CONTAINMENT MODELING TEST ON THE SPREAD OF COVID 19 EPIDEMIC IN FRANCE

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Abstract. *Starting from the E.W. Montroll's point of view about the "Social dynamics and the quantifying of social forces" from the case of France the authors show that it is possible to reduce the problem of the diffusion of the Covid 19 pandemic to a simple entropic problem on substitution structures which can be modified by social actions likely to force it to regress. However, they show that, for avoiding resurgence of infection, containment as practiced in democratic countries will be unable to eradicate the spread of the virus without strong exogenous constraints such as absolute isolation of contact cases and mandatory vaccination.*

Index terms*: Dynamics, Pandemic, Covid19, Complex Systems, Category Theory.*

1. Introduction and formulation of the theoretical problem of epidemia spreading

A pandemic is typically a complex problem based on a butterfly effect [1] and / or the appearance of a "black swan" [2]. It leads a total change of the ways of living and the running of economy. This is a highly nonlinear, multi-causal problem characterized by multi-scale feedbacks. It is now established that, based on interactions between agents acting freely, such systems nevertheless give rise to fairly simple emerging macroscopic laws which cannot be reduced nor a simple Markovian chance because the correlations can operate over long periods of time and distances and, no more to deterministic laws defined locally in a differential manner according to S.I.R. models explaining an "internal pic" [3]. Local behavior

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cannot be represented within complete, compact, dense and regular spaces. These behaviors disperse contaminations according to tree structures and negative curvature spaces whose regularization it is difficult to think analytically.

Nevertheless, their dynamics often display behavior responding to global laws of the power law type, namely $f(x, \blacksquare s) \blacksquare \sim \blacksquare x^s$. In this regard, we will read with interest the reference [4] which otherwise provides an extensive bibliography of the laws of epidemic contaminations to which we will usefully refer. These power laws have the bad idea of giving rise to divergent series, and therefore to normalization difficulties, but they generally have the good idea of being renormalizable [5] for categorical reasons that we will not consider here while already detailed in ENEC Meeting (injection / surjection isomorphism of 'a categorical object obtained by merging additive monoid and the multiplicative monoid) [6].

The characteristic of renormalization is expressed simply by means of laws of the type $f(kx) \blacksquare = \blacksquare M_f(k)f(x)$. Let us specify how this characteristic is much more disruptive at the paradigmatic level than one perceives from the simplicity of the formula. Scientific education has accustomed us to consider the notion of function and the associated concept of natural differential equations. These concepts are based on the now intuitive notion of location, of instantaneous speed at any point, of derivative and continuity of the function: $f(x):x \blacksquare \rightarrow \blacksquare df(x) \blacksquare / \blacksquare dx$. However, this apparent evidence comes up against serious difficulties when the functions in play are not smooth and for example are continuous but not derivable. Then, the concept of velocity loses its relevance, and consequently the disappearance of any uniform convergence, even the separability of “points” which can then be dependent on scales. the completeness of the representation can then be called into question [6]. All the physics associated with the notion of energy, obviously based on the notion of velocity, in other words, physics based on Noether symmetries (among others invariance of laws vis-à-vis displacement in space-time) and beyond on the concept of action etc is then compromised by irregularity of the reality. History and memory then prevail in a physical science which for the most part (except thermodynamics) had evacuated these notions. Facing this complexity such as a pandemic, rational thought must be reconstructed from a renewed mathematical basis (spaces with negative curvature, branched networks, autosimilar geometries to return to the global local link, dualities, Choquet capacitive measures, non-separability etc.) [7].

After having considered renormalization as a separation of variables on the multiplicative monoid, the idea is then to consider particular

functions corresponding to the following Cauchy relation: $f(a+b)=f(a)+f(b)$ relation which we will observe that it operates in the same way this time on the additive monoid. In both cases the separation excluded on the variables nevertheless operates on the functions. It follows from this last constraint that $[f(x+dx)-f(x)]/dx=f(dx)/dx$ which is a "differential" concept very different from the concept of velocity $df(x)/dx$ and which will call into question the concept of locality by implicitly affecting a monadic structure, – therefore holistic behavior – at the core of a behavior far from an evolution which can no longer be based on the notion of an optimal transport of the virus, temporal trajectory etc.

Technical reasons (batteries behavior [8]) serving as a guide and the categorical reasons mentioned above [6,7] lead nevertheless to the existence of universal geodesics in the order of scales (seen in standard cases by means of expressions in the space of Fourier) irreducible to temporally parameterized trajectories (which means that these expressions do not have inverse transformations). For historical reasons [8], we have called "dual transfer" the optimal transfer. The term dual here refers to the incompleteness of its representation by means of fractional differential equations. This representation, however standard, finds its completion only in association with the Riemann zeta function ($\zeta(s) = \sum(1/n)^s|_{n \in N^*: [1,+\infty]}$ with $s = \alpha + i\theta$) equipped with the functional relation between $\zeta(s)$ and $\zeta(1-s)$ [6,9]. The behaviors considered are nevertheless optimal in the sense of a principle of least action (or least cost) because their basis is based on the conservation of Hausdorff content of the dynamic site on which are grafted pre-sheaves opening to zeta functions definition and properties ($\forall \alpha = 1/d < 1$, $\eta < 1$ then $\eta(u) \times n^{\alpha} \sim 1$ for "d" the dimension (almost surely non integer), α – cantorian dimension, and η scaling factor. This modeling amounts to assuming that a certain definition of the phase space of the dynamics is an invariant but that each point is characterized by a surjection. Far from the confusion which reigns in the minds, often attached to the sole standard paradigm of an optimal behaviour based on dense geodesic gradient-flow parametrized with time, the notion of "dual transfer" does not admit a local internal closure, but strong interaction with the whole of the environment. The confusion arises from the fact that this closure is nevertheless possible for the "dual transfer" model if $\alpha=1/2$, that is to say if the Riemann hypothesis is realized, namely when dynamics can be related to a pure stochastic process.

The consequences of this analysis are mainly the laws that govern the system no longer consider only the scales except exogenously.

$f(k \cdot \times \cdot x) \cdot = \cdot k \cdot \times \cdot f(x)$ but adds the scaling power laws $(kx)^{\alpha} \cdot = \cdot k^{\alpha}x^{\alpha}$ take on their full meaning since they respond jointly to the additive Cauchy relation and to the renormalization rules with a breaking of the concept of locality. This new evidence which brings into play both the status of additive monoid over distances in scales, but also their multiplicative status of a monadic core leads to a natural logarithmic immersion aiming at a linearization of the dynamic representation from which it follows as differential consequence that $log[(1 \cdot + \cdot \varepsilon)x] \simeq \alpha log(x) \cdot + \cdot \alpha\varepsilon$, formulation which implies $d[log(x)] \cdot / \cdot dt \cdot = \cdot \varepsilon \cdot / \cdot dt \cdot = \cdot const.$ if "x" is a state variable of the dynamic system associated with the "dual transfer" and if "t" is the clock time of any experimenter (different from any internal parametrization if even this is possible). As far as the infinitesimal evolution in the order of the scales is governed by a geodesic propagation speed (for example by means of a process of local exponential relaxation convolved by a fractal geometry for example in the TEISI model [10]) we find a vision of propagation in the order of scales to which L. Nottale gave a relativistic formulation several decades ago. The important point here is that the relevant variable of the dynamics is $log(x)$ and not (x). It is at this step that the ideas about social influence considered by E. W. Montroll [11] find their full meaning.

As the bibliography shows, it appears that the dynamics of pandemics depend on power law, however, even if it is customary to say that the growth of contamination is exponential, this is not the case for the simple reason that for the structure of $R_0 > 1$ the rate of contamination along the self-similar trees is naturally bounded and can be tuned by adapted social behaviors, endogenous (quarantine, barrier gestures, distancing) or exogenous (vaccination, collective immunity, isolation). Thus by writing $x \cdot = \cdot N(t)$ the number of people infected at time t, in absence of any "social" force, the constant rate of change in the logarithm of a population turns out to, $d[log(N(t)] \cdot / \cdot dt \cdot = \cdot F[N(t)]$ with, for example $F[N(t)] \cdot = \cdot k \cdot - \cdot \alpha N(t)$ "Evolution" is then the well-known sequence of "replacements". Then the distribution will be $S \sim \log(N(t)/[1-N(t)])$ The solution is given through a couple of "S-curve" type evolution and an applied “force” depending of the factor k/α generates a change of trajectory (acceleration / deceleration).

This formulation is easily understood here in the thermodynamic statistical framework as the expression of the configuration entropy of contaminated people, among a possible set of people able to be contaminated, normalized by the factor k/α. The symmetry of the

formulation making it possible to formulate in exactly the same entropy way the dynamics of non-contaminated people, given the social decision factor k/α. It is easy to understand that the lock down of the people at home, applied when the saturation of the beds resuscitation in hospitals is reached, leads to an inverse dynamic, both dynamics, as dual structure, being combined according to their respective speed and their amplitude.

Given the functional constraints to which the problem is subjected, in particular the constraint of self-similarity and the non-separability of sets of agents, this of Cauchy's constraint, we shall note that the global dynamic is expressed in a synthetic abstract space (categorical-features). From this point of view any attempt for designing microscopic models, followed by a summing, appears be counterproductive because requiring an excessive number of supernumerary local hypotheses and ultimately a regularization to fall back on global behaviors. While effective due to the number of degrees of freedom this approach has all the chance of to miss the understanding of axioms and relevant parameters.

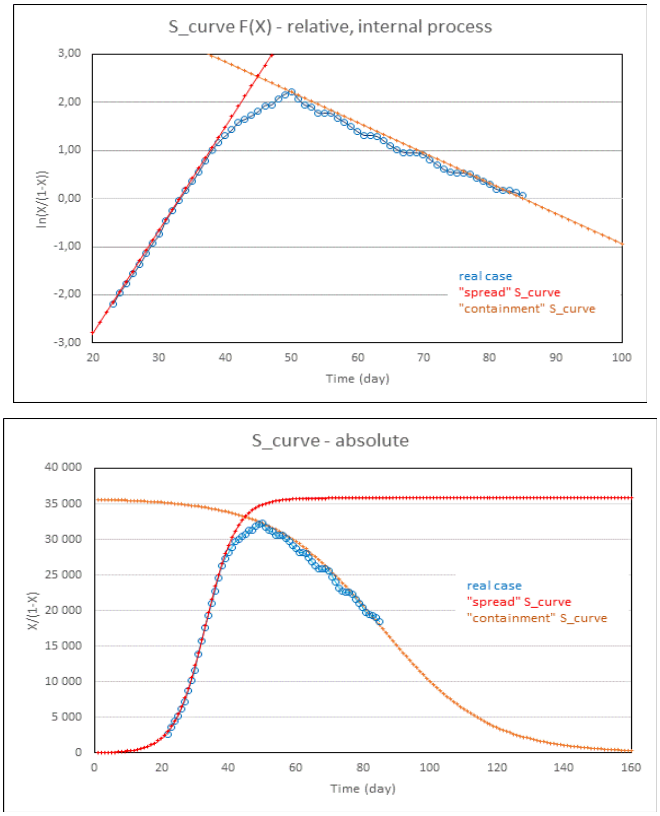


Figure 1. First set of the pandemic for all France pointing out S-curves of spreading and the symmetrical role of the containment of social relationship.

2. Synthesis of experimental data

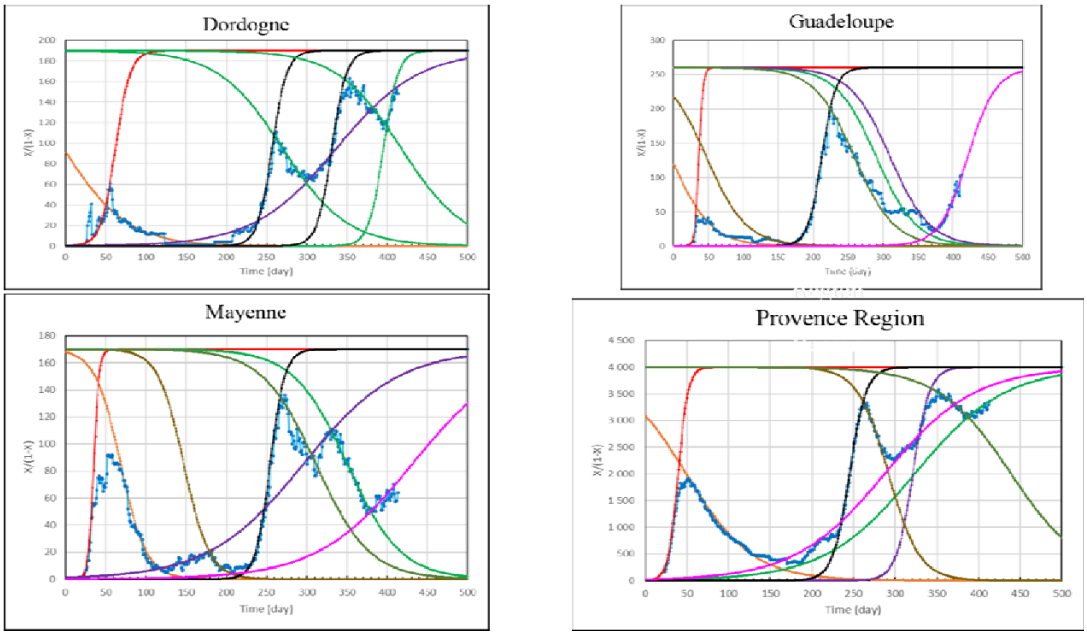
The experimental data obtained along the couple of year 2020-2021 confirm, – subject to specify the reasons namely the monadic origin justifying global approach here proposed-, the relevance of a macroscopic model which highlight some critical behaviors that political managers must know and consider.

- *S*-curve type evolution is confirmed for the epimedia in accordance with the equation suggested from the theoretical part above.
- *S*-curve is also confirmed for the effect of the lock down. The change of trajectories with the effect of containment is delayed.
- The *S*-curve are subjected to small oscillations of its évolution due to the irregular and discrete structure of the sub-geometry characterized by a set of branching. Estimation of containment effect (with scale effect, probably reduced to a stable laws)) is clearly obtained from the experimental curves.
- The model authorized a linear representation very useful to forecast the evolution.
- The analysis must be detailed over the different Region to estimate the role of location with respect to the core of epidemic, the role of local culture, the role of interconnexion, etc
- The renormalization can be used to distinguish the role of the containment over the epidemic. The analysis highlights the limited role of the containment to releases the epidemic remaining. The renewed contagion is clearly observed on the curve pointing out the need of additional social constraints to eradicate the pandemic.
- While in the same range, different velocities of epidemic spread (slope) are observed.
- 3 scale levels & classification (country, region & department) are analysed.

The experimental data represented according to above approach lead to the following observations:

- ✓ The impact of containment is characterized by the emergence of a renew force (post-containment social force), much less effective than the initial. The number of patients cured was reduced accordingly (estimate of the "spread of the epidemic" at t=140 obtained with the sole containment).

- ✓ This (post-containment) force becomes representative of the internal social behavior when society is facing the spread of the Covid (two forces stay in permanent interaction). When constraints are released a stationary adaptation is found but this adaptation is more or less efficient.
- ✓ The parameters (velocity, delay and limits) define precisely the evolution. A couple of characteristic are determining: "reaction efficiency", i.e. "velocity" and the of response to social decision, the delay. These can be different depending on the nature of the social force applied (i.e. the set of decisions taken into account, social adaptability, etc ...).
- ✓ Regions and departments do not react in the same way, with different components:
- ✓ Some continue to decrease since de-containment (memory effect).
  - Others, having experienced a new spread, have controlled it or are in the process of controlling it (adaptation effect).
  - Some departments show a decrease almost at a standstill (balance of forces).
  - Some departments are experiencing the beginning of new propagation, detectable on a very small scale, with a future reaction.



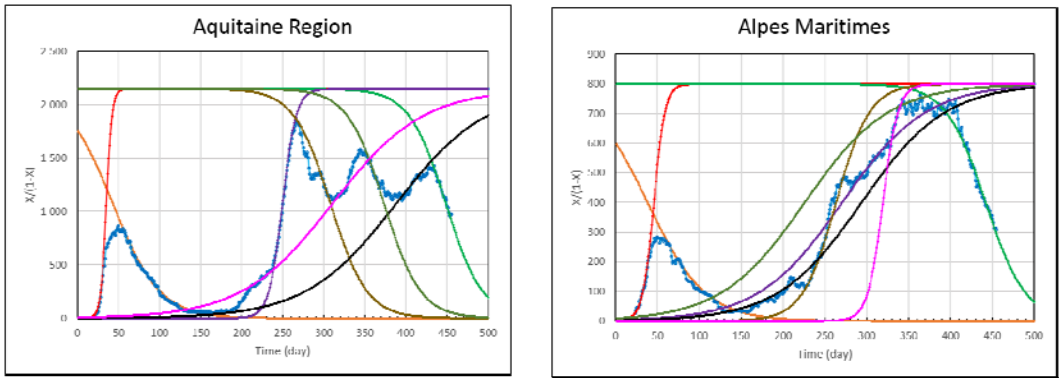
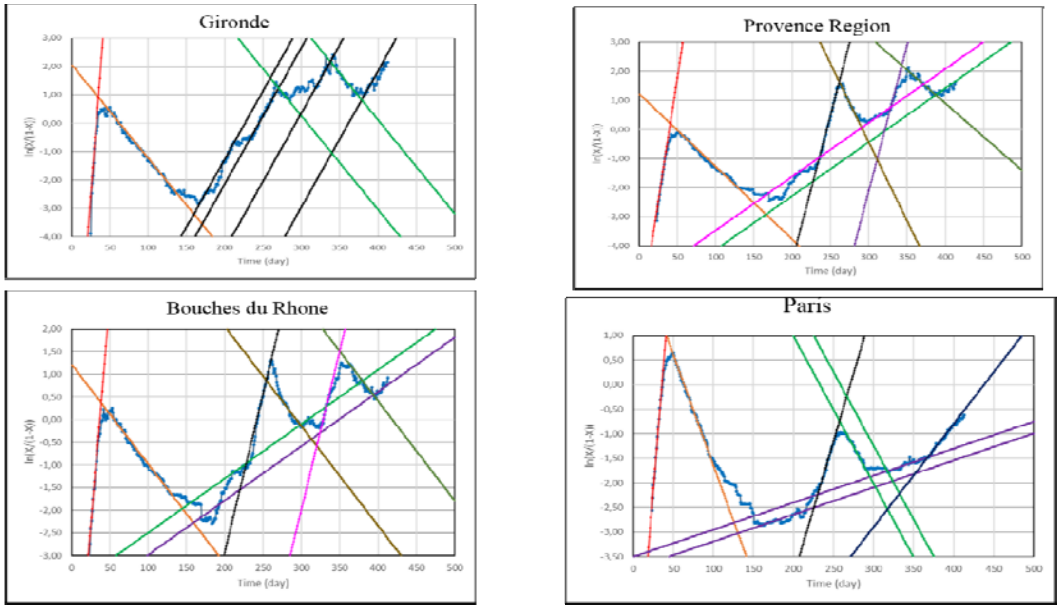


Figure 2. Example of the complexity of the dynamics of spreading and containment of epidemic in some of French countries and in a couple of regions (in the south of France) Increasing curves points out the spreading and decreasing curves points out the role of the containment of the physical distances etc. The last couple of figures synthesizes the data up to May 2021. We can observe that when containment is relax spreading start again with a conservative dynamic. The shape of the curves suggests the role of the time renormalization (See linear regressions).



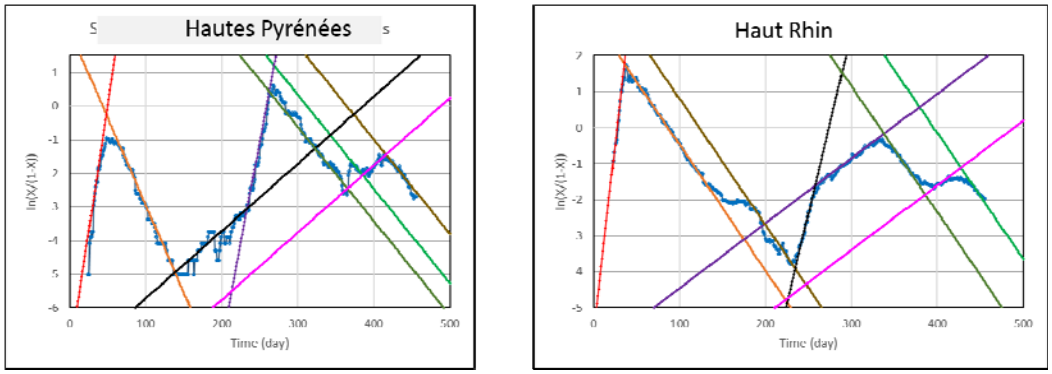


Figure 3. Example of linearization of the S-curves pointing out the universality of dynamics and the small fluctuation of their Increasing curves points out the spreading and decreasing curves points out the role of the containment of the physical distances etc. The last couple of figures synthesizes the data up to May 2021. Please observe the parallelism of the dynamics pointing out the relevance of the renormalization. We can observe that when containment is relax spreading start again with a conservative dynamic (clear renormalization effect observed above). The most interesting point is the fact that the containment is not enough to release the pandemic.

3. Conclusion

Far from the logistic type model like S.I.R. [12] the entropic approach is an holistic model based on renormalization and self-similar properties of the dynamics. The data show very clearly the stability of the dynamics of contamination and the regression induced by the containment measures which, when released, leads to the resumption of the epidemic at exactly the same stage as it would have been in the absence of containment '(see time renormalization curves properties). This observation shows that vaccination will be the only radical remedy to face the pandemic and the future multiplication of variants.

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