Cliophysics: A scientific analysis of recurrent historical events

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Version of 29 August 2020

Provisional. Comments are welcome.

Key-words: Experimental physics, historical events, comparative analysis

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Abstract

Named after Clio, the Greek goddess of history, cliophysics has for purpose to use the methods of experimental physics in order to conduct scientific analyses of historical events. Firstly, it is shown that cliophysics is in several respects a continuation of the four-century long development of physics. Secondly, we review the guidelines suggested by physics. The most important is that, in view of the fact that there can be no scientific analysis of single events, cliophysics must rely on the analysis of *clusters* of similar events. Then, we emphasize (and illustrate by an example) that, whether in physics or in cliophysics, tests of qualitative models can be quite as satisfactory as (more standard) tests of quantitative mathematical models. Finally, we describe some examples of cliophysical investigations conducted over the past three decades. In our conclusion we express confidence in the fact that cliophysics may help government leaders to take well informed strategic decisions.

Clio is the Greek goddess of history and cliophysics is a neologism built on the model of “astrophysics” or “geophysics”. It designates the study of historical events with the methods of physics and more precisely of experimental physics.

Single events versus clusters of similar events

If we say that single events can only be understood in an anthropomorphic way whereas clusters of similar events can be understood in a scientific way, this statement will probably appear fairly unclear to many readers. That is why we start by illustrating that important distinction through a real historical case.
At the same time this example will allow us to mention some of the vivid discussions we have had with Prof. Dietrich Stauffer, to whom this special issue is dedicated.

A mysterious event

Dietrich Stauffer, one of the founding fathers of econophysics and sociophysics, manifested a great interest for history, particularly after his retirement. For instance, he was much surprised to learn that on the night from Saturday 26 to Sunday 27 of August 1944 the German “Luftwaffe” conducted a bombing raid on Paris, followed in the early morning by an attack of fighter planes which straffed some of the streets of Paris[1]. Prof. Stauffer’s astonishment was due to the fact that this was a very special night. It was two days after Paris had been liberated from German occupation by a French and an American armored division and this very night followed a great celebration of the liberation led by General de Gaulle on the Champs Elysées and in which several hundred thousand Parisians took part. Prof. Stauffer was so convinced that the Allies had total air supremacy that, at first, he could hardly believe that such a bombing really happened. Then, there was a second thought which crossed his mind. Whereas these night raids in fact attracted little attention (although some hundred persons were killed and several fires started) why were they not conducted a few hours earlier when the Champs Elysées Avenue was crowded with so many people? Clearly, that would have been a disaster and a great setback for the Allies[2].

Anthropomorphic versus scientific understanding

Why did we mention this event?
The answer is simple. Although mysterious in several respects, this episode *cannot* be analyzed in a *scientific way* simply because it is a *single* event. To get a better

[1] See “Chigago Daily Tribune”: 28 Aug 1944, p.3; “Los Angeles Times”: same date, p.2; “New York Times”: same date, p.1.

[2] There have been many accounts and also movies (e.g. Lapierre and Collins 1964) about the liberation of Paris but the bombing seems to have been ignored. Conducted by the “IX FliegerKorps”, the raid involved 111 aircraft, mostly Junkers 188 bombers, in successive waves of 20 from south to north. The bombs killed 189 people, destroyed 430 buildings but avoided all historic places like the “Louvre” or the “Arc de Triomphe” which would have been easy targets (Marchand 1985).

understanding, all we can do is to collect more historical evidence. For instance, one may ask where the bombers came from, whether they were identified by Allied air defense radars and, if so, why there was no interception. Another interesting question is whether the obvious lack of air superiority over Paris was limited to night attacks or also extended to daylight attacks.

While such answers may in a sense provide a better understanding, they will certainly not lead to a *law* permitting predictions. The kind of understanding they allow can be called an *anthropomorphic understanding* in the sense that it is based on a cascade of human reactions. We use the term "cascade" because this kind of explanations come about in successive steps. For instance, if we learn that the bombers were identified but no interception was ordered, in the next step one may ask what was the reason of that decision. Clearly, each answer will raise new questions in an endless chain.

During World War II, apart from Paris, several other capitals were liberated from German occupation by Allied forces: Rome (4 June 1944), Brussels (4 September 1944), Athens (15 October 1944), Amsterdam (8 May 1945), Copenhagen (8 May 1945). If at least some of these liberations had also been followed by a night raid, there would be a pattern of recurrent events which in turn could be the starting point of a scientific explanation. As far as we know, it is not the case which means that the Paris bombing will remain a single and isolated event.

Testing quantitative and qualitative models

As we said above, the hallmark of scientific analysis consists in the successful testing of laws. These laws, we will argue here, can be quantitative as is usually the case in physics but can also be qualitative as is often the case in cliophysics.

Are there in the social sciences laws in the sense of physics?

Quantitative laws will state that, under a number of specific conditions, one shall observe an effect whose magnitude is predicted by the law.
The curvature by the Sun of light rays originating from distant stars, as predicted by Einstein's General Relativity is a well-known illustration.

Finding such laws is an ambitious objective which can only be achieved for phenomena which are simple enough in the sense of depending upon a small number of parameters. As an illustration, in Appendix A we discuss the case of a long standing economic law. Is the quantity theory of money (already stated by David Ricardo in 1810) a law in the meaning defined above? It will be seen that it has indeed some predictive power but only in situations of massive increases of the money supply, for instance those which occur in time of war. The moderate variations of the money supply seen in peacetime appear too weak to trigger a change in price level that clearly

stands out from the background noise (consisting in inherent price fluctuations).

However, it would be a mistake to focus exclusively on quantitative models. Social and historical mechanisms can often be described by qualitative models which can be tested quite as effectively as quantitative models.

How to test qualitative models in physics?

In this and the next subsections we explain how experimental comparisons can be used to test qualitative models first in physics and then in the social sciences.

Suppose you are living in the time of Galileo (1564-1642) and Descartes (1596-1650) and you ask yourself what are the forces involved in the phenomenon of free fall. A first idea is to try Galileo's method of dropping balls of different sizes and densities from the tower of Pisa. However, with the poor means of observation available in that time, this method will not work.
Another approach is to try clever comparisons, for instance by observing and analyzing the fall of (a) steal balls (b) soap bubbles (c) feathers.
As one knows, there are 3 forces at work. (i) the weight mg (ii) the buoyant force (iii) the friction of air. In (a) one sees almost only (i). In (b) the buoyant force (ii) is magnified and by trying bubbles of different diameters, one can identify its characteristics. In (c) it is the friction of air which is amplified and by trying feathers of different sizes, one can identify its characteristics. In his publications Galileo does not report that he used such a comparative method although it would have given him a better understanding of the phenomenon of free fall.

Note that the description given above is a simplification for there is also the Coriolis force due to the rotation of the Earth and the "added mass force" discovered by Friedrich Bessel in 1828 and which results from the fact that the ball transfers a fraction of its acceleration to air molecules.
Incidentally, this shows that even a simple phenomenon like free fall must be decomposed into its diverse components to become intelligible. We come back to this point later on.

How to test qualitative models in history?

The idea is quite simple. It often happens that a historical question which cannot be settled clearly at the level of one country can be cleared up very easily when the field of observation is enlarged to similar cases in neighboring countries. As an illustration we focus on an episode which occurred during the Second World War.

In France a great debate has been raging for decades (and still resurfaces now and then) which concerns the attitude toward Germany of the French Communist Party (PCF) in 1940-1941. The PCF was a member of the Comintern (also called "Third International") which is a federation of Communist parties from across the world.

A common and fairly natural belief is that, just as NATO is basically controlled by its most important member, the United States, so the Comintern was controlled by its most important member, the USSR. The question is whether this was a rigid or a flexible control.

In the first case one would expect all Communist parties in European countries occupied by Germany to start resistance actions only after the German attack on the USSR on 22 June 1941 (remember that the non-agression pact between Germany and the USSR was signed on 23 August 1939).
On the contrary, if one can identify resistance actions before June 22 it will support the thesis of a flexible control. In short, the challenge here is to decide which one of the two models, rigid or flexible, is correct. Although the models are qualitative (or, if one prefers, of the dichotomous $0-1$ type) they are perfectly well defined.

The historical evidence is summarized in Appendix B. It turns out that whereas in France early resistance actions (i.e. before June 22) involved few people and can therefore be denied by some, in the Netherlands early resistance by the Communist Party of the Netherlands involved thousands of striking workers and therefore can hardly be ignored.

More broadly, in the past 60 years there have been recurrent debates in France about many aspects of the German occupation but, to our knowledge, there has not been a single attempt to establish comparisons with other occupied countries. A comparison with Denmark would be particularly enlightening because, as in France, an official government remained in the occupied country; in most other countries a government in exile was established in London.

The previous example shows that comparative analysis may solve fairly easily problems which otherwise cannot be settled conclusively. Such a neglect of the power of comparative history is all the more surprising in a country like France which has had several renowned pionneers in comparative history, e.g. Marc Bloch, Pierre Chaunu and Fernand Braudel.

Requirements for a scientific analysis of historical events

The requirements listed below are not different from those commonly accepted in any experimental exploration done in physics. In fact, these conditions are not special to physics but common to all sciences. The reason is that they derive from an crucial imperative of *simplification*. The real world is inherently complicated[3]. If

[3]Note that we do not say “complex” for we keep this word for systems whose elements have many long range interactions. It is true that, due to symmetry properties, a system in which all elements interact identically with all others is fairly easy to model mathematically but, leaving aside this specific case, in a general way systems with more interactions are capable of rich and well structured responses. The immune system, the genome or the brain are complex systems whereas

we wish to *understand* it we cannot tackle it head on. To split a rock or a diamond one needs to identify its fault lines. The human mind cannot develop an understanding from models which contain too many parameters. Unless one renounces to any intuitive understanding (which is is what is done in econometrics), simplification is essential.

Complicated episodes should be decomposed into simpler components

In the title of the paper we did not write "a scientific analysis of history". Instead, we used the word "event". The reason is simple. Our objective is not to understand history globally. For instance, it is impossible to analyze scientifically the French Revolution of 1789 for it has many aspects: the meeting of the Estates-General, the confiscation of the property of the Catholic Church, the storming of the Bastille and of the king's palace (namely the "Tuileries") in August 1792, and so on. Clearly these are very different facets and they must be studied separately.

This decomposition prerequisite is the same as in physics. Usually one tries to avoid experiments in which different effects are mixed up.
This requirement is a direct consequence of the simplicity imperative.

One should study clusters of similar events

In the previous sections we have already discussed a prerequisite that all scientists know very well but that one is often tempted to forget, namely that there can be no scientific analysis of single events. That is why in the title of the paper we did not write "of historical events" but "of recurrent historical events". Single events can only be analyzed in what we called an anthropomorphic way.

The word "similar" in the title of this subsection makes reference to a specific mechanism (in physics we would say a specific "effect"). Sometimes this mechanism can be defined easily. For instance, the confiscation of Church property is a well defined effect. In the time of the Reformation it was common for sovereigns who became Protestant to confiscate the estates of the Catholic Church.

However, there are also situations in which the mechanism which is at work is not immediately apparent and will emerge only gradually through a comparison of various historical episodes.

One should focus on cases for which the effect is strongest

In principle the effect of buoyancy on free fall can be observed when a lead ball is replaced by as steel ball, but in reality the difference is so small that the effect will be lost in the background noise.

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the stock market is a complicated system in the sense that there are many kinds of investors (as well as a great diversity of companies) but each investor interacts with only a limited number of other investors; moreover, the high level of noise precludes the emergence of stable and well structured responses.

In Appendix A we show that changes in the money supply will visibly affect the price level only if they are massive enough. This rule should be kept in mind when one selects historical cases. It is a waste of time to study second order effects or cases in which the main variable changes by less than 5%.
Here is an illustration.

In Richmond et al. (2018) it was shown that a sudden death spike in a population is usually followed 9 months later by a trough in the birth rate. For instance a terrible famine in Finland in the fall of 1867 led to a sharp fall of the birth rate 9 months later due to the fact that difficult living conditions reduced the conception rate. Why did this effect not attract earlier attention? It is certainly because it can only be observed following massive death spikes (e.g. the influenza epidemic of Oct-Nov 1918 is another example). For less massive death spikes, the birth rate trough is masked by the natural fluctuations of the birth rate.

Further recommendations

Although less crucial than the previous requirements, the following recommendations will facilitate cliophysical analysis.

Use broad sources and databases

Presently, just by browsing through historical papers one comes immediately to the conclusion that historians study mostly the history of their own country. It is fairly clear that in such conditions the cliophysics approach that we develop in this paper is doomed. The reason is obvious. This approach can only work if one has access to a wide collection of cases from which one can then select those which seem particularly appropriate for well-focused scientific studies. To limit oneself to the events of one's own country is similar to astrophysicists who want to understand how stars work but would limit themselves to starts similar to our Sun, thus ignoring red giants, blue stars and all intermediate cases of the Hertzsprung-Russell diagram.

Nowadays, thanks to the Internet, to the development of digitized newspaper archives (e.g. those produced by ProQuest), to the fact that many old books are available online, the conditions are fulfilled which allow the broad investigations advocated in the present paper. However, there is still room for improvement; presently (in 2020) less than ten major newspapers, mostly American, have digitized all their archives.

Apart from the Internet there has been another revolution. The language barrier which for centuries has been a formidable obstacle has nearly disappeared. Over the past 5 or 6 years the quality of the translations has improved dramatically to the point of becoming quite acceptable[4].

[4] An easy way test of a translation software is to perform a "circular translation": $A \to B \to C$. With a good software,

Prefer primary sources

A last consideration can be added. Historians make a distinction between primary and secondary sources. Whereas primary documents are supposed to be written by the very persons who took part in the events, secondary sources are written by historians based on what they read in primary sources. What would be the analog in physics of relying on secondary sources?

When you use primary sources it is like doing the experiment yourself. When you use secondary sources it means that you tell another person (namely the historian) what experiment you wish him to perform. Then, when you get the results you can never be sure how the experiment was really conducted. In other words, this adds a layer of uncertainty to the whole process. What you get is a mixture of the primary account and the feelings and biases of the historian. What the historian records (or leaves out) depends very much upon his own interests and opinions.
In short, whenever possible it is always better to work with primary sources. Fortunately, in the future more and more archive sources will become available online. Naturally, the persons who took part in the events are rarely objective but their prejudice is usually easier to identify than the bias of the "sanitized" accounts of historians.

Avoid anthropocentric reasoning

In his book "The rules of sociological method" the French sociologist Emile Durkheim (1894) takes great care to emphasize that social events should be studied like "things" ("comme des choses" in the French text), in other words they should fight anthropocentric temptations. What does he mean with this advice? Because social scientists are human beings just as the people whose behavior they study they may be tempted to substitute their own thoughts to those of these people.

Here is an illustration in the form of a dialog.
"Why do people commit suicide? Well, because they are sad and depressed.
In which season are people most likely to be depressed? Well, in winter time when the days are short and nature is at a standstill".
This sounds plausible enough.
Yet, in the northern hemisphere suicide rates are minimum in December and maximum in May. Surprising, isn't it?

As this is an important point let us give another illustration. In June-July 2020 there were daily demonstrations in Portland, Oregon. Why? A possible answer may involve explanations about the attitude of President Trump, the "Black lives matter" movement and so on. Clearly, these are anthropomorphic explanations. To get a

C, although not identical to A, has the same meaning; as if the software was able to catch the meaning!

Durkheim-like view one should watch these demonstrations with the eyes of a "Martian". He does not understand what the demonstrations are about but he can see that over past decades there were recurrent demonstrations in Portland (Wilson 2019). Having observed that special feature, our Martian naturally expects that any new spark will trigger more demonstrations. In other words, he will be led to a correct prediction without knowing any of the idiosyncrasies of the situation.

Ideologies in Durkheim-like view

Ideologies (e.g. Christianism, Islam, Communism, anti-Communism, neoliberalism and so on) have played and continue to play an important role in history. How can we represent them in a Martian-like perspective? Very simple. We need only to be able to estimate the strength of the inter-individual attraction created by these ideologies and this can be done by setting up some appropriate *sensor*, e.g. the percentage of people who attend religious service. In other words, the strength of the ideologies is sufficient, we do not need to bother about their contents, that is to say whether the persons are Baptists, Catholics, Mormons or Quakers.
It is important to realize that the challenges and difficulties faced in cliophysical studies were also present throughout the development of physics.

Distinctive features of the development of physics

Physics, so far the most successful science, was graced with three favorable circumstances.

(1) Over several centuries physicists did not have the experimental means to explore the microscopic structure of matter. Thus, willy nilly, they had no other choice than to focus on the laws of *macroscopic physics*. Would they ever have discovered the simple law which rules the refraction of light if they had started from the atomic level[5]?

(2) In scientific observations the main obstacle is what is called the *background noise*. High background noise reduces the signal-to-noise ratio and makes the detection of patterns and laws more difficult. Significantly, the discovery by Kepler around 1600 of the three laws which rule planetary orbits was made on a system (namely the trajectory of Mars around the Sun) subject to little background noise. Then, in the following centuries, physicists moved gradually to the study of systems with ever larger fluctuations. Hydrodynamics with its inherent turbulence was a difficult challenge and after that came microscopic quantum phenomena for which the very notion of well defined deterministic trajectories disappears.

(3) Finally, in each of its new fields, physics started from the *simplest possible* system: the two-body case before the three-body problem, the ideal gas before real

[5]Finding a simple microscopic definition of the refractive index would already be a serious difficulty.

gases, the hydrogen atom before lead or uranium atoms.

Why did we recall these milestones in the development of physics? The reason is simple. We are convinced that they provide valuable guides for the development of cliophysics. This is explained in the following subsection.

Guidelines for the development of cliophysics

The previous observations give the following guidelines for a sound development of cliophysics.

Macrocliophysics The first of the points mentioned above teaches us to start by studying the laws of macrocliophysics.

At first sight this may seem somewhat counter-intuitive. As the "atoms" of cliophysics are human individuals we are in a situation completely opposite to that of physics. Not only do we know these "atoms" but we are part of them. Naturally enough, one is tempted to use our knowledge of humans to explain social phenomena through the characteristics of individuals[6]. That would be a mistake, however. Statistical physics has been developed only fairly late in the history of physics and it is still a challenging field. Can we predict from the properties of water molecules that its boiling point is 100 degree Celsius? For cliophysics the difficulty is even much greater because of the multiple degrees of freedom of individuals.

Noise reduction The second of the points made above can explain why cliophysics has not yet been developed. Socio-historical phenomena are very diverse which means a high background noise unless it can be reduced by a smart selection of the phenomenon under observation. Astrophysics teaches us how to do that. Clearly, the trajectory of Jupiter follows the three Kepler laws with much higher accuracy than the trajectories of asteroids for the latter are subject to the gravitational attraction of the planets which come across their orbits. In the same way the international relations of a small country will be subject to more interferences and perturbations than those of a major power.

Simple cases The third of the points made above suggests that we should start by studying the simplest possible systems; "simple" here means involving a small number of factors. This seems obvious enough but often it comes in conflict with our personal interests. As citizens and members of certain communities (whether religious, linguistic or ethnic) we have specific interests. The main imperative of cliophysics is that in our investigations we must avoid such anthropocentric tendencies[7]. To convince ourselves that this is a crucial point one needs only to recall that

[6] Paul Lacombe (1894) has tried to develop a science of history based on the psychological features of individuals but its attempt led nowhere, which is quite understandable because ultimately psychology relies on an understanding of the brain, a system of overwhelming complexity.

[7] We use the word "anthropomorphic" to mark the difference between humans and non-human (including non-living) entities. The word "anthropocentric" refers more narrowly to the personal interests of individuals, for instance people

in the historical development of science the temptation to put humans in central position has been a major obstacle. Geocentrism or the rejection of the evolution of species are classical examples. This anthropomorphic attitude is still present in our time.

What will be the future of cliophysics?

Reasons for pessimism

In 2002 one of the co-authors (BMR) published a book which already contained several of the ideas explained in the present paper. Then, two things happened, each of which was rather disappointing.

- In the wake of the publication there were a number of reviews. One of the reviewers who understood very well the purpose of the book came up with the following argument.

> "You say that when you have several similar recurrent events you can predict that the outcome of episode number $n + 1$ will be basically the same as the outcomes of the previous n cases.
> Well, let us apply this rule to your project. In the past, there have been already several attempts to make history more scientific. As far as we know, they all failed. Thus, can we not conclude that your project will also be unsuccessful?"

Naturally, this conclusion holds only if all other conditions remain more or less unchanged [8] .
This was a clever argument. However, it holds only as long as there is no change of paradigm. The fact that successive geocentric models were unsuccessful does not mean that a heliocentric model will also fail. We believe that the transition to cliophysics represents a change of paradigm.

Nevertheless, even if the previous argument does not apply, one must recognize that what happened in the 18 years since the initial publication confirmed that sad prediction in the sense that this approach attracted no attention and was not used by other researchers.

In a sense this is hardly surprising. One century ago, in the time of social scientists like Emile Durkheim (see Durkheim 1894), Vilfredo Pareto (see Pareto 1919) or Marc Bloch (see Bloch 1924), such a project may have been understood for in that

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may be more interested in their own country than in others.

[8] Some two thousands years before Kepler, astronomy had already emerged from astrology thanks to a number of Greek scientists who designed and carried out wonderful experiments. Then, after Claudius Ptolemy (100-170) further progress stopped. Ptolemy's tables were only used by astrologists and geocentrism was held as the only possible truth compatible with the Bible. In other words, first in Greece and then in western Europe favorable "conditions" (which ones we do not know exactly) occurred which allowed the emergence of astronomy.

time the methodology of physics served as a model for social scientists. After the Second World War the situation changed completely for instead of physics, American social scientists started to take econometrics as their model and they were soon followed by the rest of the world[9]. Yet, whereas physics is a highly successful field, econometrics turned out to be a failure (except perhaps for short-term management). How can one get an understanding from a model which has 20 parameters?
As a result, earlier innovative and promising attempts, like the one by Pareto mentioned above, were completely forgotten.

So, is there no hope? In the following subsection we explain why there are nevertheless some reasons to be optimistic.

Some examples of previous cliophysical investigations

It is likely that in order to become convinced by the approach of cliophysics, our readers need to see that it works. The best way would be to try it themselves by applying this approach to a question in which they are interested. However, before devoting some time to such an investigation they may wish to see to what extent previous investigations were successful. This leads us to list some of the studies performed during the past three decades. Instead of listing a large number of studies just by name, we prefer to explain in some detail just a few. Other studies can easily be found on Internet by using as key words the names of some of the co-authors.

- The "Central Intelligence Agency" (CIA) was created in 1947 to fight Communism worldwide. Similarly, the Catholic order of the "**Society of Jesus**" (SJ) was created in 1540 to fight the Reformation in all European countries. The objectives were similar, namely to get close access to political leaders in order to influence their decisions and to weight on public opinion through a control over teaching institutions[10]. Yet, there was also a crucial difference in the sense that, at least in Catholic countries, the Jesuits were working openly. In a number of cases the Jesuits went too far with the result that there were several expulsions not of individual Jesuits but of the whole Society from Catholic countries. These expulsions (almost 20 spread over 4 centuries) were compared side by side in order to identify common features (Roehner 1997a).

[9] Apart from the number of parameters and variables, econometrics also differs from physics in how it uses statistics. There are two distinct approaches in mathematical statistics. One is based on confidence intervals and the other on significance tests. Physics uses the first which has the advantage of a direct connection with the notion of measurement accuracy whereas econometrics uses the second (one, two or three stars).

[10] This activity was not limited to Europe. Founded in 1789, Georgetown University remains a prominent Jesuit school although it is also open to non-Catholic students including 400 Muslim students (as of 2007). The school's alumni include more US diplomats than any other university. For instance, CIA director George Tenet was a Distinguished Georgetown Professor in diplomacy. Georgetown has also a Liaison Office at Fudan University in Shanghai. For more details see the corresponding Wikipedia articles.

- **Separatism** is a phenomenon that has existed in all times. The fact that there have been so many separatist uprisings makes it an excellent topic for comparative analysis. As a matter of illustration let us briefly describe two cases.

In 60 Queen Boudica led a rebellion in Britain against the military occupation by the Roman army. According to the two Roman historians Tacitus and Dio Cassius, this uprising which occurred some 20 years after the conquest was largely a result of the arrogant behavior of Roman veterans who had received land grants. At first successful, the rebellion was quashed within a few months by the Roman legions.

A more successful secession was the rebellion in 1581 of the 7 United Provinces of the Netherlands against Spanish occupation. The rebellion occurred some 25 years after the region had been taken over by Spain and it is likely that here too the arrogance of the Spanish soldiers was a factor.

A broad study of many separatist movements brought to light the main factors which are at work in a long range perspective (Roehner 1997b, Roehner and Rahilly 2002). In physical terms a separatist movement is like a drop of oil in water. The oil drops do not mix because the oil-water interactions are smaller than the oil-oil and water-water interactions. This may seem a rather schematic view but in fact it gives clear political guidelines. For instance, increasing the fare and reducing the frequency of the ferry between Corsica and continental France can only boost separatism.

The previous explanation in terms of social interactions can be seen as a microsocial model. A macrosocial factor is the strength of the central government. History shows that a weak central government favors separatism. An extreme case was the Holly Roman Empire which comprised some 300 independent entities: kingdoms, principalities, free cities, and so on. The European Union faces the same risk for all 28 governments have willingly transferred some of their powers to Brussels, but unfortunately the European Commission remains a very weak and unpopular form of government. This opens the door for regional fragmentation of the kind one can already see in Catalonia.

If a weak state favors separatism, the converse is also true in the sense that successful separatist movements make states more fragile. That is why in the past 4 or 5 decades separatism has become a major political weapon. One recalls that the secession of Lithuania from the Soviet Union in 1989 gave a signal which led within a few months to the secession of the other Soviet Republic[11]. In the studies mentioned above we left aside all cases in which there was obvious foreign interference for we wanted to

[11] It is often said that it was a disintegration but this is not correct for each Republic had the right to proclaim its independence, as attested by the fact that Ukraine and Belarus were already United Nations members. On the contrary, a province like Chechnya was an “autonomous republic” within Russia which did not have the same status as the republics composing the USSR; it is true that usage of the term “republic” in both cases does hardly highlight this important distinction.

to restrict ourselves to endogenous factors. Nowadays (in 2020) it would be almost impossible to find separatist struggles not dominated by exogenous factors.
As a case in point, the US Congress has passed three successive acts which define and codify US interference in Tibet:
(i) The "Tibetan Policy Act" of September 2002.
(ii) The "Reciprocal Access to Tibet Act" of December 2018.
(iii) The "Tibetan Policy and Support Act" of January 2020. This last act is about the succession of the Dalai Lama.

To study the case of Tibet without taking into account the exogenous factors would be similar to measuring the period of a pendulum outdoor in strong wind without taking into account the effect of the wind. On the other hand it is very difficult to integrate the exogenous factors into a model because we ignore how precisely the measures defined in the acts were (and will be) implemented.

- **Fragmentation** is an effect that is strongly related to separatism. The fragmentation of Yugoslavia in recent decades shows that there is no "natural" limit to such a process in the sense that it may extend to ever smaller entities. Naturally, the successive fragmentations (and re-unifications) of China has attracted considerable attention; see for instance the study of Baaquie and Wang (2018).
- **US responses to challenges in the Pacific.** Ever since the United States took possession of the West Coast (the conquest of California was in 1847 during the US-Mexican War) it has had an hegemonic position in the Pacific Ocean. As a matter of fact, from 1850 to around 2010 it was by far the most important power of the Pacific rim to the point that President Eisenhover called it an American lake. In a book by Zengru Di et al. (2017) and in a paper by Belal Baaquie et al. (2019) US responses to successive encroachments upon its hegemony from 1880 to now were systematically studied. It turns out that during this time interval the US has been unwilling to consider a negotiated partnerships preferring to give a free hand to its military[12].

The temptation to omit external factors

In the case of Tibet external interference is quite clear but this is in fact exceptional. Most often, when a country A tries to influence a country B, neither A nor B wants to recognize that interference openly. For A it would suggest arrogance whereas for B it would imply weakness. That is why a common drawback of most historical accounts is the omission of foreign interference. This is a variant of the anthropocentric temptation discussed above in the sense that historians are so focused on their own

[12] Yet, one can remember that in April 1951 President Truman reined in General McArthur's in his plans against China. In this plan "between 30 and 50 atomic bombs" would have been dropped on China, see the interviews of MacArthur taken in 1954 but which were published in the "New York Times" ten years later on 9 April 1964 (p.16).

country that they are led to forget external factors.

To make this point one could rely on fairly general arguments. For instance, it can be observed that countries (e.g. Japan or Australia) which rely for their defense on the US nuclear umbrella can hardly have an independent foreign policy. Yet, instead of such broad reasons it may be more convincing to describe a specific case.

In May 1958 the political situation in France opened an opportunity for General de Gaulle to come back to power (remember that after having led France through World War II he had resigned in 1946). This process which lasted some three weeks from May 13 to early June is described in almost all accounts as a purely French story. Yet, General de Gaulle himself was quite aware of the importance of external factors to the point that he sent an envoy to the US embassy in Paris who pledged in his name that France would remain a member of NATO. Although almost never mentioned, this contact is duly recorded in the official archives of US foreign relations as published by the State Department (the complete collection of volumes is available on Internet). Incidentally, this pledge may explain why France left NATO only during the second 7-year presidential term of President de Gaulle.

Promises of cliophysics

Nowadays governments no longer employ astrologists but they do not have any analytical tool to help them take right strategic decisions. There is admitedly a common belief that the past can help to understand the present but this is taken as a loose statement without any real usefulness. Some leaders like General de Gaulle or Winston Churchill had a good knowledge of the past and a “sense of history” which naturally led them to establish parallels with former situations. The comparative analysis presented in the present paper systematizes what such leaders were doing more or less intuitively. The guiding principle can be summarized in two sentences. “Identify former episodes which display the same mechanism. Then, what has happened many times is likely to happen again”. When an astrophysicist wants to study neutron stars he does not rely on only one observation, but collects all available cases. The same should be done for historical events. Because they are trained accordingly astrophysicists and physicists have a special role to play in the developement of this project. For many decision makers cliophysics should be of great help.

What can be expected from cliophysics?

Limitations of physics

Physics textbooks entertain their readers in the wrong belief that the laws of physics allow us to explain *all* natural phenomena. In reality, there are many phenomena for

which the laws of physics are unable to offer successful predictions. Here are two examples.

- Can one predict the shape, size and color of clouds?
- Many solids exist in different allometric states. Can physical chemistry predict the number and characteristics of these states?

In short, although the general framework is fairly well understood, there are many questions which just turn out to be too challenging.

Limitations of cliophysics

Why was it important to make this point at the beginning of a paper about cliophysics? When scientists take a closer look at cliophysics, they come quickly to realize that cliophysics (at least as developed in this paper) can be used successfully only for specific classes of phenomena. In all other cases, just as in the physical phenomena listed above, its application would be too cumbersome and uncertain.

While honesty required us to emphasize such limitations, we wish also to give our readers a more positive perception. Subsequently we describe problems to which cliophysics has already been applied with some success; moreover in Appendix C we propose two questions that we think suitable as initiations for those of our readers who wish to try this approach by themselves.

Appendix A. Is the quantity theory of money predictive?

Just to give a sense of how difficult it is to find real laws in the social sciences we give an example from economics. What is the predictive power of the quantity theory of money?

This theory states that there is a relationship between the price level p and the amount of money M in circulation in an economy in a given year. For an economy based on a single product, A, and a single form of money, e.g. cell phone money, the relation will be as follows:

$$Mv = pQ \tag{1}$$

where v is the velocity of money, i.e. basically the annual number of transactions; Q is the quantity of A produced in one year. Clearly this equation can be easily generalized to several products and various forms of money (cash, credit card, cellphone). According to equation (1), if v and Q are stable, doubling M should double p.

This equation works fairly well when a massive amount of printed money is injected into an economy. Below we mention several cases.

Massive postwar introductions of banknotes

A case in point was the postwar occupations of Japan and South Korea by US troops

who brought with them a huge amount of bank notes (of the order of the total receipt of the budget, therefore equivalent to a budget deficit of the order of 100%) printed in the United States. This led to a considerable inflation between 1945 and 1950 whose effects are still visible nowadays through the many zeros printed on Japanese and South Korean banknotes.

Paul Volcker's battle against inflation

A second episode can be mentioned which was a practical application of the theory by Paul Volcker, the Chairman of the US Federal Reserve. In March 1980 the US inflation rate reached 14.8%. Volcker raised the interest rate (more precisely the federal funds rate) from 11% in 1979 to 20% in June 1981. The inflation rate fell to 3% in 1983 but the high interest rate had adverse side effects: (i) a sharp recession (ii) an overvaluation of the dollar which hindered US exports. After only two terms from 1979 to 1987 Volcker was fired by President Reagan. Volcker's successor, Alan Greenspan, remained chairman from 1987 to 2006.

"Quantitative easing" after the crisis of 2008

A third episode is the period of massive money "printing" (also called quantitative easing) by the central banks in the wake of the crisis of 2008.
Some economists were surprised that it did not generate any substantial inflation. In fact, it did create inflation but which remained limited to the prices of stocks and real estate. That is not surprising because the supply of money by the Treasury was injected into the economy at the level of big banks (e.g. in the US the banks belonging to the Federal Reserve system). It is natural to think that for these banks the most natural way to use this money in a profitable way was to inject it into the stock market. An increase in stock prices makes everybody happy as it creates an optimistic economic climate.

Massive money supply during the Covid19 crisis of 2020

A fourth test will be the aftermath of the Covid19 crisis which gave rise to even more massive quantitative easing than the financial crisis of 2008. Will it lift up p in accordance with equation (1)?

In conclusion one can say that, with the exception of the spectacular occupation episodes, the quantity theory of money showed limited predictive power.

Appendix B. Communist resistance to German occupation

Before giving the evidence for France we will describe the evidence for the **Netherlands**. In the Wikipedia article about the Communist Party of the Netherlands one learns of the two following actions.

- As early as 15 May 1940, the day after the Dutch capitulation, the Communist Party of the Netherlands (CPN) held a meeting to organize resistance against the German occupiers. It published a resistance newspaper called De Waarheid (The Truth).
- Then, in February 1941, there was a general strike against the arrest of several hundred Jews (United States Holocaust Memorial Museum, article "Amsterdam". On 26 February, 300,000 people joined the strike. Broken by the Germans the strike lasted only three days.

However in later deportations in 1942 the Dutch municipal police cooperated in the deportations (just as it did in France and probably for the same reason). For the whole duration of the war, 75% of the 130,000 Dutch Jews were deported.

For **France** one piece of evidence is an article in the New York Times of 21 October 1940, p.3 entitled: "Three French reds arrested. Cache of arms and Communist literature found in Lyon". Another piece of evidence can be found in a book by Alain Guérin (1972) which cites sabotage actions by Communists in early 1941.
Then, on 15 May 1941, the PCF set up the "Front National de la lutte pour la libération de la France" (National Front for the liberation of France). Clearly, the actions in France were not very visible which is probably why the debate could not be settled conclusively. It is thanks to the Dutch case that a clear conclusion can be reached.

Appendix C. Practising cliophysics: two simple problems

We have explained how, following the guidelines of physics and avoiding the trap of anthropomorphism, cliophysics may be duly developed. Then, we have listed a number of studies in which this philosophy was put to work. However, as nothing can replace personal experience, we suggest here two test-studies that are new and can be tried by our readers if they wish.

The fate of head of states after revolutions

After a revolution or a war how should the new rulers handle the former head of state, referred here as H and assumed to be a male.
There are several options: (i) to expel him (ii) to try him and then keep him in jail until he dies. (iii) to sentence him to capital punishment (iv) to execute him summarily that is to say without any trial.

In the course of centuries all these options have been tried. Moreover, if one extends the investigation to the whole world, one can collect a substantial number of cases. Cliophysics has the following message: "Before taking any decision, consider a number of past cases whose circumstances were similar to those of H.

Although very simple, such an advice has, to our knowledge, never been followed; actually, has it ever been given?

From the debates which preceded such momentous decisions, we know some of the arguments, e.g. (i) “We want a radical break with the past.” (ii) “We should take care not to create a martyr.” (iii) “A regime which starts violently will also end in violence.”

Needless to say, all such statements are usually made without any real historical basis. No attempt is made to use the past to reach a smarter decision, not even when the cases are fairly similar. One can be fairly sure that the case of Charles I sentenced to death by the English Parliament was not brought up during the trial of Louis XVI by the French Parliament one century and a half later[13].

The “production” of Loyalists

The question of the American Loyalists during the War of Independence has attracted much attention from US historians. Those Americans who sided with the British had their property confiscated and eventually emigrated to other parts of the British Colonial Empire.

Needless to say, all great changes, whether political or religious, produce Loyalists that is to say people who wish to stick to the former conditions. When Sweden became a Protestant country in the 16th century, the people who remained Catholic were “Loyalists”. As they did not enjoy the same rights than Protestant citizens, instead of remaining in the country some of them fled to Catholic countries, e.g. the American colony of Maryland. The same observation can be made in Britain where Puritans, Quakers and members of non-conformist denominations went to America (Puritans to Massachusetts and Quakers to Pennsylvania).
Apart from religious revolutions one can also consider political upheavals, e.g. the Cromwell Revolution, the French Revolutions of 1789 and 1792, the Russian Revolution of 1917, the Chinese Revolution of 1949. All of them produced Loyalists.

Religious loyalism in Japan

Religious loyalism is probably less known than political loyalism. It can be nicely illustrated by the case of Buddhism in Japan.
Hardly known in the west is the fact that during the Meiji Restoration there was an attempt to abolish Buddhism altogether, firstly by fueling distrust among the population and secondly by detaching Shintoism from Buddhism. As a result, about one half of the Buddhist temples were vandalized and destroyed with the complicity of the authorities. Subsequently, Buddhists regained some of their prestige by be-

[13] Not only were the charges similar but so was also some twenty years later the subsequent return to power of Charles II in Britain and Louis XVIII in France.

coming an important political pressure group. Additional information can be found on the Internet through the keywords: “Haibutsu kishaku”, “Shimaji Mokurai” and “Jodo-shin sect”.

Incidentally, the fact that in the west so little is known about such important Japanese events points out a major difficulty of cliophysics. In the study of physical phenomena our personal tastes play little role. On the contrary, in cliophysical studies our nationalist inclinations and cultural feelings may play the role of a filter, at least unless we take great care and efforts to set up a fairly “universal view”, just as the Martian mentioned previously would do.

How to start?

An important question comes to mind immediately. Should the investigation start with political or religious cases? As already said, this study has never been done, which means that we do not know. However, one may think that the religious cases involve fewer parameters for the obvious reason that a religion is not expected to ensure the welfare of people. Therefore one can ignore most connections with the material world.

Whereas at first sight the previous episodes look exceedingly different, as often in science, a preliminary classification may be useful. Then, it may become possible to define a few key-variables, e.g. the proportion of people killed, dispossessed or who emigrated.

Once this is done, comes the interesting part in the sense that it becomes possible to study the main determinants of this effect. Certainly, the duration of the previous regime is of importance. A regime which had lasted only a few months will hardly produce any Loyalists. A second determinant may be how strong were the links between the previous regime and the population. Thus, little by little, a better understanding may develop which in turn will allow us to ask sharper questions.

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