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Some notes on population history, the demographic transition and the demographic future of the world

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Executive summary

A short summary of human population history, a critical analysis of available empirical evidence and an interpretation of data free of reverence toward the dominant theories bring to the conclusion that up to now the human population has experienced only two demographic regimes. The first was characterized by high rates of mortality and fertility. Its main characteristic was that man did not have the capability to control fertility and intervene on mortality so that periods of high demographic growth were followed by periods of pronounced demographic decline. In spite of this, at the end, the demographic history of men has been a success story. It is then argued that around 1850 an unprecedented demographic revolution was ignited by extraordinary advancements in medicine, chemistry and biology, as well as the development of new laboratory tools and techniques that opened the way to the introduction of powerful vaccines. This allowed defeating the most dangerous infectious diseases and waging a successful war against premature death. The final result was that the economically more advanced countries reached a new demographic regime, the modern regime, characterized by low fertility and low mortality rates. The fundamental characteristic of the modern regime is the capability of men to choose and determine his reproductive behavior and to control more and more the causes of death. According to present empirical evidence, the modern regime is not characterized by a demographic equilibrium, but by vastly spread situations of negative natural growth. Finally the paper argues that, in spite of the fact that deaths take place in the natural and chronological order, the modern regime is not necessarily more efficient than the natural regime. The main reason is that in this new demographic situation economic growth brings to demographic disequilibrium and the different historical moments in which the demographic "transition" has started in different countries is creating the preconditions for migration flows of unprecedented size. A paragraph of the paper is also devoted to a revisit and formalization of Carlo Cipolla hypothesis on energy and demographic growth and to the analysis of its validity both in the past and today.

Key words: demography, demographic history, economic transition, demographic transition

JEL: J10, J11

Population history: Past, present and future

> Dalla lotta tra freni repressivi e preventivi, tra comportamento incosciente e comportamento virtuoso, tra l'essere vittime della costrizione e della necessita o attori del la scelta, dipende la sorte del la popolazione
>
> M. Livi Bacci, Storia Minima della popolazione, pg. 104

> Not only did evolution happen: it eventually led to beings capable of comprehending the process, and even of comprehending the process by which they comprehend it.
>
> Richard Dawkins, The Ancestor's Tale. A Pilgrimage to the dawn of life, p. 628

> While observing the barbarous inhabitants of Tierra del Fuego, it struck me that the possession of some property, a fixed abode, and the union of many families under a chief, were the indispensable requisites for civilization. Such habits almost necessitate the cultivation of the ground; and the first steps would probably result from some such accident as the seeds of a fruit tree falling on a heap of refuse, and producing some unusually fine variety. The problem, however, of the first advance of savages toward civilization is at present much too difficult to be solved.
>
> Charles Darwin, Descent of Man, 1874

The long run demographic equilibrium: theories and empirical evidence

According to the prevailing interpretation, until the beginning of the XVIII century the growth of human population has been extremely low, with long-run values close to zero. For example, De Santis writes: "...It should be noted that in the last 12,000 years the average rate of growth (of world population) has been basically equal to zero (0.6 per thousand). It is true, there have been turbulent phases and, especially in the most recent period after the industrial revolution, population seemed to explode. However, the last data show a slow-down of the growth rate for the majority of the world population and seem to suggest that this phase of extraordinary growth, a relatively short parenthesis in the millennial history of men, is close to its end. Therefore, available data do not contradict the theory that human population is normally in a situation of "zero growth": displacements from this condition are possible only for relatively short periods, which represent transitions between two

different phases of equilibrium."[1]

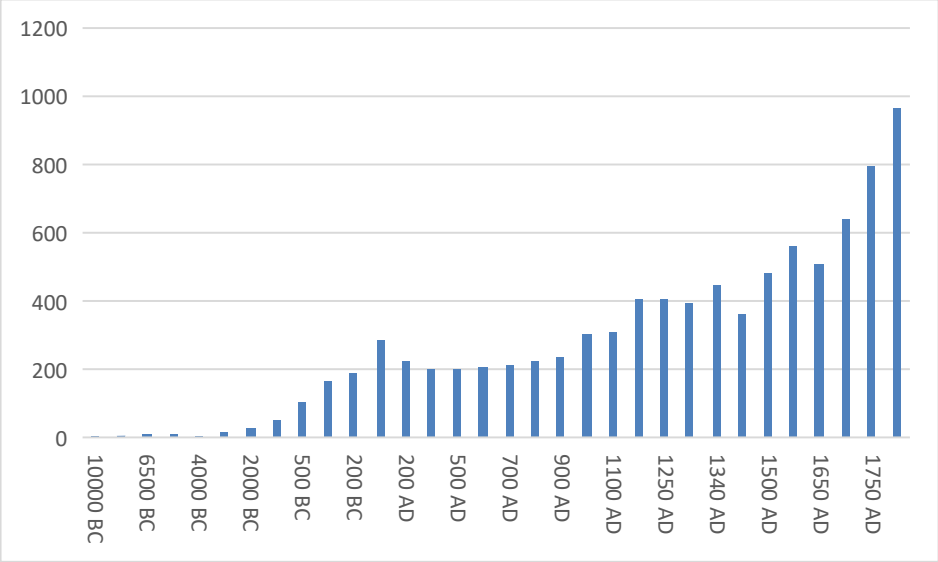
It seems to me that, on the contrary, the history of Homo sapiens is the history of a great demographic success. Biologists have identified two strategies of survival and reproduction[2]: strategy *r* and strategy *K*.

Strategy *r* is adopted in unstable or unpredictable environments. The ability to reproduce quickly is crucial. Traits that are thought to be characteristic of r-selection include: high fecundity, small body size, early maturity onset, short generation time, and the ability to disperse off-springs widely. Organisms with r-selected traits range from bacteria and diatoms, through insects and weeds, to various semelparous cephalopods and mammals, especially small rodents.

Strategy K is adopted by organisms that colonize relatively stable environments, crowded of competitors, predators and parasites. The K survival strategy is based on great parental investments in time and energy to raise a small number of off-springs. Strategy K is adopted by large organism (mainly mammals of medium-large dimensions) and by some species of birds, with long life spans and long intervals between generations and births. It is the case of the human species.

According to available estimates, human population has increased from a few hundreds of thousands in the period in which man manifested its first representational capacities to around 6 million in 10,000 B.C. and then to 770 million in 1750[3]. It seems therefore evident that also in the first two demographic phases normally defined by population historians - the hunting and gathering phase and the agricultural phase - the demographic success of the human species has been much bigger than that of the other species which adopt the K strategy, and especially of our closest relatives, chimpanzees and gorillas.

Graph 1 - World population (million); 10,000 BC, 1,800 AD



I would therefore maintain that *the equilibrium hypothesis does not represent neither an empirical deduction, nor a working hypothesis, but an eye binder that social sciences have borrowed from physical sciences*. Although not totally accepted, this

[1] Gustavo De Santis, 1997; p. 33; (author's translation).
[2] See M. Livi Bacci, Storia minima della popolazione del mondo, Il Mulino, 2002; pag. 10.
[3] 500 million lived in Asia, 111 in Europe, 35 in the Ex-Soviet Union, 104 in Africa, 18 in America and 3 in Oceania.

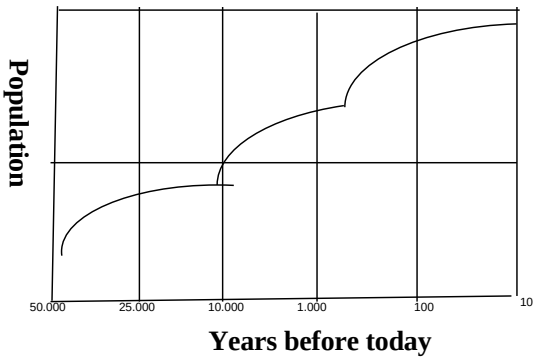
assumption pervades demographic analysis. In Livi Bacci's words: "It is generally maintained that the human species has self-regulating mechanisms that allow a fast research of the equilibrium between the number of individuals and the available resources; however, this is only partially true because these mechanisms, even when they intervene, are far from perfect and their effectiveness varies from population to population and from one period to another. As a sure proof of the failure of such regulatory mechanisms we should remember that some populations have completely disappeared".[4]

In order to express a more informed opinion, let's briefly consider the dominant theories on population history.

3 Demographic states and demographic transitions

Population's historians divide the evolution of the human race in three phases that correspond to different levels of development: the hunting and gathering phase, the agricultural phase, and the industrial and post-industrial phase. Demographic theory has paid special attention to the transition from the second to the third phase, but has recently shown a certain interest in the transition from the first to the second phase[5]. The shared opinion is that each cycle is characterized by a demographic rate of growth larger than that of the previous one, but all of them exhibit decreasing returns. Graph 1, borrowed from Livi Bacci[6], synthesizes this hypothesis.

Graph 2 - Evolution of human population



The great take-off

Archaeological evidence shows that at least between 100,000 and 30,000 B.C. two human species (the Neanderthals and Homo sapiens sapiens) co-existed in Europe and in Western Asia[7]. Until around 50,000 years ago the tools produced by both species,

[4] M. Livi Bacci op.cit; p. 8; (author's translation).

[5] The concept of a Neolithic demographic transition has been proposed by Livi-Bacci and independently in by Bocquet-Appel in 2002 .

[6] M. Livi Bacci op. cit.; p.40; in its turn Livi Bacci refers to E.S. Deevey Junior,1960; pp. 49-55.

[7] The presence of Neanderthals, our closet prehistoric relatives, is attested by numerous sites located mainly in Europe, but also as south as Iraq. It is estimated that even at the height of their occupation of Western Europe their total number never exceeded 15.000. The Neanderthals were not only characterized by a massive body and bulging brow ridge, but also by a brain with a volume slightly larger than our own. The analysis of mitochondrial DNA has

although showing some progress with respect to those of previous humans, were extremely rudimentary. The cultural level of both Neanderthals and Homo sapiens sapiens remained extremely limited, with no records of complex technology, rituals, religion and art. With regard to the Neanderthals the situation did not change until their disappearance that is dated at around 30,000 B.C. On the contrary, starting around 50,000 B.C., Homo sapiens sapiens was the actor of what has been rightly defined by numerous archaeologists a cultural explosion.

The first important signs are related to technological innovations that posit themselves at a totally different level of the previous ones. Standardized stone instruments make their appearance in the Middle East and then in South-Eastern Europe. The skeletons found together with these tools are extremely similar to ours and are attributed to the Cro-Magnon culture. Jarred Diamond writes: "Thereafter, the garbage preserved at archaeological sites rapidly becomes more and more interesting and leaves no doubt we are dealing with biologically and behaviorally modern humans"[8].

New materials, such as bones and ivory, were used for the first time and we find instruments (needles, awls, engraving tools) aimed to easily recognizable specific goals and multi-piece tools. Man acquires a new proficiency at hunting, both developing new complex strategies -that seems to be based upon anthropomorphic thinking- and inventing new types of hunting weapons, like the spear-thrower and the harpoon, new types of stone projectile points specific for different types of games and eventually the bow and the arrow, and facilities for trapping animals. Moreover, there is evidence that the weapons were constantly modified in response to changes in environmental conditions.

Fishing is documented for the first time and also in this case the instruments are immediately rather sophisticated (hooks and harpoons), while the invention of the rope allows the construction of lines and nets. The man of Cro-Magnon builds houses and saws clothes; this made possible his survival in weather conditions that the more robust Neanderthals had not been able to cope with.

This phase of creative explosion reaches its apex with the first fascinating artistic production (paintings, sculptures and music), while the jewels found in numerous tombs not only testify the presence of aesthetic taste, but also of a social stratification of which the jewels are the communication instruments.

In the same period the human race expanded to the yet unexplored areas of Eurasia and reached all the other continents. Australia and New Guinea, at that time joined together, were the firsts to be colonized between 40,000 and 30,000 years ago. It is an event of extraordinary importance because it implies the presence of a technology that in other parts of the planet is documented only after 30,000 years: navigation. The archaeological sites document that the colonization and adaptation to the enormous range of environmental and climatic situations present in the Australian/New Guinean continent took place in a relatively short period of time.

Then man reached the coldest areas of Eurasia (the Neanderthals had reached only Northern Germany and Kiev). This was made possible by a superior capacity of making dresses and building shelters.

The colonization of Siberia, dated around 20,000 years ago, opened the way to the colonization of the American Continent, the last to be reached by men. The first men

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shown that they were a separate species from which we departed around 700 000 years ago.

[8] Jared Diamond, 1997; p. 39.

arrived in North America, through the Bering land bridge that had emerged, due to glaciations, around 13,000 B.C. . The first archaeological sites, whose dating appears sufficiently accurate, go back at around 12,000 B.C. As it had already happened in Europe and Australia, the expansion of the human race, documented by numerous Clovis sites, was extremely rapid. In around 1,000 years the "Americans", reached Patagonia, an event that could seem extraordinary, but that in fact requires an average process of expansion toward South of 13 Kilometers per year, a very small distance for nomadic populations of hunters and gatherers.

In a book published in 1996, Steven Mithen[9] has advanced an explanation of what I will call the "Great Take Off"[10]. According to the English archaeologist, between around 50,000 and 30,000 B.C. the human mind made a last and definitive step forward in its evolutionary process, acquiring a new "module" that connected and integrated a series of cognitive functions, specialized intelligences that were already present but that up to that moment had worked separately or had a very limited level of integration.

The analysis of the evolution of the human mind proposed by Mithen is based on a large archaeological documentation and on recapitulation [11], i.e. a comparative analysis of the development of the cognitive capacities of the child and of the human species from the moment in which, around seven million years ago, it departed from the chimpanzee.

I find this idea suggestive and rich of many potential applications[12]. It allows defining the period in which mankind appeared and, therefore, the moment from which we can start to analyze human population history: it is the moment in which Homo sapiens sapiens began to invent and innovate, a capacity whose extension and far reaching consequences represents the most relevant difference between the human species and all other animal species. A long run vision of the cognitive and inventive process also shows that, although not linear and cumulative, this process has been progressively accelerating and increasing in intensity, as a small ball of snow that descending along a mountain slope acquires increasing speed and becomes a large avalanche[13].

I think therefore correct to see man's history, from the Great Take Off on, as the manifestation of a new cognitive stage, and therefore as a single process: "A disinterested observer taking the long view from another planet might see our modern culture, with its computers, supersonic planes and space exploration, as an afterthought to the Great Leap Forward. On the very long geological time scale, all our modern achievements, from the Sistine Chapel to Special Relativity, from the Goldberg Variations to the Goldback Conjecture, could be seen as almost

[9] Steven Mithen, 1998.

[10] Jared Diamond has defined this event the great leap forward, while Mithen has chosen the expression big bang. In my opinion neither definition correctly captures the nature of the event. It has not been a great leap forward because since then the human race has never landed, but is still flying, higher and higher; it has not been a big bang because it was not an event that took place in a single moment of time and from which everything else can be derived in a deterministic way.

[11] In Mithen words: " ... recapitulation proposes that the sequence of developmental stages that a juvenile of a species goes through, its ontogeny, reflects the sequence of adult forms of its ancestors, its phylogeny; Steven Mithen, op. cit., p. 66; see also Stephen Jay Gould, 1977.

[12] This invasion of the space of cognitive sciences by an archaeologist has produced, as it would have been easy to forecast, a series of criticisms by the scholars of these disciplines (see, for instance, the exchange between Stephen Jay Gould and Steven Pinker in the NYR, October 9, 1997 and the articles by Merlin Donald and Howard Gardner also in the NYR, May 28, 1998.

[13] This metaphor should not be taken literally. I am convinced that the construction of knowledge is not a strictly cumulative process, but that requires together with creation of new visions also the destruction of accepted positions, i.e. Khunian "revolutions".

contemporaneous with the Venus of Willendorf and the Lascaux Cave, all part of the same cultural revolution, all part of the blooming cultural upsurge that succeeded the long Paleolithic stagnation."[14]

Figure 1 - The Venus of Willendorf (around 25,000 B.C.) and some drawings in the Lascaux cave (around 17,000 B.C.)

This phase is also characterized by a new power relationship between men and environment. The proto-human species that lived before the Great Take Off were simply subjects, as all other living beings, to the general law of evolution, adapting themselves to the environment also through a continuous process of speciation that we have not yet been able to fully reconstruct. Starting from the Great Take Off, this relationship becomes totally different. It seems more and more probable that one of the first accomplishments of the man of Cro Magnon was the destruction of the other proto human species with which he had shared the planet in the previous 70-80,000 years, the Neanderthals[15]. There is also a suspicious coincidence between the arrival of our ancestors in Australia, Siberia and America and the disappearance of the mega fauna that inhabited those areas. Finally, after 50,000 B.C. man has differentiated in many races, but his capacity to produce new and more powerful technologies, allowing his survival in the most different and extreme environmental and climatic situations, has made unnecessary the process of speciation that had characterized the previous periods.

The first economic transition

The most recent and reliable dating has confirmed that the transition from a production system based on hunting and gathering to one based on agriculture and husbandry began around 10,000 B.C. The transition took place independently in few areas, distributed in four continents, over a very long time horizon[16].

In the Middle East the presence of agriculture is documented by numerous sites dated at around 8,500 B.C. and that of husbandry at around 8,000. In China agriculture

[14] Richard Dawkins, 2005; p. 36

[15] However, as noted by Jarred Diamond, we do not know if this was due to our mental and technological superiority or was the result of the involuntary diffusion of new germs.

[16] The domestication of local plants and native animals originated only in five areas: the Middle East and more precisely in the area known as the Fertile Crescent which includes at present Israel, Jordanian, Lebanon, Northern Syria, the South East of Turkey, Iran and Iraq; China (the valleys of the Yellow River and of the Yangtze River); Central America, and more precisely Central and Southern Mexico and some surrounding areas of Central America; the Andes region and probably the Amazon Basin; the Eastern part of the United States. Other possible candidates, but in this cases the evidences are not definitive, are the Sahel, the tropical area of Western Africa, Ethiopia and New Guinea. See J. Diamond (op. cit) pp. 100, 126 e 127.

appears just a little later, while in Central and South America we have to wait up to 3,500 B.C. and in the United States up to 2,500 B.C..

The first conclusion suggested by these data is that, in a global perspective not limited to the Eurasian continent (inclusive of Northern Africa), the beginning of the first economic transition is distributed over a time span of more than 6.000 years, an interval that becomes even longer if we include Australia and the islands of the Pacific Ocean where agriculture was introduced by the European colonization.

The reason why the transition took place starting around 10,000 B.C. has received numerous explanations. One of the most recent refers to climatic change[17]: the end of the last glacial era determined a relevant increase in temperature. Climatic change in itself, however, is not a sufficient explanation because it cannot account for the large time difference between the introduction of agriculture in the Fertile Crescent and in America, for the fact that in large areas of the planet agriculture was never "invented" and that numerous populations living in areas perfectly suited from a climatic point of view never introduced agriculture. Therefore, climatic change can represent only a necessary prerequisite for the introduction of agriculture.

The other fundamental question that has not received a final answer, but respect which we have only interesting hypotheses, is why agriculture has been independently introduced in certain areas and not in others. Moreover we still know very little of how this process took place and developed.

There is however a general consensus that agriculture and husbandry were not invented and did not represent a conscious choice: the hunters of the late Paleolithic could not choose between something which existed and something which did not exist and of which they did not know anything. Agriculture and husbandry were the by-products of choices that were made without any awareness of their consequences[18]. The following zoological interlude gives support to this thesis and offers an interesting reference point to discuss the role that agriculture has played for the development of human society.

Ants invent agriculture

Around 50 million years ago a species of South American ants "invented" agriculture and abandoned the previous situation dominated by warfare and hunting[19]. The two genera of farmer's ants, Atta and Acromyrmex[20], live in the arid, semi-tropical and tropical areas of South, Central, and North America. Leafcutter ants cut leaves from plants and trees and grow fungus on these cut fragments. They use this fungus to feed their larvae (the ants themselves mostly imbibe plant sap from the cut leaf fragments).

The production process is extremely complex. It begins with the location of a suitable harvesting place. When an ant scout finds a suitable bush or tree, it lays a scent trail back to the nest and summons the foragers. They cut out pieces of leaves, petals, and various other plant parts from the vegetation and head clumsily back to the nest where they hand the harvest to smaller ants, who then rush it to one of the many culture gardens. The leaves are then processed into smaller and smaller fragments by smaller and smaller ants, until the thoroughly masticated result is placed into the growing

[17] W. Dansgaard, J.W.C. White e C.B. Stringher, 1989; Peter J. Richerson, Robert Boyd, and Robert L. Bettinger, 1989.
[18] J. Diamond, op. cit. p. 105.
[19] Leafcutter ants are the only animals besides humans who grow their food from living matter.
[20] At present there are 38 species of Leafcutter ants.

culture.

These fluffy-looking fungus cultures are tended by the tiniest ants who roam inside the numerous galleries that ramify throughout the culture and harvest special nutritional bodies produced by the fungi called "gongylidia". These tiny ants then distribute their bounty to the rest of the colony. In order to protect their fungus cultures and combat invading fungi pests, these ants employ antibiotics produced by Streptomyces bacteria.

How did the transition from a warfare and hunting regime to a farming regime take place and how can we explain it? Obviously it was not an invention, but an unconscious process of co-evolution, that is of reciprocal adaptation of three species (the ants, the fungi and the bacteria) that has originated one of the most intricate examples of mutualism in nature.

The introduction of farming and the resulting production process had relevant consequences on the life of the Leafcutter ants. In the first place, a division of labor made possible by a centralized production system whose output is distributed to all members of the colony or accumulated; in its turn the division of labor has brought to the evolution of ants of different shapes and size, suited to the task to be performed, and consequently of a complex social caste system. Another consequence has been the construction of urban centers whose relative dimension, number of inhabitants and organizational complexity is comparable with that of our biggest towns. Finally, it must be underlined that, although Leafcutter ants are a dominant species everywhere they life, the transition to farming has greatly reduced their aggressiveness.

Also men "invent" agriculture

Although with a fifty million year delay with respect to ants, also men "invented" agriculture. The most probable explanation is that also for men the introduction of agriculture was not a conscious choice, an invention that we can ascribe to an unknown Gyro Gearloose of the late Paleolithic. The complexity of the phenomenon, the length of the time interval over which the beginning of the "transition" is distributed, the different ecosystems in which the process took place suggest that the research of a single engine of transition from the gathering phase to agriculture represents a useless and probably methodologically wrong exercise[21]: if it was not an invention, it was evolution.

It seems more interesting to try to reconstruct the sequence of events that led to agriculture and husbandry. As it is standard procedure in the literature, let's take as reference point the Fertile Crescent, the area that offers the richest and qualitatively more abundant amount of information. It should however be stressed that this approach is not without negative consequences since it brings to generalize a phenomenon which was probably unique under many respects[22]. Hopefully future research in the sites of autonomous origin of agriculture will allow describing the sequence of events that led man to agriculture and husbandry, providing comparative data sufficient to point out differences and similarities between them.

Numerous sites in the Fertile Crescent document the life and the habits of the hunters

[21] For a recent review of existing theories and an effort of building a more complex model, see: Gregory K. Dow, Nancy Olewiler, and Clyde G. Reed, 2007.

[22] Hopefully future research in the sites of autonomous origin of agriculture will allow describing the sequence of events that led men to agriculture and husbandry, providing comparative data sufficient to point out differences and similarities between them.

and gatherers that lived there between 19,000 and 8,000 B.C.[23]. We have already pointed out two fundamental events that posit some of the necessary premises for the transition to agriculture: the evolution of a modern human mind and a climatic change that made cultivation possible in large areas of the planet. In the 10,000 years preceding this first fundamental transition numerous other changes and innovations produced the necessary conditions for a progressive advancement toward agriculture and husbandry. In the first place, a change from a situation in which subsistence was based mainly on large games to a situation in which the majority of games was small and in which gathering became relatively more important. This process was accompanied by an increase in the activity of land management, which fostered the growth of wild plants especially suited to human diet. There is also strong evidence that the gatherers of the late Paleolithic had a very deep knowledge of the plants growing in their territory and used an extremely large number of them. Mobility decreased so that a certain level of sedentary existence, not only seasonal, came before the introduction of agriculture. At the same time, the process that brought to the cultivation of the first plants, sustain the thesis that a sedentary existence is a prerequisite and not a consequence of agriculture[24]. This period also witnessed the appearance of technologies for harvesting, treating and storing crops which permitted a more intensive utilization of wild plants.

All these events would not have been sufficient if in the meantime plants and animals had not registered a process of co-evolution[25], putting the premises for their cultivation[26]. It is still an open question why the transition to agriculture started in Eurasia, and more precisely in the Fertile Crescent and in China, before than in other continents. A possible explanation is that these areas had a comparative advantage due to the fact that they had the largest number of animals[27] and plants[28] that represented possible candidates to domestication.

[23] Between the most relevant we can recall: Habu Hureyra, excavated by Hilman (G.C. Hilman, S.M. Colledge and D.R. Harris (1989), "Plant food economy during the Epipaleolithic period a Tell Habu Hureyra, Syria: dietary diversity, seasonality and modes of exploitation", in D.R. Harris e G.C. Hillman (eds), Foraging and farming: the evolution of plant exploitation, Unwin Hilman, London; pp. 240-268) and Mureybet, Tell Aswad, Jericho, Jarmo and numerous others natufian sites.

[24] Also in this case there are evidences pointing in the opposite direction: it would seem, for instance, that in Mesoamerica cultivation was inserted in a dispersed and mobile hunting system.

[25] In the first phase of domestication plants evolve in such a way as to attract the opportunistic consumption of humans that provide to transport and disperse the seeds, favoring the reproduction of the plants. At the same time it is evident that the foraging activities of men, as well as that of the other animals, were directed toward the most appealing and attractive fruits: the biggest, more colorful and tasty. Through this mechanism man fostered the evolution of plants toward characteristics, which presented better qualities for the consumer. In other situations human selection fostered mutations that in nature would have been harmful or even lethal for the plant. It is the case of peas. Man preferred those in which the mechanism of explosion was for some reason inhibited. It is also the case of wheat and other grains: man "selected" mutant ears that did not loose the seeds.

[26] Plant domestication can be defined as the process of growing a plant and cause, consciously or unconsciously, a genetic modification that makes it more useful to the human consumer.

[27] There are 148 species of mammals (herbivore or carnivore) that weight more than 100 pounds and therefore can be defined medium-large. Among these only 14 were domesticated before the XX century, and only 5 have become relevant all over the world (the cow, the sheep, the goat, the pig and the horse). The other 9 have remained confined to specific areas.

[28] Between the more than 200 000 species of wild plants growing over the planet only a few thousands are edible and only a few hundreds are cultivated. The vast majority of these, however, has given a marginal contribution to human alimentation and could not have sustained the development of our species. Around 80% of present agricultural production comes from a dozen of species (grains: wheat, maize, rice, barley and sorghum; soya; tubers: potatoes, manioc, and sweat potatoes; sugar cane, sugar beet; banana) and more than half of the calories consumed by human population come from wheat and other grains.

Did the first economic transition cause a demographic transition?

The transition from a productive system centered on hunting and gathering to another system based on agriculture has certainly been a fundamental step in the economic history of the human race. Some demographers have argued[29] that this economic transition has also determined a demographic transition. For this hypothesis to be true, it is necessary to prove that both economic systems were characterized by a specific demographic state and that the introduction of agriculture determined the transition from the first to the second state.

The prevailing theory is that, during the hunting and gathering phase, fertility rate was relatively low and just sufficient to keep the population level constant. According to Kingsley: "The circumstantial evidence suggests that throughout hominid evolution the long run birth rate was kept as low as possible consistent with survival - as low, that is, as the death rate".[30] The same author estimates the number of children per woman between 4 and 6. Livi Bacci explains this low fertility rate as follows: "The high mobility of hunters and gatherers due to continuous displacements from one hunting area to another, made it heavy and dangerous for women to carry non autonomous children. For this reason the time span between deliveries was probably rather long so that a new birth would occur only when the previous child was self-sufficient."[31] Livi Bacci supports this statement remembering that the average fertility rate of !Kung women has been estimated in 4.7 children per woman and that an analysis of the settling down process of this population has shown a reduction of the average distance between deliveries from 44 to 36 months. He also recalls that two surveys of anthropological studies find a positive fertility differential between agricultural societies and societies practicing hunting and gathering (the first 6.3 versus 5.7, the second 6.6 versus 5.6). It was however death the most important instrument of demographic control, through a typical Malthusian mechanism. "If under favorable conditions a hunting and gathering population expanded, it would become denser, the environment would become depleted, contagious diseases would spread, or warfare would set in". Therefore: "Zero population growth was the rule not the exception"[32].

The second element necessary to validate the thesis of the first transition is to show that the demographic state was substantially different. The first indication is found in the fact that starting from 10,000 B.C. the rate of growth of human population, although very low, was higher than that prevailing in the previous period. On the basis of Biraben estimates, Livi Bacci states: "...it is incontrovertible that with the spreading of agriculture the growth of population increased of various order of magnitude and the ceiling of resources imposed by the ecosystem to hunters and gatherers was enormously raised"[33]. A similar opinion has also been expressed by Davis: "According to my estimates the growth of human population for some 12,000 years, preceding the industrial revolution- the period of rise and spread of agriculture - was of 4.4 percent per century. This was a small pace by present-day standard, but it was nine times faster than the estimated growth during the 40.000 years before the agriculture epoch"[34].

[29] Massimo Livi Bacci, op. cit, and Bocquet-Appel, J.P.op.cit.
[30] In Massimo Livi Bacci , op. cit, p. 49.
[31] Massimo Livi Bacci, op. cit. pag. 57.
[32] In Massimo Livi Bacci, op. cit, p. 51.
[33] M. Livi Bacci, op. cit. p. 51.
[34] In Massimo Livi Bacci, op. cit., p. 52.

These statements are based on the assumption that, for a given territory, an economic system based on agriculture and husbandry allows the survival of a number of individuals greater than that allowed by a system based on hunting and gathering.

According to "classical theory" the main driving force of demographic growth was the decline in mortality brought about by a substantial improvement in the nutritional level ensured by agriculture and husbandry. According to an alternative, and today prevailing theory, the introduction of agriculture determined, on the contrary, an impoverishment of the diet that became also less differentiated and created a favorable situation for the diffusion of infectious diseases. But sedentary life determined an increase in fertility more pronounced than that of mortality since it reduced the cost of children in terms of parental investments and increased their returns. Inside an agricultural system children have, in fact, a greater utility. In practice, the increase in fertility was the result of a reduction of the time interval between deliveries and an increase of the duration of the fertile period, together with an increase in the probability of conception.

The empirical evidences on which the theory of the first transition stands seem weak and largely insufficient. They are based, in the first place, on the level of world population in three periods, 50 000 - 40 000 B.C., 10 000 B.C. and the year one, for which we obviously do not have any primary statistical information, but only very uncertain estimates subject to a very large error[35]. Once deduced from these estimates that the rate of growth after 10 000 B.C. has been higher than in the previous period two alternative explanations have been given. According to "classical" theory, the two demographic states had similar fertility rates, but the agricultural state had a lower mortality rate; according to a second view, based on studies of fertility and mortality of hunters and gatherers that have survived till our time, in the agricultural phase both fertility and mortality rates were higher, but also the differential between these two parameters was higher.

In conclusion, the arguments on which the hypothesis of a first transition stands are not very robust. My impression is that the idea of a "first transition" has been born out more than from available data and information, from an analogical extension of the "second transition": if the transition from agriculture to industry has provoked a demographic transition, why a similar phenomenon should not have taken place also as a consequence of the transition from hunting and gathering to agriculture? Other data and arguments weaken even more this theory.

In the first place, Mary Jackes and Chris Meiklejohn[36] have recently questioned the hypothesis of a jump in fertility, brought about by agriculture. On a very accurate and documented study of three archaeological sites in Portugal they reach the conclusion that a total fertility level of around eight can be considered as biologically feasible for the early Neolithic.

But, even if we accept the hypothesis that the net rate of growth of a population is normally higher in an agricultural economy that in an economy based upon hunting and gathering, in order to estimate the impact on human population of the transition from the first to the second system we need to take into consideration how this

[35]The data are those estimated by Biraben and published in 1979; see J.N. Biraben, 1979.

[36] The study concerns some Portuguese sites covering the period from 6000 to 4000 B.C documenting the transition from the Mesolithic to the Neolithic. The study, based on an extremely accurate analysis of the skeletons excavated at the sites of Moita, Casa de Moura and Arruda, reaches the conclusion that the last phase of the Mesolithic was characterized by a progressive increase in fertility due to a change in life-style and resulting from a reduction of the interval between deliveries. See Mary Jackes and Chris Meiklejohn, 2004

transition took place.

As we have seen, on a world scale, the beginning of the agricultural phase span over a period of more than 10,000 years between around 8,500 B.C. -when the presence of agriculture is clearly documented in some archaeological sites of the Fertile Crescent- to around 1,700, 1,800 A.C when agriculture was introduced in Australia and in the Eastern (Western) areas of the United States by Europeans[37]. Moreover, also the diffusion of agriculture from the centers of independent origin toward neighboring areas spans over a long period of time. In central-northern Europe, for instance, the transition to agriculture took place between 5000 and 3500 B.C. and was very gradual. There are evidences that around the beginning of the fourth millennium the populations of this area started to show a lower mobility and that, in the following period, subsistence was ensured not only by agricultural products but also by hunting. A possible explanation is that the adoption of agriculture by population coming from the South increased the amount and the concentration of games in certain areas facilitating their exploitation by populations of hunters.

These evidences show that the dualism between hunters, on one side, and farmers, on the other, is an extreme simplification of a more complex reality which was characterized, for a long time, by the co-presence of four types of human communities: (1. communities of hunters and gatherers; 2. communities of farmers and shepherds; 3. communities of hunters and gatherers that devoted part of their time and energy to agriculture; 4. communities of farmers and shepherds that devoted part of their time and energy to hunting and gathering) and that only after a long interval of time the second type of community became prevailing.

In reality, the process that brought to the progressive substitution of communities of type 1 with communities of type 2 was a long one and sometimes probably not-even a linear one. This implies that if we want to evaluate the impact of the introduction of agriculture on demographic growth we would also need to know not only the differential on the average rate of growth between agricultural communities and hunter's communities, but also the weight of the various types of communities in the various periods.

We have then to remember that to speak of agriculture tout court is too much of a simplification. In the first place, the introduction of the plants that were to become one of the most important nutritional sources of human population has taken place in various steps, spread over many millennia[38]. In the second place, the development of agriculture in the Middle East and in Europe was characterized by the presence of a relevant activity of husbandry. Animals have allowed farmer's communities not only to consume proteins without hunting, but have also increased the efficiency and productivity in a series of agricultural tasks, and more generally for transport. Due to the lack of the right animal species, this type of mixed agriculture has been totally

[37] This last date shows that during this very long phase, local populations remained in the hunting and gathering phase in large areas, apparently very well suited to agriculture, like Australia and North America.

[38] In the Fertile Crescent and in Europe there were three main phases, each characterized by a growing complexity of the process of domestication and cultivation. In the first, between 9,000 and l'8,000 A.C. the species domesticated and cultivated were mainly grains and pulses. The second around 4,000 B.C., concerned some fruit trees (olive, fig, date palm, pomegranate and grapes) and some species of nuts, all relatively easy to domesticate because they grow from seeds or from grafting. These plants however demand at least three years to produce the first fruits and therefore their introduction and cultivation process requires the life of the farmers to be completely sedentary. The plants domesticated in the third phase were fruit trees requiring grafting such as apples, pears, cherries and prunes. The introduction of new plants in different areas continued also in the following centuries following new contacts with other countries and received a very big impulse in the XVI and XVII century due to the "discovery" of America and Australia.

absent in large areas of the planet - namely in Central and South America- until very recently[39].

It is then evident that agricultural production has been enormously enhanced by the discovery of metals. The first tools used by farmers, many already present in the gathering phase, were made of wood and stone. The discovery of metals bought to the introduction of more efficient tools, for instance the plow with iron share, documented for the first time in Palestine around the tenth century B.C.

Other innovations fundamental for the development of agriculture came from the invention of more refined technologies for processing and storing agricultural products. Windmills and water mills were developed at the end of the Roman period, together with fertilization and crop rotation. The capacity to improve animal species and to develop new ones through selective breeding began to be developed at the beginning of the XVIII century[40]. In the same period extremely relevant technological development were registered, but it was with the industrial revolution that the main phases of the agrarian production process were mechanized.

In conclusion, from 10,000 B.C. until today we register not only the co-existence of communities of farmers with communities that were not or were only partially based on agriculture, but of farmers' communities at different level of organizational and technological development. Therefore, if the hypothesis that the transition from hunting to agriculture caused a demographic transition lacks of sufficient empirical evidence, the idea that it is possible to locate a moment in time in which the transition to agriculture determined an acceleration of population growth at the global level seems even less founded.

Let's now go back to the ant's tale to evaluate the hypothesis that the introduction of agriculture has represented a main break in human history and the main engine of the following social and cultural development. As we have seen, there are extraordinary parallelisms between the impact of the introduction of agriculture on the Leafcutter ants' society and on human society. In both cases the introduction of agriculture has generated a sophisticated division of labor, an extremely articulated society, the construction of big towns and the birth of urban life.

The differences are equally instructive: ants' agriculture has remained mono-product for 50 million years, no other animal species has been domesticated to support agricultural production, the division of labor has not been supported by technological innovation, but by biological evolution (ants have not invented tools, but their bodies have adapted to different functions); although the other ants have not learned agriculture, they have not been destroyed; Leafcutter ants have remained inside their ecosystem and have not invaded the planet even though the number of the members of the species increases through the colonization of new territories and not through a more intensive utilization of the territory of the community.

This comparison does therefore strongly suggest that it was not the "invention" of agriculture to set on course the socioeconomic development of the human kind, but the continuous application of his creative and innovative capacity.

The modern economic and demographic transition

[39] The use of animal to pull the plow and agricultural carts is documented starting from 3,500 B.C. in the Fertile Crescent, while in Europe the use of horses to pull the plow goes back to the IX century.

[40] The initial lack of crop rotation and the use of the cut and burn technology obliged farmers to move their villages quite often.

Starting in the second half of the XVIII century, Europe has experienced an extraordinary demographic transformation that has then progressively affected all the other countries of the world.

The prevailing theory is that what we are witnessing is a transition from a traditional demographic regime, characterized by high fertility and mortality to a modern regime, characterized by low fertility and mortality rates. Both these regimes are described as regimes of equilibrium with population rates of growth close to zero. According to this interpretation, the transition is already completed in numerous countries: "The last two centuries have witnessed the birth, development and conclusion of the modern demographic cycle of the Western world"[41].

I will maintain that the phenomenon is much more complex and that the difficulties in interpreting it and the following errors of interpretation have been generated by the effort to force inside a single interpretative scheme two episodes of population's history totally different. As a matter of fact:

- Inside the so called "demographic transition" there are two phases that totally differs from each other for what relates both to the dynamic of the demographic indicators and to their determinants;
- The real fracture of the traditional regime is to be located in the transition from the first to the second of these phases;
- The present transformation is not leading to an orderly and efficient regime, but is a transition between two different types of disorder and inefficiency: the first due to the incapacity of men to control "natural" phenomena, the second to his incapacity to manage, in a socially oriented way, his capacity to control them;
- Even in the countries where the present demographic transformation has been lasting longer and has determined the most relevant changes, its conclusion is still far away;
- There are no sufficient indications to infer that the final outcome of the present demographic transformation will be a situation of equilibrium brought about by similar values of birth and mortality rates;
- On the contrary what seems more probable is that only massive migration flows caused by the co-presence of countries characterized by a structural shortage of labor and countries with a structural excess of labor can play a balancing role.

The two phases of the demographic transformation

The first signal of the unprecedented demographic transformation that was going to affect human kind in the XX century was the appearance in Europe of a rate of population growth higher than those registered in previous periods: between 1750 and 1850 European population grew by 88.3%, increasing from 111 to 209 million, in comparison, for instance, to a growth of 24.7% in the previous 150 years and of 51% between 1200 and 1340.

The few available data show, however, that until 1880 the increase in life expectancy was rather modest (on the average one month per year) and that in numerous European countries life expectancy remained below 40.

For what relates to fertility available information shows a small decline in England and a very slight increase in Sweden. Moreover, with the exception of France, in 1850 the fertility rates of all main European countries were still on line with the values that

[41] M. Livi Bacci, op. cit, p 140.

characterize traditional demographic systems. In conclusion, although between 1750 and 1850 the increase in population was anomalous; at the end of the period there were not sufficient indications to forecast the demographic transformation that was going to affect the world in the following years.

It is starting in 1850, for what relates to fertility, and in 1880, for what relates to mortality, that demographic indicators begin to show unprecedented changes (Table 1).

Between 1750 and 1880 life expectancy increased by 0.6 months per year in England, by 1,3 months in France and by 1 month in Sweden. Between 1880 and 1950 the average increase is generally of more than 4 months per year, with a maximum of 6.2 months in Russia, whose starting value was extremely low, and of 3.9 months in Sweden, whose starting value was already rather high. Life expectancy will continue to grow also, although in a more moderate way, in the second part of the XX century bringing to a substantial alignment not only of the European countries, but also of many developing countries with a much lower GDP per capita.

Even more impressive are the declines in fertility rates. The reduction is on the average of 50% between 1850 and 1950, while in the following 50 years the fertility rates of many countries will decline below the replacement level.

Table 1 - Life expectancy and Total fertility rate (TFR) in selected European countries: 1750 - 2007

	1750-1759	1850-59	1880	1950-1955	2010-15	1750	1850	1875	1950-1955	2010-15
	Life expectancy					Total fertility rate				
United Kingdom	36.9	40	43.3	69.3	80.4	5.28	4.56	3.35	2.18	1.92
France	27.9	39.8	42.1	67.1	81.8		3.27	2.60	2.75	2.00
Sweden	37.3	43.3	48.5	71.7	81.9	4.21	4.28	3.51	2.24	1.92
Germany			37.9	67.5	80.6		5.17	3.98	2.13	1.39
Italy			35.4	66.3	82.8		4.67	4.50	2.36	1.43
TGhe Netherlands		36.8	41.7	71.9	81.3		4.98	3.98	3.05	1.75
Russian Federation			27.7	58.5	69.8				2.85	1.66

The standard approach to the demographic “transition” does not distinguish between these two phases providing a single explanation to both of them based mainly on Malthusian mechanisms, and on the hypothesis that balancing mechanism are at work. This is how Livi Bacci synthesizes this position: “The more aggregate level of explanation locates the first engine of change in the decline of mortality starting in the middle of the XVIII century. The decline in mortality is imputed partially to exogenous factors -a lower impact of epidemic cycles, the disappearance of plague - partially to the lower impact of famines due to the improvement in economic organization, partially to social and cultural practices that contributed to slow the diffusion of infectious diseases and improve the survival, especially of the youngest. The decrease in mortality determined, at the aggregate level, an acceleration of economic growth and a greater pressure on resources. This, in its turn, activated mechanisms that lowered fertility through a reduction in nuptiality and the diffusion of voluntary birth control.

The new equilibrium point is reached only at the end of the process of mortality decline, whose timing depends on the development level of each population. ... At a less aggregate level, greater attention is paid, in the transition process, to the reproductive choices of the couples induced by the social transformation activated by the industrial revolution. The inception of the industrial and urban society causes an

increase in the relative cost of children upbringing, who will start to produce income and become economically autonomous at a much higher age than in agricultural societies; this requires greater investments in health and welfare and precludes the possibility to work, especially to women. The increase in the cost of children is seen as the main determinant of the reduction in fertility. Its impact was facilitated by a lower social control of traditions, institutions and religion and by the fact that it was accompanied by the economic and social development of European societies. Diffusion mechanism contributed to the spreading of the phenomenon from cities to countryside, from the rich and more educated to the deprived, from central to peripheral geographical areas."[42]

It should be noted that, in the first place, there is no time coincidence between the demographic events that just described and the explanations provided. As we have just seen, the most dramatic increases in life expectancy and the most relevant declines in fertility took place in the second half of XIX century and in the first half of the XX century. There is no doubt that this period was characterized by a tremendous increase in industrial production, urbanization and welfare. But in all this period, agriculture remained the prevailing sector, rural population exceeded urban population, the increase in welfare although generalized was relevant only for a limited share of the population. Therefore, if the impact of the increase in the cost of raising children can represent an interesting argument for the period after WW2, I find it difficult to see its relevance for the previous period. In the second place, and this is the basic point, economic progress and urbanization cannot by themselves increase life expectancy and reduce fertility without an adequate medical knowledge and at least an elementary awareness of the reproductive process.

This argument is implicitly suggested and corroborated also by Livi Bacci who states that up to the middle of the XIX century - with the exception of few limited cases such as France, the first country to register a decline in fertility- birth control was unknown and medicine had done very little in reducing mortality.

On the contrary, studies of England and Italy, two countries very different with regard to economic development and social setting, have shown that between 1870-80 and 1950 two third of the decline in mortality were explained by the control of infectious diseases (mainly children diseases), respiratory system and intestinal diseases. As a consequence, about two third of the increase in life expectancy were due to the decline in mortality in the first 15 years of life[43]. If the improvements in general life conditions have certainly contributed to the phenomenon, the direct and indirect contribution of the growth in medical knowledge (vaccination, more effective medicines, development of new surgical methods and especially the diffusion of personal hygiene) had certainly a prevailing impact. At the same time the existence of a positive correlation between economic development and life expectancy is not sufficient to prove the presence of a causal relationship since economic development and medical and biological advances took place at the same time.

Coming now to fertility also Livi Bacci has maintained that the main cause of its decline is voluntary birth control, a mechanism more powerful and flexible of those employed in traditional societies.

[42] M. Livi Bacci, Ibidem
[43] M. Livi Bacci, ibidem

Transition theory revisited

It seems, therefore, that the empirical evidence and an interpretation of available data, free of reverence toward dominant theories, show that human population went through two phases only.

The first regime that began to disappear around the middle of the XIX century is a "natural regime" with high fertility and mortality rates. The fertility rate is normally higher than 4.5 children per woman and ranges between this value and a maximum theoretical fertility rate of around 8. Birth control is extremely limited and takes place or through social customs that influence nuptiality and age at marriage or at the individual level trough infanticide[44].

The control of death was even more limited. Technologies and knowledge capable to prevent and cure fatal diseases were totally lacking and humankind was exposed without any defense to recurrent epidemic crisis. Men had also very little defense against natural events that caused dramatic oscillations of food resources and famines. A relevant contribution to a early death was also provided by man strong inclination to provoke and get frequently involved in devastating wars. As a consequence in the natural regime life expectancy ranged between 20 and 35 years and probably never went above 40.

In conclusion the main characteristic of the natural regime was that man did not have the capability to control fertility and intervene on mortality. It is only starting from around the middle of the XIX century that man began to acquire this capability and it was mainly this that opened a new era in the demographic history of men.

The second half of the XIX century witnessed the beginning of extraordinary advancements in medicine, chemistry and biology, together with the development of new laboratory tools and techniques. This opened the way to the development and introduction of vaccines[45] that allowed defeating some of the most dangerous

[44] John and Pat Caldwell have already underlined the fact that the impact of birth control in pre-industrial societies has been over-estimated: "We have devoted considerable effort to identifying the field evidence upon which these claims rest. Most of the evidence is surprisingly insecure. The whole intellectual edifice has been created by demographers borrowing from anthropologists and by anthropologists borrowing from demographers, in each case using lower levels of scholarship in scrutinizing the borrowed information that they would have felt impelled to use when building upon the work of people within their own disciplines. Certainly there was some fertility control, at least among the elites at the height of Imperial Rome and among the late seventeenth-century Geneva bourgeoisie as modem Europe began to emerge. Women in Africa and elsewhere have long postponed the resumption of sexual relations after birth in order to give their infants a greater chance of survival. But the evidence for birth control as a method of ensuring families or communities of limited size in traditional societies is just not there". Rather convincing is also their idea that in pre-industrial societies birth control was absent not only because of lack of technical knowledge but also as a consequence of a fatalistic vision of life. "Our experience in researching pre-transitional societies in sub- Saharan Africa and South Asia is that the usual reproductive behavior of the human race over aeons has been to think of births and deaths as being essentially capricious and requiring little planning or consideration."The same authors also provide an interesting explanation of why the idea of birth control has been so largely accepted: "This belief meets a range of intellectual needs. Anthropologists often feel at peace with themselves only when they have concluded that cultures, although different, are in a sense equal. One sign of this equality is the ability to employ human intelligence to achieve optimal reproduction within the circumstances of the society. Some family planners seized upon this concept because they felt more comfortable and more likely to succeed if they concluded that they were not initiating a fundamental first-time change in the society in which they were working but instead were allowing that society to resume its ancient ways -although with new means- after a period of disequilibrium which followed colonial penetration. Many of these ideas, including the overarching concept of the "Stone-Age affluent society", flowed from Carr-Saunder's 1922 book, The Population Problem: A Study in Human Evolution, which aimed at showing that earlier societies had been capable of looking after themselves before the disorganization that followed the arrival of the missionaries"; John C. Caldwell and Pat Caldwell, 1997; pp. 15 and 16.

[45] After the first experiments against smallpox conducted by Jenner at the end of the XVIII century, the vaccine for cholera was discovered in 1879, for anthrax in 1881, for rabies in 1882, for typhoid fever in 1896, for plaque in

infectious diseases [46] . The discovery of aspirin (1899), penicillin (1929) and streptomycin (1943) represented other fundamental steps in the fight against premature death.

The discovery of DNA structure, whose long term consequences are still difficult to estimate, marks the beginning of the second half of the XX century. The progress in medicine accelerates with the development of new drugs and the introduction of organ transplants. As a consequence, as we have already seen, life duration has been increasing and continue to do so, going beyond any previous expectations.

At the same time the diffusion of the understanding of the reproductive mechanism, the introduction and diffusion of contraceptives safer and easier to use (namely IUD and the pill) allow couples to control fertility and to choose the number of children they want.

Therefore, what characterizes the present demographic regime is the capability of men to choose and determine his reproductive behavior and to control more and more the causes of death. The result is a regime that, according to present empirical evidence, presents a negative or nil population growth.

In conclusion, our thesis is that up to the moment in which the socioeconomic consequences of the industrial revolution created the premises for a growing control of fertility and mortality the demographic regime was characterized by a long run positive rate of natural growth that was however largely checked by natural events and wars. At the end of the transition we find post-industrial societies with low fertility and mortality rates and a negative or nil natural growth rates. The positive relationship between economic growth and demographic growth that characterized the natural regime not only has turned negative in the modern regime, but in the countries well advanced along the demographic "transition" economic growth tends to increase demographic disequilibrium.

The spread of fertility control and of the capability to victoriously fight against an increasing number of diseases took quite a long time, which explains why the demographic transition has been a long process for the countries that entered this path firsts. By now almost all the countries of the world have initiated their hike toward a modern regime, but the great majority is still scattered along the way, their position depending mainly on the date of departure, but also on many other economic, political, religious and ideological variables. However, the countries in which the demographic transition started later have found the path already well paved and if the right political and ideological conditions were present could travel all the way in a much shorter time, as it has been the case for instance for China.

Energy and demographic growth: revisiting Carlo Cipolla hypothesis

In the *Economic History of Population* Carlo Cipolla[47] noted that man as all plants and the other animals is a energy converter. Before the agricultural revolution man was able to extract energy only from biological converters, while his muscles were

1897, for diphtheria in 1923, for typhus in 1937, for influenza in 1945, for polio in 1955, for measles in1964, for mumps in 1967.

[46] In 1847 Ignaz Semmelweis suggested that those that attend a delivery should wash their hands; in1867 Joseph Lister published a volume titled "Antiseptic principles of the practice of surgery" in which illustrates antiseptic surgical methods, whose adoption will bring to a drastic reduction of deaths from infection decrease. In the 1870s Louis Pasteur and Robert Koch established the germ theory of disease stating that a specific disease is caused by a specific organism.

[47] Carlo Cipolla, 1962

the only source of energy he could use to sustain himself and reproduce.

The agricultural revolution that lead with time to the agropastoral system that has dominated the world well after the beginning of the industrial revolution, produced a notable increase in the energy that men could extract from the other biological converters. The process was later on enhanced by numerous innovations and discoveries. Some increased the efficiency in the extraction of energy from biological converters: the introduction of new plants and their diffusion in new territories, the improvements in existing tools and the discoveries of new ones, technological innovations for working metals, etc.; others such as the water mill and wind mill increased the energy available.

In the words of Cipolla, the industrial revolution; "is the process that allowed to start the large scale exploitation of new energy sources using inanimate converters" and "changed farmers and shepherds in operators of mechanical slaves"[48]

In extreme synthesis Cipolla argues that the growth of human population and the speed at which it takes place depend on man's capacity to increase the amount of energy extracted from the environment both as food and as fuel, while the extension of the territory, the amount of natural resources available and man's capacity to exploit them represent the limits of demographic growth.

Until the beginning of the 1960s, Benjamin Franklin definition of man as a tool-maker was largely accepted and the appearance of the human race was associated with the appearance of this capacity[49]. In October 1960 Jane Goodall observed for the first time two chimpanzees strip leaves off twigs to fashion tools for fishing termites from a nest. Since then the capacity of many animals to make and use tools to obtain food or provide protection has been largely documented as well as the fact that the same species make different tools in different geographical areas.

It remains however true that the difference between the tools produced by man and those utilized by other animal species is enormous. Such difference is to be ascribed to what must be considered the basic and unique characteristic of the modern human mind -which has began to manifest itself only in the last 50,000 years or so- the capacity to invent, innovate and continuously introduce new technologies in the form of new tools and new organizational structures and social processes and easily transfer them to the following generations. In other words, only the modern human mind has been capable of generating a continuous and cumulative process of technological innovation.

Also ants have succeeded in originating and managing a complex production process. However, not being capable of inventing new technologies they had to evolve in a variety of shapes and dimensions. In general, the necessity to adapt to different climatic situations or to the availability of different resources brings to the selection of the individuals more fitted for the environment and to the tasks to be performed. Given a limited interchange with other territories and/or sexual taboos this brings to speciation. Man has being capable to cope with analogous situations trough technological and social innovation. As a result, the physical characteristics of man have changed very little giving rise only to different "races" with very limited genetic differences.

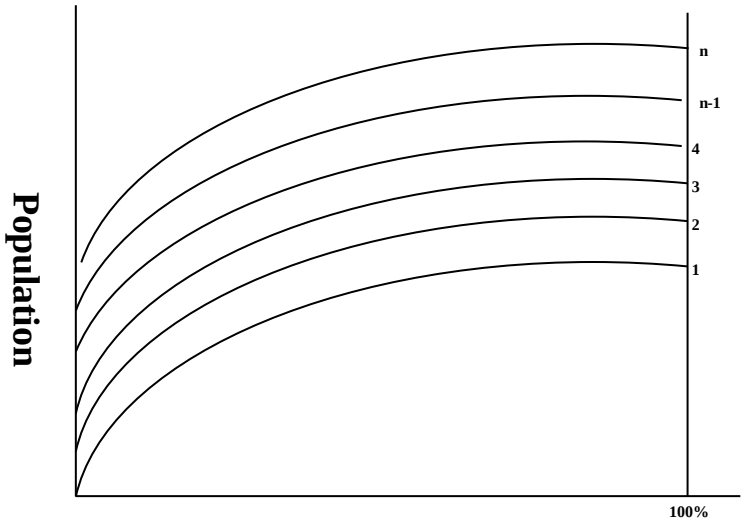
Let's now assume that, in any given time interval, the growth of human population

[48] Ibidem
[49] This position was for instance held by the archaeologist Louis Leakey.

depends, as suggested by Cipolla, on the available amount of energy in its various forms that, in its turn, depends on the extension of available territory, on its natural resources and on the technology used to exploit such resources. Therefore, in each period, human population can dispose up to a given maximum amount of energy. At the same time, the amount of energy that will be extracted will depend on the amount of population living in the territory, while the amount of population that can be sustained will depend on the level of energy utilization. Population growth and the level of utilization of energy represent, therefore, an action-reaction system.

The short run curves of action-reaction do necessarily exhibit decreasing returns. Increases in the level of energy utilization will require a more than proportional amount of population, while increases in the amount of population will require more than proportional increases in the level of energy utilization.

Graph 3 - Population and level of utilization of available energy



In the long run, the bundle of resources can be expanded by the enlargement of the territory, by increasing the amount of available natural resources and by introducing new technologies. This will determine an increase in the maximum amount of energy available and in the maximum amount of population that can be sustained. Graphically, the process can be represented by an upward translation of the relationship between the level of population and the level of energy utilization.

There are no evident reasons why the expansion path -the locus of points associated with the maximum amount of population sustainable and the maximum level of energy that can be produced by any given bundle- should not be characterized by constant returns. This would imply that proportional increases in the level of energy available could be associated with proportional increases in population.

The increase in total population will however depend also on a series of exogenous factors that, during the natural regime, men could not control and on events produced by man itself. Plagues, famines, wars have determined interruptions in population growth or even population declines. Depending on the situation, these cases are

represented by:

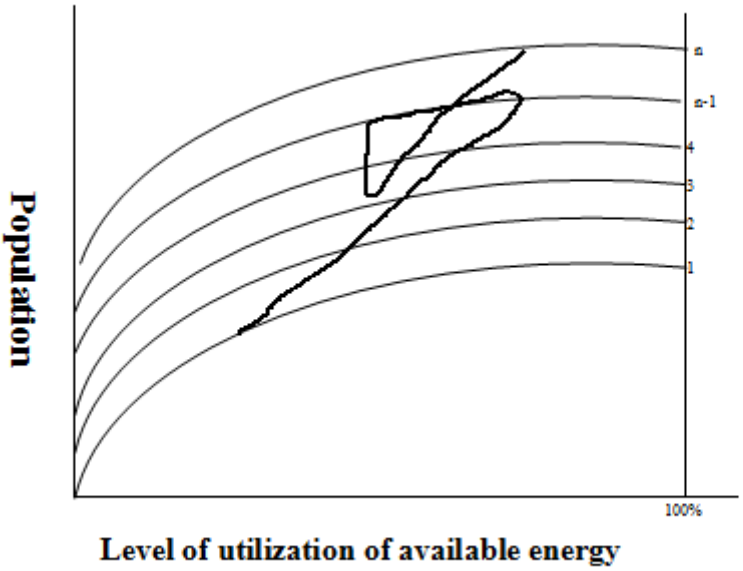
- A backward movement along a given action-reaction curve, implying only a reduction in the level of utilization of a constant amount of available energy;

or

- Downward movements of the action-reaction curve, implying a reduction in the bundle of territory, resources and technologies and, therefore, in the total amount of available energy.

The second phenomenon could intervene also if, for a smaller level of population, lower curves could become more efficient.

Graph 4 - An example of a possible path of population expansion.



The specific relative impacts of social and individual control on fertility and of exogenous factors in determining the historical expansion path of a given population can be dealt with only by empirical analyses that exceed the aim of this work. What interests us here is the fact that up to around 1850, the evolution of human population has been determined by the amount of available energy and by exogenous events, in the almost total absence of instruments capable of modifying the "natural" rates of fertility and mortality.

At the theoretical level the previous representation of population growth as a function of available energy and exogenous events remains valid also after 1850 and not only for underdeveloped countries. However, this phase presents totally new characteristics. In the first place, due to technological innovation, the amount of energy available has grown and is growing more than population and the lack of resources in certain areas of the planet is to be ascribed only or mainly to distribution problems. In the second place the number of births has been more and more determined by the choices of the couples.

Therefore, in the present phase this representation can provide indications of the maximum amount of population that could be sustained under given hypotheses of

distribution, but has lost its capacity to capture the presence of self-regulating mechanisms activated by the relation between economic growth and demographic growth.

Finally given that we are already in a decelerating phase of demographic growth and that, with very high probability, world population will start to decline before the end ofthe4 century, today energy problem is mainly an environmental problem.

From natural inefficiency and disorder to rational inefficiency and disorder

It has been maintained[50] that the traditional demographic regime was inefficient and disorderly, while the modern regime is more efficient and orderly. The inefficiency of the natural regime was due to the fact that "in order to obtain a low level of growth (society) needed a very large amount of fuel (births) and wasted an enormous amount of energy - deaths". The disorder was provoked by the randomness of death due mainly to the frequent mortality crisis that hit people of every age and condition so that "the probability that the natural priority of generations was subverted was very high."

In this perspective, the modern regime is more efficient because the same level of population growth is obtained with a much lower number of children per woman[51] and more orderly because the natural and chronological order of death connected to age is respected.

In Livi Bacci opinion, the result has been "largely positive". However: "Although today populations are tremendously more "economic" and efficient than those of 100 o 200 years ago, they have acquired new elements of vulnerability. The demographic order of mortality has not eliminated the risk of disorders that, exactly because more rear, makes more vulnerable those affected (the lost of the only son, the lost of parents in young age). Family's structure is much more fragile in front of the risk. Aging, beyond certain limits, strongly hampers the social dynamic. Lastly, a very low fertility, much below-replacement, produces costly diseconomies that could result unbearable in the long run."[52]

Even with this proviso, I deem this evaluation of the effects of the so-called second transition too optimistic since it does not consider some of its most relevant consequences.

With respect to the past it does not take into account the dramatic implications and outcomes of the mass migrations that have affected European countries during the XIX century and the beginning of the XX century. For a minority migration was a success story, but for the large majority it meant leaving behind their loved ones, landing in foreign countries where the greetings were far from warm and enthusiastic, miserable living conditions and cultural uprooting, returns often in situations worst than the previous ones.

More recently, the "transition" has been responsible for the dramatic demographic growth already experienced by developing countries while an even more dramatic one is going to strike the poorest countries in the world. It seems to me that nobody can maintain that for these countries demographic growth has represented and will represent an engine of development. It has been and it will be the origin of physical

[50] Massimo Livi Bacci, op. cit.
[51] "Women must have a half a dozen of children to be replaced by the following generation" ibidem.
[52] Massimo. Livi Bacci, op. cit. , p. 174

and moral misery and as always the highest price has been paid and will be paid by the weakest, and especially by children.

Finally, in the countries where the "transition" has reached a more advanced stage, the classical vision of a final equilibrium proposed by Livi Bacci is totally disavowed by the present demographic trends that are very far from bringing order and efficiency.

It is true that the probability of death before 50 is extremely low and that for older people it is strictly related to age. However, it is also true that what we are witnessing is an inversion of the slope of the age pyramid, a phenomenon that cannot be defined "natural" according to standard evaluation parameters. Moreover, although I deem excessive and not motivated the fear that acceptable welfare systems cannot be maintained in the future, population aging has already provoked sizable backward steps of the welfare systems in a large and increasing number of countries.

The most relevant element of social and economic disorder caused by the "transition" is however represented by the decline of WAP and by its consequences on the labor market.

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