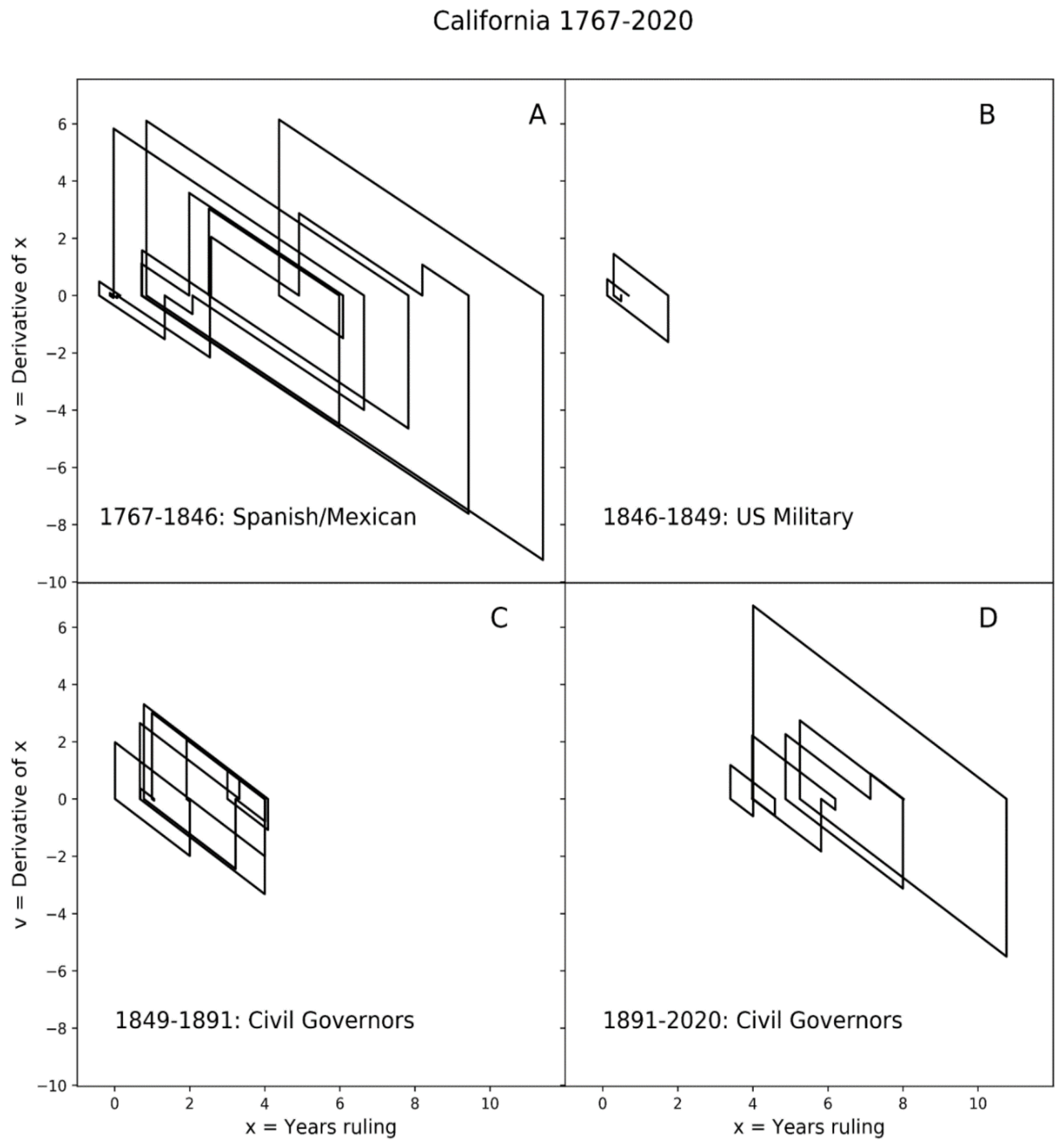

Figure B3. California timeline phase plane by stages
Note. Time evolution of the phase plane of California in stages between 1767 and 2020. Time stages correspond to (a) Spanish/Mexican rulers, (b) US Military rulers, (c) Civil rulers 1, and (d) Civil rulers 2.

In Figure B3(a), there are no specific attractors, perhaps because the data were insufficient or because they are intrinsically random. The military governments (Figure B3(b)) have very short periods and insufficient information to draw a conclusion. The times of the civil governments were divided into two, Figures B3(c and d), to highlight the significant stability after 1891 with nearly no TIOs of less than four years.

References

Aguilera, M., Morer, I., Barandiaran, X., & Bedia, M. (2013, September). Quantifying political self-organization in social media. fractal patterns in the Spanish 15M movement on twitter. In ECAL 2013: The Twelfth European Conference on Artificial Life (pp. 395-402). MIT Press. https://doi.org/10.7551/978-0-262-31709-2-ch057

Alesina, A., & Perotti, R. (1996). Income distribution, political instability, and investment. European economic review, 40(6), 1203-1228. https://doi.org/10.1016/0014-2921(95)00030-5

Araujo, K., & Girola, L. (2009). ¿Se acata pero no se cumple?: estudios sobre las normas en América Latina [Obeyed but not complied?, studies about standards in Latin America]. Lom Ediciones, pp:228.

Astrada, L. M. (1987). La gobernación de Tucumán en el Río de la Plata y su frontera sobre el Chaco [Government of Tucuman in the River Plate and its border with Chaco]. Quinto centenario, (12), 171-186.

Banerjee, S., Erçetin, Ş. Ş., & Tekin, A. (Eds.). (2014). Chaos Theory in Politics. Springer. Softcover reprint of the original 1st ed. 2014 edición (3 Septiembre 2016). ISBN-10: 9402401164. https://doi.org/10.1007/978-94-017-8691-1

Bernal-Meza, R. (2013). Chile entre Gran Bretaña y Estados Unidos [Chile between Great Britain and United States] (Ph.D.dissertation, Facultad de Ciencias Económicas. Universidad de Buenos Aires).

Bishop, Robert, "Chaos", The Stanford Encyclopedia of Philosophy (Spring 2017 Edition), Edward N. Zalta (ed.), https://plato.stanford.edu/archives/spr2017/entries/chaos/

Bussiere, M., & Mulder, C. (2000). Political instability and economic vulnerability. International Journal of Finance & Economics, 5(4), 309-330. https://doi.org/10.1002/1099-1158(200010)5:4%3C309::AID-IJFE136%3E3.0.CO;2-I

Clendinnen, I. (1982). Disciplining the Indians: Franciscan ideology and missionary violence in sixteenth-century Yucatán. Past and Pres. https://doi.org/10.1093/past/94.1.27

Cukierman, A., Edwards, S., & Tabellini, G. (1989). Seigniorage and political instability. Centre for Economic Policy Research, London (United Kingdom), pp: 53. https://doi.org/10.3386/w3199

de Albornoz, C. L. (1990). Las desnaturalizaciones Calchaquíes y sus efectos en las poblaciones trasladadas al Valle de Choromoros [The forced Calchaquies resettlement and its effects on the moved inhabitants to Choromoro Valley]. Anuario de estudios americanos, 47(1), 199-240. https://doi.org/10.3989/aeamer.1990.v47.i1.576

De Florio, V., Sun, H., & Bakhouya, M. (2014, November). Mutualistic relationships in service-oriented communities and fractal social organizations. In 2014 Second World Conference on Complex Systems (WCCS) (pp. 756-761). IEEE. https://doi.org/10.1109/ICoCS.2014.7060956

de las Casas, B. (1552). Brevísima relación de la destrucción de las Indias: Crónica de Indias [A Short Account of the Destruction of the Indies]. Ed.: Verbum, Madrid, España, pp: 100. ISBN 9788413371689.

Fan, C., Guo, J. L., & Zha, Y. L. (2010). Fractal analysis on human behaviors dynamics. arXiv preprint arXiv:1012.4088. https://doi.org/10.48550/arXiv.1012.4088

Farberman, J., & Boixadós, R. (2006). Sociedades indígenas y encomienda en el Tucumán colonial. Un análisis comparado de la visita de Luján de Vargas [Indigenous societies and encomienda in colonial Tucuman. A comparative analysis of the visit of Luján de Vargas]. Revista de Indias, 66(238), 601-628. https://doi.org/10.3989/revindias.2006.i238.319

Filipe, J. A., & Ferreira, M. A. M. (2013). Chaos in humanities and social sciences: an approach. 12th Conference on Applied Mathematics APLIMAT 2013 Proceedings, Eslováquia.

García Hamilton, J. I. (1984). El autoritarismo y la improductividad en Hispanoamérica [Authoritarianism and unproductivity in Latin America]. Emecé, Buenos Aires.

Guegan, D. (2009). Chaos in economics and finance. Annual Reviews in Control, 33(1), 89-93. https://doi.org/10.1016/j.arcontrol.2009.01.002

Holland, A. C. (2017). Forbearance as redistribution: The politics of informal welfare in Latin America. Cambridge University Press. https://doi.org/10.1111/1468-2427.12942

Hurst, H.E. (1951). The long term storage capacity of reservoirs. Transactions of the American Society of Civil Enginiers (1116): 770-808. https://doi.org/10.1061/TACEAT.0006518

Jia, R., Roland, G., & Xie, Y. (2021). A Theory of Power Structure and Institutional Compatibility: China vs. Europe Revisited (No. w28403). National Bureau of Economic Research. https://doi.org/10.3386/w28403

Kaplan, T., & Gray, L. J. (1985). Effect of disorder on a fractal model for the ac response of a rough interface. Physical Review B, 32(11), 7360. https://doi.org/10.1103/PhysRevB.32.7360

Kaufmann, D., Aart. K., Mastruzzi, M. (2010). "The Worldwide Governance Indicators: Methodology and Analytical Issues". World Bank Policy Research Working Paper No. 5430. http://hdl.handle.net/10986/3913

Khan, A., Siddiqui, S. H., Bukhari, S. H., & Iqbal, S. M. H. (2020). Human Development, Political Stability and Economic Growth: The way forward. Review of Economics and Development Studies, 6(2), 351-361. https://doi.org/10.47067/reads.v6i2.213

Lascano, L. C. A. (1992). Historia de Santiago del Estero [History of Santiago del Estero] (Vol. 14). Ed. Plus Ultra. ISBN:9789502110349.

Liu, S. H. (1985). Fractal model for the ac response of a rough interface. Physical review letters, 55(5), 529. https://doi.org/10.1103/PhysRevLett.55.529

Luna, F. (1993). Argentina se hizo así [Argentina was done by this way]. Cuadernillo I; Edit. Agrupación de Diarios del Interior; ciudad de Buenos Aires; páginas 40-41.

Mandelbrot, B. B., & Mandelbrot, B. B. (1982). The fractal geometry of nature (Vol. 1). New York: WH freeman.

Mandelbrot, B. B., Wallis, J. R. (1969). Robustness of the rescaled range R/S in the measurement of noncyclic long run statistical dependence. Water resources research, 5(5), 967-988. https://doi.org/10.1029/WR005i005p00967

Medina, J. T. (1896). Juan Núñez de Prado y Francisco de Villagrán en la ciudad del Barco: un documento interesante para la historia argentina [Juan Núñez de Prado and Francisco de Villagrán in the city of Barco: an interesting document for Argentine history]. Ed.:José Toribio Medina, Santiago de Chile, Imprenta Elzeviriana.

Mennin, S. (2010). Complexity and health professions education: a basic glossary. Journal of Evaluation in Clinical Practice, 16(4), 838-840. https://doi.org/10.1111/j.1365-2753.2010.01503.x

Montes, A. (1998). El gran alzamiento diaguita [The great Diaguita uprising] (1630-1643). Estudios: Centro de Estudios Avanzados, (10), 57-70.

Olivieri, R. (2018). Manual de Historia Argentina Colonial [Manual of Colonial Argentine History]. Cuadernos Docentes. Resistencia-Chaco, Instituto de Investigaciones Geohistóricas (IIGHI) CONICET-UNNE, 2018, 330 pp. https://doi.org/10.30972/fhn.0312914

Packard, N. H., Crutchfield, J. P., Farmer, J. D., & Shaw, R. S. (1980). Geometry from a time series. Physical review letters, 45(9), 712. https://doi.org/10.1103/PhysRevLett.45.712

Pajkossy, T., & Nyikos, L. (1992). Impedance of planar electrodes with scale-invariant capacitance distribution. Journal of Electroanalytical Chemistry, 332(1-2), 55-61. https://doi.org/10.1016/0022-0728(92)80340-A

Palacios, E. (2012). Las Pequeñas Fortalezas españolas como origen edilicio de las ciudades argentinas del siglo XVI [The small spanish fortresses as original model of the Argentine cities of the 16th century]. Revista Cruz de Sur, 2(3), 75-135.

Parlitz, U. (1998). Nonlinear time-series analysis. Nonlinear Modeling, 209-239. https://doi.org/10.1007/978-1-4615-5703-6_8

Peled, A. (2000). The new sciences, self-organization and democracy. Democratization, 7(2), 19-35. https://doi.org/10.1080/13510340008403658

Puit, J. D. (1995). Corrupción en el Perú: Breve reseña histórica [Corruption in Peru: Brief historical overview]. Anuario de Derecho Penal, 1995. Biblioteca Virtual Miguel de Cervantes.

Rigoli, L. M. (2018). Fractal Structure and Complexity Matching in Naturalistic Human Behavior (Doctoral dissertation, University of Cincinnati). http://rave.ohiolink.edu/etdc/view?acc_num=ucin1523634803453736

Samimi, A. J., Abedini, M., & Laharemi, S. H. (2012). Political Stability and Inflation Tax: Evidence From MENA Region. Middle-East Journal of Scientific Research, 11(1), 85-89.

Scartascini, C. (2016). Database of Political Institutions Codebook, 2015 Update (DPI2015). Inter-American Development Bank. Updated version of Thorsten Beck, George Clarke, Alberto Groff, Philip Keefer, and Patrick Walsh, 2001. "New tools in comparative political economy: The Database of Political Institutions." 15:1, 165-176 (September), World Bank Economic Review. https://doi.org/10.1093/wber/15.1.165

Selvam, A. M. (2017). Nonlinear dynamics and chaos: applications in meteorology and atmospheric physics. In Self-organized criticality and predictability in atmospheric flows (pp. 1-40). Springer, Cham. https://doi.org/10.1007/978-3-319-54546-2_1

Shi, K., & Bai, M. (2020). Using Grey Model To Predict The Governance Indicators In China And India. Journal of Grey System, 32(1).

Stamm, J. S. (1985). The uncertainty principle in psychology. Behavioral and Brain Sciences, 8(4), 553-554. https://doi.org/10.1017/S0140525X0004509X

Takens F. (1981) Detecting strange attractors in turbulence. In: Rand D., Young LS. (eds) Dynamical Systems and Turbulence, Warwick 1980. Lecture Notes in Mathematics, vol 898. Springer, Berlin, Heidelberg. https://doi.org/10.1007/BFb0091924

Terán, J. B. (1927). El nacimiento de la América española. Obras completas. Tomo VIII [The birth of Spanish America. Complete works. Volume VIII]. Ed.: Universidad Nacional de Tucumán, 1ra Edición, Serie: Obras completas, pp:197.

Uddin, M. A., Ali, M. H., & Masih, M. (2017). Political stability and growth: An application of dynamic GMM and quantile regression. Economic Modelling, 64, 610-625. https://doi.org/10.1016/j.econmod.2017.04.028

Wolf, A., Swift, J. B., Swinney, H. L., & Vastano, J. A. (1985). Determining Lyapunov exponents from a time series. Physica D: nonlinear phenomena, 16(3), 285-317. https://doi.org/10.1016/0167-2789(85)90011-9

Zimmerman, D. W. (1977). British influence in the modernization of Chile, 1860-1914. Ph.D. Dissertation University of New Mexico.

Zinny, A. (1879). Historia de los gobernadores de las provincias argentinas. Volumen 1. Adelantados, Gobernadores y Viceroyes del Río de la Plata. Descubridores, Conquistadores y Gobernadores del Tucumán [History of the governors of the Argentine provinces. Volume 1. King's representative, Governors and Viceroys of the River Plate. Discoverers, Conquerors and Governors of Tucumán]. Serie La Cultura Argentina.