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Some un-noticed insights in Gini's cyclical theory of populations

1. INTRODUCTION

Corrado Gini was just 28 years old when he elaborates the first formulation of his Cyclical Theory of Populations (CTP). Let us read the sentences where he introduces his core ideas, starting from the analogy between populations and organisms, and the role of lower social classes in promoting population renewal:

> "The populations currently dominant in all countries do not constitute the direct descendants of dominant populations in times past. The explanation is simple. *The individuals of a society, i.e. the cells of an organism*, are endowed with a certain *reproductive power*. What is not commonly evaluated is its magnitude (..). If differences depended merely on chance, there would follow variations without rules from one generation to the next. Instead, the differences are continuous and in evolution. *This suggests a constant relationship between the different reproduction rates of individuals and a certain circumstance*. This circumstance cannot be pinpointed with certainty: it is wealth, it is the degree of culture, it is intelligence, it is refinement. It is all these things together, but it does not coincide with any of them. It is what we are accustomed to designating with the expression "civilisation": the greater or lesser *dependence* of our activity *upon the primordial and instinctive needs of the organism*, rather than on centuries-old needs and effects, which may be said to be more elevated than the psyche and the senses. Those people belonging higher up in the social ladder, those forming the upper classes, generally have a much *weaker reproduction rate than the lower classes*. Each nation thus figures at a certain moment in world history almost exclusively for what their managing classes are and what they are worth, but its future depends instead directly on what other classes, which currently wield negligible influence, will be and what they are worth" (Gini, 1912, pp. 9, 12, *our italics*).

These sentences evidence that Gini - using Newton's aphorism - was building on ideas from the most influential scientists of his time, from Arsène Dumont (1890) - who linked depopulation (i.e. both a lower fertility and lower self-esteem) with social capillarity (synthesis of freedom and well-being in democracies) - to Vilfredo Pareto, whose theory of "cir-

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culation of elites" (first appeared in Pareto, 1906[1]) Gini partly endorsed, although he imputed the decline of the leisured classes to the drying up of the reproductive power rather than to Paretian *dégénérescence*. Unlike Pareto however, Gini was stressing the "organicist" analogy as the key for organising and classifying the stages of population evolution:

> "Many phenomena of the evolution of peoples are illuminated by the consideration of demographic turnover between social classes: however, what is still to be explained is the general pattern of this evolution. A certain regularity is discovered: like organisms, peoples have a period of growth, maturity, senile decadence" (Gini, 1912, p. 36).

Let us supplement the 1912 text with two passages drawn from the 1929 Chicago conferences, where Gini was invited by to lecture on his CTP. In the first one, Gini highlighted the key driving role of "internal" forces, which today we would call "endogenous", as opposed to "external" ones, as the key determinants of reproductivity dynamics:

> "(As with organic forms) human populations evolve independently of any outside influence, according to modern biological viewpoints, by the drive of inner forces. Not that outside circumstances remain uninfluential: yet they (..) appear secondary compared with the constant causes represented by inner forces" (Gini, 1930, p. 11).

In the second one Gini contrasted his cyclical theory against Malthus theory of geometric increase:

> "(There are) two different population theories. The first, the theory of geometric propagation (…) hypotheses that the reproductive power of populations remains constant over the generations. The second theory holds, instead, that *the reproductive power of populations follows a cyclical pattern*, more or less analogous to that of the power of the growth of individuals (...). For the populations of bacteria and yeasts the existence would be ascertained of a maximum density in which the reproduction of individuals would be compensated by deaths (Pearl, Reed 1923) (…). Many experiments have demonstrated that *this limit is due to inner factors*, dependent on the same living organisms, and not to environmental factors (...). *The key to the evolution of nations lies in the different growth of their different population categories* (…). The upper classes are generally insufficient to maintain their numerical proportion by reproductive force alone. To fill the voids, an upward current tends to occur from the middle classes to the upper classes and from the lower to the middle (…). Is this turnover a purely economic or social phenomenon? Or do its roots lie in more intimate factors of a biological nature? Undoubtedly, *the economic differentiation of societies stems from the different reproductive rate of the families. But it is equally certain that economic and social differentiation together result in the different reproductive rate* of individuals and accentuate the consequent demographic turnover" (Gini, 1930, pp. 12, 15, 22, *our italics*).

[1] In Pareto the different types of societies can be characterised by what he terms "circulation of the élites", determined by the differences in the process of renewal between the classes currently governing and those governed: "Whatever the underlying determinants might be, it is undisputable that after a certain period (the aristocracies) disappear. History is a cemetery of aristocracies" (Pareto, 1916, p. 82).

The reaction to Gini's conferences in Chicago (published later in the volume "Birth, Evolution and Death of Populations", 1930) by the American scientific community was amazingly negative. This criticism is summarised in the harsh, sometimes mocking, review by Edward Reuter (1931), then president of the American Sociological Society. Reuter qualified Gini's approach in the CTP as anecdotal, scientifically vulnerable due to the lack of direction from reality, supported by a chaotic combination of information from different sources (historical, biological, statistical), in most cases contradictory or irrelevant. Most of all, he criticised Gini's approach as tautological, or even "essentially magical":

> "A cause outside of the phenomena is posited to explain economic, social and political reality; and the cause is outside of facts whether it is located in biology or Providence. (...) If the position is a biological one, to cite historical occurrences in proof of a force that is used to explain the historical occurrences is logical circuity" (Reuter, 1931, p. 647).

What were the reasons for such severe criticism, especially given that only a few years later Gini's "*Prime linee di patologia economica*" (Gini, 1935) was to receive the highest accolade at Harvard from Robert Merton (1936a)?

A crucial role may have been played by the different scientific approaches between the Chicago school, where Reuter was a leading scientist, and the Harvard school, where Gini was closely connected with Pitirim Sorokin, who in turn was developing a "Social Cycle" Theory (1937), based on the alternation of societies according to their 'cultural mentality'. Indeed, while Chicago was polarised on field research, Harvard, which boasted leaders like Merton and Parsons, was the bastion of a theoretical approach to sociology.

But what mostly matters was probably the conflict around population policies, between Gini on the one hand, and the supporters of the *optimum population theory* and birth control, on the other, as well documented in Cassata's reconstruction (2007). This conflict had already been incubating since the 1927 Geneva conference, where Gini's nationalist and populationist positions were overwhelmed by the prevailing neo-Malthusian approach. The dispute was rekindled in Chicago in 1929 by Gini himself, who criticised the *optimum theory* and proposed the alternative concept of an optimum region, where "a nation can increase its population without reducing the well-being of its members". In the two subsequent years Gini both worked at improving his critique to the foundations of the optimum theory (Gini, 1931) and played a key role in the fall-out between the IUSSP and the Italian Council for Population Studies. The background of the attack of American sociology upon Gini's CTP may lie in these hotly debated issues[2].

[2] In this sense we believe that Reuter's scientific critique actually represented a weapon thrown against two politically important targets: the first one was that of population policies, and of the underlying political choices - the Fascist regime - that Gini was representing. The second target was Gini's power as a "regime scientist": attacking the prestige of his theories was thus a weapon against his popularity.

All this considered, we cannot but stress that the first formulation of the CTP appeared long before the Twenties. Therefore, we aim to revisit Gini's way of reasoning by appropriately contextualising his CTP within the scientific thought of the early 20th century, focusing primarily on Gini's early ideas, in order to highlight their richness in regards of both scientific categories and epistemological approaches. These were already well present before Gini's political engagement. This will enable us to identify several limitations of Gini's thought, but also to better grasp his contributions to different areas of social sciences, not yet adequately understood.

Overall, we see at least three major Gini's contributions in the CTP that add up to his anticipation of cybernetic ideas already noted elsewhere (Dagum, 1987). The first one is the systematic use of what he named the *method of models*, anticipating the later concept of *abduction*. The second is the ubiquitous use of *structural interdependences* - between subpopulations as well as between factors - as a concrete tool for investigating population dynamics. The third, resulting as a non-trivial corollary of the second, is the dual use of the concept of structure.

The following pages focus on these three innovations.

2. BEYOND "MATH AND STAT": THE METHOD OF MODELS

In a later paper about the role of Mathematics for Statistical Sciences (Gini 1959), Gini revisited his well-known idea of a mathematics just of service ("the simplest possible") to statistics. This paper was widely cited in most subsequent reviews of Gini's work as the Manifesto of the Italian Statistical School - and, possibly, of Gini himself (Giorgi, 2011) - in contrast with R.A. Fisher's view of statistics as a branch of applied mathematics. However, the paper proceeded far beyond this. We believe that the section dealing with the "method of models" is of utmost importance:

> "Between the deductive method of Mathematics and the inductive of Statistics, the method of 'models' largely used in Physics and which at present is being accepted with favor by economic sciences, may be considered to offer a compromise. It represents, indeed, an application of the hypothetical-deductive method, which consists in *the construction of hypothetical-theoretical schemes or models, from which systems are deduced necessarily* (…) in such fields of vanguard as today that of Physics, often dealing with *problems that are on the border-line of our knowledge and cannot therefore take as their starting point a previously acquired knowledge of facts*. The method is crowned with success when the deductions can be submitted to immediate control (..) In the case of demographic and biometric enquiries, Statistics have had recourse to schemes and models but, as they can avail themselves of a wide range of facts, they (are) ready to modify them when that experience increased." (Gini, 1959, p.5, *our italics*).

A few lines later Gini stressed the importance of hypotheses in this method:

> "In the hypothetical-deductive method, which is generally followed in Mathematics, the process of deduction is always slow and laborious as compared to the moment of the hypothesis itself, which is often forgotten (..). (As) Bertrand Russell (says): "in Mathematics one never knows if what is said is true or false until one knows whether the hypotheses on which they are based are true or false"" (Gini, 1959, p.7).

We feel that, already in the early formulation of his CTP, Gini resorted implicitly to the "method of models" that he believed is appropriate for those problems "*that are on the border-line of our knowledge*". Gini stated that the "method of models" is an instance of the hypothetical-deductive method. However, with all caution that any epistemological classification requires, we believe that the method is instead an instance of abduction.

Abduction is the third Aristotelian form of syllogism. It differs from the other two forms, i.e. deduction and induction, by a permutation of its components. All three syllogisms consist in drawing a conclusion from the welding of two premises, combining a rule, a result and a property. Deduction draws a particular result from a certain rule and a property; induction draws a general rule from a particular result and a property. Abduction draws the property from *combining a hypothetical rule with the ascertainment of a result*: [I] (*minor premise* or hypothetical rule) if property *X* were true (antecedent), then fact *Y* would occur (consequent); [II] (*major premise* or certain result) the observed unit *T* satisfies the fact *Y*; [III] (conclusion) it is a reasonable conjecture (until proved otherwise) that unit *T* possesses property *X*. In the abductive syllogism the major premise relates two parts belonging to two distinct domains of reality: the antecedent ("if property *X* were true") and the consequent of the rule, that is, what we want to explain.

The Aristotelian concept of abduction, originally recovered by James S. Peirce and posthumously organized by his scholars in the monumental Collected Papers, reappeared in the debate on scientific discovery thanks to the work of Norwood R. Hanson just a year before Gini's 1959 paper. In the "Patterns of discovery" Hanson (1958) convincingly showed that abduction by (mathematical) models represented the road-map to discovery in the physical sciences, from classical mechanics to modern physics. The role of abduction by models became exceedingly important with 20th century physics, when it became critical to relax the link with intuition, which would have unavoidably stopped scientific development at the stage of mechanics. An abductive syllogism allows one to depart from a given interpretation of the empirical world, taken as a whole - i.e. from a given Gestalt (Köhler, 1929) - to switch to a new, innovative, interpretation of reality. Such a 'Gestalt-switch' has been described as "handling the same bundle of data as before, but placing them in a new system of relations with one another by giving them a different framework" (Kuhn, 1962, p. 85). Theories work as tools to recognize Gestalt; different theories stem from different perceptions. "Theories put phenomena into systems. They are built up "in reverse", retroductively. A theory is a cluster of conclusions in search of a premise" (Hanson, 1958, p. 90).

In particular, the larger the distance in the semantic content between the two statements of the major premise, the greater will be the discovery power of the abductive syllogism. Let us clarify this crucial point. In 1908 C.S. Peirce, reasoning on scientific creativity, coined the concept of musement, "a kind of rational intuition" (Salas, 2009), meaning "the power to establish connections between different objects in different Universes". Paolucci (2012, p. 12) reminds us that the "play of musement" for Peirce meant connecting two different realms of experience without a rule governing such a connection". However, we believe that a rule exists: it consists in maximizing the distance between the two realms, through the counter-factuality of the hypothesized rule. This is why the greater the semantic distance between the two domains, the greater is the ability of a theory to apply a machinery working in a better known reality domain to the subject domain (Micheli, 2012, p. 4). And this power will become maximal - though highly falsifiable - when the logical antecedent is *contrary-to-facts*, i.e. *counterfactual*.

Nevertheless, reasoning by models also requires a constant effort to reconcile observations with the particular Gestalt underlying the adopted mathematical model, as summarised by the underlying hypotheses, what Garding (1977) termed the (more or less consciously adopted) model's *influential metaphysics* (Micheli, 1993). This reconciliation requires a two-level consistency check on the adopted model: its *inner consistency*, dealing with the logical coherence of the model internal structure, and its *external consistency*, against empirical evidence.

In the domain of social sciences, model-based abductive procedures have a far different meaning from what happens in exact sciences. Kepler's counterfactual conjecture ("let us assume that the orbits of Mars are elliptical") proved to be a factual truth of the physical world. But this success cannot be straightforwardly replayed in the so-called pre-paradigmatic disciplines that, lacking a robust theoretical corpus, use abductive inference to explore 'new' interpretations of phenomena whose "data-generating model" is lacking. Nonetheless, even if in social and demographic sciences a shift in the influential metaphysics adopted cannot aim to "capture the truth", it can however aid to integrate the nuances of a reality which inevitably eludes an overall vision. This is not at all a small matter[3].

[3] The 8th Charles Peirce's lecture at the Lowell Institute in 1903 was entitled How to Theorize, but Peirce himself wrote "Abduction" in bold letters on the first page of his manuscript (Swedberg, 2012), a clear-cut identification of innovation with the third form of syllogism.

Table 1 – *Abductive structures in some classical models in population dynamics. [IM= (the underlying) influential metaphysics]*

MODEL & GESTALT OR. UNDERLYING INFLUENTIAL METAPHYSICS (IM)	HYPOTHETICAL RULE ("COUNTER-FACTUAL ANTE-CEDENT")	LOGICAL CONSE-QUENT: POPULA-TION GROWTH PATH	RESULT & CONCLUSION	COUNTER-INTUITIVE PROPERTIES & PARA-METERS
Malthusian growth **IM**: "sympàtheya" (constant "Newtonian" force due to the constancy of "passion between sexes")	Population growth rate remains constant over time.	Exponential evolution (growth or decay) of total population size.	Population growth in absence of "checks" is exponential. Main confirmation: developing countries during the Demographic transition.	Population growth is unlimited. Doubling time is invariant during evolution.
Logistic growth (Verhulst 1845) **IM**: "Newtonian" interaction between Malthusian force and environmental friction	Population growth rate is linearly decreasing in population size (or density)	Logistic growth of total population size	Population growth in the presence of environmental "checks" is "logistic". Main confirmation: laboratory population.	Population growth is continued but its asymptotic limit is a steady state ("carrying capacity")
Stable population (Lotka & Sharpe 1911) **IM**: Interaction between constant forces (Newton/Malthus) in age-structured framework.	Age-specific fertility & mortality schedules remain constant over time.	Long-term evolution is "Malthusian" at a pace given by Lotka's "intrinsic" growth rate. Long-term age distribution is invariant ("stable") and ergodic.	(First) Main confirmation: the intrinsic rate correctly predicts US demographic stagnation in the 1930s (Dublin-Lotka 1925).	Current growth rate (outcome of interplay between processes & structure) is distinct from "intrinsic" rate determined by process only. Long-term age structure determined by process only (and independent of initial structure). Fisher's Reproductive value: effects of initial structure on growth path.
Diffusion by social contacts & contagion (McKendrick 1911). **IM**: Mass-action principle (statistical mechanics)	Social contacts between susceptible and infective individuals are like collisions between particles of a perfect gas: C=βXY	Cumulative epidemic curve is logistic.	Social contact rules are sufficient to "explain" infection transmission.	Infection incidence per unit of time ("epidemic curve") is bell-shaped but not Gaussian. "**Full contagion**" principle (everyone infected sooner or later).
Diffusion by social contacts & immunity acquisition (Kermack-McKendrick 1927). **IM**: Mass-action principle (statistical mechanics)	Social contacts between susceptible and infective individuals as particles of a perfect gas: C=βXY	General epidemics curve	The model correctly predicts pandemic trends in the absence of interventions (e.g. Spanish in 1918).	**Threshold theorem**. **"Incomplete contagion"** principle: epidemic fades out without infecting everyone.
Prey-predator interaction (Lotka 1925, Volterra 1926). **IM:** Mass-action principle (Lotka) vs "Encounters principle" (Volterra) + interaction between constant forces.	1.Contacts between the two species obey: C=βXY. 2. Forces determining the numerical responses of population abundances to "contacts" are constant.	Lotka-Volterra-type (conservative) oscillations	LV model explains a range of "cyclical" datasets for which only exogenous explanations (e.g. meteorological or environmental forcing) were available	**Cyclic "principle"**: antagonistic interactions of predatory type yield oscillations in the abundance of the two species.

All the success stories in population mathematics have been the outcome of counter-factual hypotheses drawn from other fields of reality, which benefited from more robust scientific paradigms. The intuition that the social contact patterns underlying infection transmission might be represented by "borrowing" from statistical mechanics the mass-action law - which describes the macroscopic behaviour of a perfect gas based on the disordered interactions between its particles (Manfredi and Micheli, 1994) - allowed mathematical epidemiology to take off. This is what science mainly asks of the otherwise frail abductive procedure: to discover "useful", that is non-trivial, results. As George Box used to say: "*All models are wrong [i.e. counter-factual, A/N], but some are useful*".

The working principles of abduction and counter-factual hypotheses in some of the key models of population dynamics are summarised in Table 1. All these models start from a few counter-factual statements that are so far from reality as to appear sometimes incomprehensible. However, the (mathematical) elaboration of these hypotheses yields counter-intuitive, and useful, results. All these discoveries took place between 1910 and 1925: the core period of Gini's scientific production. Despite lacking personal ties or elective affinities, the method of models recalls the intuition of Vito Volterra in his inaugural academic year speech in 1901 in Rome (Volterra, 1906): "Experience teaches us that models were useful and still serves to steer us in the newer, more obscure fields of science, in which one gropes for a path".

3. COUNTER-FACTUALS, RESULTS, "LATENT" EFFECTS

Currently, human as well as life sciences are definitely acknowledging the key role played by the "method of models" in scientific discovery: "*Good science is abductive, not hypothetico-deductive*" (Rozeboom, 1997). This lends considerable value to the counter-factual hypotheses that Gini used as departure points to draw some of his counter-intuitive results. His main counter-factual, when, at the age of 28, he first sets up the CTP, was the analogy between population and organisms. But his (Gini was surely unaware of Pierce's work) use of this analogy was fairly innovative for his scientific time:

> "In the field of political economy the mechanical analogy is not the only one to have been used. Another is the organicist analogy. (…) For the analogy to be of a heuristic nature it is necessary that (..) the object from which the image is taken is better known than that to which it refers. It is the same principle which is applied in mathematics: when one performs a generalisation of an operation or concept, (…) one must begin by looking for the essential characteristics of the organism and then verify whether they are found in society. (…) Modern biologists define it (the organism, A/N) as a system in stationary equilibrium endowed with self-preservation. By system I mean a continuous and discrete set of bodies bonded by stresses and constraints (Gini, 1952, p. 75-78).

And once again (ibidem, pp. 86-88):

> Strictly speaking, if one considers the whole organism, there is never perfect self-preservation. Each action and reaction leaves behind it a change, albeit slight. We are not dealing with self-preservation, but with adaptation. And the succession of adaptations produces the evolution of the organic being (..) An exclusive characteristic of organisms is the faculty of self-reequilibration. And resettlements, caused by the imperfect power of self-reequilibration, overlap with adaptations, caused by the imperfect power of self-preservation, in giving concrete form to the evolutionary process of the organism".

What gives scientific credit to the young Gini is his capacity to break down the metaphor of the organism into its built-in functions. Interdependences between bodies or factors, self-preservation and self-reequilibration are terms that, albeit generically originating with Spencer's Principle of Biology (1899), are used with a new articulation for the time, and anticipated those of system, homoeostasis and morphogenesis that are systematically investigated in Wiener cybernetics (1950), as Dagum (1987) first emphasizes. Yet there was much more in Gini's early thinking. In his review of the First Lines of Pathology (published the year before), the 26-year-old Merton (1936a), Gini's assistant at Harvard on a course on "self-regulation phenomena of social organisms", praised Gini's neo-organicist analogy as an instrument to interpret society as a system, whose merits he underlines - sharply contrasting with Reuters' review - both in its inner consistence, namely its ability to produce non-evident results, and in its external consistence. All properties - it may be noted - of argumentation "by models":

> "The significance of the contribution is primarily twofold. It presents a rounded, logically consistent and above all fruitful analytical scheme (termed neo-organicism). Second, this theoretical analysis when applied to empirical materials succeeds in performing the all-important function of science – of integrating into a coherent structure apparently contradictory observations and theory." (Merton, 1936a, p. 324).

What can we say about the limits of Gini's approach? For this, it is sufficient to decompose (see Figures 1,2) Gini's main abduction, and compare it to a syllogistic representation of the stable population model proposed about at the same time by Lotka (Sharpe and Lotka, 1911). If Gini's minor premise ("if populations behave as organisms") of the organicist abduction is worth of the highest consideration, we remain discouraged by the commonplace, not evidence-based, formulation of his major premise, mostly resting on the authority of ancient historians or on a few, erratically collected, contemporary examples, as Reuter pointed out. Therefore it is worthwhile to consider other syllogisms used by Gini in the CTP, which, although less central in Gini's scheme, are much more revealing of Gini's scientific awareness.

Figure 1 – *Abductive structure of Lotka's stable population model (Sharpe and Lotka, 1911) and its application to US demographic trend in 1920-1930 (Dublin and Lotka, 1925)*

MINOR PREMISE: HYPOTHETICAL FORMULATION OF A RULE

(ANTECEDENT/IF) THE MODEL → (CONSEQUENT/THEN): THE GROWTH PATH

(Antecedent/if) the Model	(Consequent/then): the Growth Path
If the age patterns of fertility and mortality of remain constant for a sufficiently long period of time	then the population converges to a long term growth path with an "intrinsic rate of natural development", invariant and ergodic (i.e. independent by the initial structure), different from the current rate of natural increase.

MAJOR PREMISE: RESULT

The U.S. intrinsic rate estimated in 1911 correctly predicts demographic stagnation in the 1930s

CONCLUSION

The intrinsic rate (unlike the rate of natural increase, which depends on both processes and structure), is a good predictor of future dynamics

COUNTER-INTUITIVE PROPERTIES

a) Also the long-term age structure is ergodic, i.e. determined by process only and not by the initial structure.
b)The effect of initial structure on growth path reduces to a multiplicative *momentum* (Fisher's repr.value)

Figure 2 – *The structure of Gini's main abduction in the CTP (Gini, 1912, 1927)*

MINOR PREMISE: HYPOTHETICAL FORMULATION OF A RULE

(ANTECEDENT/IF) THE MODEL → (CONSEQUENT/THEN): THE GROWTH PATH

(Antecedent/if) the Model	(Consequent/then): the Growth Path
If human populations follow the organismic rules i.e. behave as a system of interdependent factors endowed with self-preservation, self-regulation.	then populations will be characterised by lyfe-cicle parabolas similar to those observed in biological organisms

MAJOR PREMISE: RESULT

Populations (and their subgroups including lineages, social classes etc) observed by the ancient historians of the ancient time exhibit life-cycles much alike those of organisms

CONCLUSION

Conjecturing a model of interdependencies (among species or factors*) is reasonable for human populations.

COUNTER-INTUITIVE PROPERTIES

a) In case of interdependence among factors, the model explains Dumont's "dépopulation" theory;
b)) In case of interdependence among species, the model explains Pareto's "élites' circulation" theory.

Note: * See the subsequent discussion in section 4.

Among these syllogisms we focus on the one where Gini (1929) predicted, by using the net reproduction rate, the long-term decline in the birth rate of European population despite the current rate of natural increase was still largely positive. This argument has brought Cassata (2007, p. 24) to interpret the origin of the CTP as a combination of the Western Sunset syndrome (Spengler, 1918) with "the use of a coarse statistical tool":

"The nightmare of the Western Sunset seemed to be scientifically endorsed, and the forecast served to increase concerns. What translated a slight, temporary decline in births into an imminent, apocalyptic demographic crisis was a sort of optical deformation, stemming from a mistaken underlying hypothesis: assuming that fertility levels at the date in question remained constant throughout the fecund life span of a cohort of women, Kuczynski's index overlapped a fictitious cohort on an actual cohort, (..). Fruit of a misunderstanding, amplified by the use of a coarse statistical tool, the nightmare of 'empty nests' ended up legitimising the adoption throughout Europe of pro-natalist policies.".

Based on our previous arguments about the use of abduction in the early CTP, we believe that an alternative interpretation to Cassata's one is possible. Surely the net reproduction rate (universally known as R_0) was crudely popularised by Kuczynski (1932), giving the impression of a "coarse statistical tool". Nonetheless, since 1930 Gini leant his developments not on Kuczynski's popularization but on the robust Dublin and Lotka (1925) seminal work on "The true rate of natural increase" (notably, Dublin and Lotka were jointly invited by Gini to publish in Metron an upgrade of their work). Now, while R_0 responds to the "Ginian" need for mathematics to be "as simple as possible", is far from being a coarse tool. Instead it is the key parameter of a well-developed mathematical theory (Diekmann *et al.*, 1990). In particular, in population mathematics it represents an explicitly calculable ("extrinsic") measure of the long-term - i.e. "latent" - evolution of the population, of which Lotka's intrinsic rate r represents the "intrinsic" measure. As such the use of R_0 requires caution, keeping in mind the intrinsic nature of a mathematical model as an "if-then" logical argument, hinging upon a counter-factual premise, i.e. the constancy of a frame (in the stable model this is given by the time-constancy age-specific curves of fertility and survival).

Therefore, deducing the coarseness of the use Gini made of R_0 to forecast the future birth rate, from the change of the fertility parameters evidenced in the 1950s studies, based on the analysis by generations, would ignore the correct "if-then" use made by Gini:

if births and deaths were to continue at the current rate (minor premise), 1000 women born in 1927 would give birth to only 910 daughters in France, only 830 in Germany… (1930, p. 53)".

To our opinion this is a conscious implementation on Gini's part of an abductive argument, based on Lotka's stable population model which in turn has (Figure 1) all those properties (metaphoric translation, counter-factuality, counter-intuitive properties) which Peirce attributed to abductive syllogism.

Once more, we cannot forget that good abductions need robust "models": internally and externally, comparing a set of alternative conjectures (i.e. a set of alternative models), to select the one most 'consistent' with reality. What, in Merton's opinion, was a strength in Gini's times, was absolutely unsatisfactory for Reuter (1931), who challenged both the lack of rigour (“internal consistency”) and the underestimation of the empirical verification step of the conjectural moment (“external consistency”).

As for “internal consistency”, it is a matter of fact that at Gini’s time, the largest part of fine innovators in human sciences, i.e. those who attempted to explore ‘mathematically’ (i.e. logically) “latent” structures, used loose arguments. When Pareto (whose Manual of Political Economy was known to Gini in 1912) stated (in 1946) that his purpose in the 1916 Sociology Treatise was to “search for experimental reality by applying to the social sciences some methods which carried out their proof in physics, chemistry and astronomy”, he was in line with the “method of models” of Gini’s CTP. Yet neither text contained a single equation!

But what about the “external consistency”, i.e. the comparison with the facts? No doubt, in the CTP the model was verified or disproved not by statistical means but by references to historic macro-periods or national macro-examples, at times lost in early historiography, or by recourse to various statistical sources which were not always pertinent. Yet it is also true that in 1912, when Gini wrote “I fattori demografici”, only very few lucid scientific minds were able to construct their empirical data and cross them in a search for ‘concomitant variations’ with which, according to the fourth canon of J.S. Mill (1884), to verify or reject their conjectures. These exceptions included Émile Durkheim in *Suicide* (1897) (where he imported data from French and Italian psychiatrists), or Francis Galton in Natural Inheritance (1894) (where he constructed quasi-experimental data on the statures of fathers and sons) or even earlier John Snow (who, to explain the different geographical incidence of cholera in 1854, mapped London into hundreds of blocks and found a significant relation between the raging of the disease and the company supplying drinking water). Many influential scientists, as Arsène Dumont (1890), purely relied on historical sources, exactly like Gini.

The same cannot be said for Gini, perhaps due to the fact, mentioned above, that he produced theories which were always and only universal, or perhaps due to his failure to realise that in the social sciences “for some problems there may exist an infinite number of conjuncts” (Wunsch, 1988).

4. TWO WAYS TO ENDOGENISE REPRODUCTIVITY IN A SET OF INTERDEPENDENCES

The importance of Gini in 20th century science is not limited to the anticipatory use of abductive syllogism. Perhaps more importantly, Gini formulated, along the lines of the emerging Mathematical Ecology, models interconnecting more than one factor (or force), or more than one species (or subpopulation), of a single system which may reveal non-manifest dynamics to those analysing factors (or species) one at a time. Let us therefore revisit the relevant passages of the CTP, by overlaying the Gini's texts quoted in the Introduction, in order to better understand how the young Gini worked. In his choice of working by organicist analogy (the reference to Pearl and Reed's experiment is revealing), the heuristic nature of an organism wa not just evocative. It was a well-structured concept, identified by a bundle of interdependences between 'forces' or 'bodies' which together define a Gestalt, that of "organism", understood as "the set of mutually bound bodies, endowed with self-preservation" (Gini, 1924). It was the intrinsic structure of the model of interdependences combined with the (counter-factual) constancy of the coefficients of interdependence - systematically recalled in "the constant drive of inner forces" of which Gini spoke in 1915 - that led to non-evident or "latent" results. We note that this process was to repeat itself ten years later, when Lotka (1925) and Volterra (1927), separately developing their prey-predator models, would not only launch Mathematical Ecology, but would also endow the applied and social sciences with one of the most extraordinary interpretative metaphors ever produced.

There is a novelty, therefore, in these passages of the young Gini: fertility was not explained only by factors external to it, but it was analysed within a fully endogenous framework given by an "organicist model" of interdependences. This scientific programme was implemented along a double track, both consistent with the organicist analogy. In 1915 Gini worked on the interdependences between several "species" (low and high classes, country-folk and town-dwellers, populations or nations interacting through migratory flows). On the other hand, in 1924 Gini worked on interdependences between opposing and complementary forces, inner in a system (or species), whose interaction triggers a cyclical dynamics of the system (or species) as a whole.

Gini's point of reference for interdependence between species was Pareto's theory of élites circulation, with whom he establisheed close scientific relations. For interdependence between forces Gini's main reference were *Spencer's Principles of Biology* (1899). Just as *Individuation* and *Genesis* are in Spencer (1899) the two opposing, inversely correlated, forces which triggers a *cyclical moving equilibrium*:

> "(We'll) prove the inverse variation between Genesis and Individuation (..). A greater demand for Individuation, be it a demand caused by some spontaneous variation or by an adaptive increase of structure and function, inevitably diminishes the supply of Genesis (..), conversely, survival of the fittest, acting on a species that has, by spontaneous variation or otherwise, become more prolific, cannot again raise its lowered Individuation, so long as everything else continues constant" (Spencer, 1899, pp. 461-463).

[4] Gini's long-term "structure" is produced only by the classes which are now 'low'. Similarly, Lotka's ergodic structure depends solely upon the fertile age classes.

Similarly to Spencer, Gini identifies two basic inner factors for the voluntary limitation of births. In 1945 Gini will define them as follows:

> "a higher propensity to reflect and to act logically, deriving from the increasing importance of rationality in social life (and) a weakening of the instincts which determines a growing inadaptability to circumstances unfavourable to reproduction" (Gini, 1945, p.92-94).

One cannot but see an anticipatory role played by Gini in the strand of models of interdependences between forces, in which in the following decades there would be a number of contributions. These include, just to list some, the generalisation of the logistics curve as the outcome of interaction between Malthusian and Smithian forces[5] (Amoroso, 1929); Goodwin growth-cycle model (1967) based on the metaphorical transposition of Lotka-Volterra prey-predator interaction to explain in Marxian terms the capitalist cycle through the conflict between profit and labour; Wrigley (1969) endogenous explanation of Ancien Régime fertility as the outcome of the homeostatic interplay among demo-economic and social forces; the explanation of post-transitional changes in fertility choices as the outcome of the interaction between opposing logics of identity and interest (Micheli 1985; 1987); and the Lotka-Volterra representation of Malthus' principle of population (von Tunzelmann, 1986).

As illustrated by the previous examples, the idea of explaining waves in fertility and reproduction *lato sensu* by the interaction between two complementary and opposing interdependent principles, has become a locus classicus of the history of population theory, continually adapted to respond to new scientific questions. According to the thinking of the social sciences in the 1960s, bridging "the systems of factors or forces" (Gini, 1912) and "the networks of sub-populations" (Gini, 1915) corresponds with a key category, that of structure: "the whole set of interdependent elements" (Boudon, 1969), which may be expressed as a "system structure" in the case of interdependences between forces, or as a "network structure", in the case of interdependences between species or actors. The same model – that is, the same structure - can be arrived at from distinct influential metaphysics. In such cases, there may surface, abductively, identical latent properties– intrinsic and non-evident - of the structure itself. We believe that this is not just a trivial corollary of the Gini's use of a set of interdependencies to explain the dynamics of population. Therefore, on this point as well, Gini's intuition was well ahead of its time, in spite of his glaring indifference toward empirical evidence. After all, as Burch (2012, p. 4) firmly highlights:

[5] Luigi Amoroso derived a simple extension of the logistic equation from a set of interdependent relations describing the interplay between two forces, namely the Malthusian force (that he also calls "Orthesian") and the "Smithian" force, where the latter expresses the relationship between "subsistences" and population.

> "logical positivism and behaviorist psychology have confined scientific work to 'ob-servables,' forgetting the fact that many of the most important scientific theories deal with things that have never been seen, but are 'known' only through their effects".

5. LIMITS AND LEGACIES OF THE CTP: REVERSING THE SIGN OF THE BALANCE

We have revisited Gini's CTP starting from its early versions, in order to focus on those parts of Gini's scientific thinking that were developed prior to his political and ideological engagement. This might be considered still insufficient by all those who instead stress the continuity between early Gini's thought and his subsequent ideological involvement. Indeed, Gini's involvement with Fascism was rather consequent than subsequent to his early ideas. As Anna Treves (2001, p. 228) wittily highlights, "it was Gini's conviction of the absolute supremacy of his scientific thought that made him definitely "fascist", because in this way he could interpret the fascist movement as "Ginian". From this standpoint it is not at all our aim to conceal, by a merely rhetorical use of techniques for evaluating the empirical consistency of a model, the ideological role of Gini - in the Twenties - as a strategic scientist for fascism (Cassata, 2007, p. 15).

Given this necessary premise, much has been said about the limitations of the CTP, from the inadequate role attached to empirical verification of conjectures to the drive to construct universal theories, both consistent with the spirit of the time and consonant with the personality of the scientist. Gini's claim to construct universal theories - the Comtian legacy of a "total science of society" sociology - caused him to shelve his theoretical heritage only a few years later, when the universalist approach reached its terminus (Cassata, 2007). And his dominant character prevented him from taking on board the suggestion of his young admirer Merton (who in 1936b, p. 894) places Gini firmly among the "giants" of the social sciences) and shifting with scientific humility from 'grand theories' to 'middle-range theories' that

> "involve abstractions, of course, but they are close enough to observed data to be incorporated in propositions that permit empirical testing" (Merton 1949, p. 39).

Despite these limitations, some aspects of Gini's contribution are worth being adequately appreciated. In revisiting the CTP we discerned at least two anticipatory hubs of the subsequent scientific thinking of the social sciences.

First of all, the pattern of argumentation recurrent in the CTP, which Gini will call (1959) the "method of models", seems to anticipate the rediscovery of the abductive syllogism (from Peirce to Hanson). Obviously, Gini's construction (and the related application) of abductive reasoning was still frail. His failure to realize that the same real data can be described by more than one conjectural model challenges the rigor and effectiveness of his use of abduction. Nonetheless we believe that Gini's intuition about abduction is firmly established.

Reasoning "by models" then led Gini - linking him with scientists of the Golden Age of Theoretical Ecology - to interconnect reciprocally "external" factors or species (two distinct Gestalt therefore) in order to predict at least potentially cyclical results. On the one hand, through a "scheme" of vital interdependences among "sub-populations" or "species", able to reproduce, albeit in its narrative statements, Lotka and Volterra's patterns of biological interactions, the meta-populations of demographics, and also models for the dynamics of social structures. On the other, through a "scheme" of interdependences among factors or forces, which was to find its more complete expression in the wage-profit model of Goodwin (1967). Gini's ability to read the dynamics of fertility along both distinct lines (forces and species) made him the - unacknowledged - forerunner of the bridging role of the fundamental concept of "structure", which was to become in the 1950s a key focus of scientific debate in the human sciences.

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References

AMOROSO L. (1929), "L'equazione differenziale del movimento della popolazione", *Rivista Italiana di Statistica*, 1, 151-157.

BOUDON R. (1969), *A quoi sert la notion de structure?* Paris, Gallimard.

BURCH T.K. (2012), "Comment on Micheli's Gestalt Switch in the Idea of Context", *Sociologica*, 3, 1-6.

CASSATA F. (2007), *Il fascismo razionale. Corrado Gini tra scienza e politica*. Rome, Carocci.

DAGUM C. (1987), "Corrado Gini", *The New Palgrave Dictionary of Economics*, 1987, vol. 2, p. 529.

DIEKMANN O., HEESTERBEEK J.A., METZ J.J. (1990) "On the definition and computation of the Basic Reproduction Ratio", *J. Math Biology*, 28, 365-82.

DUBLIN L., LOTKA A. (1925), "The true rate of natural increase as exemplified by the population of the United States,1920", *Journal of the American Statistical Association*, 20 (151), 305-339.

DUBLIN L., LOTKA A. (1930), "The true rate of natural increase as exemplified by the population of the United States. Revision on the basis of recent data", *Metron*, 8, 107-119.

DUMONT A. (1890), *Dépopulation et civilisation. Etude démographique.* Paris, Lecrosnier et Babé.

DURKHEIM E. (1897), *Le suicide*. Paris, Alcan.

GALTON F. (1894), *Natural Inheritance.* London, Macmillan.

GARDING L. (1977), *Encounter with Mathematics*, Berlin, Springer.

GINI C. (1912), *I fattori demografici nell'evoluzione delle nazioni*. Torino, Flli Bocca.

GINI C. (1915), "Fattori latenti della guerra", *Rivista Italiana di Sociologia*, 19,1-51.

GINI C. (1924), *Patologia economica*. Milano, Tenconi.

GINI C. (1930), *Nascita evoluzione e morte delle nazioni. La teoria ciclica della popolazione e i vari sistemi di politica demografica*. Roma, Libreria del Littorio.

GINI C. (1931), *Le basi scientifiche della politica della popolazione.* Catania, Studio editoriale moderno.

GINI C. (1935), *Prime linee di patologia economica* (4th edition), Milano, Giuffré.

GINI C. (1945), *Teorie della popolazione*. Roma, Castellani.

GINI C. (1952), *Patologia economica*. Torino, Utet.

GINI C. (1959), "Mathematics in Statistics", *Metron*, 19 (3-4): 3-9.

GIORGI G.M. (2011), "Corrado Gini: the man and the scientist", *Metron*, 69(1), 1-28.

GOODWIN R. (1967), "A Growth Cycle", in Feinstein C.H. (ed), *Socialism, Capitalism and Economic Growth*, , Cambridge, Cambridge University Press, 54-58.

HANSON N.R. (1958), *Patterns of Discovery: An Inquiry into the Conceptual Foundations of Science*. Cambridge, Cambridge University Press.

KOHLER W.H. (1928), *Gestalt Psychology*. New York, H. Liveright.

KUCZYNSKI R. (1932), *Fertility and Reproduction*, New York, Falcon Press.

KUHN T.S. (1962), *The Structure of Scientific Revolutions*, Chicago, University of Chicago Press.

LOTKA A.J. (1925), *Elements of Physical Biology*, Williams & Wilkins Company, Baltimore.

MANFREDI P., MICHELI G.A. (1994), "Ecologia matematica e matematica delle popolazioni", in GUERRAGGIO A. *et al.* (eds.), *La matematica italiana dopo l'Unità. Gli anni tra le due guerre mondiali*, Marcos y Marcos, Milano, 671-733.

MERTON R.K. (1936a), "Review of "Prime linee di patologia economica" by Corrado Gini", *American Sociological Review*, 1(2): 324-25.

MERTON R.K. (1936b), "The Unanticipated Consequences of purposive social action", *American Sociological Review*, 1 (6): 894-904.

MERTON R.K. (1949), *On Theoretical Sociology*, New York, The Free Press.

MICHELI G.A. (1985), "Identity and time as fertility determinants", in Contribution of Italian Scholars, Iussp XX General Conference, Firenze, 143-158.

MICHELI G.A. (1987), "Exploring theoretical frameworks for the analysis of demographic fluctuation", *European Journal of Population*, 3, 177-201.

MICHELI G.A. (1993), "Modèles: logique, sémantique, cycles de vie", *IUSSP Conference Proceedings*, Montréal, vol. III, 361-376.

MICHELI G.A. (2012), "On understanding human contextualized action: two shortcuts to be strongly advised against", *Socio-logica. Italian Journal of Sociology on line*, 3.

MILL J.S. (1884), *System of Logic Ratiocinative and Inductive*, London, Longmans, Green & Co.

PAOLUCCI C. (2012), "A Few Remarks on Musement and Abduction." *Socio-logica. Italian Journal of Sociology on line*, 2.

PARETO V. (1906), *Manuale di economia politica con introduzione alla scienza sociale*, Milano, Società editrice Libraria.

PARETO V. (1916), *Trattato di sociologia generale*, Florence, Barbera.

PARETO V. (1946), *Scritti sociologici,* Torino, Utet.

PEARL R., REED L.J. (1923), "On the Mathematical Theory of Population Growth", *Metron*, 3 (1), 6-19.

PEIRCE C.S. (1908), "Neglected Argument for the Reality of God", in *Collected Papers of C.S.Peirce*, vol. VI, Cambridge, MA, Harvard University Press, 1974.

REUTER E.B. (1931), Book Reviews, Population, by Corrado Gini *et al.*, Harris Foundation Lecture, Chicago U.P., *American Journal of Sociology*, 36(4), 646-649.

ROZEBOOM W.W. (1997), "Good science is Abductive, not Hypothetico-Deductive", in HARLOW L. *et al.*, *What if there were no significance tests?*, New Jersey, Erlbaum, 366-391.

SALAS E. (2009), "Abduction and the Origin of 'Musement'. Peirce's "Neglected Argument on the Reality of God"", *International Philosophical Quarterly*, 49(4): 459-471.

SHARPE F.R., LOTKA A.J. (1911), "A problem in age distribution", *Philosophical Magazine*, 21, 435-438.

SPENCER H. (1899), *The Principles of Biology*, London, Williams & Norgate.

SPENGLER O. (1918), *Der Untergang des Abendlandes*, Wien (It. Transl. Parma, 2002).

SWEDBERG R. (2012) "On Charles S. Peirce's Lecture 'How to Theorize' (1903)", *Sociologica*, 2, 1-27.

SOROKIN P. (1937), *Social and Cultural Dynamics*, Cincinnati, American Book Company.

TREVES A. (2001), *Le nascite e la politica nell'Italia del Novecento*, Milano, Led.

VOLTERRA V. (1906), "Sui tentativi di applicazione delle matematiche alle scienze biologiche e sociali", *Giornale degli Economisti*, Ser 2, 23, 436-458

VOLTERRA V. (1927), "Variazioni e fluttuazioni nel numero di specie animali conviventi", *Regio Comitato Talassemico Italiano*, 81, 1-142.

VOLTERRA V. (1934), "Remarques sur la note de Mr. Regnier and Mlle Lambin", *Comptes Rendus de l'Academie de Science*, 199, 1684-1686.

VON TUNZELMANN G.N. (1986), Malthus' Total Population System: a Dynamic Reinterpretation, in COLEMAN D., SCHOFIELD R. (eds.), *The State of Population Theory*, Basil Blackwell, Oxford, 65-130.

WIENER N. (1950), *The Human Use of Human Beings*, Boston, Houghton Mifflin.

WRIGLEY E.A. (1969), *Population and History*. London, Weidenfeld and Nicolson.

WUNSCH G. (1988), *Causal Theory and Causal Modeling*. Leuven, Leuven University Press.

Appendix
The population-dynamic model of the CTP in a nutshell

As pointed out in the main text, readers of the Cyclical Theory of Population (CTP) will hardly find any mathematical equation in Gini's exposition. However, although exposed in fully qualitative terms and sometimes confusing outputs with the underlying dynamic mechanisms, the CTP represents a first attempt to explain population reproduction dynamics as an endogenous outcome of a complex interdependent system. In this appendix we support our thoughts of section 4 by concisely summarising the features of Gini's «grand scheme» in an attempt to highlight its structure of interdependent model. In doing so we mainly follow Gini's Chicago 1929 conference.

Briefly, Gini's scheme is a multi-scale formulation endogenously linking the top scale (population) with the bottom scale (the individual) by an appropriate meso-scale, represented by the social structure. The corresponding building blocks are (a) a generalised density-dependent (DD) scheme for the growth of single populations (including also its social groups, family lines, etc.), reflecting the organicist life-cycle "parabola", as described by the sequence youth-maturity-senescence; (b) a scheme for social mobility between different social groups under heterogeneous fertility, taken as the ultimate determinant of those density-dependent factors that shape the organicist lifecycle; (c) a nonlinear multiregional scheme aimed to capture the interactive dynamics between the lifecycles of different populations, where the non-physiological migration flows, i.e. those leading to the collapse of a population and to the "cyclical switches between civilizations", depend on the activation of suitable thresholds. These blocks are pictorially represented in Figs. A1-A2.

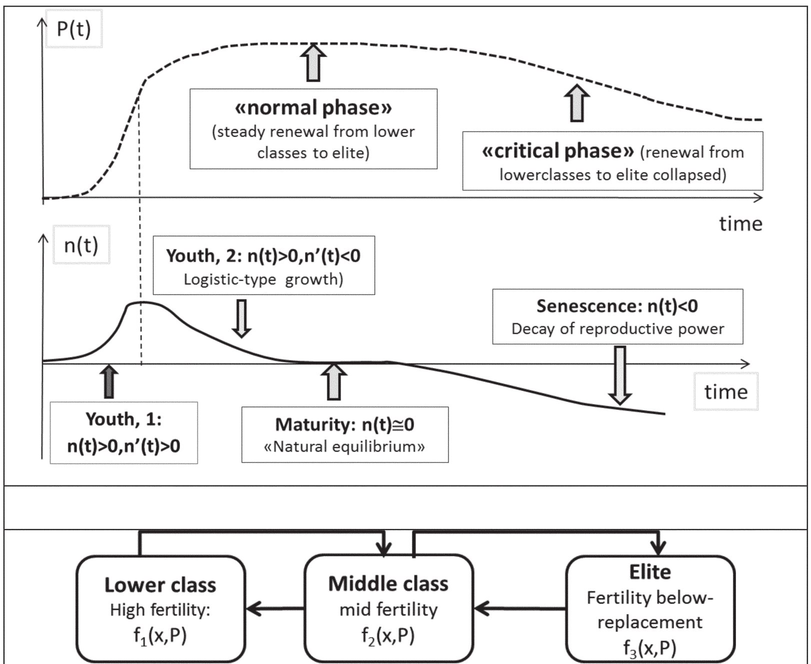
The generalised DD scheme for the organicist population life-cycle "parabola" in Gini's words - is illustrated in the top panel in Fig. A1, respectively reporting the hypothesised temporal trend in the population growth rate, n(t), and the total population size, P(t). The two graphs sharply differ from the idea of DD dynamics prevailing at the time, mostly based on Pearl's work on logistic curves (Pearl and Reed 1920) and postulating, along Verhulst's original form, an ever decreasing rate of growth. In particular the accelerated growth (n'(t) > 0) initially observed in the youth phase (denoted as "Youth 1" in Fig. A1) is motivated by the hereditary nature of prolificiness as an individual characteristic. Here Gini's scheme anticipates all attempts to capture the capability of human populations to grow faster than exponential. In this particular phase the hereditary mechanism increases the proportion or "more prolific" individuals, and therefore the chance, under random encounters, of meeting them, thereby raising the average population prolificiness. During this phase international out-migration allows to attenuate population pressure. However this effect will eventually come to an end, and the population will first switch to a growth phase at declining rate (denoted as "Youth 2" in Fig. A1), as a prelude to the achievement of a quasi-equilibrium phase, representing population maturity. This phase, possibly characterised by oscillations about a roughly constant trend eventually comes to an end, and the senescent phase, characterised by decreasing growth rates, emerges as a consequence of the "slow exhaustion of reproductive power"[6].

This interplay between various DD effects is however not just postulated but it is instead endogenously linked to an intermediate scale, namely the interactive social mobility dynamics between the population "social classes" (Fig.

[6] The first attempt to supply a simple mathematical formulation for a mechanism similar to Gini's population parabola was done by Vito Volterra in 1934.

A1, bottom panel; this is a main Gini's example of what we termed "inter-dependence between sub-populations"). The engine is represented by the heterogeneous fertility of the different social groups, whereby lower classes have higher fertility and higher classes are possibly below-replacement. It is the higher fertility of lower classes, jointly with the mechanism of social mobility, that allows to counterweight the insufficient fertility of the elites, thereby ensuring the population to keep its equilibrium size. Gini terms this phase, where the renewal ensured by the lower classes allows to constantly sustain the population size, the "normal phase" of the population parabola. This phase ends when the renewal allowed by higher fertility lower classes collapses, pushing the population into its "critical", or senescent phase.

Figure A1 – *Gini's "organismic" life-cycle «parabola» of "single" populations and its determinants. Top panel: temporal trend of the population growth rate n(t), and of the corresponding total population size P(t), acknowledging the three phases of youth, maturity, and senescence. Bottom panel: flow-chart of the underlying social mobility model. Quantities fi(x,P) represent the density dependent age and social class-specific fertility rates, Pi(x,t) the population aged x in social class i (i=1,2,3), and B(t) the total births at time t*



$$B(t)=\sum_{i=1}^{3}\int_{\alpha}^{\beta} f_i(x,P(t))P_i(x,t)dx\ ,\quad P(t)=\sum_{i=1}^{3}\int_{\alpha}^{\beta} P_i(x,t)dx$$

The critical phase, where the traditional incapability of the elites to sustain the population is accelerated by the intervened crisis of high fertility groups, would lead to population extinction in a closed system. In an open system this might however activate (provided some conditions hold) the "pull-type" in-migration threshold. Immigration flows have the potential to stop population decline, and therefore to generate a new wave of population growth (Fig. A2). Obviously the resulting population might then have experienced ethnic changes, and in general a "switch between civilisations".

Figure A2 – *The (multistate) migration link between the organicist life-cycles of two different populations A, B*