The Technological Shift at the Start of the 21st Century.
The Theory of Coenoses: Malthusianism with a Schumpeterian Twist.

(XV Annual Congress, the IEA, June 24-29, Istanbul).

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Abstract. The theory of coenoses (Badalian, Krivorotov, 2007, 2006), presented below, models the mechanism of a technological shift to a new era.

For example, at the start of the 20th century, the search for increasingly dear coal led to the development of diesel machinery for servicing much deeper mines. Then, there was diesel powered shipping, land transport and tractors in order to reduce shipping costs and produce more food. During the evolving technological shift of the first half of the century, coal-based economy dominated by the British Empire was gradually replaced by the more productive oil-based economy dominated by the US –thus resource problems were resolved.

Before WWI on the background of rapid industrialization and globalization, resource hunger led to inflationary prices, first and foremost, for energy and food. This caused political tension. During WWI, the crucial technologies of the 20th century: the oceangoing diesel-powered ship, the plane and the lorry – were speedily refined to the level of initial commercial applications. Their arrival loosened the grip of coal-based infrastructure, the basis of British dominance. The wartime hurried evolution of the internal combustion engine was accompanied by widespread, diesel submarine led destruction and a massive "write-off" of coal based infrastructure. The resulting dramatic political shifts were finalized after WWII. Between wars, there was a switch from globalization to autarky – local industries and agriculture grew regardless of their efficiency, as the base for national survival in the situation of an acute financial crisis, with the Great Depression as its pinnacle. Thus, through wars, in a purely Malthusian fashion, rose the next leading economy. Starting from the 1950s, it would be powered by oil and dominated by the US, on the background of the fading British Empire.

It is unsettling that these old patterns seemingly come back to haunt us again, as we enter the 21st century. Our increasingly dire shortages may be pointing at the need for a similarly dramatic technological advance as we strive for super deep drilling and Arctic exploration, while also trying to increase food production. It becomes clear that the tensions rising within the dominant oil economy may be jeopardizing its ability to serve as an adequate source of sustenance for growing global populations. This already caused sharp increases in the value of lands on the far periphery, turning them into the current political and military hot spots. Also, the ongoing financial crisis uncomfortably mirrors the weakening of the British pound at the start of the 20th

century, when it was gradually outgrown by other rising national currencies, such as the dollar, the mark and the frank. This all, taken together, raises an unsettling question. One wonders whether we might be moving to yet another repetition of the events at the start of the 20th century, albeit on a new, more threatening level of technological and military sophistication.

Keywords: energy, energy consumption, energy resource, geoclimatic zone, labor theory of value, marginalist theory of utility.

1. The Two Paths of Development: Western and Eastern Lineages.

With growing fears[1] on approaching our resource limits, the current shortages seem increasingly more Malthusian in the most classical sense of "vice and miseries". However, ours would not be the first resource famine in history. While thoroughly devastating, its previous appearances did not manage to permanently stop the relentless growth of wealth and population. Learning from past experiences may provide a critical tool for handling our current problems.

Historically, there were at least two approaches to dealing with dire resource shortages.

1. ***Radical***, by developing a brand new pattern of *land use*[2]. A move towards domesticating the next *geoclimatic zone*[3] helped in unlocking its rich untapped resources providing thus a new growth potential. Such breaks of continuity were specific for the European tradition. Historically, the related immense social strife was amply rewarded by the sustained growth of wellbeing, which became pronounced after the 1850s (Findlay, O'Rourke, 2007, Clark, 2007 etc). The path to prosperity led through a drastic technological and social shift with all the related dislocations, such as, for example, the two world wars accompanied by a switch from coal-based economy of the 19th century Britain to oil-based economy of the US[4]. Usually, the new zone required more powerful technologies, which were developed under the stress of inflationary shortages. By channeling the "excess" population into the emerging industries as the older ones stopped providing sufficient returns, Malthusian pressures[5] resulted in a tremendous surge of

[1] New Limits to Growth Revive Malthusian Fears Spread of Prosperity Brings Supply Woes; Slaking China's Thirst. By Justin Lahart, Patrick Barta and Andrew Batson WSJ, March 24, 2008; Page A1

[2] The term *land use* unites technological means and social institutions, which together support a specific style of land exploitation, such as irrigation agriculture of the first civilizations, coal economy based on railroad infrastructure for land locked areas etc. In the appendices A-C below, a given system of land use is characterized by its production of goods in order to support specific densities and life levels of population. We model a given land's ability to support population through the carrying ability of land.

[3] Historically, there was a notable progression of such zones: from 1. the deltas of the great rivers in Mesopotamia to 2. the arid Mediterranean to 3. the heavily forested Western Europe, 4. the Atlantic lands of the Age of Exploration, 5. the British Empire of the industrial era, and, finally, 6. the huge expanses of the US and the globalized world around it.

[4] John Roberts (1989) persuasively showed its gradual unfolding between two world wars.

[5] We define Malthusian pressures as growth of the so called "excess" population that can't be absorbed within an existing economy and the related land use. Reaching an inflationary peak caused by intense resource hunger signals

innovative changes – starting the Schumpeterian "creative destruction". Historical evidence shows that, in order to sustain the initial short-term gain from innovative technologies, a dramatic institutional change was needed. This meant building a brand new infrastructure based on the unique inelastic resource of each emerging geoclimatic zone, such as railroads of coal-based 19th century or auto roads for the modern oil economy. This radical approach allowed the West to escape from the Malthusian trap, albeit not without substantial cataclysms, dislocations, bloodletting and struggles. The Western style economy of sustained growth grew as the fruit of a relentless, centuries-long pattern of territorial expansion, which fed off untapped resources of the next virginal zone. The cause for this preference is relatively straightforward – it implies availability of an "empty" geoclimatic niche. It must be either scarcely populated (such as early medieval Europe still covered with dense forests) or bearing a population that could be displaced or physically eradicated (rural population of Britain, which was displaced by enclosures, or Native Americans at the time of white settlement in the North).

2. *Incremental*, which is more typical for the East or Latin America. Much denser patterns of human settlement made it impossible to radically rethink existing land use. Thus, resource shortages tended to be resolved through incremental technological improvements, by gradually increasing the productivity of the land. Of course, the Eastern-style economy of cyclical growth didn't amount to eternal peace – incremental changes tended to end in bloody "dynastic cycles"[6]. However, in this way, waves of barbarians crashing on the Eastern "shores" could be somehow merged with the older social structures. Historically, this led to the preservation of (mostly) autocratic patterns of power[7] and existent social institutes. Ensuring continuation and coexistence of many variations of the traditional land use, over time they piled over each other[8]. The traditional institutes proved themselves quite capable of absorbing novel technologies and

the exhaustion of the then zone. Historically, this was resolved either through globalization and drawing in the resources of far periphery, as it happened from the 1980s, or by switching to a new pattern of land use, as it happened between two world wars. See models presented in Appendices A-C at the end of this paper.

[6] The proponents of the so called structural demographic theory (Goldstone 1991, Nefedov 2003, 2004, Turchin 2003a, b, Turchin, Nefedov 2008, Korotaev 2006) showed that, in traditional societies, resource shortages tended to cause severe crises periodically approaching the level of a demographic catastrophe within the regime of the so called dynastic cycles.

[7] Traditional autocratic regimes tend to strive for preserving social equilibrium by suppressing everything unpredictable, which, of course, includes the economic change.

[8] The book by Ronald Findlay and Kevin O'Rourke (2007) is chockfull of examples showcasing incremental buildup of social institutes and technologies in the East. In one of the striking examples of coexistence (2007, 52), cities of Iran and Transoxiana "had an interesting dualistic structure, with an Arab military *rabat* or cantonment, with mosque and markets attached, adjoined to the original four-gated Persian *shahristan* or walled city, symbolizing the fusion of the two cultures that was taking place. In addition to the Arabs and Iranians one must never lose sight of the military presence of the Turks, who would eventually gain the ascendancy". Another example of a resulting triumph of "creative synthesis" is provided by the Andalusian economy. According to Thomas Glick (1994, 977) cited from Ronald Findlay and Kevin O'Rourke (2007, 58) it was "melding… Indian agriculture, Roman and Persian hydraulic techniques, and a legal regime of water distribution combining elements of Arab and Berber tribal norms, Islamic law and Roman provincial customary law."

the majority of invaders, despite periodic severe interruptions of the related dynastic cycles followed by resumption of traditional land use patterns (Goldstone 1991, Nefedov 2003, 2004, Turchin 2003a, b, Turchin, Nefedov 2008, Korotaev 2006).

The European lineage[9] of evolutionary development is the main topic of our theory of coenoses[10]. It models the process whereas Malthusian shortages unleash a Schumpeterian burst of "creative destruction" (see the Appendix A).

Within the European lineage the entire society is molded around the leading technology of its time. This marriage of the man and technology became especially visible starting from "enclosures" in Britain, which brought people to factories, by forcefully uprooting them from their villages. It reached its highest point in the consumer society, an offshoot of the mass production of the 20th century. Though much less obvious earlier, this principle was at work for the entire European lineage. For example, Mesopotamia was the creature of its irrigation agriculture. The Roman Empire could spread out only thanks to the sophistication of the Roman road. The medieval Europe rose in the aftermath of the technological revolution described by Lynn White (1964) – the wheeled plough, the castle, shock troops, horse harness etc. It was pulled together as the Latin Christendom of monasteries and bishoprics, which served as the forefront for domesticating the territory economically (forest clearings, market fairs, specialized

[9] In fact, there was a significant degree of confluence and interchange between diverse societies, which will be explored further in our future work. For example, both Persia and Rome depended on advanced technologies of water management (the qanat and the aqueduct systems respectfully) and used free hired labor in their projects as opposed to the corvee labor of the first civilizations. Also, as Europe lived through the medieval era, China experienced similar fragmentation, perhaps due to the specifics of leading technologies of the time. However, for the sake of the model's clarity, we started with the West, since Western societies persistently exhibited a more pronounced tendency for discontinuity. This significantly eased the job of modeling evolutionary changes throughout historic eras.

[10] This is a biological term (from Greek). It means a tight knit community of mutually dependent organisms. They survive and reproduce together as a group by developing reasonably stable hierarchical feeding chains. Its application to social organisms within our theory of coenoses presents an extension of the term to the social realm – the feeding process is implemented through economy, as hierarchical chains of production. On the lower tiers are the so called producents or workers, while the control is supplied by the so called consuments or higher hierarchical tiers of power structures, from landowners to entrepreneurs. A coenosis thus will denote the complete lineup of a particular historic era, with its unique power institutes, economy, customs and mores. Among examples of historic coenoses are such diverse societies, as Mesopotamia of the first civilizations starting from 5 thousand years ago – where feeding chains were based on its sophisticated irrigation agriculture – or the consumer society of the US – whose wellbeing and even survival is based on the economy of mass production built around auto roads. Both of these societies leapt to excellence within their era. They are equal in the sense that each of them managed to master a new geoclimatic zone, which had few uses before. Thus, their land became the base of their success, since the new zone under domestication was rich with untouched resources. Their productive exploitation became possible only with the help of emerging technologies of the time. These technologies also defined the extent of the zone's territory in the most general context as providing the necessary production environment. Within this line of understanding the US land before colonization was a virgin geoclimatic zone in the same sense as the British hinterland was opened for industrial production thanks to railroads. Similarly, the arrival of the early modern technology, based on the mill managed to unlock the Atlantic coast of Europe with its rich water & wind energy and other natural resources. This new zone rose on the periphery of the earlier agricultural zone, which was domesticated during the Middle Ages.

production, support of pilgrim roads etc). France, as we know it to this date, was built around its ubiquitous canals serving as a transportation and energy system[11].

In contrast, the East piled its technologies around existing social structures, easily sacrificing higher returns for the sake of preserving social order. Findlay and O'Rourke (2007, 130) presented a vivid illustration of this point by comparing effects of the Black Death in the West and in Egypt. In its aftermath, the higher mobility of European peasants due to their reduced numbers led to the rise in wages on the background of a fall in rents. In a sharp contrast, the Mamluk rulers of Egypt succeeded in maintaining high land rents despite the severe loss of population. Findlay and O'Rourke deduce that this implied much lower mobility of peasants, dependent on the extensive irrigation system maintained (or neglected at its convenience) by the state. This was the landmark of the older system of land use based on irrigation, which can be traced up to the first civilizations and continues to play a central role in the modern East. It could hardly be abandoned even with lower demographics, as the conditions of arid climate placed a great value on any producing land.

In no way would the East-West dichotomy presented above mean that there were no incremental changes in the West. As illustrated by our current embrace of "green" oil supplements, including ethanol, solar/wind power etc, substitutes and incremental changes are eagerly used whenever possible, in order to alleviate dire shortages of the dominant inelastic resource of the time. However, as shown by John Roberts (1989)[12], such substitutions can only be taken so far until the related technological shift exceeds the assimilatory capacity of a society. Then, it leads to a widespread systemic destabilization amid a switch to a new system of land use[13]. Meanwhile, in the eastern lineage, the resulting systemic failure tended to lead to a Malthusian reduction in population, after which the growth could be resumed again, albeit on a somewhat higher technological/institutional level (as stated in the structural demographic theory (Goldstone 1991, Nefedov 2003, 2004, Turchin 2003a, b, Turchin, Nefedov 2008, Korotaev 2006).).

In the case of western societies, their radical approach to resolving dire resource shortages through developing a brand new system of land use, more than proved its merit. Historically, it allowed a notable increase in production, while also absorbing the growth in population via territorial expansion and rise of new industries[14]. Its benefits became especially visible starting from around the middle of the 19th Century. After the Industrial Revolution, there was a provable improvement in the overall level of wellbeing. Researchers generally agree that, from around that time, European societies broke through Malthusian constraints. For example, it was convincingly shown that wages were decoupled from land rents and gradually outpaced them

[11] We further elaborate on the related technologies of these periods in the Appendix B.
[12] He convincingly showed that the period between the two world wars can be best understood in the context of a switch from the coal to oil-based economies.
[13] The shift to a new land use pattern is modeled in the Appendices A-C below.
[14] We assume that the European line was fully formed after the Gregorian reforms, the basis of the rising Latin Christendom (1050-1080).

(Findlay, O'Rourke, 2007), (Clark, 2007), (O'Rourke, Williamson, 2005). This discontinuation of the earlier rigid ties between wages and land rents and the attained happier mode of sustained growth was generally seen as a farewell to the Malthusian world (Clark, 2007)[15].

However, this impressive achievement should never be understood as a one-time event sufficing for all time to come. Instead, the Western world mastered a laborious mechanism of escaping the Malthusian trap. This was achieved by entering into periods of fast territorial and/or economic expansion each time that resource shortages manifested themselves again. Speedy development of new patterns of land use allowed domestication of "virginal" zone, resolving thus shortages, for a time. Note, that exhausted zones tended to lose their earlier advantage if, as it was often the case, they reverted to Eastern style patterns in an attempt to preserve fragile social stability as their growth stopped. In this sense, the government of Louis XVI, which sacrificed advanced mechanical looms by Jacques de Vaucanson in order to please the powerful guild of Lyons, didn't differ much from the Mughal emperors. Note, that soon thereafter, France was bloodied by the Malthusian double "punch" of revolutions and Napoleonic wars – its demographic growth was resumed only after WWII. Meanwhile, Britain was growing exponentially, quadrupling its population within a century, on the basis of its industrial prowess. The aforementioned mechanical loom turned into one of the centerpieces of its spectacular success. In Paisley, on the British side of the Channel, it produced immense returns, while the original machine was collecting dust in a French museum.

Today, the well known dichotomy of the rich North (West) versus the poor South (East) is turning social struggle into a case of geographic stratification. The Northern side is seemingly reaping all the rewards, while the Southerners are reduced to paying the price. But, in a purely Malthusian fashion, none of the players of this brutal game is ever able to escape without a price. Just as it was predicted centuries ago, the rich become subject to "positive checks" by voluntarily reducing their rates of procreation. Meanwhile, the poor are being decimated by "vice and miseries" on the background of high birthrates. Of course, many would gladly accept the fate of the "unlucky" rich, who manage to preserve their lavish lifestyles by abandoning their procreation. One should never forget, however, that rejection of this bothersome act might have been among the chief reasons leading to the physical disappearance of the Roman world[16].

Nowadays, there is also the unsettling question as to the final limits of the constant expansion in the Western fashion. From purely ***endogenous*** factors, which the Western world fully mastered, such as perseverance, work ethics, technological sophistication and, one might add, a fearsome

[15] These results were mostly obtained by using time series and popular statistical models, including input-output matrices and other models for studying links between factor prices and factor endowments (O'Rourke, Williamson, 2005; Findlay, O'Rourke, 2007, Clark, 2007).

[16] While the Pagans tended to evade the burden of familial commitments, the Christians espoused larger families. The higher positions, relinquished by the fading Pagan elite, were gradually filled by the socially advancing Christians. Most importantly, the army became predominantly Christian, which, as many historians believe, provided a major reason for accepting Christianity as the Roman state religion by Constantine the Great.

degree of ruthlessness, the possibility of such an expansion now also begins to depend on much more rigid ***exogenous*** constraints. Even if problems of "finding" unoccupied land, free for domestication, were somehow resolved, there exists a new limit placed by the industrial pollution and the ongoing global warming.

Historically, "finding" an "empty" zone and mustering its resources was a crucial part of the Western solution. As Western world gradually encompassed ever larger territory, there was a notable fall in costs of transportation. Soon, even the most basic foodstuffs could be brought from afar. Thus, the Malthusian restrictions of the industrial Western world could be resolved by bringing in the resources of the underdeveloped world. Historians contend that there is an uncomfortable link between the rise of the Industrial revolution in Britain and slavery, which was essential for supplying its machines with cheap American cotton[17].

Also, it is hardly a coincidence that the same date, the 1850s, marked both the escape from the Malthusian trap in the Western world and the radical breaking point in weather patterns, which announced the ongoing global warming as shown, for example, in (Haigh et al, 2004). This date also marked the start of Western colonialism and the widespread white settlement in the colonies. Using advanced technological means, starting from railroads and transoceanic shipping lines, the industrial infrastructure enabled systematic removal of a wide range of resources from the "South".

The hard "Western" solution of wiping the board clean and starting anew in another place led to finding ever new innovative patterns of land use upon exhausting the growth potential of the then leading zone. Since at least the mid 19th century, it provided immense rewards. Forging a new technological paradigm at the start of a new era led to thriving off resources, which previously were of little use[18]. However, this historical ability hinged on the availability of "empty" lands, opened for development by a leap up the energy consumption ladder. It remains to be seen whether a radically different, less energy-hungry recipe can be found for our age of global warming.

Once again, we may be entering the dangerous zone of global competition on the level of the most basic staples. Up to the industrial era, the rather high costs of transport reduced the trade to relatively high value goods, which, most often, had no local substitutes. This meant that, save for the short intermission of the Roman Empire, which brought practically everything from afar, local industries were rather enhanced by trade than threatened. Surprisingly enough, our current

[17] "The link between the Industrial Revolution and the extension of the slave plantations in the New World on which the essential raw material was cultivated could not therefore be more obvious, carrying with it the uncomfortable implication that the Revolution itself would not, or at least might not, have occurred at the time and place that it did had it not been for the Atlantic "triangular trade" connecting flows of raw cotton from the Americas with exports of cotton textiles from Lancashire and the supply of slaves from the west coast of Africa." (Findlay, O'Rourke, 2007, 334).

[18] 2 world wars and the double Oil Shock in the 20th century.

dependence on basic staples, from corn to oil, from faraway lands, eerily resembles the pattern developed also by the Roman Empire, albeit on a smaller scale. It is well known that in that case, resource substitution with products of Roman far-flung colonies led to the gradual depopulation of Italy. The Italian production on all price levels, from prestigious specialties, such as *terra sigillata* from Arezzo, glass from Aquileia, silver and metalwork of Campania etc and up to the most basic staples, such as the cereal agriculture of Campania, ended by being outsourced. The best production went to the East, rich with resources, labor and consumers. The more basic staples were outsourced to Germany and Africa. (Haussig, 1980, 27-38).

The results are well known. The depopulated West was overtaken by barbarians, who, since they were settled far from cities, managed to survive the scourge of the Justinian's plague of the 6th century. The latter nearly wiped out the urban centers along with the culture of the classical antiquity. Very slowly population was replaced through the shift to a new land use pattern – from the Roman latifundia to the subsistence agriculture and the manor. Thus was ended the lone noticeable spike in the more or less smooth curve of the global population growth (Goldstone 1991, Nefedov 2003, 2004, Turchin 2003a, b, Turchin, Nefedov 2008, Korotaev 2006). It marked the end of a lengthy development based on the use of muscular power, starting from the large work-gangs of the first civilizations and ending with the draught animals of the classical antiquity. The development that followed laid the foundation for the distinctly Western societies, which originated in Europe after Commercial Revolutions and Gregorian reforms. The next surge of growth was based on harnessing the huge natural energy sources, from the hydro/wind power of the early modern era to the non-renewable hydrocarbons of coal and oil. In midterm, there was thus a switch from relying on human density to technological, labor saving solutions, as it progressed from the mill to our oil economy coupled with capitalism. This line of development is modeled in the Appendix B.

Today, there may be a new era looming on the horizon. A better understanding of the specific European mechanism of dealing with resource shortages becomes especially important during yet another inflationary rise and resource hunger. In the purely Malthusian fashion, it is accompanied by an increase in political tensions on the background of a new round of shortages, first and foremost, of oil and also food.

Historically, a step by step domestication of at least 6 distinct geoclimatic zones: from the deltas of the great rivers of the first civilizations to, most recently, the terrains of the US – produced an evolutionary "clade"[19], or a well defined line of successor societies leading up to the modern US. The amazing synchronicity of these historic eras shown below hints at the inner logic of domesticating a zone. Each particular economy ended with a collapse, oftentimes ecologically tinged, as a related demographic surge exhausted the resources of its zone. Then, after lengthy

[19] This is a biological term, which implies a line of successor organisms, for example, the one that, starting from the so called 'Common ancestor' of apes, at its end produced the man.

turmoil, development was resumed again by finding a new economic mode to use another, previously barely producing zone and its virgin resources, relieving thus environmental stresses.

Today, the emerging world presents the last frontier for the spread of modernity. However, the forbidding exogenous constraints listed above may disallow yet another application of the tried and true recipe of the past. Starting from the birth of civilization several millennia ago, the man used to solve resource problems by reaching out with the help of more powerful machines. First, there were simple machines, such as the lever, powered by large work gangs. Then, there was a switch to fossil energy – the recipe, however, didn't change in its essence. This shows the tremendous scale of the challenge ahead. As we stand on the threshold of possibly dramatic changes, cooperation on the scale of the entire planet may be the only thing that separates us from a gigantic event of destruction. There are already many voices expressing concern and proposing viable solutions (Stiglitz, 2005). It would be simply unforgivable, if the old division of North versus South stands on their way.

2. Development of an Economy as a Means of Feeding off a Specific Geoclimatic Zone.

In his acclaimed book "Guns, Germs and Steel" Jared Diamond (Diamond, 1999) showed the geoclimatic differences between Eurasia and the rest of the world. Seen from the viewpoint of labor expenditures, the über-cultures grown outside of Europe, such as the early ripening rice and maize, possess fantastic productivity, on the condition of substantial reserves of manual labor[20]. Historically, they could absorb significant growth of the labor force, feeding the ever growing populations by adopting incremental technological changes. In contrast, European cultures, such as wheat, were less productive and more technologically intensive. Providing lower returns per unit of spent labor, they formed the basis for capitalism, demanding labor saving solutions, heavy on energy use and technology.

Within the European line of development, most historians distinguish at least six grand periods, on the scale of the first civilizations, classical antiquity, the Medieval Era, the Age of Exploration, the Industrial Era, and the current oil-age of the US-style mass production. Each of them was unique, with a noticeable ***break of continuity*** in-between – more or less prolonged and destructive "***dark ages***". While there was no shortage of wars in history, events between these periods were so extraordinary and accompanied by such great upheavals and migrations on the scale of massive *Völkswanderungen* that they stuck in the memory of generations.

[20] By emphasizing the productive capacity of the land we build up on the concept first developed by the Physiocrats in the 18th century. François Quesnay and his followers, contrary to the Mercantilists, believed that the wealth of a nation lies not in its stocks of gold and silver, but rather in the size of its net product, yielded only through agriculture. We widen up the concept of land use by treating it in its most pure biological sense. Thus, we consider that any use of a given land is productive if it promotes the survival of its population. This understanding marries value and labor as the means of utilizing a given territory through agriculture, industry and any other possible productive uses, for example, such as conservation.

1. The historic accounts and archaeological data testify of the fury unleashed during the Catastrophe of the Bronze Ages of the 13th century BC[21].
2. Its devastation was amply matched by the one wrought by the immense tide of barbaric invasions, surging in destructive waves from the fall of Rome in the 4th century and up, until the Normans settled in Europe following their raids of the late 8th-9th century.
3. Then, there stands out the lengthy tumultuous period between the 1348 Black Death and the wars of Reformation, the so called religious wars of the 16th Century, which redrew the map of the Atlantic coastal regions, previously considered of little use.
4. The French and British competition in the 18th century, oftentimes carried out far away, by proxy, in the North America[22], was an important, often overlooked factor of the American Revolution. It was followed by the bloody French Revolution, brought forth by the related overextension and famine, ending with the Napoleonic wars, often called the world war of the 19th century. Thus were extinguished the British hopes on getting their resources from overseas, pushing them instead towards industrialization
5. The rise of mass society of the 20th century was announced by a series of great revolutions and two world wars
6. Most recently, we are facing a wave of terrorism that may be announcing the start of another period of insecurity on the background of massive human movements, with entire countries supported by the cash sent home by migrant-workers.

The distinctiveness of temporal-spatial locations where these great historic periods took place provided a valuable hint as to their nature. Each of them unfolded in its own specific geoclimatic zone, with well defined borders[23]. The unique economy/power-institutes/ownership structure of the time evolved in order to maximize the utility of its innate features. Below, we provide a concise description of these zones, with the historic part of the model provided in the appendices A and B at the end of this paper.

1. In the tiny area of the deltas of the great rivers**,** *the communal economy of the irrigation-agriculture* of the first civilizations, powered by large work-gangs, rose on harvests presumably greater than today. (3400BC, Uruk – 1190BC, the Catastrophe of the Bronze Ages). The superior productivity of the irrigated alluvial mud-soils supported the prerequisite high density of population.

[21] The Trojan War described by Homer presents one of its many devastating events. The catastrophe completely destroyed the Mycenaean city-states. The mighty Hittite Empire disappears after 1180, leaving tiny successor Neo-Hittite states. Egypt survives by the skin of her teeth, as Ramesses III managed to muster sufficient funds to employ many of the Ekwesh, Teresh, Sherden, Shekelesh that faced him in the massive invasion of the so called Sea Peoples. (Drews, 1993)

[22] The very fact that it was possible to fight by proxy in the faraway overseas colonies illustrates the immense size of white migration out of Europe.

[23] A territory could be quite rich with a particular resource – i.e., Russia is rich in oil – however, with a territory unsuitable for the related infrastructure (in Russia, it is hard to build auto-roads amid swamps) it could not support also the related economy, providing no appropriate food base for building a coenosis.

2. The arid Mediterranean of classical antiquity, unsuitable for widespread irrigation, proved perfect for the *market-economy* of the *poleis* (the olive/vine). Orchards were grown for profit, with grain supplied from the older zone, i.e. Egypt. (479 BC, the end of the second Persian invasion of Greece – 378 AD, the battle at Adrianople at the start of Germanic invasions). Technologically, it was based on mechanics and powered by oxen, with slave labor for high value production aimed at market[24].

3. Following the "dark age" of invasions-disarray, the heavy clay soils of cleared-off forests of Medieval Europe, of little-value within the Roman market-oriented economy, were tilled with the heavy wheeled plough. (800, Charlemagne – the 1348 Black Death) The *manor-based subsistence economy* was powered by the horse, fed with affordable oats as opposed to the more expensive barley.

4. ??Plus natural resources??With most of the wastelands cleared off, the growing demand for forest products, such as fish, meat and wood, which previously could be acquired for free, led to the rise of commercial husbandry/fishing of the Atlantic coast**.** This was an alternative to farming, unsuitable for these lands. (1415 Ceuta, 1517 Reformation – the 1775-83 American revolution) The gun-armed caravel of the North Atlantic enabled the European Age of Exploration, with *economy based on water-wind power of shipbuilding, mills*.

5. Britain didn't have a dense network of full flowing rivers, which could be used for creating a canal-river based transport and hydropower system rivaling France. It also had shortages of timber, but she more than made up for her shortages by using the local substitute, coal, the inelastic resource of the industrial era. (1815[25]– the 1860s, when Britain lost its technological edge with the first inflationary peak of *coal* (Hobsbawm, 1969)) First the *railway and then the steamship* opened up land-locked territories, spreading *white farming settlements* all over global temperate zones. This contrasted with limited networks of the mostly coastal bases and other strongholds maintained, at huge cost, by the earlier colonial powers (Spain, the Netherlands, Portugal etc).

6. The huge US-territory was mostly located within the extreme climate, previously out of the reach of the farmer. It was domesticated by developing the unique *oil-based economy of the conveyer produced mass car*, with artificial irrigation, massive use of fertilizers/ herbicides/pesticides, aggressive selection and genetic engineering, cheap rural electrification enabling widespread irrigation, and speedy transfer to the market. (The 1920s – the 1973-81,

[24] "As far as we can judge, the prices for wheat, wine and donkeys were basically formed by the operation of free-market forces, that is the fundamentals of supply and demand in a monetized economy… The prices in private sales seem, on the whole, to be "real" prices arrived at individually by market bargaining rather than being standardized, customary or notional prices." (Rathbone, 1997, p.211) "A detailed land register from Italy, the Trajanic inscription from Veleia, shows that much Italian land was privately held and could be valued in monetary terms". (Duncan-Jones, 1990, p. 127)

[25] 1815 was not the date of the Industrial Revolution, just as the 1920s did not mark the arrival of the mass car – both events took place at somewhat earlier time. Instead, 1815 and the 1920s marked the starting moment, when the new patterns of land use attained economic importance for their respective coenoses.

when the double whammy of Oil-Shocks demonstrated the limits of oil-based economy for the first time)[26].

Each new period evolved on its unique territory feeding off its specialized economy, which was created step after a laborious step, so as to better utilize the distinct features of its terrain. As soon as the native zone was fully domesticated, its winning technological/economic style spread to its margins. The latter, less productive within the dominant economy of the time, would form the nuclei of the next zone, by the very virtue of surviving in their harsher place. The grand historic sequence above conforms to a geography-based outlook, which traces economic diversity to local geoclimatic conditions (Diamond, 1999, 2005). Similar understanding is pursued by evolutionary economics, which attempts to look at man and society as yet another biological system.

There seems to be wealth of data explaining European historical rhythms as a progression of domesticating ever larger/harsher geoclimatic zones. A Dutch historian, Romein, (Kindleberger, 1996, 36), suggested "the law of interrupted progress", resembling the Schumpeterian “punctuated-evolution” (Schumpeter, 1939) – "any country pioneering in a new, more highly developed phase of civilization reaches a threshold or barrier beyond which it is extremely difficult to proceed, with the result that the next step forward has to be made in another part of the world". This helps to explain “dark ages” between periods as the time of transition. Contrary to Malthusian pessimism, there is ample evidence for teleology in European history achieved through geographic expansion. Despite occasional setbacks and bloodshed, populations grew more or less relentlessly, both through the increase of ploughed farmland and its productivity. The amount of accumulated wealth, though not necessarily happiness, rose steadily and spectacularly[27]. This view is indirectly supported by the Ricardian “comparative advantage”, such, as, for example, gained by Britain – due to its shortage of timber, its economy grew after accumulation of knowledge on how to use its abundant coal as a more than viable substitute. Taken to the extreme in a seclusion of a new location such life-changing adaptations may provide an evolutionary edge to a newcomer, by forming the foundation for a brand new economy of the future leader.

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[26] Despite wars allegedly fought for oil, there is an intense going debate as to the degree to which the US economy is still dependent on oil. In the early 20th century, the industrial countries were dependent on coal to such an extent that, as depicted by (MacMillan, 2001), the world leaders during the 1919 Versailles Convention did their utmost to find a sufficient source of coal for any formerly warring country. They considered that the only guarantee for assuring a lasting peace. Similarly, today, regardless of actual percentages of energy generated from oil, one only needs to recollect the Oil Embargo or imagine a similar event in the 2000s, while our cars may be consuming overall much less energy, but the majority of economic functions, say, in the US, would still grind to a standstill.

[27] We speak of wealth accumulated on a societal level, which in no way does not presuppose a better nutrition on the individual level –the latter, as shown in (Clark, 2007) stayed comparatively stagnant, at least up to 1800. The societal wealth, in contrast, implies an ability to support an increasingly large population.

Within the proposed model, the process of domesticating the next zone is offered as a common base for diverse branches of economics with the potential of bridging their disagreements. Domestication transcends merely populating a place and means a lot more – ***creation of a specific highly productive and mutually dependent multilayered ecosystem, which we call coenosis***[28]. It stands out in its age and time because of the unsurpassed efficiency of exchange flows between its basic level of producents (workers) and the controlling level of consuments (entrepreneurs). By maximizing the ***utility*** of its resources per unit of ***spent labor,*** the overall ***wealth*** of the system is being created as if out of "thin air". This biology-tinged understanding is loaded with important implications listed below:

1. A break of continuity between coenoses.

- For example, a shift to a new geoclimatic zone would imply the exhaustion of the growth potential within the previous one as most people wouldn't leave their lifestyles willingly.
- A *Völkswanderung* and upheaval at the start of a new era can be explained by a natural assumption that, at the end of the previous coenosis, as its own resources gradually dwindle, its wealth and know-how would spill out in exchange for faraway human/natural resources. The availability of this wealth during the period of getting OUT translates to more food at the margins. Thus is started a demographic spurt. As marginal lands tend to be less productive within the then prevalent economy, historically, this spurt led to the well-known phenomenon of the "invading barbarians" drawn in by the manpower needs of the core.

2. Creation of a new specialized economy.

- With marginal "wastelands" usually ill suited for the dominant economy of the time, the said "barbarians" end up creating a new economy, more suitable for their zone.
- The efficient domestication of a new zone, merely "wastelands" within the older economy, historically implied a switch to more powerful, energy-wise, technologies. This explains the well-known paradox of "uncivilized barbarians" – compared to their "civilized" predecessors tending to be higher up the energy consumption ladder.

3. The existence of a dominant inelastic resource for any given coenosis.

- A succession of ever more difficult zones was historically domesticated as its inhabitants learned how to use their calorically richer sources of energy[29]. Each historical coenosis can

[28] According to the Merriam-Webster dictionary, biocoenosis (biocenosis) pertains to an ecological community especially when forming a self-regulating unit. http://www.m-w.com/dictionary/biocoenosis.It is derived from a Greek word koinōsis sharing or common, like in **koinos** kosmos (shared world). In biology, there is a well defined differentiation between communities adjusted to their specific habitats, say, of a lake and a forest. Each of the latter has to develop specific mechanisms of "land use", which, in human societies, correspond to technologies, forms of ownership etc. Despite their marked differences, related to their respective habitats, each coenosis be it in a lake or a forest still consists of similar tiers of producents and the controlling consuments, allowing mutual coexistence through creating flows of mutually beneficial exchange within their specific environment. More about this in (Badalian, Krivorotov, 2006A, B, C)

[29] Calorically richer sources of energy were used for developing technologies for domesticating more difficult lands. While increasing the overall food production from a previously underutilized zone in order to feed a much larger population, they did not necessarily provide a better nutrition on the individual level, which, as shown in (Clark, 2007) stayed comparatively stagnant, at least up to 1800. Historically, the sources of energy progressed as follows.

thus be characterized through its main inelastic resource, the indispensable centerpiece of its unique economy, which allowed it to leap up the energy consumption ladder. At the end, everything boiled down to the land, domesticated during a given period. It became the ultimate source of any goods produced and consumed by the related society. However, as we progressed in time, the land in use was increasingly hard to cultivate and demanded ever more powerful tools, leading to step by step ascension up the energy consumption ladder. Among its steps, from today, were oil of the 20th century, coal of the 19th century, timber/water of the "long 16th century" (sailing-ship/mill), horse power of forest clearances of the 9th-13th centuries, oxen of the classical period and work-gangs of the first civilizations.

4. Labor and utility.

- Giving credence to the labor theory of value, domestication of a new zone would thus mean creation of new objects of value. This understanding helps in bridging up the labor theory of value with the marginalist concept of utility. Within a given economy, a population would go extinct, if a unit of spent labor didn't produce sufficient utility for its reproduction. *Statistically, reproduction of labor through adequate creation of utility per unit of spent effort serves as the only criterion for survival.*
- The *law of diminishing utility* may thus be the underlying cause for a fall in reproduction rates typical for the rich society of the ageing dominant as it comes closer to exhausting the prevailing energy source of its zone[30]. A simultaneous growth of utility (from practically zero) on its much less affluent borders exhibits itself through a population surge. Such a demographic disparity, leading to a *Völkswanderung,* seems characteristic for the twilight of the older coenosis. As the rich society of the dominant power of its times, from Rome to modernity, slows its reproduction rates, its poor neighbors tend to accelerate them.

5. Price.

- The criterion of survival through growth of utility provides an insight into the process of pricing. In the most generic form, applicable both to human and natural coenoses, the unit price of the main inelastic product of an era must measure the cost in production of its last and costliest indispensable unit, since, to assure its arrival to the market, the less expensive

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1. The first civilizations evolved in highly productive areas – using the muscle-power of large work-gangs. 2. Arid Greek islands couldn't support such densities, therein their switch to mechanics, with trained slaves in market-oriented-industries. 3. The medieval Europe – the horse (White). 4. The Age of Exploration – natural forces (wind/water) in early-industrial-mills and sail-ships. 5. Britain – coal, with coaling stations all over the world. 6. The mass economy – oil.

[30] (Clark, 2007) wrote of overcoming the Malthusian limitations in the western societies starting from the 1800s. He proves his thesis by tracing the growth of individual wealth. Malthusian resource shortages, however, relate not to the individual wealth, but rather the single most important measure of biological success, which is the rate of reproduction. Note that, Malthus presented the individual wealth as an important factor in achieving the Malthusian goal of curtailing the population growth – he correctly noted that the reproduction of the higher classes is stopped voluntarily, since they strive to preserve their level of consumption. It would seem that, currently, this is exactly the case for the developed world, where the birth rate is falling as a way of preserving one's personal wealth. This creates a room for the migrant workers from the developing world, who gradually move in, in order to reclaim the depopulating European cities.

units must also be sold at that price. This allows both determining the current price level for a product by assessing the cost of procuring its last indispensable unit and the start of substitution, as its growing costs stop being justified by its utility. Meanwhile, the start of substitution may lead to developing a Ricardian advantage at the faraway margins, which are less encumbered by the weight of crucial infrastructure tying them to the dominant resource. Reliance on a new abundant and cheap resource in a new place may start yet another cycle of domestication.

- While a new energy source may be abundant in its zone, for using it to its full advantage a specialized infrastructure must be built. Only part of the overall resource goes up in smoke, while its cumulative bulk remains materialized in the crucial infrastructure of its era. Thus, the more of it was consumed up to date by a given society, the bulkier its resource-related infrastructure – its uninterrupted supplies become more critical for that society's survival. The cost of this infrastructure, such as, in the case of oil: highways, filling stations, refineries, global trade/financial networks, wars etc, may be born by the society at large, but it adds up to the overall costs of the resource, reducing its marginal utility. Gradually, this infrastructure permeates the entire existence of the dominant society, and becomes part of its identity, both economically and socially. At its twilight, the older zone solidifies around its infrastructure. For example, the US is built around its roads, while England is still the land of railroads[31]. The place taken up by a working infrastructure can't be vacated easily – historically, substitutions with less expensive energy sources per calorie meant the end of an era. Even if there were no other underlying reasons, a switch to the next zone seems necessary in order to provide room for building the next infrastructure.

6. Currency as the means of monetizing the newly created value within a coenosis.

- Within a given society, its ***currency*** serves as the main means of exchange, by ***monetizing*** the value created within its zone[32]. The amount of currency in circulation can serve as a gauge for the size of that space. At the end of a coenosis the sum total of its currency tends to explode commensurate to the great expansion of its zone. This produces the well known phenomenon of "***price revolutions***" during globalization[33], well before the inflationary peak at the start of a new coenosis. After reaching the peak (homologous to 1913) this usually implodes into a rampant inflation – such as the one that, at a later date, facilitated power transfer to extremists, represented by Hitler. During this post-peak period, the amount of

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[31] An unscientific evidence for this assertion can be easily obtained: the evening trains off London to Cottswolds etc are filled to the brim with Citi types and other people, employed in London, whereas in the US the employees heading from a metropolitan city to their suburban must hop into their cars, even if those were parked at some distance. Also, modern US enterprises, including dentists, gyms, schools etc, tend to move to malls accessible via major auto roads.

[32] Without differentiating fiat/commodity/paper/credit and other money categories.

[33] I.e., the price revolution of the Age of Exploration – started from the 1450s. The specie came from the European silver mines, depleted after 1610, well preceding the post 1545 lush flow of gold/silver from America. Today, the money supply is swelling again because of global demand. Modern financiers "mint" "credit"-money (derivatives) replacing the earlier "metallurgic"/specie money. Pinching this hot air balloon already caused the current credit crunch. The offered cure consists of printing more money by the FRS. Meanwhile, the "real" money piles up in the sovereign funds of the developing producer-countries.

printed money stops corresponding to real products of the zone, signaling the collapse of global trade, replaced with autarky and economic fragmentation. Despite the accompanying poverty and disarray, autarky is the season for new adaptations in the seclusion of diverse localities, sheltered from buffeting global winds.

7. The cyclical nature of development.

The concept of a coenosis evolving within the natural limitations of its zone buttresses the notion of the generally cyclical nature of historic development[34]. Apparently, anything once born must advance through pronounced and logically ordered stages of development: youth, maturity, and, eventually, aging and death or, in societies, its close equivalent, homeostasis. A coenosis usually has two distinct stages of life, **IN**, feeding off its native zone, and **OUT**. During the latter stage it must reach outside of its zone for new sources of its vital resource[35], disrupting thus life within traditional communities, destroying their sources of livelihood and pushing them to migrate and gain knowledge from outside, and, in the process, igniting new “hotspots” for the next period of growth.

3. A Historic Era as a Lifecycle of its Main Inelastic Resource.

Each historical society grew around its main inelastic resource, the fulcrum of its existence, which defined nearly all its aspects, from the prevailing forms of ownership (Badalian, Krivorotov, 2006, 2007) to its popular lore. It can be argued that the economic fortune of a coenosis turns on the hairpin of its resource’s availability, passing through a sequence of stages. Entry to a virginal zone means abundance of this resource, which, as a rule, was not considered valuable before – i.e., coal and oil were known, but barely used for millennia. After learning how to better utilize it, as a rule, first in the quality of a substitute for the inelastic resource of the earlier era, the locality in question begins to thrive long before the arrival of more advanced technologies. For example, the population of Britain grew starting from the so called Agrarian revolution of the 17th century, long before its industrial machinery could bear any fruits[36].

Historically, there is an indirect but persistent relationship between the following trifecta[37]: substitution of the older resource with a new and much cheaper, calorie-wise, energy resource; increase in food availability/affordability; and demographic boom. Note that, at the beginning, the functionality of a new energy source is rather limited, as there is no specialized infrastructure for its use/retrieval. The benefits, however, show up from the start – even a relatively small fall

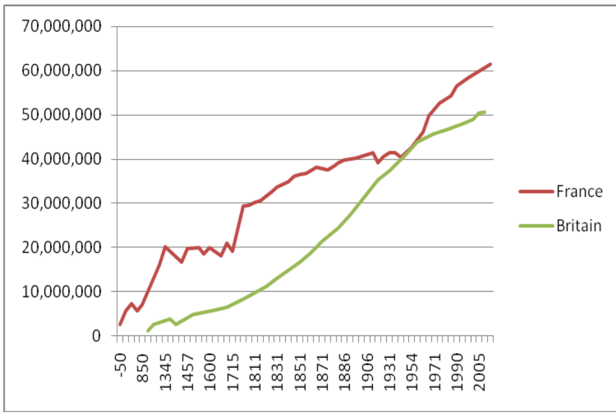
[34] C.Perez (2002) showed that lasting “gold ages” come after busts caused by the first appearance of the same technology.

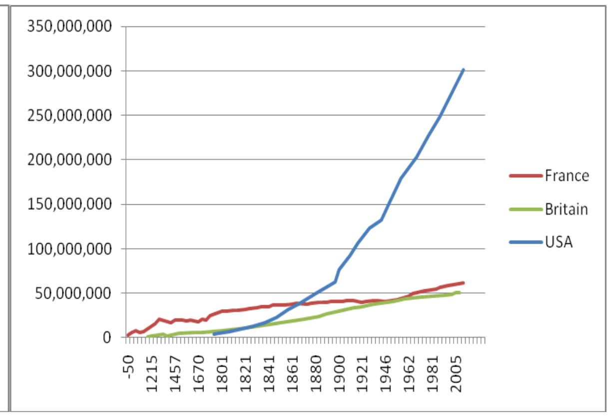
[35] (Ackland, 2007) described a process of “cultural hitchhiking”. As beneficial genes advance, preexisting traits are carried along in a cultural package. Geographic inhomogeneity produces 2 boundaries. The temporary "diffusion boundary" holds the wave’s advance into poorer areas until its gradient becomes sufficiently large – in our terminology this corresponds to the close periphery of the initial zone. The "subsistence boundary" corresponds to the margins of the **“OUT”** zone halting the wave. At diffusion boundaries, the winning technology may pass to indigenous people, resulting in a permanent "cultural-boundary" between cultures with equivalent technology.

[36] G.Clark (Clark, 2002) showed a gain of a third as much of the arable after substituting wood with coal for heating.

[37] The Encarta dictionary describes trifecta as a series or set of three things, factors, or influences.

in demand may significantly reduce inelasticity, lowering thus the overall price pressure[38]. Historically, entry to a new zone produced a spurt of exponential growth, visible on the demographic charts below – considerably more food was produced by freeing resources, such as land and labor, previously devoted to procuring energy. The demographic curve for the aging dominant tends to show a reverse relationship. The shortages of its main energy resource along with a ***fall of its marginal utility per unit of spent labor*** coincide with the rising costs of supporting the increasingly global infrastructure for its retrieval/distribution. Historically, these costs were covered by rapidly rising seigniorial rents, levied both on its population and, most importantly, on the faraway margins. Despite its growing wealth, this strained the older economy, increased its labor costs and social stratification, causing outsourcing and a fall in birthrate.





Pic.1[39] Pic. 2

Sources: the National Institute for Statistics and Economic Studies, France, INSEE http://www.indices.insee.fr/ (regular population surveys for fiscal reasons were conducted in France from the 1740s, before that, there are estimates only); Survey: Population of the United Kingdom, 1688-1950 (a graph is provided in (Harrison, 1973, 25); *U.S. Census Bureau Population Division*. The first decennial census of the U.S. population was taken in 1790, as decreed by the Constitution, for obtaining population counts needed for Congressional apportionment.

Pic.1 shows three periods of growth for France[40], interspersed with periods of relative homeostasis and demographic oscillations – 900-1345, 1715-1811, 1954-1971, respectively: medieval forest clearings (horse-power based economy); French absolutism with its *dirigiste*

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[38] By reducing the total amount of the resource needed, the cost of its last indispensable unit tends to fall drastically.

[39] From 1750 and up to our days European statistics are sufficiently documented (Mitchell, 2000). Several historical logistics of demographic growth are presented in (Cameron, 1993, 16). Of course, one needs to use a pinch of salt when dealing with the earlier numbers, which can only be estimated. While each of these estimates can be revised, both up and down, which happens indeed periodically with the arrival of new information, the majority of authors note a sustained drop in the French population following the 1348 Black Death. After that event, due to numerous local famines, population numbers exhibited a pattern resembling auto-oscillations, holding at more or less the same level until the rise of countrywide transportation system via rivers and canals during the reign of Louis XIV. Since a full-blown analysis of demographic trends for such a period clearly exceeds the scale of this article, we refer the readers to the excellent bibliography of works on the period, including data on population, land holdings and price movements, provided in (Fischer, 1996, 448-474)

[40] Population censuses were conducted in France from 1740 and up. Source, French statistical Institute INSEE7 http://www.populstat.info/Europe/francec.htm

government (mills/canal building); and the EU (the US-style oil-powered economy, with a search for oil substitutes, for France mostly nuclear power plants). Similarly, population growth in 1811-1954 Britain (Pic. 1) was supported by its coal economy. Meanwhile, the unprecedented population curve[41] for the US (Pic.2) reached its top speed during the 20th century, exhibiting 3 periods of steep ascent: 1850-1900, 1920-1930, 1946-1962, respectively, post-civil war development, which opened the country to railroad building; the “roaring” twenties; and the post WWII baby-boom, with the last two of these spurts within its unique oil economy.

Some may object, when we see the “dominant” inelastic resource of an era, such as oil today or coal before, as the fulcrum of its economy. Most economists state that, in monetary terms, oil, despite its growing dearness, accounts for barely a small percentage (in low single digits) of the US economy. However, due to numerous multiplier-effects, it in fact permeates its entire existence, in this case, from fertilizers to plastics to transportation[42]. The economic importance of any inelastic resource, such as oil, can’t be measured directly through its costs, but rather through the boost or erosion it gives to the overall economic productivity of a nation[43]. It is not only that its absence would bring the related economy to a standstill as it happened, indeed, during the 1973-81 Oil Embargo. Even more important is the burning need of obtaining oil from any source, at any cost, since, as yet, there are no viable substitutes. This drives up the costs of living. Aside from wars, substitution of oil with biodiesel etc already led to the doubling and tripling of prices for corn, sugar, bread with commensurate increases in the costs of raising livestock (meat, eggs, milk). The cost of vegetables and fruit also goes up, due to petrochemical-based fertilizer/pesticides and transportation. Rising prices for commodities are in fact fairly typical for the end of a historic era. I.e., in the 18th century England, shortage of wood forced to redirect

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[41] The first decennial census of the U.S. population was taken in 1790, as required by the Constitution, for obtaining population counts needed for Congressional apportionment. (*Source: U.S. Census Bureau, Population Division* Campbell Gibson and Emily Lennon). All data from U.S. Bureau of the Census.

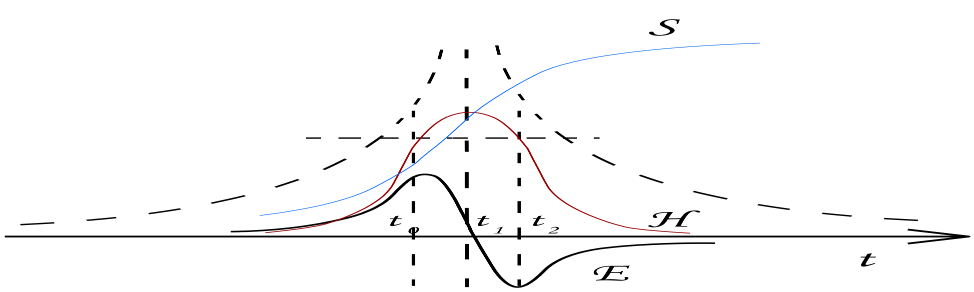
[42] "Back in 2004, when oil was a little over $40 a barrel, economists at Standard & Poor estimated that every $10 increase in the cost of a barrel of oil subtracted about a quarter of a percentage point from the economy's growth rate. Trouble is, the higher prices get, the more harmful each $10 increment becomes, according to Beth Ann Bovino, an S&P economist." Danijel Zezelj. A Volatile Combination. How much Damage from Steep Oil Prices and the Housing Bust? Business Week. October 29, 2007. P. 30. Also, there is now a direct influence of energy prices on everything else, most notably, food. "The price of grain is now directly tied to the price of oil," says Lester Brown, president of Earth Policy Institute, a Washington research group. "We used to have a grain economy and a fuel economy. But now they're beginning to fuse." “Indeed, farm groups say that energy costs in transportation and packaging have boosted food prices more than the price of corn has”. GLOBAL FOOD CRISIS. Siphoning Off Corn to Fuel Our Cars. As farmers feed ethanol plants, a costly link is forged between food and oil. *By Steven Mufson. Was*hington Post April 30, 2008; Page A01

43 “As the use of such [oil-based] fertilizer spread, it was accompanied by improved plant varieties and greater mechanization. From 1900 to 2000, worldwide food production jumped by 600 percent. Scientists said that increase was the fundamental reason world population was able to rise to about 6.7 billion today from 1.7 billion in 1900.” “Vaclav Smil, a professor at the University of Manitoba, calculates that without nitrogen fertilizer, there would be insufficient food for 40 percent of the world's population, at least based on today's diets”. “Prices at a terminal in Tampa, Florida, for one fertilizer, diammonium phosphate, jumped to $1,102 a ton from $393 a ton in the last year, according to JPMorgan Securities, which tracks the prices”. Cited from:.Shortages threaten farmers' key tool: Fertilizer. By Keith Bradsher and Andrew Martin. IHT. April 30, 2008
http://www.iht.com/articles/2008/04/30/business/30fertilizer.php

dramatically more acreage for growing the so called "coppice" woods, driving up costs of food. Similarly, the most recent peak of food prices took place in the 1970s[44], at the time of oil shortages. Centuries ago, the Netherlands went one step further, digging up its peat and selling it off to buy grain, whose cost increases were slower as compared to fuel. A corn-exporter thus was turned into a corn-importer as it sold the very soil under its feet. Such is the recurring pattern of a "dominant" resource of an era driving up the living costs of the populace until the older economy becomes unsustainable and breaks up in a widespread turmoil.

Fischer (1996) noticed the amazing similarity of inflationary peaks from the 13th century up to the 1980s. Two opposite trends ran simultaneously, somehow compensating for each other. Typically, the price for food and commodities was driven up by the scarcity and the increase in seigniorial rents, while prices for industrial products actually fell. People were pushed to cities, which accelerated technological advance. During an inflationary run, the consumer goods' basket, which excludes "volatile" food and fuel, tended to distort the overall picture. As it is indeed the case today, falling prices for industrial goods, such as flat-screen televisions and PCs, hide the rising seigniorial rents (tuition, insurance), while the dangerous inflationary pressure of fuel/food keeps adding up. These two trends affect diverse groups differently, adding to the already sharp rise in social differentiation, typical for the end of an era.

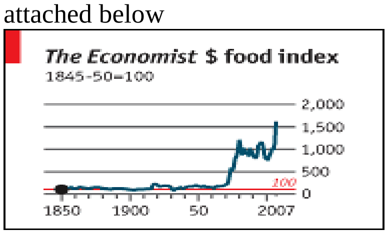
4. The lifecycle of a coenosis



Pic. 3

On Pic.3, the blue **S**-curve graphs the utility of the dominant resource, which is a function of the cumulative supply of the dominant resource, while the Hubbert's bell-curve[45] (red **H**) measures

[44] See the graph of food prices from http://www.economist.com/opinion/displaystory.cfm?story_id=10252015, attached below



[45] In the 1950s, to the derision of most oil professionals, K.Hubbert predicted oil shortages of the 1970s.

the production growth. The H-curve thus corresponds to the marginal utility of the resource[46] (first derivative), since it maps the growth potential, derived from a particular resource, dominant within its zone. Apparently, the more room for unhindered growth the higher its marginal utility seen as s steeper rise in its procurement. The black double-curve E (second derivative) represents the speed of this growth throughout the entire lifecycle of the resource, with critical breaking points: t_0, t_1, t_2. The pace of growth reaches its maximum at t_0 and then slows down. After reaching 0 at t_1, it turns negative until t_2, and then slowly goes up. E-curve represents our concept of marginal inelasticity[47] of the dominant resource within a zone, calculated for each point within the lifecycle of this resource.

In their turn, the short periods delineated by points t_0, t_1, t_2 have their important functionality in the lifecycle of a coenosis[48].

1. Left to the ***maximum of inelasticity*** at t_0 there is a period of strong growth, with easy pickings for the leader, while the resource's price isn't yet too high. Two possibilities exist, depending on the stage in the lifecycle. At the start of a coenosis, while everyone else is fighting for the diminishing supplies of the older resource, the leader develops a ***Killer App***[49] – as a rule, this specific application modifies an already existing technology, and is based on utilizing a cheaper substitute. As such, it possesses of such immense and life-changing power that it would be able to influence and shape everything yet to come. Or, we are still in the middle of a coenosis and resources are still plentiful, the winning economy solves its problems by radiating

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[46] Hubbert used the output of a well for modeling the US oil industry. Deffeyes (2001) used this approach for the globalized world. With the lifetime output of a well seen as its utility spread over the period of exploitation, each amount maps a point in the lifecycle. Hubbert used two axes, ***t*** (time in years) horizontally and ***y*** (yearly output, mln-barrels), vertically. Replacing t with x (mln-barrels) and measuring y in mln-dollars, the curve would map the marginal utility through yearly output, preserving its bell-shape. A point on a curve (yearly-output-dollars/yearly-output-barrels) represents the unit price at a specific point of a lifecycle. This curve estimates the marginal utility of oil resource for the geoclimatic zone of the US, while its extension (Deffeyes, 2001) models it for the larger world.

[47] Elasticity is usually presented as $\frac{dQ}{Q} / \frac{dP}{P}$ the ratio of relative changes per unit of resource to its price per unit. By averaging to units of quantity and price, this measure aims to represent the aggregated market response to price movements and other changes in market parameters related to revenues, incomes etc. In contrast, marginal inelasticity or partial derivative of $\frac{\partial P}{\partial Q}$ introduced by the authors is localized, measuring inelasticity at the current quantity of resource and its price. Austrian-school-like, this measure relates to elasticity in the same way as marginal utility to general utility.

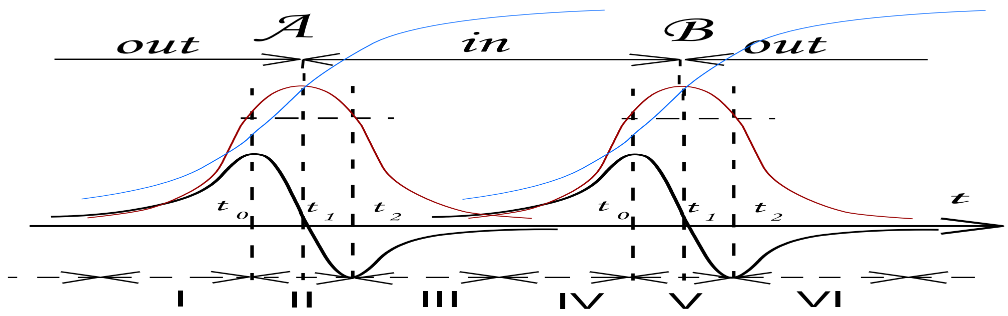
[48] Our concept of mapping the axis x into time t using the utility curves S,H,E of resource distribution is further explained in Appendix C.

[49] This is a term borrowed from the IT (Information Technology). A Killer App, which stands for a Killer Application, denotes a technology of such immense and life-changing power that it is able to influence and shape things yet to come.

to the close periphery of its initial geoclimatic zone. Prosperity increases along with the reach of trade flows.

2. The maximum of inelasticity at t_0 marks the start of destabilization. At least some customers reject the older resource. Unable to justify its exorbitant prices, they resort to substitutions. That is why, between t_0 and t_2 inelasticity steadily decreases until its minimum at t_2. Thus is overstretched the old infrastructure. Its grip on the economy breaks at the inflationary peak t_1, when the resource turns elastic again. This is the time of an ongoing switch, with uses for any available substitution. Note its start well before the inflationary price peak at t_1.
3. Right of t_2, easy substitutions come to their limit. The time has come either for building a specialized infrastructure for the brand-new resource (during the IN period) or expanding the infrastructure of the older resource outside its initial geoclimatic zone (OUT). For example, the US developed the Model T, its unique Killer App, promoting a switch to oil, in 1908, well before there were any good roads. Meanwhile, the Great Depression coupled with the environmental disaster of the Dust Bowl related to the tractor[50] showed the need in infrastructure, which was built during the 1930s New Deal. It included rural roads, rural electrification/irrigation, as a base for mechanized agriculture. The second-stage (OUT) of globalized oil infrastructure fully functioned from the 1990s, as a sophisticated network of oil refineries, tankers etc, connected through the Internet and financed by the petrodollar.

If we accept the H-curve as an approximation for a K-wave, as prices tend to follow the utility, a full coenosis can be depicted as a sequence of two curves. Its heyday AB (IN) starts with the destabilization at the inflationary peak A of the older resource. It ends with the inflationary peak B of its newfound resource that marks the exhaustion of its inner resources along with the necessity to get "OUT", searching far and wide for more of the same.



Pic. 4. The stages I-VI are explained below, in ch.4.

[50] In the 1920s 5.2 million acres were added to the 20 million acres in cultivation, with 50,000 acres-a-day stripped of prairie grass that held the soil. (Egan, 2006)

Both A and B mark a switch to a new (right of A) or wider (right of B) zone in order to exploit its resource. However, the situation right of B seems significantly less dramatic – the resource itself doesn't change, even though it has to be retrieved from a much larger zone. While it means a need in globalized infrastructure, to be built at a great cost and effort, the related turmoil can't be compared with a massive switch to a totally new resource. The latter tends to be accompanied with destructive events on the scale of two world wars of the 20th century. The new ownership/power institutes are shaped by and during this power struggle.

5. The Amazing Synchronicity of Historic Stages.

As shown in (Badalian, Krivorotov, 2006, 2007), historical coenoses displayed amazing synchronicity as they advanced through their lifecycle stages. We illustrate this process below with the case study of two coenoses: the industrial age of the 19th century and modern mass society, which flourished during the 20th century.

***I. The early period of growth*.**

The demographic charts on Pic. 1-2 show that both Britain and the US had a growth spurt well before the inflationary peaks of 1812 and 1914, which marked the birth of their respective coenoses. That is why these two eras are being compared routinely. For example, (Berry, 1987, 100) notes that the period of growth at the beginning of the 20th century was an "economic revolution, analogous … to industrial revolution". "In the US from 1880 to 1910 wealth increase reached 250% along with 220% rise in industrial output, seeding new industries – chemical, rubber processing, production of combustion engines, turbines etc". Similarly, in England the industrial revolution, from its very beginning well before the Napoleonic Wars, was fueled by the growth of the factory-based textile industry, while seeding a number of other new industries related to steam (Hobsbawm, 1999). In both cases, the new energy resource led to a dramatic increase in arable land. In the case of Britain, substitution of scarce wood with plentiful coal became economically important as early as the "Agrarian revolution" of the 17th century (Clark, 2002). Among other things, coal provided an alternative to firewood, previously collected in communal forests. Thus, its mass use enabled widespread enclosures of commons, freeing land for the production of food. Despite inhuman workhouses, more food meant a rapid population growth (Pic. 1) The US, in its turn, jumped to the oil age straight from using wood[51]. Prior to WWI, oil's economic importance grew based on the immensely popular Model T, gas-powered small farm machinery, substituting whale oil for lighting, instead of developing an expensive town-gas infrastructure. Thus, from its very beginning, the gas-powered machines had important productive uses.

II. Destabilization: entry to a new zone: a newfound dominance.

[51] Due to the absence of a sufficient coal distribution infrastructure in this huge country, the use of coal, even though it was mined in significant amounts, was mostly restricted to industrial applications within towns. Most importantly, the famous mass steel production in Pittsburg provided the base for the 20th century.

After the first inflationary peaks of their periods (WWI and the Napoleonic wars), both the US and Britain acquired new importance, as the creditor and the workshop of the world respectively. For the US, it all started as pure serendipity – with a sudden opening in the European grain trade. As described in the third volume of the Cambridge Economic History (*Engerman, Gallman, (Eds.),* 2000.)[52], this initial opportunity was handily built on by the US[53]. Its immense prairie land, which was barely inaccessible to mule teams, was finally cleared off in the 1920s using the tractor. A noted historian Roberts (1989) stressed the difficulties of switching from coal to oil economies, which, in his opinion, greatly contributed to the lengthy turmoil between the two world wars. Apparently, this could be only understood in hindsight. While coal infrastructure lay in shambles after WWI, the 1919 Versailles conference was busy negotiating a map with sufficient coal resources for all former belligerents, seen as essential for a "lasting" peace (MacMillan, 2000).

III. The end of "cheap" substitutions: building a full-scale specialized infrastructure.

The end of substitutions "on the cheap" hit the US during the Great Depression. Further exacerbated by the mass rural displacement due to the Dust Bowl, it conditioned the public for the New Deal. This was the time, when a specialized oil based infrastructure was built: including such not-for-profit projects, as rural roads to the market, rural electrification/irrigation. Similarly, Britain in the grip of the post-Napoleonic deflation also faced the need of building a railway infrastructure. In the 1830-40s, as early industrial jobs evaporated, the real income per head was steadily falling, "the age of (cheap) industrialization based on such things as textiles was giving way to the age of railways, coal, iron and steel… In the 1840s the spectre of communism haunted Europe" (Hobsbawm, 1999, p. 75-78). The temporal similarities were quite striking. In the 1930s, 4 quite dissimilar countries, the US, Germany, the USSR and Japan, despite their fierce ideological differences, proceeded to build their unique versions of oil-based infrastructure[54]. The relative merits of their handiworks would be checked during WWII. In contrast to this stage in the 20th century, during the 19th century Britain had no peers. Historically, it was the only coenosis, when a homologous equivalent for WWII was avoided. Apparently, a series of European revolutions in 1848 sufficed: by finally crushing walls, previously confining people within their inherited social strata. Thus were created abundant supplies of labor, both professional and manual, for the nascent European industrialization.

IV. Radiation of the winning economy to its close periphery.

The Marshall Plan, albeit significantly more institutionalized, had an eerie resemblance to the post-1848 industrialization, which also handily spread the winning model of the-then dominant to its close periphery. The European resurgence, both in the 1840s and 1940s, was funded by the dominant (respectively, Britain and the US), based on its winning technology, and the related

[52] the Turks stopped the flow of Russian grain by closing the Straits during WWI, thus creating unsatisfied European demand.

[53] There was also Argentine etc, which is out of the scope of this article.

[54] The New Deal programs of rural irrigation/electrification eerily resembled projects pursued by the SU/Germany. Around the Great Depression, Stalin presided over the infamous Holodomor in the Ukraine, with small-holders replaced with tractor-powered collective-farms.

economy/lifestyle (as far as culturally acceptable). The exchange flows enriched both the dominant and the new entrants, just as its zone showed its limits.

***V. The 2nd inflationary peak: the dominant loses its technological edge*.**

Following the inflationary peaks of the 1860s and the double Oil Shocks of 1973-81, respectively, the dominant of the time (Britain or the US) lost its technological edge to the countries of the "second echelon". During the 19th century, this created an opening for Germany and the US, which could develop their unique specialized economies, based on chemistry/electricity and oil respectively. In the 20th century, similarly, Germany and Japan, followed by the Dragons/Tigers etc, led in electronics and fuel-saving technologies.

***VI. Globalization: a swift expansion of the zone, including its size, wealth and control over commercial flows*.**

Soon, the upstarts would lose their spark, since the age of the dominant resource of the time was not yet passé. Closer to the end of century, both in the case of the 19th and the 20th centuries, the dominant produced its "Swan Song", a technological breakthrough, the basis for building the global infrastructure of its dominant resource – which was the iron steamship and the Internet respectively. The giant exchange flows of the modern oil-based globalization were enabled by the container ship, funded by financial/communication networks. The PC and the Internet created in the US made outsourcing both possible and profitable. Similarly, Great Britain reached its zenith during a homologous stage of the previous century[55]. The British-built global coal-infrastructure consisted of a dense network of coaling stations, British navy patrolling the seas, and global railroads. The river-like dendrites of railroads collected goods from entire continents to the ocean's shore. Then great steamships could carry them off to London. Turning every exchange, regardless of its parties, into a three-way trade centered in London added significant seigniorial fees. Even as the British industry stagnated (made "hollow" by outsourcing (Hobsbawm, 1999)), the empire grew rich, making it into the fervent proponent of free trade. Today, the direct control from the US may be likewise faltering. But, just as it was the case a century earlier, the global exchange flows are still supported by the three-way trade based on oil-flows and paid for with the petrodollar. China plays an important role – it sells its products to the US using its dollar-denominated profits to buy supplies/technologies elsewhere. Currently, as the military mishaps are weakening the dollar, the euro-zone, led by the Great Britain, is positioning itself to the central role.

6. The End of a Coenosis.

As the mass-production coenosis of the US-style oil-economy approaches its geoclimatic limits gradually beginning to wane, the universal currency for global trade has moved front and center. Its stability becomes paramount for monetizing the diverse globalized world, supposed to be run smoothly within the folds of the dominant economy of the time. Amazingly, this functionality is preserved whether the dominant is the creditor (Britain) or the debtor (the US). At the first

[55] Just the direct payments from India amounted to 2/5 of the British budget (Hobsbawm, 1999).

glance the differences seem stark. In the British Empire, its satellite-countries had economies of deficits and the dominant thrived on enormous interests charged for its loans. Today, both the raw-material-suppliers (the Saudi Arabia, Russia etc) and industrial-service powers (China and India) run economies of ***proficits***, essentially lending their earnings to the developed world (including the euro-zone), so their citizens would be able to buy more imports. It would seem that China that pollutes its environment to industrialize for the sake of the developed world or Russia that trucks away its natural resources to more or less the same address would be able to dictate their conditions to their debtors. The reality is, of course, the direct opposite. Neither China nor Russia nor any other supplier-satellite can easily divest of their paper "profits" and thus must support the leading currencies or lose the accumulated funds. While they can and do indeed diversify their holdings among a basket of currencies, there is no sensible way China can use a trillion dollar it holds – 10% of US GDP. Not that it can freely buy western companies it fancies without first asking either the US Congress or Euro-parliaments or both for their kind permission.

Immanuel Wallerstein of the "world systems" theory found that in 500 years of European dominance there wasn't a single instance of "periphery" moving up to the "core". As the dominant country of the time had faded, its position was taken up by a "near-core" one. The use of universal currency further strengthens the asymmetries of global exchange. I.e., in Russia, its currency reserves deter the development of its domestic industries – it is easier and cheaper to import than to build. Joseph Stiglitz (2005) demonstrated the asymmetric nature of global markets and proposed ways for making them more equitable. However, there is also a systemic problem, hardly correctable by the boldest policy changes. Historically, a new coenosis was rightly considered "wastelands", barely suitable for the dominant economy/technological style. To unleash its true potential, it had to develop a unique adaptation (economy + technology) to its zone. This, along with the burden of the growing seigniorial rent for the dominant's crucial infrastructure of the global trade, was, perhaps, the most important reason for the "break in continuity" between coenoses (Badalian, Krivorotov, 2007).

In our age of global warming on the background of arms proliferation, the old recipe of increasing energy consumption may be in a need for dramatically new solutions. In our next paper we'll show that the switch to future energy-saving technologies may be somewhat alleviated by something so simple (and incredibly hard to pull through fierce human resistance) as an orderly replacement of the dominant currency with carbon credits, suggested by J. Stiglitz. A precedent for such a switch already exists (the euro). With the right implementation it might be made Pareto-efficient for both the creditors and the debtors helping them towards a soft landing. The authors would be happy to falsify their theory by voiding its dire predictions of a fiery global conflagration in 10-25 years or so.

Appendix A. Modeling the European Historical Lineage.

As noted in the abstract, the model offered below is dealing with the European line of development and explains its reliance on technological muscle as compared to the relative technological backwardness of the Eastern societies. These differences were well pronounced starting from the 16th century. A particular society is understood as a coenosis, a community consisting of interdependent producing and controlling tiers. To survive on a given territory it develops a specific form of *land use* as a special cultural package, comprising all the necessary skills, including its unique technological style, social institutes, forms of ownership etc. As shown below, after being formed this package can be used for passing these skills forth as immutable bundled know-how, which is well identifiable and transferable across the board. Historically, the eastern and western societies differed as implementing incremental and radical approaches to incorporating the needed technological advance. In the East cultural packages pertaining to different eras tended to meld together in a complex societal fabric in order to coexist spatially. Meanwhile, in the West they were rather first created and then destroyed, thus, they succeeded each other temporally, with a pronounced dominance of the very latest package, while the others were present at its background as elements of its dominant infrastructure. This tolerance towards earlier, perhaps currently less efficient models, which could coexist with the current mainstream on a peer basis, explains the relative technological backwardness of eastern societies. While they escaped the more painful write-offs typical for western societies, the coexistence of diverse packages did not lead to a clean slate and could not provide uncompromising institutional support needed for new technologies to realize their latent promise.

That is why a complete model of a western coenosis would consist of two clearly identifiable stages: the formation of a cultural package and, then, its write-off as it is transformed itself into an infrastructure for reaching out for the resources of its faraway periphery, as soon as its inner resources were gradually exhausted. Since the conditions on the periphery were quite different from whatever a coenosis was formed to live off, its initial cultural package had to adjust to a new geoclimatic situation and then be dispersed in the most physical sense of this word. At the end, the gradual dissolution and diversification of the initial cultural package would help in seeding the future growth spots. The model below presents the first stage, when an immutable cultural package of a given era is formed, manifesting itself during its "Golden Age[56]"For a complete 2-stage model this should be supplemented by the addition of the second part, modeling the stage of reaching OUT. While the creation of the distinct cultural European packages, up to this date, followed the line of climbing up the energy consumption ladder, the infrastructural part is related to the dissolution of the said packages as they were stretched over a much larger Ecumene. It followed a supplementary line of developing the leading material of the era as a basis for its far reaching infrastructure. Among the latter: bronze for the Bronze Age of the first civilizations, generic iron for the Iron Age of the classical antiquity, the bog iron of medieval Europe, first large smelters of the preindustrial era, the pig iron of the Industrial Revolution, steel for the mass society of the 20th century, silicon and man-made nano-materials as we are reaching out and seeding the next technological growth pole. In this sense, it is possible to envision the transformation of our society, which, during millennia, staked its future on using the ever more powerful machines, pursuing the uninterrupted line of mechanics. It is already being supplemented by a competing line of electronics, potentially leading to a trade off

[56] Golden Ages within the last two hundred years, and their dynamics including bursting bubbles etc were extensively researched by Carlota Perez in the context of interrelationships between technological revolutions and financial capital (Perez, p.5,24,26,43-44,53-55,76,109,124,133,154,167,171).

of more power for more precision achievable through a shift to a line of tiny, better calibrated mechanisms. In our future works, we plan to present the second part of the model and, based on the apparatus of the theory of coenoses, explore a switch from relying on power to relying on precision. This would be completed by exploration of current trends already molding our future.

Modeling the shift in the land use patterns for historic European societies.

To model a switch to a new pattern of land use one must overcome a fundamental problem. Most anyone looking at, for example, the 19th century Britain, and then turning her gaze, say, towards the 20th century US, would certainly agree that there were indeed major differences. In the first case there were people in funny hats climbing into sooty trains, and, then, suddenly, here comes the oil age, with people in T-shirts and jeans riding in cars. But even if most would easily concur that in between these two snap images there was a seminal switch, an unanswered question remains: to what, when and how. Is there indeed an exact moment, when one age ends and the other starts? Does the change have anything to do with actual inventions and their timing? Well, perhaps, not that much – otherwise, ancient Greece, where Heron of Alexandria invented the steam engine as early as the first century AD, would have grown into the first industrial power. Historical evidence shows that inventions happened more or less haphazardly. All attempts to find clusters, bearing witness to the so called Schumpeterian burst of innovations, were, as to this date, mostly unsuccessful.

Nevertheless, it makes sense to rephrase the initial question and try to find instead something altogether different: a striking feature repetitive through centuries – serving as a sort of an advance notice for dramatic changes yet to come. It turns out that there was indeed such, the so called "Golden Ages", which used to precede an era neatly. Historically, they represented a short burst of glory – a strange mix of incredibly advanced and anachronistic features – tinged at its very summit with a bluish blush of death.

The volcanic rise and, in a short half-century, ignominious fall of the Athenian Empire, which managed, nevertheless, to seed the world with the Hellenism, is the first to come to one's mind. There were other similar periods, less known to the public, but no less striking in their short and magnificent bloom and the ability to influence the others. Among them, the "sudden" urbanization of the Fertile Crescent, with large cities rising "overnight" in a tiny territory covering barely tens of square miles, while before only small communities could eke a living. (Nissen, 1990, 15-39) And then, after a short flourish, the Sumerians, the original "black-headed" people were there no more, disappearing under waves of Semitic tribes. Nevertheless, the newcomers would further spread the initial Sumerian cultural package of irrigation agriculture. At times, perhaps, it was passed well beyond their immediate sphere of contacts – the civilizations of the Nile, the Yellow River, or the Indus – could they have been somehow helped to their own specific versions of irrigation agriculture? Centuries later, the rise of the Carolingian Empire from the end of the 8th century was based on the remnants of the Roman administration and apparently, possessed no steady economic foundation. However, it developed its notable "shock troops", an early forerunner for the future knight armies of the Latin Christendom. During the crusades, the latter would impress the Byzantines with their rough clothing and magnificently plentiful iron, the technological basis for the medieval economy and its massive forest clearings. A similarly unusual pattern was also present in the Netherlands

(1580-1633). The latter rose as "the first modern economy", with a short bloom in a "no-man's land" next to the sea, that could support only a few forlorn souls before. Soon, they would sell the very soil under their feet, and swiftly fade. But, before their fading, their entire package, including finance, trade, logistics, early manufacture etc would be passed on, to Britain and, perhaps, less directly to France, the next dominant. Then, there was Britain. After losing its Northern American colonies and, along with them, any reasonable hope of getting secure supplies of timber and iron, the inelastic resources of the time, it suddenly rose as the "workshop of Europe", right in the midst of the Napoleonic wars. One would think that its commerce was rather helped, instead of being hindered by the "continental blockade" maintained by its mortal foe. In contrast to most of the examples above, Britain did not fade, at least, not at once. Instead, it managed to build the infrastructural foundation for its steam economy in the depth of the so called Great Depression of the 1830s. Then, it surged forth, creating an Empire, with sun never setting over it. Similarly advantageous was also the fate of the US, the current leader. It first rose to international prominence as the main supplier during the WWI. Then, it boogied itself to "speakeasies" during the "Roaring Twenties", just as the world tried to mend itself from its wartime hurt. During the Great Depression, the US managed to build a wide infrastructural foundation for its fledgling oil economy and then returned back to prominence, supplying the allies during WWII and then giving a boost to their economies with the Marshall plan. So, actual scenarios of a particular historic case of a prominent and short bloom could vary wildly, responding to the quirks of their respective eras. However, the overall pattern within the European line of evolution was quite stable, presenting itself as a suitable base for developing a model, outlined below in the Appendix B.

The Schumpeterian creative destruction is unleashed during the Malthusian inflationary peak.

The examples above provide evidence of short, but quite pronounced periods of dramatic technological advance. So, one would expect to also find the evidence for the related clusters of inventions. This search may be in vain, as no such observable clusters were discovered (Badalian, Krivorotov, 2006). Instead of thinking up new things at the time of their dire need, people in a hurry made do with whatever they got. Hard pressed by shortages, they were forced to rethink and readjust many preexisting, most often, mismatched technologies, until the latter fitted each other as a hand in a glove. Thus was created a transferable recognizable ***cultural package*** setting a given era apart. The mechanics of this process, when the Malthusian pressures caused a Schumpeterian wave of "creative destruction", were quite uniform across ages.

As a rule, Malthusian resource shortages started a notable mass exodus to rapidly expanding cities. Regardless of an era, it was caused by the loss of utility within traditional occupations, as noted by Fischer throughout his book (Fischer, 1996). Surprisingly, this applies even to the case of the medieval era, where towns in general were few and far between. Thus, while supplies of all the other resources were dwindling, there was a singular resource, whose supply instead was rapidly growing. The cheap mass labor force was, as a rule, conveniently congregated in towns. Thus, facilitating its gainful employment was comparatively easy. If, however, that wasn't done on time, rising pressures could lead to revolts, often, on the background of major wars. Apparently, the fork, where the future dominant and all the others, most prominently, the already fading leader, parted their ways, can be traced to their respective ability or the lack of thereof to *productively utilize this mass excess labor*. For the one, who was able to arm this human mass with appropriate business techniques and tools, as to this date, more powerful energy-wise each and every time, it spelled immense riches. Sooner or later, through huge suffering and struggle, but somehow, by the skin of their teeth, avoiding wholesale slaughter, these riches would gradually trickle down. For anyone else, this human mass writhing in pain would, instead, constitute the source of any imaginable trouble. Since this displaced workforce was quite inexperienced, using it was never too easy and couldn't be accomplished within old business models and without tweaking up the preexisting technologies. Its gainful employment was thus contingent on substantial technological advance and total rethinking of the existing business practices. Among notable examples are: the early industrial factory[57] or the conveyor belt in Detroit.

Note that the employment of the "unwanted masses" usually acquired brutal and strikingly inhuman forms, such as the British workhouse or slavery in the ancient Greece, where people were bought and sold as chattel[58]. At this moment in history, the Malthusian pain is widespread and more or less unavoidable, and, compared to others, the future leader gets a substantially better deal, if we measure it suffering-wise. At the end, everything boils down to a single point – inasmuch off-putting the circumstances, a lot more people must be fed. Thus, the only objective at this moment in history seems to be a substantial increase in the carrying capacity of the available land achieved through a prompt shift to a new, more efficient land use pattern. For example, at the end of the 18th century, demographic pressures and resource shortages were similarly pronounced both in France, the fading dominant, and Britain, the future power. In the interest of preserving the social concord and saving jobs endangered by mechanical progress, the French royals went to great lengths and routinely sacrificed technological advance. This did not save them from the guillotine of the French revolution. Napoleon continued their tradition, by channeling the excess labor into his armies, which also could house the better technologies unacceptable in the more staid civic environment. Meanwhile, the British grew rich in the middle of wars, not infrequently benefiting from French inventions[59].

[57] The high density of urban population provided the cheap labor force for new types of occupation, as shown by the rather unusual initial reason for employing orphans in the sweatshop "By 1774, Arkwright had two factories complete with water frames and two new water-powered looms, but he had no workforce. Local spinners and weavers worked their own hours in their own homes. Unused to wage labor, they valued their independence too highly to work 16 hours a day inside a factory, and they found the new machines difficult to master. Arkwright was forced to hire poor children and orphans… as spinners and weavers. By 1790, his mills employed as many as 5000 workers, most of them children" (Bland, 1995, 9)

[58] This form of owning a human as mere property was repeated during the early industrial era only, as a means to satisfy market demands (black slavery – cotton, serfdom in Russia – grain).

[59] See, for example, the circumstances surrounding the rise of mechanized production of textiles. The early machines for complex pattern weaving were invented by Jacques de Vaucanson. Being of humble origins he rose to become a French Immortal, a member of the prestigious French Academy of Sciences, and was appointed to the position of the general inspector of the Royal manufactures in Lyons. In 1743 (40 years before the 1785 Cartwright's loom) he invented a fully programmable loom, operated by punch cards. This invention was rejected by the powerful Guild, mindful of preserving their jobs, and sent to collect dust at the Museum of Arts and Sciences in Paris. Then, yet another Frenchman, Joseph Marie Jacquard, simplified Vaucanson's design. During the 1801 French Industrial Exhibition (the famous English Exhibition at the Crystal Palace was in 1851), his machine received the Bronze medal and an order of the Honorable Legion for his inventor personally from Napoleon. In 1806 the machine was destroyed by the Lyons Guild of Weavers. In 1810 it was imported to England. A small Scottish city of Paisley gave its name to the popular shawl design, formerly known as a *buta* in India. The first all-wool patterned shawls were made in Paisley in 1823. Since the Jacquard loom used *punched cards* instead of a *drawboy*, it eliminated human

In a way, two drastically different solutions to the unavoidable Malthusian debacle must be differentiated. One pertains to a *Mercantilist tradition* and was concentrated on divvying up the existing resources. Since those, a-priori, were always limited, this inevitably led to wars and revolutions and other events of Malthusian bloodletting and "cleansing". Meanwhile, a hitherto "empty" place reclaimed by rejects and misfits, who, at the beginning, tended to congregate in towns, may have opened a rare opportunity for a different, *Smithian-style* solution. Facing little resistance, since everything had anyway to be built straight from the scratch, their accumulated manpower could succeed in creating new value, as if out of "thin air", where before there could be found none.

We would like to conclude this short overview with two lengthy quotes: the first comes from Eric Hobsbawm, a renowned British historian, who provided a fitting description of the Smithian version of the process described above; and, after that, we switch to Carlota Perez, who introduced the concept of an immutable *technological style*.

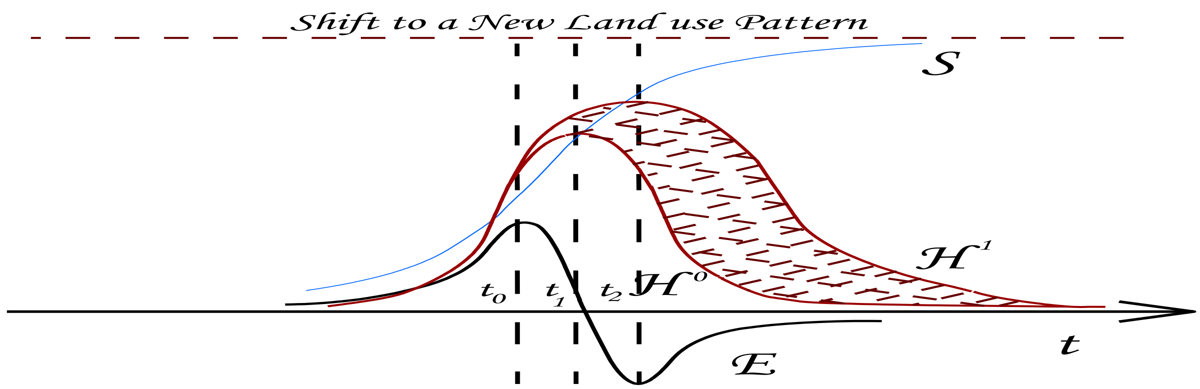
E. Hobsbawm wrote the following paragraph for the industrial Revolution in Britain, but, in fact, it could be used to describe the rise of a specific cultural package for any new land use system.

"The novelty lay not in the innovations, but in the readiness of practical men to put their minds to using the science and technology which had long been available and within reach; and in the wide market which lay open to goods as prices and costs fell rapidly. It lay not in the flowering of individual inventive genius, but in the practical situation which turned men's thought to soluble problems. This situation was very fortunate, for it gave the pioneer Industrial Revolution an immense, perhaps an essential push forward. It put it within the reach of an enterprising, not particularly well-educated or subtle, not particularly wealthy body of businessmen and skilled artisans, operating in a flourishing and expanding economy whose opportunities they could easily seize. It other words, it minimized the basic requirements of skills, of capital, of large-scale business or government organization and planning, without which no industrialization can succeed". (Hobsbawm, 1999, p. 60)

After being formed, a specific cultural package is then passed forth in its immutable form, as a fixed technological style, a recognizable characteristic of its era. Eric Hobsbawm showed it through examples, and Carlota Perez formulated the concept directly. "Perez defines a "technological style" as a sort of "ideal type" of productive organization or best technological "common sense" which develops as a response to what are perceived as the stable dynamics of the relative cost structure." She and other authors show that, "Thus, it demands a high level of

errors and reduced qualifications and the size of the workforce drastically. These looms, large and expensive, demanded a shift from cottage industry to factories. In 1840s, following its tremendous English success, the machine was finally reintroduced to France. Then all that remained was waiting for a lucky break to gain a foot in the door. The Franco-Prussian war of 1870-1871 halted exports of shawls from Kashmir, resulting in the collapse of Indian industry. By 1870 a woven Jacquard shawl could be bought for £1 and an identical patterned cotton shawl for a few shillings. (*The Kashmir Shawl*, 1973), (Ames, 1986), (Clabburn, 1996), (Levi-Strauss, 1987) skills, capital expenditures etc, which cannot be provided by most "emerging" nations. This, in fact, solidifies their secondary position, as they start lagging both technologically and institutionally". (Perez, cited in (Tylecote, 1993, 36))

A short description of the model of switching to a new land use pattern.



Pic. 3A[60]. Modeling a shift to a new land use pattern: the increase in the use of substitutes opens up a narrow window of opportunity (cross-hatched) between the bell-curve of the initial marginal carrying capacity of the land H^0 and the bell-curve modified by adding substitutes H^1. NB: Carrying capacity of land **S** is understood as utility of land use.

The model below describes the development of a new ***land use pattern*** for a given territory or geoclimatic zone. Its similarity to the model of the main inelastic resource (presented above and in App. C) should not be surprising. Within the European line of development, supplies of the specific main inelastic resource of a given historic era serve as the proxy for measuring the carrying capacity of the land – namely, its ability to feed its population. At the end, everything must come from the land, which is the ultimate source of all goods, be they agrarian, mining or industrial. That is why our model is in no way restricted to market economies. The opposite is rather true – it applies to everything dependent on the carrying capacity of a particular territory measured through its main inelastic resource, even if such a resource appeared in a specifically "non-agrarian" form, i.e., as coal or oil.

1.***The economic growth and its gradual deceleration.*** The economic growth of a new geoclimatic zone starts with a wide radiation of preexisting technologies from the dominant. Initially, this causes no noticeable changes in power and social structures. However, there is a surge in demand – traditional habitats are gradually destroyed pushing people to move to cities, where survival rates tend to be higher. This starts a demographic boom, with rising resource shortages within the existing system of land use.

[60] As above, in Pic.3 – **S** is the logistics of the carrying capacity of a given geoclimatic zone (reflecting both the growth of its utility and the related buildup of Malthusian pressures as the growth of utility gradually slows down), **H** – the marginal utility of its land, and **E** – its inelasticity in the sense of finding suitable lands for radiation within the given system of land use. The deceleration of the land's carrying capacity **H** starts at the point t_0, marking the start of the plateau for **S**, as the ability to support further demographic growth on the given territory is curtailed and people start moving to marginal lands, with much lower utility.

2.***The Schumpeterian creative destruction is unleashed during the Malthusian inflationary peak.*** As shown on Pic.3, due to the demographic growth, the carrying capacity of a given land S gradually approaches its breaking point t_1, while t_0 already marks the starting point of growth deceleration for the marginal utility of the land H. After that, the resource stops paying for itself – the growth of returns lags behind the growth of expenses forcing people to gradually reject the leading inelastic resource in favor of its substitutes. People are pushed to marginal lands and towards accepting substitutions, despite their lower quality and hidden costs[61]. Thus starts a period of acute resource deficiencies, when growth in demand can only be satisfied by substitutions – an inflationary peak $[t_0, t_2]$. It is at that very time that new technologies of the Schumpeterian "creative destruction" taken together lead to a rise in the carrying capacity of the land. Somewhat compensating for the destructive power of the Malthusian trap, the land, formerly thought of as marginal, temporarily regains its ability of absorbing the "excess" population. Historically, the inflationary peak led to urbanization, with "excess" population being sucked into towns, to eke their living in new and unusual occupations. The related surge of substitutions helped to prolong the older pattern of land use[62], causing a temporary boost to land's utility. Thus was produced an extremely narrow, but quite crucial and fruitful window of opportunity[63]. A parallel institutional change, as the "rejects" congregated next to each other in towns, cleared the vestiges of the old and provided a much needed room for a shift to a new pattern of land use. Not surprisingly, the related periods are remembered in history as "Golden Eras" (Perez, 2002), with very short intense flourishing. Despite their brevity and utter fragility, these Golden eras, such as the rise of the Athenian Empire, the Netherlands 1580-1633, etc. served a crucial role. Historically, it was the time for urban growth creating the all-important technological and social foundation for the entire next coenosis, especially, its recognizable technological style (Perez, 2002). Returning to our curves, the elasticity of the old resource,

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[61] Today, for example, a shift to biofuels leads to higher food and environmental costs.

[62] Today, global production of biofuels is already rising annually by about 300,000 barrels a day. "That goes a long way toward meeting the growing demand for oil, which last year rose by about 900,000 barrels a day. Without biofuels, which can be refined to produce fuels much like the ones made from petroleum, oil prices would be even higher. Merrill Lynch commodity strategist Francisco Blanch says that oil and gasoline prices would be about 15% higher if biofuel producers weren't increasing their output. That would put oil at more than $115 a barrel, instead of the current price of around $102." "Mr. Blanch at Merrill Lynch says he expects new oil from producers outside the Organization of Petroleum Exporting Countries to taper off to as little as 300,000 barrels a day by 2011 -- about the equivalent of today's annual increase in biofuels production. Production from OPEC is tougher to forecast, in part because of the unpredictable political forces that shape the group's decisions. Last year, however, the cartel's output, including that of new members Angola and Ecuador, declined by about 400,000 barrels a day, according to the IEA. OPEC has lately decided to hold production at its current levels despite oil prices in excess of $100 a barrel.
"As Biofuels Catch On, Next Task Is to Deal With Environmental, Economic Impact. By Patrick Barta, WSJ. 03.24.08., Page A2.
http://online.wsj.com/article/SB120631198956758087.html

[63] There is a significant time lag between discovering a new resource and creating a full fledged land use system, able to feed off its utility. For example, oil was well known in biblical times – some geologists (Deffeyes, 2001) see Bible as a good oil finding manual. However, the first commercial uses if oil can be dated from 1848, when kerosene was first developed spurred by an inflationary rise in whale oil prices. In 1858, the famous well in Titusville started producing. However, the radiation of oil economy US-style had to wait until the 1950s.

temporarily boosted by the availability of substitutions, starts to slowly increase. It is as if people literally push at the curve, turning it up. For a short period of time, it changes, acquiring an upward shape. From t_0 to t_2, the old resource and its substitutes start to shift places, with the former becoming more elastic and the latter more inelastic. This signals that the process became irreversible. Though still fragile, the new land use system is already established and the period of initial destabilization may be already behind.

In historic societies, the inflationary peak itself, resource substitutions upon reaching it, and the gradual rejection of the older inelastic resource along with the related form of land use, usually attain quite painful forms. While the few "Golden" growth poles[64], cited above, flourish, around them there are widespread destabilization, wars and revolutions, on the background of seismic geopolitical changes and acute food and resource shortages. Taken together, this leads to a complete shift in land use patterns while also reshaping all major social institutions. Starting from the point t_2 a growing shift towards substitutes leads to the rise of competing systems of land use.

3. ***Growth failure due to the Malthusian trap leads to a deflationary trough and pushes towards building a brand new infrastructure of land use.*** As described above, the growth, which starts at the end of a period on the strength of substitutes, is extremely fragile. Its narrowness is defined by the restricted size of the so called "growth poles" (such as Detroit in the 1920s) and by practical absence of any infrastructure for the new type of land use (there were yet no auto roads then). Such growth is predestined to fail shortly because of the narrowness of demand for its product – as yet the majority of population is not involved in the new system of land use and/or gets pushed to marginal lands, where the Malthusian trap awaits. Failure of demand causes deflationary pressures, homologous to the Great Depression of the 1930s. it had parallels in the past – there was a notable depopulation, say, of the Sumerian cities after 2200 BC, or the Netherlands after 1663. The deflationary conditions, with the corresponding fall in prices, for both labor, resources and food, temporarily boost the marginal utility of the land, causing a flurry of investments into infrastructure projects supporting the new system of land use (the 1930s: the public projects of the New Deal in the US, autobahns of the Nazi Germany and huge projects in the USSR). Such investments become feasible amid major population displacements leading to affordability of labor. Thus, through suffering, the new land use system obtains a wide infrastructural foundation, preparing it for the next stage.

4. ***Radiation of the complete cultural package: the new system of land use + its infrastructure.*** We will show that, historically, this opened up a new, barely touched geoclimatic zone. Within the 'European' line of evolution, we can pinpoint at least six such zones, starting from the first civilizations and ending with the mass society of our days. Each and every time, the Malthusian trap was overcome by unleashing the Schumpeterian "creative destruction"', as only new technologies tightly enmeshed with appropriate institutional changes could open up a new land

[64] We treat the concept of "growth poles" in the context of our theory of coenoses, not specifically related to the known theory of the same name associated with Francois Perroux, a noted French economist. (Bocage, D., 1985)

along with its resources. In short, thus was created a new pattern of land use, a coenosis. After a painful shift, at least decades long (i.e., switch from coal to oil in 1914-1945), population growth was resumed, due to a dramatic increase in the carrying capacity of the new zone. Europe depended on technological advance for its very survival – which may explain the phenomenon of European military buildup and its propensity towards colonization as soon as it gained sufficient technological muscle, somewhere from the 16th, 17th Centuries.

Below, in the Appendix B, we will illustrate the model presented above with examples of starting points for six historic societies. We depict their "Golden Ages", which grew rich "on the cheap", by developing the cultural package of an era. This would lead to a novel land use opening up the next geoclimatic zone, the birthplace of its unique coenosis. In all known historic societies, the initial short, but intense periods of growth led to urbanization, often, in extreme forms. Providing support to the Schumpeterian concept, towns grew during a daring leap into the unknown – they furthered technological advance, creating preconditions for dealing with the specific needs and demands of an up and coming zone. Historically, such periods were extremely short. The corresponding "hot growth poles" could arise and exist, as any other unusual physical phenomenon, only within a very narrow 'Window of Opportunity', which provided extremely high returns, of the type of "skimming the cream", an early adopter "premium" for a shift to a new system of land use. In a large part, these gains were attained by dismantling the older system, which, at that moment, was insupportably costly[65]. We end the story just as these hot growth poles were hit with a depression[66], with their further growth hindered by the lack of an appropriate supporting infrastructure[67]. Serving as means of opening up a specific territory, previously of marginal utility, all the basic resources of any rising economy, including its novel, calorie-wise more powerful energy sources, the related social institutes and the technological infrastructure, were strictly territorial and boiled down to domesticating a specific geoclimatic niche by its coenosis.

Appendix B. Historic growth poles: from Sumer to Detroit.
Forming a living coenosis provides the means to feed off a specific land.

Below, we describe the Golden periods of 6 known historic societies within the European line of development. In our future works, we plan to expand this model by exploring the significant confluence between diverse societies, evolving during the same time span. Presumably, their

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[65] According to (Clark, 2002) in Britain, a switch to coal from wood increased the arable by about a third, previously occupied by renewable forests (coppice woods).

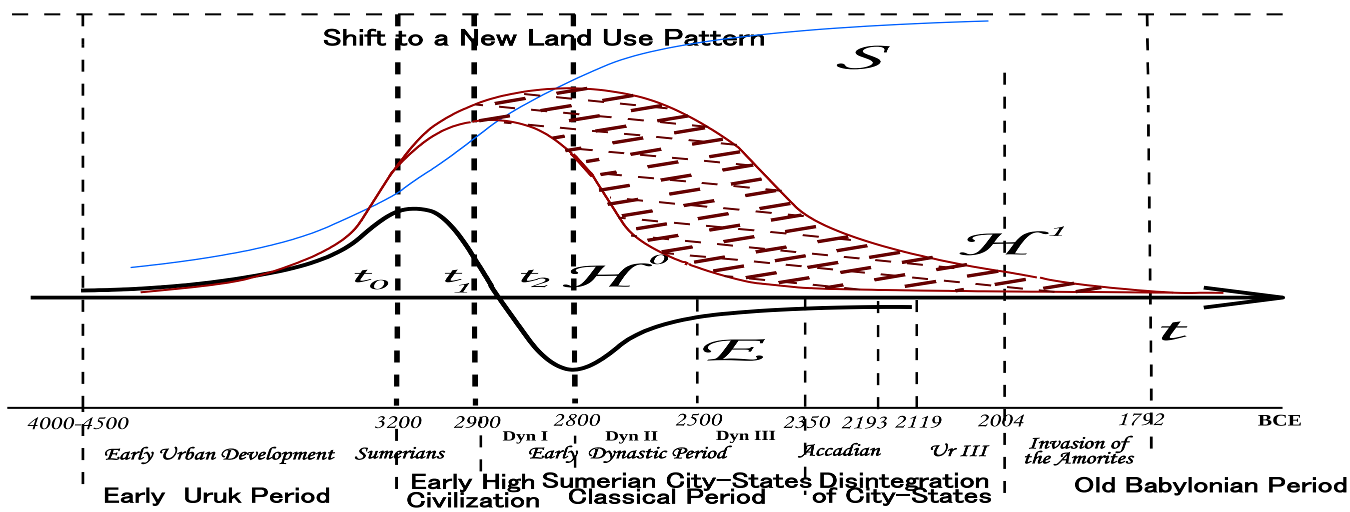
[66] "***One fact that jumps out from the figure are the long periods where a high percentage of all countries are in a state of default or restructuring*. *Indeed, there are five pronounced peaks or default cycles in the figure*.** The first is during the Napoleonic War. The second runs from the 1820s through the late 1840s, when, at times, nearly half the countries in the world were in default (including all of Latin America). The third episode begins in the early 1870s and lasts for two decades". (Reinhart, Rogoff, 2008)

[67] For example, the wartime destruction of the costly system of coal-related infrastructure (comprising coaling stations, British navy, financial system based on the pound etc) led to the high profitability of diesel based shipping "The cropland used to feed horses and mules peaked in 1915 at about 93 million acres; 79 million acres for maintaining work animals on farms and 14 million acres for producing their feed. (Olmstead & Rhode. 2001, pp. 663-698). This land was freed up for the production of food. Later on, however, tractor usage caused immense environmental problems of the so called Dust Storms of the 1930s, requiring a costly shift towards mechanized farming during the New Deal (rural electrification, mostly for irrigation; rural roads to the market etc).

unmistakable similarities could be caused both by social/technological transfer and planetary climatic changes[68].

1. ***The deltas of the great rivers – the resource of alluvial mudsoils for irrigational agriculture (Tigris, Euphrates, the Nile, the Yellow River).*** *The rise of Sumer as a growth pole for the new irrigation-based system of land use. Large manmade canals and super high density of population in the new urban centers (Kish, Lagash, Ur, Uruk).*

The old system of land use was based on the direct use of mudsoils in the deltas. This became possible, when the initial stages of aridization ca. 6000-3200 BC in the previously swamped lands of Mesopotamia created natural canals, which could be improved with a few tools. The alluvial mudsoil of the deltas prior to extensive canal building of the later stages presented an extremely limited resource, covering barely tens of square miles (Tigris and Euphrates in Mesopotamia, and the Nile in Egypt). Because of its small size, the primary type of land use of nearly-natural irrigational agriculture with smaller local canals couldn't support sufficient population for maintaining the bureaucratic institutes of the territorial state, which later became typical for this era.[69]



Pic. 3.1 The Classical Sumer – a Hot Growth Pole for the first civilizations.

The new system of land use, able to support the rise of civilization, demanded massive earth-moving projects (dams/canals and tilling with the plough). Since the utility of this land resource can be measured through its returns, it does not differ much in this sense from the case of oil. With land, the returns come from harvests, which measure the utility and the carrying capacity of the soil for a given technology $\dot{x}$ of land use respective to the total amount of harvested grain x,

[68] See footnote 3.

[69] Immediately before Sumer, we see the rise of the Ubaid settlements (5300-4000 BC) with primary patterns of not very densely populated cities. The land use is mostly based on natural floods bringing in the fertile mudsoil. (Nissen, 1990, 65) points at dramatic changes in the pattern of land use with the rise of densely populated Sumerian cities.

needed for reproducing the spent labor. This brings us back to the equation (3.1). The turning point in the initial logistics for the first civilizations corresponded to the maximum marginal utility of the initial area (under old land use system)[70] and can be dated ca. 2900 BC, with the rise of kings in Mesopotamia and Egypt. The king's rule and enforcement became the institutional foundation for building and supporting larger dams and canals, allowing addition of more land of somewhat lesser quality to the initial extremely rich soil, thus laying the base for a new land use system. This process is traceable through the start of immense building projects and the widespread radiation of cities during the early dynasties I, II, III in Kish, Uruk, UR ca. 2900-2350 (the classical Sumer of Gilgamesh and Enkidu) or the Ancient Dynasty in Egypt. After that, the logistics of utility entered its plateau causing a Malthusian overpopulation[71], whose effects were noticeable from the Akkad Dynasty and up to the Third Dynasty of Ur, which ended with the invasion of Semitic tribes. Thus, reaching the breaking point of the logistics of utility initiated a revolutionary period of wholesale transformation, facilitating the creation of main institutes and land use infrastructure for the next period of the territorial state. During this time, the resource deficiencies were already well pronounced, but the existing technologies of canal building and rudimentary ploughing were quite sufficient for stretching cities further into desert, which exposed them to drought, in order to support the demographic growth. The achieved density provided massive work gangs, crucial for supporting the labor intensive dam and canal infrastructure within a new social system of corveé labor. At this time, there is a notable competition between two hyperboles. The first one represented the growth of population needed to build and maintain the increasingly labor intensive infrastructure. Its opposite – the carrying capacity of the soil placed outside restrictions on this growth. ***The growth pole of the classical civilization of Sumer*** arose in a very narrow window of opportunity, immediately followed by a Malthusian depression[72]. Exceptional conditions for the related Schumpeterian spurt of technological growth were created as the marginal utility of the initial territory started falling after exhausting the extraordinary potential of the initial narrow zone. However, there were still sufficient resources, which could be made available by developing appropriate technologies. Such technologies as ploughing and canal building substituted for the falling carrying capacity of the initial land by settling marginal lands. The plateau of the logistics signaled insufficiency of substitutions and ignited a period of wars, from the start of the Akkad dynasty and up to the

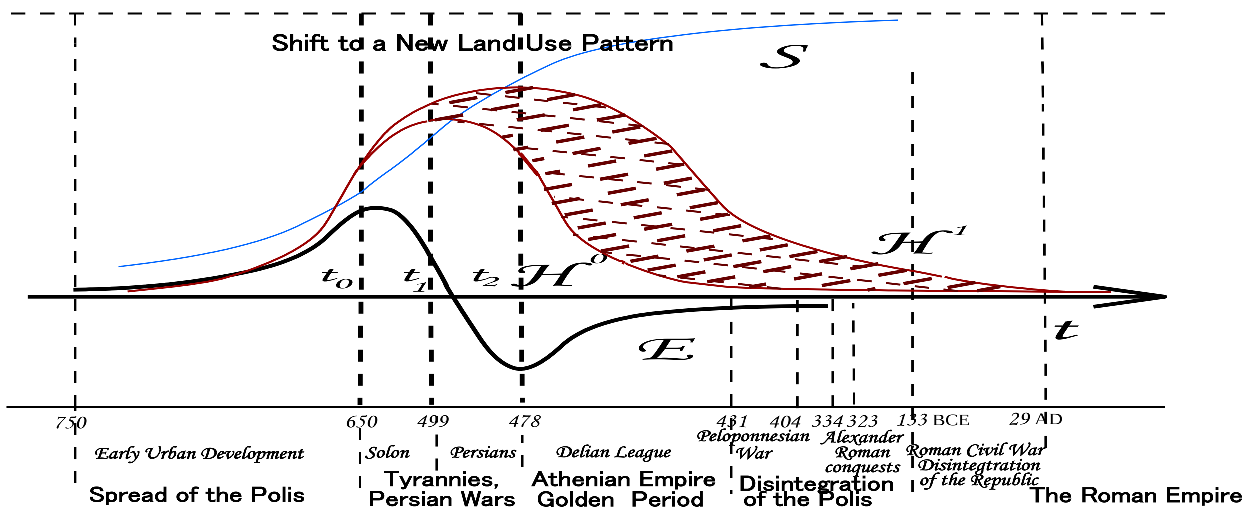
[70] Ca. 3250 BC., because of climatic changes, a wide swatch of earlier swamps had been dried out, creating a dense network of small natural canals. The data shows an immense explosion of settlement sizes. Early Uruk ca. 2800 BC (Early Dynasty I) covered as much as 5.5 square kilometers. This is an extraordinary size for an early city, even when compared with much later settlements – Athens at the time of Themistocles (2.5 square kilometers), Jerusalem of Agrippa I at 43 BC (1 square kilometer). Even Rome at the time of Hadrian ca 1st century AD was only twice as large as Uruk 3000 years earlier. (Nissen, 1988, 71-72).

[71] The breaking point of the logistics ca. 2800 BC was related to the completion of the settlement in the initial territory (Sumer), its further aridization and the increase in catastrophic floods as people settled closer to rivers. This pushed towards building the centralized infrastructure of dams and large canals, extending far into desert. The latter couldn't be done without establishing a new institute of the king power for the classical Sumer of Gilgamesh and the Great Flood from ca. 2900 to 2350BC. (Nissen, 1988)

[72] "… the conventional explanation that the empire was overextended ("too many mergers and acquisitions" was the way he [Prof. Weiss of the Yale] described the consensus description of Akkad's fall in a 1996 article in The Science)". (cited from Linden, 2006, p.152). Its cities were stretched far into desert and thus were wiped off during a severe drought episode, interrupting habitation evidence for 3 hundred years. Similar events of settling on marginally productive lands under demographic pressures typically end in an economic collapse, greatly reducing demand and starting thus the deflationary spiral. The short period of fragile renovation during the Third Dynasty of Ur, ended with a similar period of overextension. The Elamites invaded Sumer, then, they are followed by the nomadic Amorites, pushed to agricultural areas by a severe drought.

replacement of the Sumerians with the Semitic population (2350-1792BC). The next period of growth was supported by the rise of the territorial state and the spread of the fully formed cultural package of civilization (laws, the economy of corveé labor, gradually supplemented by "privatization" through the spread of large-scale rental farms, tenant holdings etc), starting from Hammurabi[73].

2. ***The classical antiquity of Greece-Rome. The main resource – light soils in the Mediterranean area,*** exploited within the novel land use system of seafaring/commerce. *Its growth pole – the Athenian Empire became the birthplace of the cultural package of the classical era. It consisted of: specialized farming/ craftsmanship, poleis, seafaring and military conquest based on the phalanx (legion) and the trireme.*



Pic. 3.2 The Athenian Empire – a Hot Growth Pole for the classical antiquity of Greece-Rome.

Starting from the 13th century BC the old system of land use for cereal production had been spread from the deltas to rainfall areas made borderline productive by the use of the scratching plough. Thus it began to involve a much larger area, including the arid territory of the Mediterranean basin – marginal lands for the irrigation agriculture. The demographic growth led

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[73] In the modern Sumerian historiography the beginning of the Akkad Dynasty is related to the end of the classical Early Dynastic period in Sumer, when its city-states bloomed. The Dynasty of Agade of Sargon the Great coincides with the time of turmoil, civil and other wars (2350- 2193), ended by the Guti invasion. "The period was undoubtedly one of turmoil and civil war…" (Wooley, p.63). In 2119-2004 BC the Third Dynasty of Ur presented the high point of the centralized government, after which the system becomes unsupportable and is replaced. "…"Generally speaking, Sumerians recognized only centralized and communal ownership of arable land"(Nemet-Nejat, p.260) with "… detailed information for a centralized administration of agricultural production. Similar accounts from the Neo-Babylonian period provided evidence for large-scale rent farms, that is, privatization. "(Nemet-Nejat, p.259). the rule of Hammurabi presented the time of the territorial states, with the cultural package of the Sumerians radiating up to the Northern Mesopotamia."The movement to northern Mesopotamia during the early second millennium BC was probably spurred by the search for fertile, arable land"(Nemet-Nejat, p.20-31, p.256-263).

to the rise of the polis and the olive/wine trade-based economy[74]. The trade routes through the stormy Hellespont were made accessible by a new seafaring technology, the penteconter[75]. The Ricardian advantage was provided by the so called Solonian model[76]. Starting from the 6th century BC, Solon promoted a switch from cereal to olive/wine production, with active trade economy based on monetary exchange[77]. Poleis rose on marginal lands unsuitable for cereal production, but good for olive/grape harvests. The ensuing rapid demographic growth led to the period of active colonization by the "excess" population, providing important beachheads for Greek metropolises, first and foremost, in the fertile lands of Asia Minor and the Black Sea. Upon reaching the breaking point of the resource logistics these colonies became crucial for stretching the dwindling resources through exchange and grain imports. Their importance was underscored by the "life or death" clash with Persia[78]. Similar to the rise of Sumer, the classic civilization of Greece rose within a narrow Window of Opportunity. From the one side, the marginal utility of the agriculture of the scratching plough was falling, which led to its gradual rejection as the base for their economy. From the other side, this could still be compensated by a sizable investment in the hi-tech navy, which opened up access to new sources of food[79]. The

[74] According to (White, 1970) poleis arose on marginal lands, which were expropriated from the so called tribes, the initial form of settlement, by independent groups, oftentimes, wandering mercenaries returning from overseas appointments. These marginal lands were mostly arid, hilly, unsuitable for cereal production.

[75] In the 9th century BC, the Greek penteconter was already developed into a superior man-of-war or a perfect pirate ship, depending on the user's preferences. It had a composite keel, battle ram and could go as fast as a modern racing boat (so called heavyweight eights, where there are no restrictions on the weight of rowers, in addition greatly aided by a sliding seat). Thanks to its naval seaworthiness and battle qualities the Greeks gained a significant share of the Mediterranean trade. Its early prototype can be found in the long and low Mycenaean galley "whose prows rise straight from the keel", which possibly originated around the island of Syros (Casson, 1991; 42). Mounting this galley, the Mycenaeans crushed the Minoan sea dominance (the so called "talassocratia") and replaced them as the dominant sea power starting from around 1450. The main difference between the competing ships was in their functionality. The graceful Minoan ship carried a hard-footed sail as befits a merchantman. In a sharp contrast, the Mycenaean ship (like its offspring, the penteconter) was equipped with a stepped mast carrying a loose-footed sail, which could be easily stowed away in the case of a naval battle, when the maneuverability and the speed attainable by rowers were essential. "The fifty-oared craft was … ninety feet long … ideal for sea raiding, low enough to be hidden behind some promontory while stalking the prey, swift enough to dash out and overtake a clumsy merchantman… and light enough to run, if chased, to the protection of the shore, no matter how shallow the water." At some point of the 13th Century a band of Mycenaean chieftains joined forces to overtake Troy. Known under the name "Akaiwasha" they were part of the migration of the Sea Peoples (Casson, 1991; 42. 39, 34), which summarily caused the so called Catastrophe of the Bronze Age (Drews, 1993).

[76] This market-oriented model was thoroughly researched by A. Toynbee, who referred to it as the Athenian model. (Toynbee, 1995,)

[77] "During the period immediately preceding the seventh century B.C. the Greeks had, agriculturally speaking, slowly adapted themselves to their new environment and had developed the cultivation of the vine and olive to such a degree that olive oil and wine, together with their pottery, became their principal exports". (Hodges, 1992, 195) According to (White, 1970), the olive was imported, supposedly from Asia Minor, before the 7th century BC. "There can be little doubt that it was this enormous volume of trade that virtually forced the people of the Mediterranean into adopting a medium of exchange, rather than continuing to base their commerce on direct barter. Reputedly, Croesus of Lydia, a small state in northern Anatolia, introduced a form of currency in about the year 700 BC. This ruler introduced the first true coins, pieces of metal stamped with a guaranteed weight and purity. A hundred years later the Greek cities were all issuing their own bronze and silver currency, a practice that was soon to spread throughout the civilized world". (Hodges, 1992, 195)

[78]The latter was the dominant country of that time, based on cereal production with the scratching plough by the free farmer. Persia had to defend the competing Phoenician system of maritime trade, which was crucial for supplying it with necessities (metal, timber etc).

[79] Themistocles persuaded the Athenians to invest 100 talents of silver, the entire output of the mines in Laurium, belonging to the entire community (modern equivalent to$60 billion) to the purpose of building 200 triremes.

growth started around 750 BC with rapid expansion of the Greek city-states (Starr, p.205) with the likelihood that the growth of the demographic logistic began from the 9th and peaked in the 5th century BC (Cameron, 1993, p.16). ***The growth pole was formed on the basis of the Athenian Empire and the Delian League (478-431BC)*** after Persian Wars. In this short time of bloom, less than 50 years long, resource shortages were already acute, but could still be somehow compensated technologically. The new technological style was based on the trireme[80], production of quality pottery and the olive/wine press. After that there was a Malthusian depression, manifesting itself by the start of the Peloponnesian war (431-404 BC) and the decline of city-states after 400 BC (Starr, p.340, p.359). This was followed by Alexander the Great and the start of the Roman conquests. The next (Pax Romana) logistic of growth would start only after establishing the system of Principate by August, around 50 AD (Cameron, 1993, p.16). With the addition of the Roman fighting machine, which played a significant role in the economy, the technological style accepted its immutable form, as the "olive-and-gladius"[81] style. The Hellenistic cultural package formed within the Athenian Growth Pole (478-43BC) was aimed at alleviating the falling marginal utility of subsistence agriculture by substituting its cereals with the olive-wine oriented agriculture. It was based on rapid technological advance utilizing mechanics and simple machines, especially the lever (the press, the oar and the spear of the phalanx, which itself worked as a wedge utilizing the combined weight of soldiers). For a while, the new technological style could compensate for the loss of the land's utility. The plateau of the logistics manifested itself through wars, when substitutions became insufficient. Starting from the Peloponnesian war of 431BC and up to the rule of Octavian Augustus in 29 AD, the Mediterranean was engulfed in wars – the Malthusian overpopulation led to the radiation and desperate competition of three contemporary versions of the state sponsored market-oriented system: Greece, Carthage and Rome. The Roman model won, at the cost of destroying the subsistence cereal production by free citizen-farmers of Campania, formerly the breadbasket of Rome and the recruiting base of its legions up to the end of the Punic wars. Instead, the winning model was based on the trade-oriented specialized latifundia and the legion, which now was increasingly manned by barbarians. Thus, the legion was turned into the prime means of colonization and Romanization of the conquered lands – after finishing their term of service the legionaries were rewarded by landholdings. The Roman model functioned as a monetary, tax-based system up to the debasement of its currency at the end of the 2nd century[82].

3. ***The Medieval era. The main resource – the heavy clay soil of the Western Europe.*** *The rise of the Carolingian Empire and the commercial revolutions of the 11th-12th centuries* (Stock, 1983, 32) (Pirenne, 1937, 51-52*) marked the appearance of a new system of land use in the Western Europe foreshadowing the birth of the Latin Christendom: it was based on forest*

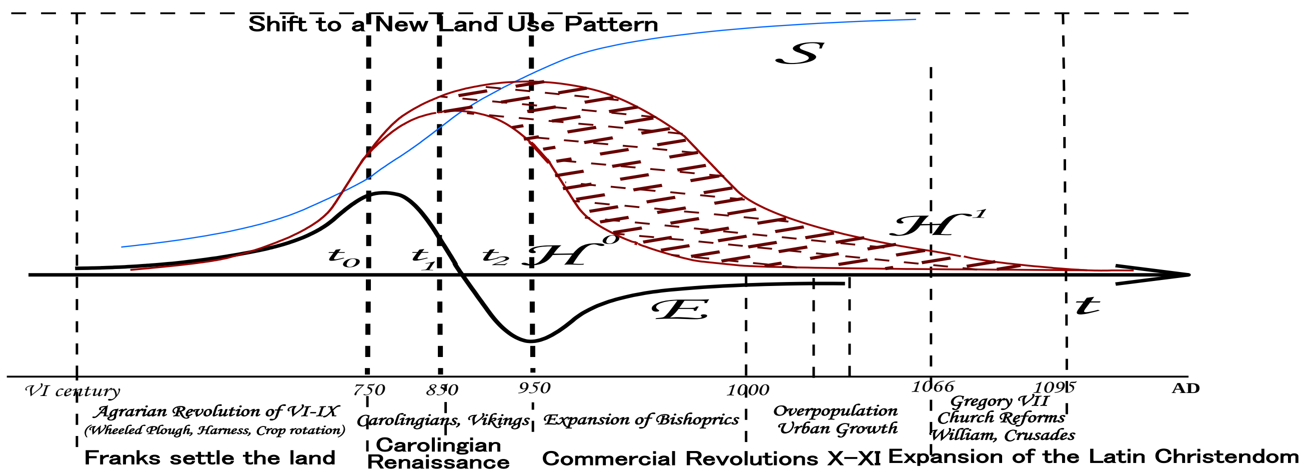
Besides their crucial role during the Greek-Persian wars, these triremes helped in opening up new routes of shipping, with a better access to the grain of the Black Sea region.

[80] Unlike the Phoenician vessels, such a ship would have been capable of countering the strong currents of the Hellespont and so entering the Black Sea, and it is important to notice that it is from this period onward that Greek trade with the Black Sea coasts began to take on a major role in the country's economy. (Hodges, 1992, 202).

[81] Gladius is the short sword of the Roman legionnaire.

[82] "Economically, the twin pillars of the Roman Empire were agriculture and commerce. Agricultural surpluses (production in excess of that required to maintain the cultivator and his family), though small in terms of the individual cultivator, bulked large when collected and concentrated through taxation. They provided the resources that supported the army, the imperial bureaucracy, and the urban population. Effective marshaling of these surpluses, however, depended on the unimpeded flow of commerce throughout the empire". (Cameron, 1993, 41).

clearings for the subsistence manorial economy. The growth of institutional ties between the manor and the medieval town provided the support for the technological package of the heavy wheeled plough and three-field crop rotation.



Pic. 3.3 The Carolingian Empire/Commercial Revolutions – a Hot Growth Pole for the Medieval Era.

The earlier Roman agricultural system – significantly more advanced in its agrarian practices, but considerably more limited in its size, being restricted to comparatively light soils – was buckling under the heavy demographic pressure and the decline in technological skills due to the relentless tide of barbaric invasions. Nevertheless, the barbarians had the rudimentary skills, which, after some refining, enabled forest clearings, greatly increasing the area under cultivation. The new type of land use eventually led to ploughing of heavy clay, but fertile soils, considerably increasing the carrying capacity of Western European territory. Documentation of this period of the so called Dark Ages is rather scanty. However, its development can be traced through corresponding events. The very beginning of the cycle can be dated from the Justinian's Plague of 541-2, during which the population of the old urban centers, which were mostly Roman and Celtic, was basically wiped out. The Franks settled down closer to the end of the 7th century[83]. Simultaneously, starting from the 7th century and the rise of Islam, the Arabs entered the Mediterranean, causing the blockade of the Byzantine and Italian trade, which culminated with two sieges of Constantinople[84]. Meanwhile, the Muslim Spain pushed towards the Franks[85]. Amid the widespread barbarization, the Roman market-oriented latifundia practically disappeared, though it was later reborn within the subsistence economy as large holdings based on *demesne*. The latter flourished under the Carolingians, closely resembling the Roman colonate. The subsistence agriculture of small holders and tenants was the only other system of land use that survived the carnage. The start of the demographic growth could, perhaps, be traced to as early as the 6th-7th centuries, still on the base of utilizing the Roman land use pattern. The

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[83] One might cite the widespread adoption of the use of the horse shoe and stirrup, the invention of the horse collar, and the invention of the windmill which provided a basis for the leap forward in the late eighth century (Liebeschuetz, 2001, 315). … the age of Migrations or the Dark Ages, that is the years from c.400 to c.650 AD, the period when the classical Roman world was changing into the world of the Middle Ages. (Liebeschuetz, 2001, 1)
[84] The first siege of Constantinople took place in 674-678, the second in 717-718.
[85] The Arabic advance into the Western Europe was stopped by the Carolingian Empire, starting from the decisive battle of Tours (732)

lighter soils were freed due to the death toll taken by the plague and could be tilled anew by a slightly heavier version of the Roman plough still powered by oxen. Upon exhausting the available supply of such soils, closer to the Carolingian times, more innovations were gradually added, on the base of the specific adaptations of the Germanic tribes: abundant iron and the introduction of oats, a good and affordable fodder for the horse. The heavy wheeled plough was later followed by the adoption of three-field rotation system. Lynn White (1962, 40) wrote about the agricultural revolution in the 6th-9th centuries[86]. It can be conjectured that the incremental spread of this new land use system became the economic and demographic foundation of the so called Carolingian Renaissance of the late 8th, 9th centuries, which allowed paying for its huge expenses for wars and governance (mess halls etc). The rising growth pole took its shape, when the Pope, as the highest authority of the land, blessed Charlemagne as the Holy Roman Emperor conferring on him the mission of christening the newly conquered pagan territories. Alas, the Carolingian blossoming was cruelly interrupted by the Malthusian surge both from within the empire and from the outside, from the Norman invaders. The latter somehow compensated for their menace by bringing the new social institute of primogeniture and the infrastructure of the motte-and-bailey castle, which divided the large holdings to smaller hereditary parcels, still preserving the system of demesne. The new technologically more sophisticated level of land use of forest clearings tilled by the heavy wheeled plough demanded a leap to the next energy level – either horses or a heavy team of oxen must have been used to break the heavy soil.

The invasions and turmoil lasted over a hundred years after Charlemagne. The growth of economy and population was resumed with the expansion of Bishoprics starting from the 950s, a period, mentioned as the start of the first demographic logistic for Europe by (Cameron, 1993, 16). This was followed by the Commercial revolutions of the 11th century. This period presented the continuation of the initial Carolingian ***growth pole***. Its primary feature was the start of massive forest clearings enabled by the rise of a new land use institute of free labor under urban-style ordnances (Pirenne, 1937, 66-85). This new level of organization, technological sophistication and personal motivation allowed domestication of this previously under-occupied territory. Thus was started the coexistence of two land use systems – the dwindling returns from the earlier one, mostly based on demesne, were supplemented by the newer plots coming under cultivation within the system based on free renters (Pirenne, 1937, 51-85). While the older system assured continuance, the growth of utility could only come from this newer pattern of land use. Monasteries led the way as technological heavy lifters in massive forest clearings, starting from the end of the 10th and the beginning of the 11th centuries, when they grew into important economic entities. The immense increase in use of iron is well documented[87]. The window of opportunity for the classical medieval Europe was extremely narrow. The exclusive

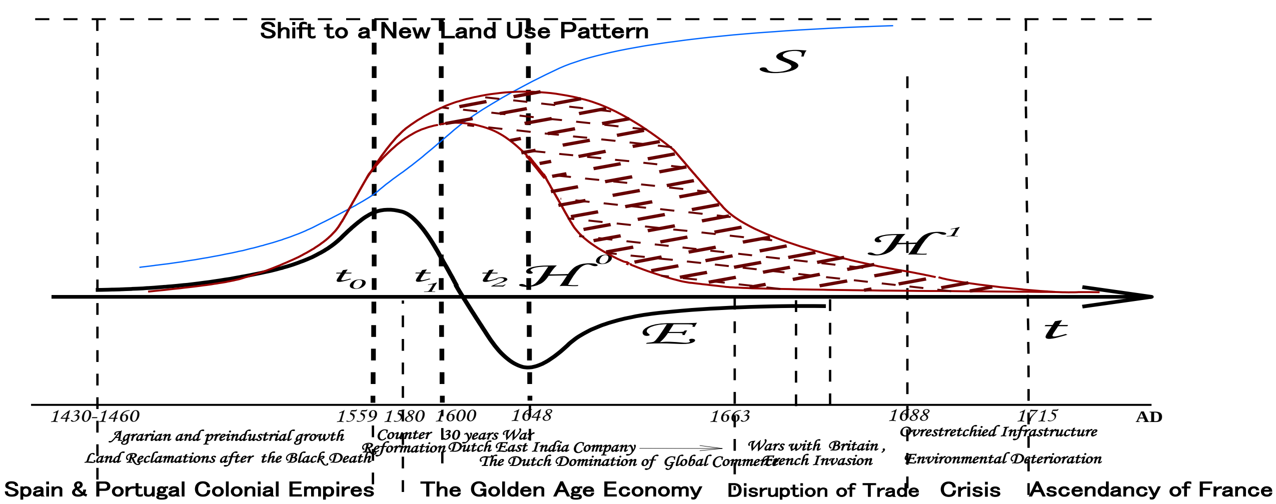
[86] "Yet it is practically unknown that northern Europe from the sixth to the ninth century witnessed an earlier agricultural revolution which was equally decisive in its historical effects... While no statistical proof is possible, it is the consensus among historians of agriculture that the medieval peasantry used an amount of iron which would have seemed inconceivable to any earlier rural population, and that the smithy became integral to every village… For example, it is believed that a new type of felling axe, developed in the tenth century, does much to account for the great new extension of arable land beginning about that time... A few tools, however, notably the plough, have been studied in much detail". (White, 1964, p. 40-41)

[87] "Iron was long a rare and costly metal, used almost exclusively for arms and for cutting edges…One aspect of the rapid development of northern europe in Carolingian times was the opening of great new iron mines... King Desiderius was overwhelmed by the spectacle of the massed and glittering Frankish armor and weapons: "Oh, the iron! Alas, the iron!" he cried." (White, 1962, 40)

conditions for the related major technological advance arose between the drop in the marginal utility of the land (exhaustion of the promise of the initial small scale subsistence agriculture) and, as yet, still substantial land resources, which could be made available only on the basis of newer technologies of the horse team, the heavy wheeled plough, using the new institute of free labor. The Malthusian crisis soon followed, starting from the 11th century, as the plateau of the demographic curve marked the limits of the carrying capacity of the land. From the 950s and up to 1095 (the first crusade) the demographic growth could still be absorbed within the European zone, as technological innovations allowed a new type of land use – towns grew amid mass forest clearings. After 1095 the system of Latin Christendom was fully formed and ready to radiate to its close periphery. The cultural package including both the technological and the institutional parts was fully formed and became immutable dating from the reforms of Gregory VII, which established the Pope as the head of the system of the Latin Christendom.

The expansion of the Latin Christendom starting from the 11th century was led by the pope and the knight army, riding the horse and clad in the heavy metal armor. Forest clearings spread within a huge territorial addition beyond the Oder etc. Mass migrations from Western Europe included crusades to the Holy Land, colonization of Slavic lands, conquests of Scotland, Ireland etc, the Albigoan crusade, with the south of France conquered by the royal French armies, the Reconquista in Iberia and other similar movements[88]. The monetary basis for trade and initial urbanization, serving as the means to open up technological bottlenecks, was provided by the Saxon silver[89].

4. ***The early industrial period. The main resource – water, for transport (rivers/canals) and energy (waterwheel)****. The new system of land use – specialized agriculture*, with its products made accessible via waterways (bulk trade, commercial fishing and husbandry).



[88] This included such unusual events, as the Children's Crusade in 1212, which is currently believed to consist of displaced poor (Raedts, 1977)

[89] Economically, the twin pillars of the Roman Empire were agriculture and commerce. Agricultural surpluses (production in excess of that required to maintain the cultivator and his family), though small in terms of the individual cultivator, bulked large when collected and concentrated through taxation. They provided the resources that supported the army, the imperial bureaucracy, and the urban population. Effective marshaling of these surpluses, however, depended on the unimpeded flow of commerce throughout the empire. (Cameron, 1993, 41).

Pic. 3.4 The Netherlands – a Hot Growth Pole for the Early Modern Era.

The new system of land use arose as a substitution for the increasingly scarce arable, and then gradually replaced the subsistence economy of the medieval era (crop rotation, wheeled plough). It allowed utilization of the lands of the Atlantic seacoast, generally unsuitable for cereal production. The start of the growth can be dated from the third quarter of the 15th century and up to the first quarter of the 16th century, gradually spreading from the Pyrenees to Spain and France on the one side (there was a notable metallurgic center in the Navarre) and to the Northern France-Netherlands on the other side[90]. This first spurt ended in a few decades after the bloodletting of the 30 Years war 1618-1648, when the cultural package was already fully formed. Fernand Braudel referred to this period, which was thoroughly researched, as the Long Sixteenth Century. *The growth pole[91] was formed in the north, around the Netherlands.* In the economic history of that country it is remembered as the Golden Age[92] (1580-1663). Similar to the aforementioned case of the brief blooming of the Athenian empire, this tiny country also experienced an explosive growth and then swiftly faded. Starting from the Thirty Years war and especially intensifying from 1663, there were drastic Malthusian shortages[93], well known to historians[94]. During the period of the Golden Age, rivers, augmented with canals, and hydro-power came to the forefront as the foundation for a new infrastructure, an essential component for domesticating the territory of

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[90] Iron smelting in the so called farca demanded a source of hydropower: for crushing and transporting the ore and powering the bellows. As the size of this furnace grows, iron smelting gradually migrated to France, rich with powerful rivers and qualified and inexpensive labor (Bodin). Similarly, the cloth and fluitschip-making in the early manufacture of the Netherlands was powered by wind/watermills, used for sawing of timber and finishing the cloth.

[91] (de Vries, van der Woude, 1997, 669) testify of "The explosive growth of Dutch trade … which extended established trade routes connecting Iberia with Baltic to the Mediterranean, the White Sea and ultimately to Asia, Africa, and the Western Hemisphere multiplied and enriched the flows of commodities that reached the ports of Holland and Zeeland."

[92] In 1578 Amsterdam embraced the rebel cause, and in the following decade the new republic achieved its *de facto* existence. From then until the third quarter of the seventeenth century, this new state grew quickly in strength, dominated the economy of Europe, and constructed a trading empire that spanned much of the world. This was its Golden Age. (de Vries, van der Woude, 1997, 668)

[93] Holland and Friesland … experienced a population explosion between 1500 and 1650. The number of inhabitants of these two provinces tripled (from 350000 to 1000000), a growth unmatched in the Europe of this time. (de Vries, van der Woude, 1997, 51). See also population Figure 3.1 p.51 for whole Netherland. After 1650 there is practically no population growth for 150 years, up to the 1800s.

[94] "For the European economy as a whole, the long-term course of relative prices, including the "price" of labor, is commonly explained in the context of a Malthusian model. Assume that the supply of land is fixed and that the responsiveness of production to increased demand (the price elasticity of supply) is low, particularly for agricultural products. Assume further that the demand for basic foodstuffs (grains) is inelastic with respect to both price and income while demand is progressively more elastic livestock products, industrial crops, and manufactured goods, in that order. This set of supply and demand characteristics suffices to explain the general course of prices in the preindustrial economy when one introduces (as a factor exogenous to the model) population growth or decline. Population growth increases the demand for grain more than for the other products, but it has less impact on increasing the production of grain than that of other goods. This generates rising grain prices, which, other things remaining equal, diminishes the real income of consumers, reducing their demand for the less necessary products. Meanwhile the growing population increases the size of labor force, whose employment in industry is rendered difficult by falling demand for manufactures and whose employment in agriculture drives downward the marginal productivity of labor. Labor's real wage tends to fall." (de Vries, van der Woude, 1997, 25) See also cost of living index Figure 12.4 p.628, Northern Netherlands.

France and the Netherlands. Now the productivity of their inner regions could be utilized, thanks to the dense transportation network via waterways feeding the rising national markets, which stretched the carrying capacity of the land considerably[95]. The shipbuilding technology took the lead – the cheap mass-produced Dutch fluitschip became the foundation of the country's maritime success. This greatly increased the need in energy, utilized in any available form – for example, in the Netherlands the windmill and turf, a good source of heat, were actively used. Timber became especially important, first and foremost, for shipbuilding, and also for commercial furnaces (bricks, ceramics, smelting). France had numerous full flowing rivers along with a strong canal building program on fertile, forest-rich lands, settled with a hard working population, which granted it the leadership position. Getting there took some time. The initial point of growth, between 1430 and 1460, was financed first by the Czech silver (1430s[96]), and, immediately thereafter, the gold from Guinea, brought in by the Portuguese[97]. When the Mediterranean trade was closed by the Turks following the fall of Constantinople, the center of economic activity was shifted from Florence of Lorenzo the Magnificent to Lisbon of Manolo, self-named the Magnificent. Despite the rise of commercial centers of growth in the Pyrenees and the Netherlands, the old system of land use held to its dominance – during this period, the territory, which was left fallow after the 1348 Black Death, was being gradually reclaimed. Cameron placed the start of the "second logistics" of growth in the mid 15th century, with its peak in the 16th century, and then its gradual fall in the 17th century[98]. The new pattern of land use for commercial and early industrial applications coexisted with the older ones. This assured continuance, while also stretching the dwindling land supplies for cereal production with the use of new food products and the introduction of better preservation and transportation techniques (salted fish, butter, hams and sausages, and other products of fishing and commercial husbandry). People moved to towns, where there were ample opportunities for employment in the manufacture of textiles and of other early industrial goods for sale. The breaking point of the logistics was manifested by the start of the so called religious wars (encompassing the revolt in the Netherlands and the 80-year war 1569-

[95] (Fischer) noted that before there could be a famine in one village, while there was a good harvest merely 30 miles away.

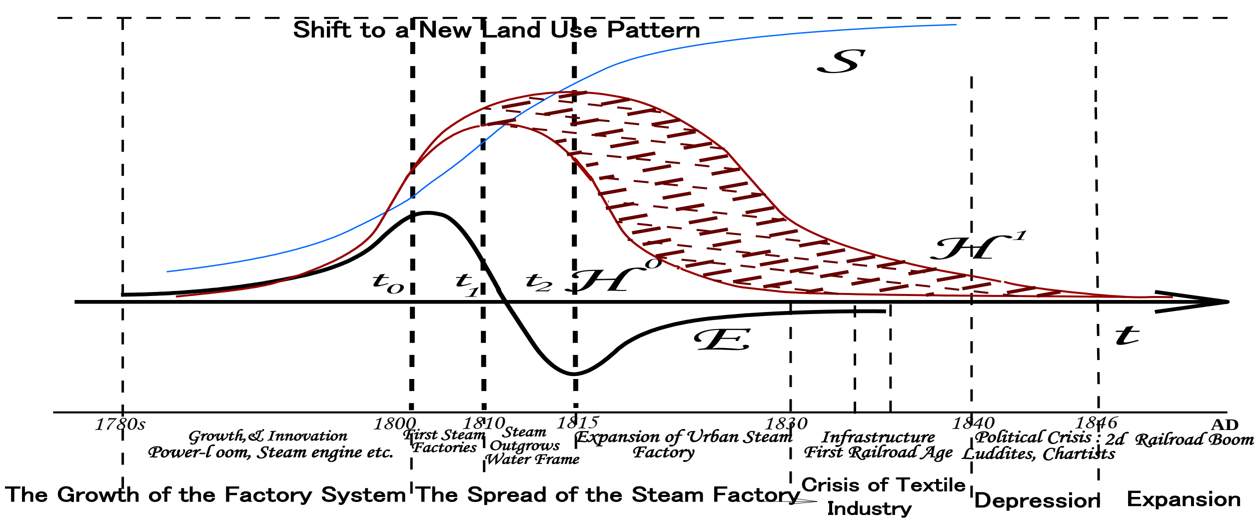
[96] Upon suppression of the Hussite Rebellion, the Czech silver paid for the dynastic needs of the Habsburgs – were covered the debts incurred by Sigismund during his elections as a Holy Roman emperor, and then for wars (1368-1437). Then, there were expenses of the Spanish Reconquista and the conquest of the Americas. Thus, silver paid for the European manufactures, flowing, first and foremost, to the Netherlands, then to France, starting the so called Price Revolution.

[97] When Spain conquered the Aztec and Inca Empires, it acquired territories so rich in silver that Spanish America became the world's leading supplier. From the middle of the sixteenth century to the end of the colonial era, it produced between 3 and 3.5 billion ounces, or a hundred thousand tons, of silver. (Garner, 1988, 898).

[98] "Sometime around the middle of the fifteenth century, after a century of decline and stagnation, Europe's population began to grow once more. Neither the revival nor rates of growth were uniform throughout Europe (as always, there was regional diversity), but by the beginning of the sixteenth century the demographic increase was generalized. It continued unabated throughout the sixteenth century, possibly even accelerating in the latter decades. Early in the seventeenth century, however, this lusty growth encountered the usual checks of famine, plague, and war, especially the Thirty Years War, which decimated the population of central Europe. By the middle of the seventeenth century, with a few exceptions, notably Holland, the population growth had ceased and in some areas actually declined. These termini – roughly the middle of the fifteenth and the middle of the seventeenth centuries – delimit Europe's second logistic." (Cameron, 95)

1648). From that moment on, any increase in population could only be fed by a shift to a new system of land use – emphasizing commercial fishing, husbandry, textiles, shipping[99]. Similar to the earlier periods cited above, the growing population was absorbed within a new, mostly urban-centered land use system, which fueled the growth of new industries[100]. The first half of this period was related to the Counterreformation, and the second coincided with the Thirty Year war 1618-1648. The plateau of the logistics was announced by the fading of the Netherlands. The growth was passed to the larger countries: France and Britain, following the period of la Fronde (1648–1653) and the English Revolution (1640-60) respectively. France became the dominant country, due to its leadership in the new technologically intensive areas of manufacture and canal building. Britain under William and Mary overtook the fading Netherlands and became the Nemesis of France. The Malthusian shortages manifested themselves in the struggle of the allied Netherlands and Britain against France for the dominant position in Europe.

5. ***The industrial era. The main resource – coal, used for transportation and as an energy source.*** *New land use system – industrial production, the factory and the steam engine, while the use of landlocked territories was enabled by steam-based transport.*



Pic. 3.5 The Industrial Revolution – a Hot Growth Pole for the 19th Century.

The growth pole of production of textiles was formed around Manchester ca. 1815-1840, with the steam-powered factory as its foundation. The Ricardian advantage of cheap production for mass markets was gained by substituting quality manual labor of experienced weavers and spinners with the cheap mechanized labor of displaced people, congregated in towns[101]. As in previous cases, the gainful use of the "excess" population was enabled by introducing new technological tools and practices. The new factory based system replaced the old manufacture, which was based on the hydropower, and thus had only a limited amount of suitable locations –

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99 "By the end of the sixteenth century the pressure of population on resources was extreme…" (Cameron, 99).

100 "Although precise quantitative data are lacking, it seems likely that the growth of the Greek population between the ninth and fifth century BC followed a logistic pattern." (Cameron, p.16)

101 The urban industrialization of 1815-1840 was mostly powered by the labor of women and children.

it had to be placed next to running water, out of large towns with their abundant labor force[102]. The steam engine became the key for unlocking the potential of the explosive urban growth, which absorbed people pushed out of the village by rising rural overpopulation. Despite the Dickensian horrors of women and children in the harsh environment of the factory and the mine, this greatly increased the productive capacity of the land, now, after the expulsion of the small holder, mostly worked by large market-oriented farms. The population quadrupled within the 19th century, especially in towns[103] (Harrison, p.25). Meanwhile, just as Britain started surging up on the strength of coal, France suffered from the Malthusian crisis, announced by the bread riots evolving into the French Revolution and continued through the Napoleonic wars. Note that, in contrast to Britain, France strived to preserve its social equilibrium and would never adopt anything resembling British forms of severe overexploitation. This more humane approach prevented the productive use of the "excess" labor through the adoption of machines, despite the remarkable level of technological sophistication[104]. The start of the British factory system as early as in the 1780s can be traced to the switch of the already existing machine technologies to a new source of power – from the waterwheel to coal[105]. The factory-based growth pole in Manchester still actively used the old infrastructure – canals[106], which were built on a large scale after 1768[107]. The "excess" population migrated overseas. The shift to a new, urbanized system of land use can be traced to the 1800s[108]. *The 1810s marked the breaking point of the logistics of the previous type of land use based on hydropower,* as the numbers of country-based factories grew only up to this date (Ashton, 1971, 52). With the rise of the steam factory, which could be built far away from the river, people started moving to towns[109] – the mass adoption of steam led to widespread urbanism. From 1815-1840 there was a notable increase of diverse applications for

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[102] " By 1774, Arkwright had two factories complete with water frames and two new water-powered looms, but he had no workforce/Local spinners and weavers worked their own hours in their own homes. Unused to waged labour, they valued their independence too highly to work 16 hours a day inside a factory, and they found the new machines difficult to master. Arkwright was forced to hire poor children and orphans – "their small fingers being active" – as spinners and weavers. By 1790, his mills employed as many as 5,000 workers, most of them children "{Bland, p.9}

[103] "… labour in the industrial age increasingly took place in the unprecedented environment of the big city …In 1750 there had been only two cities in Britain with 50,000 inhabitants – London and Edinburg; in 1801 there were already eight; in 1851 twenty-nine, including nine over 100,000. By this time more Britons lived in towns than in country, and almost one third of Britons lived in cities over 50,000 inhabitants. … water supply, sanitation, street cleaning, open spaces … could not keep pace with the mass migration …"(Hobsbawm, p.86).

[104] See the footnote 41.

[105] In the 18th century, the American Revolution became the final event of struggle by proxy between the older leader, France, and its Nemesis, Britain. Even though Britain lost its American colonies and, along with them any reasonable hope of getting the American timber and iron on the cheap, this "liberation" from old technologies could have been instrumental in its transformation into the "workshop of the world". Its investments, which previously went overseas, were thus redirected into domestic coal-based industries. The loss of the American colonies and the slave trade thus led to the growth of the factory-based textile industry, with Liverpool, a slave trade center, replaced by Manchester, Glasgow. But, the Atlantic trade still dominated – the logistics of the King-cotton kept growing.

[106] The Naviglio Grande near Milan was the first artificial canal in Medieval Europe, dated from the 1170s. The art of canal building was perfected in France, starting from Sully, the chief minister of Henry IV. The first to use pound locks was the Briare Canal connecting the Loire and Seine catchment areas in France (1604-1642) followed by the more ambitious Canal du Midi (1666-1683) connecting the Atlantic to the Mediterranean to save a month of travel. The Briare Canal was initiated by Maximillien de Bethune, duc de Sully, with support from Henry IV, in order to develop the trade of grain, and to reduce the food shortages. http://en.wikipedia.org/wiki/Briare_Canal

[107] Between 1760 and 1820 more than a hundred canals were built.

[108] See the quote in the footnote 83.

[109] From 1778 to 1800, the company of Boulton and Watt sold 496 steam engines, 164 for pumping water from mines, 24 for iron smelters and 308 for factories.

coal and steam. The logistics reached its plateau during the so called "Great Depression" of the 1830s and the related deflationary trough. The growth potential of textiles in Manchester was exhausted due to high prices for food in overpopulated cities, growing debts of textile importers abroad, which reduced the market for the British exports[110], and the low level of consumption in Britain. Thus were manifested the infrastructural problems of maintaining the needed level of demand. This period was wrought with social conflict begetting such movements, as the Luddites, trade-unionists, Chartists etc. Both workers and the middle class were unhappy and demanded improvements in their condition. The Malthusian trap was, however, somehow resolved, since the country had financial means to adopt needed reforms. The bottlenecks in infrastructure during the industrial crisis of 1830-40s were opened up by the use of the railroad, able to improve the economic use of the landlocked territory[111]. The cultural package of the industrial era was now fully formed, with considerable increases in the volume of production and consumption in Britain[112]. Instead of rivers the new land use system could now use the dendrite-like systems of railroads opening up the capacity of landlocked regions, first within the country and then abroad. At the start they rose as a substitution to the canal system, which had limited applications in such countries as Britain and the US[113]. Following the European revolutions of 1848, which cleared up the remnants of the earlier social restrictions, the cultural package of steam radiated to Europe in the 1840-60s. This solidified the British cutting edge as the "workshop of the world" up to the inflationary peak (the 1860s), whereas high prices for coal made its products uncompetitive as compared to the new challengers, first and foremost, the USA and Germany.

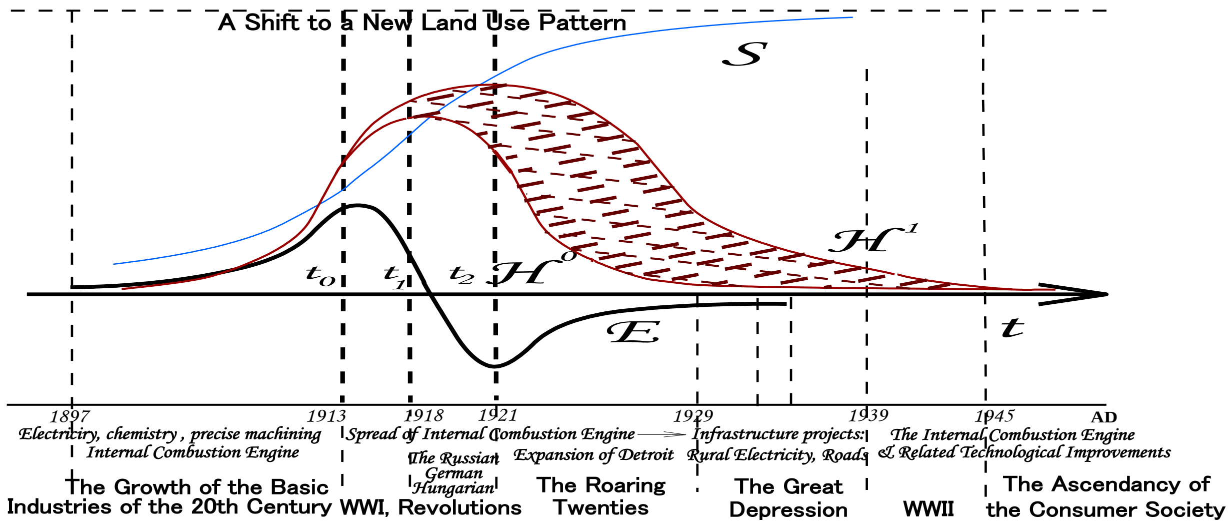
[110]"Abroad the developing countries were unwilling to export the British textiles … and undeveloped ones, on which the cotton industry relied were simply not big enough … to absorb British output. In the Post-Napoleonic decades the figures of the balance of payments shows us the extraordinary spectacle of the only industrial economy in the world and the serious exporter of manufactured goods unable to maintain an export surplus in its commodity trade" (Hobsbawm p. 76)

[111] The end of Watt's patent at the start of the 19th century led to more powerful steam engines, which he opposed. The revolutionary steam engine of Richard Trevithik built in 1812 was powerful and compact, permitting mobile applications. Among those was also the famous 1829 Rocket of Stephenson.

[112] "The poverty of the British was in itself an important factor in economic difficulties of capitalism, for it placed narrow limits upon the size and expansion of the home market for British products. This is obvious when we contrast the sharply rising per capita consumption of some goods of general use after the1840s (during the "golden age" of the Victorians) with the stagnation in their consumption earlier. Thus the average Briton between 1815 and 1844 consumed less than 20 lb. of sugar per year – in the 1830s and early forties nearer 16-17 lb.; but in the ten years after 1844 his consumption rose to 34 lb. a year; in the thirty years after 1944 to 53 lb, and by the 1890s he used between 80 and 90 lb." (Hobsbawm, p. 74)

[113] A shift towards the new system of land use took place also in colonies – the preindustrial system of latifundias, missions and other colonial strongholds (used by Spain and other early colonial empires) was replaced by settlements of white farmers throughout the global temperate zones. The advance of the British Empire was based on the so called agrarian colonialism – the Kew Botanical Gardens worked out advanced agrarian practices for cultivating the choice cultures well out of their original area of growth. The steam greatly improved the access to landlocked territories of continents and increased the range of products that could be exported. The white colonization was, first and foremost, supported by such market-oriented colonial products as cotton, sugar, tobacco etc. The new zone engulfed all the regions, where the existing population could be eliminated (the USA) or conquered (Africa, India, the colonial regions of Asia). In other regions this system didn't take hold or was greatly modified due to its incompatibility to the local social structures or because of unsuitable terrain (China, Russia etc).

6. ***The era of mass production. The main resource – oil, used for transport and as a source of energy.*** *The new type of land use was based on mass production and machines powered by the internal combustion engine: in industry, agriculture and for home.*



Pic. 3.6 Detroit – a Hot Growth Pole for the Era of Mass Production.

The growth pole of this era was based on the mass car and the conveyor and formed from 1913 to 1929[114], with a gradual advance from the famous Model T to the cheap tractor, whose adoption led to the mass tilling of the Great Plains[115]. The Ricardian advantage was gained by utilizing the abundant unskilled immigrant work force with the help of the conveyor, thus guaranteeing their high productivity[116]. Mass production of cheap goods helped in domesticating the huge territory of the US, which was mostly in the zone of extreme climate. The level of losses was significantly lowered thanks to the widespread use of the mass car, allowing timely delivery to the market. The new machinery led to the adoption of a new system of land use. Before there was a noticeable difference between the mechanized urban and the manual rural labor, but now the machine started infiltrating also into the village. This led to the massive industrialization of the agriculture, turning the village into a major buyer of industrial products. Note that this was in a sharp contrast to the earlier, coal-based industrial system. While managing to reduce the ratio of rural population, the latter couldn't free the large amount of people still needed in the village even after the introduction of the early rural machines (the horse-powered thresher, the McCormick reaper etc). Meanwhile, during this next step of mechanization, the internal combustion engine along with its numerous applications, such as the car, the tractor, the bulldozer, the excavator and other large earth-moving machinery, shifted the center of the new land use system. It was moved out from the overpopulated cities closer to any place where the excess labor could be settled and productively used. This led to the widespread projects of land reclamation, including the Hoover dam, the Golden Bridge in San-Francisco, the Everglades, the TVA and other large land use endeavors, which became the calling card of this

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[114] The Model T was first built in 1908, but the conveyor system was finalized only in 1917. The inflationary peak of coal was reached in1913. The increase of demand for the internal combustion engine can be illustrated by the following fact. The British army entered WWI with 600 lorries, ended it with 60,000.

[115] It first started as early as the 1830s, using the plow with a steel cutting edge and large teams of mules.

[116] The conveyor system could utilize immigrant workers with little or no skills.

period. Just as it was the case in earlier periods, the system of mass production wasn't known for being humane (the often-noted inhumanity of the conveyor) and led to the widespread expropriation of land and other abuses of small holders. In the US, such land grab was mostly perpetrated by economic means, mostly bank foreclosures (Steinbeck, 1997, Egan, 2006). However, those would seem almost gentle compared to the more direct forms, such as the collectivization, with 3 million or more dead of famine in the Ukraine. In the US, such severe forms of using the excess labor led to a notable leap in the carrying capacity of the land – the US population was quintupled during the 20th century, for which there was nothing comparable in the entire history. The growth started at the beginning of the century, which was marked by a technological shift from iron and early metal workshops towards steel and precise machining. *The period from the second inflationary peak of coal in 1913 and up through WWI marked the breaking point of the logistics of the old land use system (of coal and industrial revolution).* The growth pole in Detroit was formed immediately after WWI, during "The Roaring Twenties"[117], owing its success to the mass car and the mass tractor[118]. Notably, the mass car assumed great economic importance even before there were any good roads. Mechanization of agriculture and delivery system greatly reduced the need in draught animals. Millions of acres of land, previously used for grazing and animal fodder, were thus freed for food production. The diesel engine played an especially important role: for powering the large earth moving equipment and in shipping. The diesel ship gradually replaced the coal based shipping system, which depended on maintaining the expensive coal infrastructure, including a global network of coaling stations etc. The latter was largely destroyed during WWI and was never restored again (Roberts, 1989). The conveyor system of Detroit begat the technological style of Fordism, which brought great wealth to the US as it found ways to use its excess population, mostly consisting of immigrants of different kind: some squeezed out from rural areas by the advent of the mechanized farm, others moving in from abroad. As in other cases, described above, the new land use system was formed under acute Malthusian pressures, which were at their most active during the formative period from after WWI and up to WWII. WWI led to the wartime speedy development and refinement of the internal combustion engine used in the lorry, airplane and the first tank[119]. The growing Malthusian threat before WWI and up to the end of WWII caused acute resource

[117] The US staked its future on oil long before that, starting from oil discovery in Titusville in 1858, it was increasingly used for lighting, as a substitute for town gas and increasingly expensive whale oil. Meanwhile, despite its allied victory in WWI Britain was indebted, losing its status of the world's creditor, gradually losing its colonial possessions. This process becomes irreversible after India gained independence in 1947. WWI led to accumulation of world's gold in the US, creating the base for domestic investments. The dollar attained its status of the universal currency at the 1944 Bretton-Woods agreement. Meanwhile, it was just the final touch – the economic center was shifted from Britain to the US after WWI. At that moment, all technologies were already there. From the 1880s there is abundant cheap steel produced by Carnegie, from the 1910s there is a system of gas stations (the Standard Oil was registered in 1889). The 1905 Heald's machine made it possible to profile the thin uniform steel wall for the internal combustion engine. The production of the famous Model T, the first mass car, started from 1908. The initial growth was fed by the use of the mass tractor in the 1920s and the start of mechanized agriculture. *The plateau of the logistics was marked by the Great Depression of the 1930s.* The old resource of exporting to Europe was exhausted and the early use of the tractor led to the Dust Bowl. This state continued throughout the large infrastructure projects started during the New Deal.

[118] The aforementioned mass tilling of the Great Plains led to the ecological catastrophe of the Dust Bowl countered by developing special agricultural and land use techniques. Among them were: selection of new crops; spread of irrigation based on the wide availability of cheap rural electricity after completion of massive New Deal projects etc.

[119] The British army started the war with 600 Lorries and ended it with 60,000 (Roberts, 1989). During the war, 5-6 generations of the airplane were developed, a feat absolutely impossible at the time of peace, bringing it from a cloth coated Brother Wright-style model to quite modern looking fighters, scouts and bombers.

shortages, economic insecurities and overall increase of social and political tensions. In the US this led to the rise of the so called Progressives (trust-busting, government regulation, social justice, centralization of decision-making, professionalism of administration etc), including Teddy Roosevelt, Woodrow Wilson, FDR, who, taken together as a group, brokered a socially acceptable truce between trade-unions and the big business. Just as it was the case in the other periods described above, the growth pole of Detroit, an oasis of prosperity in the postwar world, was smashed full speed into the Great Depression, which demonstrated the immense power of the Malthusian trap. Thus was reached the plateau of the logistics of growth – the old resource based on exports to Europe was already exhausted, while the hard realities of switching to a new land use system became obvious (the ecological catastrophe of the Dust Bowl amid the widespread rural displacement). The large land use projects of the New Deal (the Tennessee Valley Administration, early rural roads, cheap rural electricity for such uses as irrigation etc) created the initial oil-based infrastructure for the new type of land use. WWII, just as any major war, brought the level of Malthusian contradictions to a new high. However, oil-based cultural package was already formed and, after the war, could radiate from the US to Europe, as the close periphery of the initial zone[120]. It was carried forth by the adoption of a new oil-based infrastructure, including highways, suburbia and other features of the consumer society[121].

Appendix C. Mathematical Model of Domesticating a Geo-Climatic Zone.

Below we present a deterministic model of differential equations for researching a complex adaptive system of a stochastic nature. Taking into account the possibility of discrete shocks to the system, the deterministic parameters of our model should be understood as representing averages of different sorts, such as moving averages. For dealing with statistical errors of the deterministic forecasting curves as compared to the real-life statistics such popular estimators as the MSE (mean squared error) could be used.

Our main goal is to measure the carrying capacity of a given land as ***limited*** within a narrow window of opportunity, where partaking of its resources still allows for survival. In this sense, we, for example, don't evaluate any implied risks.

[120]The Marshall plan, the 1944 Bretton-Woods agreement, the dollar as the only gold-backed universal currency etc

[121] The new style of land use allowed stretching the exhausted old land resource of the global temperate zone by introducing a new land resource – areas of the extreme climate (the Great Plains, California, Florida etc) through the spread the large mechanized farm. The Ricardian advantage comes from the use of oil – production of petrochemicals, irrigation and reclamation of territory, timely delivery to the market etc. This started active exchange between the town and the village, as the mechanized farm was always in need of more industrial products and dependent on the bank credit. Thus is created the foundation for the future consumer society. Oil grew in importance as the foundation of the global shipping and trading system, along with coal and other sources of energy used locally as oil substitutes. At the end, the level of development of any region would be characterized by the density and quality of its auto roads spreading around the sprawl of suburbia, the base of the consumer society, which became the dominant form of land use in the US starting from the 1950s. The next period of Malthusian shortages would be based with the exhaustion of the domestic supply of oil in the US. The double Oil Shocks of 1973-81 led to the rise of the competing systems of land use. Europe was oriented on using natural gas (see the gas-euro as opposed to the petrodollar) and Japan on energy preservation. The final stage of the oil economy – globalization – was made possible by the rise of the Internet and the container based shipping, bringing into the play the far periphery.

a. The Empirical Foundation of the Model – the Evolutionary Principle of Survival.

The model below is based on the following Principle of Survival (introduced above, further EPS):

(EPS) ***The Principle of Survival.***

Statistically, reproduction of labor through adequate creation of utility per unit of spent effort serves as the <u>only</u> criterion for survival.

It can be shown that, mathematically, this amounts to the principle of maximum for the function of utility $L(x,\dot{x})$ [122]. Just as in physics, the use of this Lagrange function brings us to the Euler's equation.

(1.1) $\dot{P} = F$, where $\dot{P}$ – is the marginal utility of the resource flow $\dot{x}$, and F – is the cost[123] of procuring the unit of resource x.
EPS in the form (1.1) presents the well-known Newton's equation – to bring a given system into motion (which, in this case, is understood as assuring the reproduction of the marginal utility $\dot{P}$ of this system) one must apply force F. At the same time, this also is a "Cost-Return" type equation, where returns per unit of time are measured by the speed $\dot{P}$ of the growth (of the marginal utility of the system), while costs are expressed through F or effort.

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[122] In the most general case, the Evolutionary Principle of Survival can be written in the following form:

$\delta A = \dot{x} dP$, where

- $\delta A = F dx$ – the increase in costs of procuring the resource $x = \{x_1, ..., x_n\}$
- dP – the increase in the marginal utility of the resource-flow
-

$P = \{P_1, ..., P_n\}$, $F = \{F_1, ..., F_n\}$

- $F_i(x,\dot{x}) = \dfrac{\partial L(x,\dot{x})}{\partial x_i}$ – marginal costs – i.e. the costs of procuring the last unit of the i – component of the resource $x = \{x_1, ..., x_n\}$.
- $P_i(x,\dot{x}) = \dfrac{\partial L(x,\dot{x})}{\partial \dot{x}_i}$ – the marginal utility of a single unit of the resource, as understood, say, within the concept of utility of the Austrian school.

[123] Similarly to the case of marginal utility, they are calculated as cumulative costs.

For a given geoclimatic zone, its ability to reproduce and thus increase its total biomass is limited by the availability of its crucial resource. In this case, marginal costs are defined as part of marginal utility spent in order to assure its reproduction. Thus, $F = \alpha(P)P$. By a simple substitution, we come to our main equation of EPS in the form

(1.2) $\dot{P} = \alpha(P)P$, as obviously, reproduction $\dot{P}$ is proportional to the cumulative utility of the system P.

b. Main Definitions and Assumptions.

The Concept of Utility within a Geoclimatic Zone.

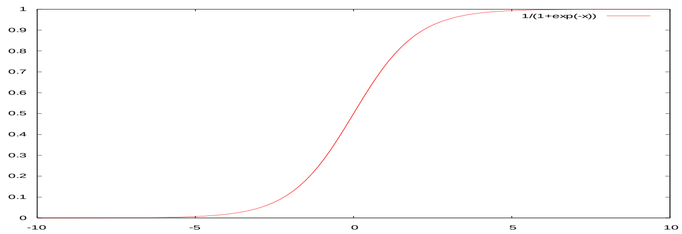
The key assumption of our model states that domestication of a new geo-climatic zone can only occur through the use of its unique energy resource. The latter becomes the main source for generating any value (or utility) in the zone via labor of its inhabitants.

As to this date, it has been convincingly shown that such zone-specific resources (coal, oil, natural gas etc) are inelastic and limited and their availability follows a logistic distribution. For each specific resource, two such logistic curves exist, first, describing its usage within the initial zone or IN, then, after a switch to the resources of the faraway periphery or OUT. The high efficacy of such Hubbert's –style curves for predicting the overall productivity of the zone was proven by correctly predicting the first peak of oil (IN) in 1973 (made by Hubbert) and the second (global or OUT) peak in 2004, marking the point, when global prices started to rise briskly (Deffeyes, 2001)[124]. It should be stressed that in no sense these peaks were restricted to oil – they also marked the start of inflation, especially for food and mineral resources.

A good example of such a logistic curve is presented by an $S-$shaped curve

[124] Below we show that there may be several such curves, each of them being defined by the acceptable cost of procurement. The latter, in their turn, define the leading technology of the time through its costs. Thus, each curve corresponds to a fixed technology. The distortion of its normally bell-curved shape means addition of a "foreign" technology. Thus, US fields, long considered exhausted, keep producing with the arrival of modern technologies of horizontal drilling, carbon dioxide injection etc. Thus, according to our calculations, the 2004 peak noted by Deffeyes, means, in fact, the peak of "light" global oil, with the peak of "heavy" global oil still waiting for us in about 10-15 years.

(2.1) $x = \dfrac{1}{1+e^{-t}}$, where t – stands for time, and x – is the cumulate of resource retrieval

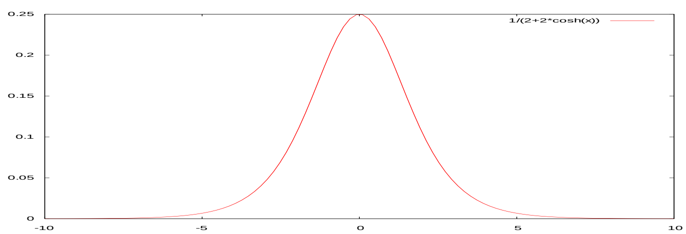


Pic. 5

Since $\dfrac{e^{-t}}{(1+e^{-t})^2} = \dfrac{1}{2+2\cosh t}$

(2.2) $\dot{x} = \dfrac{1}{2+2\cosh t}$ – is the first derivative of the logistic curve (2.1)

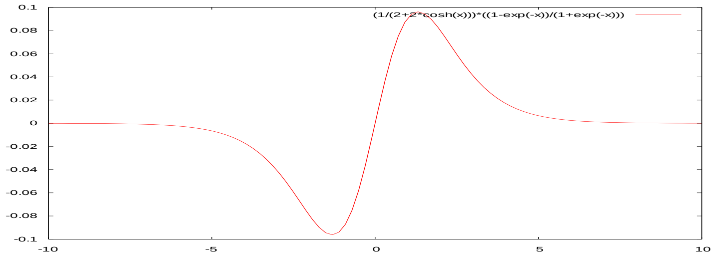
This is a bell shaped curve preferred by King Hubbert.



Pic. 6

We also use the second derivative, which was not considered by Hubbert and his followers. We will show that its double peaked curve is a good prognostic tool for the inelasticity of resource retrieval.

(2.3) $\ddot{x} = \dfrac{1-e^{-t}}{(1+e^{-t})(2+2\cosh t)}$



Pic. 7

We assume that:

- The overall utility of the inelastic resource of a zone at a given moment of time ***t*** can be measured through x, the cumulate of its overall retrieval up to that moment. Its value can be calculated, for example, by using the logistic Hubbert's curve (2.1).

Justifications for this assumption are simple. As told above, the resource doesn't simply go up in smoke and disappear, but leaves behind something material, including an infrastructure of its retrieval and use, which, as it is being built, improves the utility of its retrieval and usage. The corresponding growth of utility slows up as the logistical curve starts to flatten, showing the gradual exhaustion of the resource for the then technologies of its retrieval.

In contrast to the cumulative utility introduced above, the marginal utility of the resource is expressed through the last indispensable unit coming to the market. The condition of indispensability of this unit means that it ***must*** come to the market in order to satisfy the dire needs of the already built infrastructure. Thus, inasmuch expensive its retrieval, it is its price that would determine the overall market price paid even for the much less expensive units. As its price must be justified by its utility in order to satisfy the aforementioned EPS, thus, the rate of its retrieval (or ***velocity***) serves as a proxy for the marginal utility. For the Hubbert's curve (1) it would be equal to its first derivative (2.2)

The gradual exhaustion of a given zone can be measured indirectly through the increase in inelasticity of its main energy resource. Its growing resistance to retrieval corresponds to the cost of adding the last unit, which is indispensable for sustainable growth within the zone. For Hubbert's curves of type (2.1) this can be measured through the second derivative (or ***acceleration***) (see 2.3).

Using Hubbert's curves to measure utility, marginal utility and inelasticity, is instrumental for proving key concepts of our theory of coenoses, including the inevitable rejection of the dominant energy resource of the time as its growing costs stop to be justified by its utility, causing a switch to the next dominant resource, while also transferring the economic and political power to its birthplace zone.

Hubbert's curves measure cumulative production as a function of time. To show their link to the Marginalist theory we should also find out their relevance as utility functions. This becomes obvious as soon as we figure out that the current production (a function of time) presents a return on investments (a cumulate). Thus, the cumulative production represents the utility function of all the cumulative investments up to the date.

Technically, transformation of Hubbert's curves into logistics, measuring utilities in the sense of the Marginalist theory, can be easily achieved by introducing a cost coefficient $q(t)$, which measures costs per unit of time. Then (2.1) can be transformed to $x = \frac{1}{1+e^{-\int q(t)dt}}$, where $Q(t) = \int q(t)dt$ – presents cumulative costs. If $q(t)$ is a constant q this is simplified to $x = \frac{1}{1+e^{-qt}}$. As we see, the classical Hubbert's curve deals with costs as if they were unit constant. This restriction on costs shows that each Hubbert's curve corresponds to its own technology, within which costs can be kept constant. An introduction of a new technology, changes the costs and thus creates its own curve. Empirically, this shows as a distortion of existing production curves from their initial strictly bell shape.

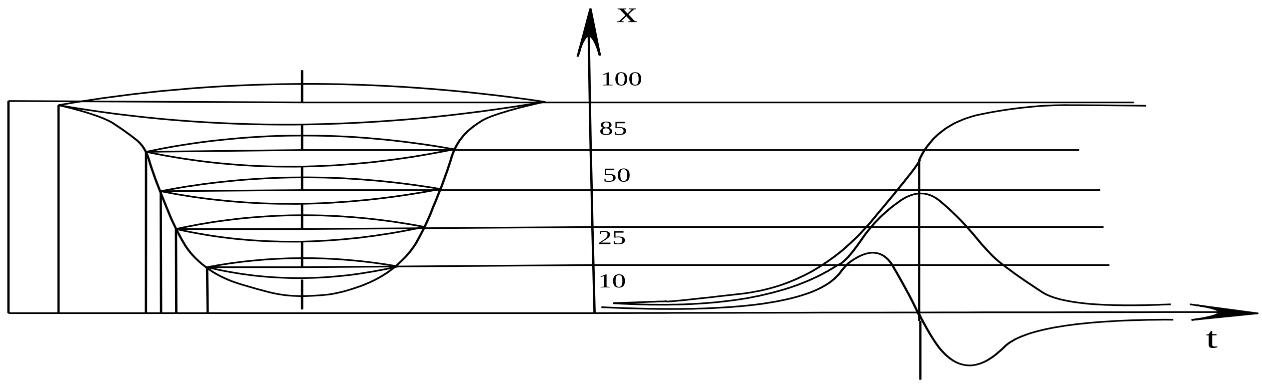
Summary.

- The utility of the inelastic resource can be measured by its cumulative production x, for example, according to its Hubbert's curve (2.1)

- The marginal utility of the inelastic resource corresponds to the (2.2), the first derivative of (2.1), which measures the volume of production per unit of time or the velocity of resource retrieval. We stress that, according to the law of supply-demand, this speed is directed by the cost per utility ratio of the last unit indispensable for the sustenance of the existing infrastructure under the current market conditions. This greatly inflates the overall price, since the market must price the entire supply according to the last and costliest unit and not according to the averages, which are much lower. Thus, today, the maximum unit price of oil approaches $100, while the average price is just $25. That is why, at this point of the lifecycle, even the costliest substitutes are eagerly used, even though they may never be used in the future. For example, at the start of the 20th century, the electricity powered means of locomotion within a city were considered a viable alternative to the coal-powered railroad, much surpassing the car, an expensive toy for the few.

- The inelasticity of the main resource within a given zone is measured by the second derivative (2.3), namely, the acceleration of the volume of production per unit of time. Just like the marginal utility above, nothing is averaged – the inelasticity is measured by the possibility of adding the last and costliest critical unit, indispensable for the sustained growth of the existing economy.

In a sample case presented below on Pic. 9, the domestication of a geoclimatic zone is presented as circular extensions of its initial core territory. The new territories bring in new sources of the main inelastic resource. Its cumulate rises along the logistic curve, reflecting the infrastructure buildup on the newer territories. Its advance along the curve affects also the marginal utility (rate of retrieval or velocity) and inelasticity (the possibility of accelerating it).



Pic. 8

Thus, our model is based on the key assumption that the utility of the inelastic resource of a zone, its marginal utility and its inelasticity present functions of the cumulate of its overall retrieval, accordingly, x, $\dot{x}$ and $\ddot{x}$. This describes the process of domesticating a zone in accordance to the EPS introduced in 1.1, where costs must be equal to returns.

c. ***The Reproduction of Infrastructure for a Specific Energy Source within a Given Geoclimatic Zone.***

As stated above, the model that calculates the utility of resources as consecutive full derivatives of the cumulative production, i.e. x, $\dot{x}$ и $\ddot{x}$, is based on the key assumption that no resources, including those already consumed, ever disappear without leaving a trace. The opposite is assumed to be true – in the process of their consumption they finally materialize from their potential form as a resource to their lasting form as material elements of the infrastructure, which facilitates the process of retrieval and improves the utility of the related resource. Among examples for our oil-dependent economy are highways, refineries, gas-filling stations, oil tankers, Internet-supported delivery chains, defense squadrons along the key routes etc, while for coal, it would be coaling stations, railroads, ports, British navies, etc.

In a sense, such infrastructures within their specific geoclimatic zones present the key form-giving core of something that may be called “an economy of coal” or “an economy of oil” etc. As time goes, it spreads even to places, which are hardly suitable for supporting the dominant infrastructure of the time. This means that the already consumed resources present nothing more and nothing less than investments into domesticating the related zone by creating its specific energy resource-dependent infrastructure. The best representative of such investments would be the cumulate, x, measuring the bulk of the already consumed resource. In fact, it is its materialization in the dominant infrastructure of the time that creates the further demand for the related energy resource. Mathematically, it can be written as a function $\alpha(x)$ of costs of reproducing an element of this infrastructure. This is shown by our main equation, whose more general form was presented in (1.2)

(3.1) $\dot{x} = \alpha(x)x$, where x – is the cumulate of production up to the date, while $\dot{x}$ – is its growth rate.

The costs of supporting the already built infrastructure are written on the right. They are proportional to x, the cumulative volume of the resource up to the date. The returns are on the left– proportional to the rate of production. Thus, the demand on resources on the left is equal to the supply on the right.

The equation (3.1) thus describes the reproduction of the indispensable infrastructure of a given geoclimatic zone and presents a specific case of ESP (1.2). The Hubbert's curves of 1.2 present solutions of this equation with specific $\alpha(x)$ – the reproduction curves for the existing oil-based economy. Another example, with a different set of $\alpha(x)$, is presented by the well-known equations of Volterra-Lotka, which describe the mutual control of levels within an ecosystem (a coenosis).

In their most general case, the equation (4) below describes the functioning of feeding chains within a coenosis as a reproduction of the dominant infrastructure of a given geoclimatic zone, even such as a forest or a lake.

In particular:

- When $\alpha(x) = 1 - \frac{x}{K}$, where K – is the measure of the maximum volume of retrievable resource, the equation (3.1) turns into the Verhulst's equation (Verhulst, 1838)

  $\dot{x} = (1 - \frac{x}{K})x$. Hubbert's curves present the solutions of this equation, when $K = 1$.

- For the case of many control levels, this equation takes a matrix form $X = \begin{Vmatrix} x_0 \\ \dots \\ x_i \\ \dots \\ x_{n-1} \end{Vmatrix}$,

  $\dot{X} = \begin{Vmatrix} \dot{x}_0 \\ \dots \\ \dot{x}_i \\ \dots \\ \dot{x}_{n-1} \end{Vmatrix}$ $\mathrm{A}(x) = \|\alpha(x_i, x_j)\|$.

- The equation (3.1) can be rewritten as $\dot{X} = \mathrm{A}(X)X$, where coefficients $\alpha(x_i, x_j)$ describe interaction between levels according to the prey-predator relationship of the Volterra-Lotka equations.

As it is well known, since we deal with a system of non-linear differential equations, there may be several typical scenarios for its solutions:

- ***Auto-oscillations*** around local equilibria (example, boom/bust cycles of capitalist economy)
- Hyper-sensitivity to the initial conditions (***Deterministic chaos***). The gradual exhaustion of its niche causes a loss of marginal utility within the system. The conditions of ESP are, as yet, satisfied, thus, the stable patterns of behavior within the system (trajectories of exchange between levels) still exist, but they are increasingly "mixed up". The reproduction within the system reaches the limits of its stability – the inflationary peak. However, the system retains its resilience and is able, in general, to recover its basic configuration as soon as the resource famine is alleviated, say, by reaching for the resources of the far periphery.
- As soon, as dependence on the dominant resource begins to breach the conditions of ESP, the old trajectories terminate and the system enters a ***stochastic mode of survival*** by any means possible. It "forgets" its base configuration and loses the ability of restoring it even after the end of the resource famine. In this sense, the older system dies.

As we see, the behavior of solutions for the basic equation (3.1) of reproduction within a given geoclimatic zone fully corresponds to its lifecycle as presented in the main part of the work.

- The logistic curves of the main inelastic energy resource serve as the upper restriction for the process of domesticating a zone. While this resource is still plentiful, up to the point t_0 of Pic.3, we are on the rising part of the logistic curve.
- As inelasticity increases past t_0 to t_1 and t_2 the behavior changes according to the model presented in Pic. 3, with a gradual substitution and, finally, rejection of the dominant inelastic resource. The breaking point of inelasticity marks the increasingly competitive behavior within the system, with solutions of Volterra-Lotka equations increasingly conforming to the logistics of deficits. As the niche is filled up, the system enters conditions of the deterministic chaos, reflecting the instability of an overstretched system. However, as it reaches out of its initial zone, the "heavy" and more expensive resource may alleviate the resource famine restoring the system, to a point as it goes up the second logistic curve of its lifetime.
- This second logistic works similarly to the first one. However, there is an important difference. After the growth of inelasticity following the breaking point t_0, the new substitutions for the inelastic resource are not directly related to the older technologies and the older resource that spawned them. Starting from the inflationary peak t_1 and further on there are unfavorable conditions for reproducing the infrastructure of the older

resource, which gradually breaks. The system enters the bifurcation mode, where its components survive in a stochastic mode, while the basic configuration is gradually "erased". As the resource famine is resolved, mainly by finding substitutes, the older elements can yet be reconfigured within the next ecosystem, but the older basic configuration is forgotten and can't be restored. Thus, after the second inflationary peak the older system disappears and the third logistic isn't possible.

The impossibility of satisfying the ESP through the exclusive use of the older dominant resource causes a bifurcation. On the one side, there is frenetic search for the next resource, able to satisfy ESP. On the other, the older system enters a truly random, nondeterministic chaos, which totally erases its basic configuration. This is well supported by historic data. After great global cataclisms between historic eras people completely forgot whatever happened before. As the former dominants exited the world arena, their values and lifestyle exited with them.

Selected Bibliography.

Abel, W. 1974. Massenarmut and Hungerkrisen im vorindustriellen Europa. Versuch einer Synopsis. Hamburg: Parey.

Ackland, G.J., et al. 2007. Cultural hitchhiking on the wave of advance of beneficial technologies. Proceedings of the National Academy of Sciences 104: 8714-8719.

Ames, Frank 1986. *The Kashmir Shawl*, Antique Collectors Club, UK.

Andersen, E. 1994.Evolutionary Economics. Post-Schumpeterian Contributions. Pinter Publishers. London N-Y.

Ashton,T.S.,1971. The Industrial Revolution. 1760-1830. Oxford University Press.

Badalian L. Krivorotov V. 2007, Russia and China: Prospects of Interaction in New Fuel-and-Energy Conditions. Far Eastern Affairs. Vol. 35-2. East View.

Badalian L. Krivorotov V. 2006, Applying Natural Sciences to Studying History: Regarding the Example of England and the Industrial Revolution. Part I, II, III. *Santalka. Filosofija.* Vol. 12, 14. Nr.1, 3.

Bartlett, Robert. 1993. The Making of Europe. Conquest, Colonization and Cultural Change 950-1350. Princeton University Press.

Berry, B. 1991. Long-Wave Rhythms in Economic Development and Political Behavior. Johns Hopkins Univ. Press.

*Bland, Celia, 1995.*the Mechanical Age. The Industrial Revolution in England. FOF Books. New York.

Bocage, D., 1985. General Economic Theory of Francois Perroux University Press of America.

Braudel, F. 1981. The Structures of Everyday Life. Civilization and Capitalism 15^{th}-18^{th} Century. Volume I. Harper & Row. NY. Fernand Braudel (1981, 70) showed that the early European societies, similarly to traditional eastern societies functioned as "biological ancient regimes", subject to Malthusian constraints.

Cameron, Rondo. 1993. A Concise Economic History of the World. From Paleolithic Times to the Present. Second Edition. Oxford University Press.

Casson, Lionel. 1991. The Ancient Mariners. Princeton University Press.

Clabburn, Pamela. 1996 *The Norwich Shawl*, HMSO, U.K.

Clark, G. 2002. The Agricultural Revolution and the Industrial Revolution: England, 1500-1912. UC Davis.

Clark, G. 2007. A Farewell to Alms. A Brief Economic History of the World. Princeton University Press.

Deffeyes, K. 2001. Hubbert's Peak: The Impending World Oil Shortage. Princeton: Princeton Univ.Press,

De Vries, Jan, van der Woude, Ad. The First Modern Economy. Success, Failure, and Perseverance of the Dutch Economy, 1500-1815. Cambridge University Press. 1997.

Diamond J., 1999. Guns, Germs and Steel. The Fates of Human Societies. Norton.

Diamond J., 2005.Collapse. How Societies Choose to Fall or Succeed. Viking.

Drews, Robert.1993. The End of the Bronze Age: Changes in Warfare and the Catastrophe ca 1200BC. Princeton University Press.

Duncan-Jones, Richard. 1982. The Economy of the Roman Empire: Quantitative studies. Second Edition. Cambridge University Press.

Egan, T. 2006.The Worst Hard Time: The Untold Story of Those Who Survived the Great American Dust Bowl. H. Mifflin.

Engerman, Stanley (Ed.), Gallman, Robert (Ed.) 2000. The Cambridge Economic History of the United States, Vol. 3: The Twentieth Century, Cambridge University Press

Findlay, Ronald; O'Rourke, Kevin. 2007. Power and Plenty. Trade, War, and the World Economy in the Second Millennium. Princeton University Press. The Princeton Economic History of the Western World.

Fischer, D. 1996.The Great Wave. Price Revolutions and the Rhythm of History. Oxford Univ.Press.

Freeman, C, Louça, F. 2001. As Time Goes By: From the Industrial Revolutions to the Information Revolution, Oxford, Oxford University Press.

Freeman, C, Soete, L. 1997. The Economics of Industrial Innovation, 3rd edn. Pinter, London.

Garner, Richard, 1988. Long-Term Silver Mining Trends in Spanish America: A Comparative Analysis of Peru and Mexico. *The American Historical Review*, Vol. 93, No. 4 (Oct.1988), pp. 898-935.

Goldstone, J.A. 1991 *Revolution and Rebellion in the Early Modern World*. Berkeley, CA, University of California Press.

Haalmeijer en D. Haalmeijer and D. Vuik. 2002. *Fluiten, katten en fregatten* . Vuik (2002). *Whistling, cats and frigates.* De Boer Maritiem, Haarlem.

Haigh J D 2004 Fundamentals of the Earth's atmosphere and climate. In Solar variability and its effects on the Earth's atmospheric and climate system *ed. J Pap, C Fröhlich, H Hudson, J Kuhn, J McCormack, G North, W Sprig and S T Wu. AGU Monograph, 141.*

Harrison, John, 1973. The Birth and Growth of Industrial England (1714-1867). Harcourt Brace Jovanovich, Inc.

Harrison, R. A. McNair, F. and Dugdill L. 2005. Population of the United Kingdom. Access to exercise referral schemes - a population based analysis. Oxford University Press.

Hobhouse, H, 1986. Seeds of Changes: Five Plants that Changed Mankind... Harper&Row, London.

Hobsbawm, E. 1999. Industry and Empire: The Birth of the Industrial Revolution, Penguin Books. New Press. NY.

Hodges, Henry, 1992. Technology in the Ancient World. Barnes and Noble Books.

Irwin, John 1973. The Kashmir Shawl, Victoria and Albert Museum.

Korotaev, A.V. 2006. Long Term Demographic Dynamics of Egypt. Cycles and Tendencies, Moscow, Oriental Literature Press (in Russian)

Liebeschuetz, John Hugo Wolfgang Gideon. 2001. The Decline and Fall of the Roman City. Oxford University Press.

Nefedov, S.A. 2003. A model of Demographic Cycles in a Traditional Society: the Case of Ancient China.*Chinese Journal of Population Science. 3: 48-53 (in Chinese)*

Nefedov, S.A. 2004. A model of Demographic Cycles in a Traditional Society. *Social Evolution & History (3):69-80*

Kindleberger, Ch, World Economic Primacy: 1500 to 1990 Oxford University Press. 1996

Kotz,D&Weir. 2007. Russia's Path from Gorbachev to Putin: The Demise of the Soviet System and the New Russia. Routledge.

Levi-Strauss, Monique. 1987. *The French Shawl*. Dryad Press Ltd

Linden, Eugene. 2006. The Winds of Change. Climate, Weather, and the Destruction of Civilizations. Simon&Shuster.

Mathias, Peter, (Ed.), Pollard, Sidney (Ed.) 1989. The Cambridge Economic History of Europe, Vol. 8: The Industrial Economies: The Development of Economic and Social Policies Cambridge University press.

Mitchell, Brian R. (Editor). International Historical Statistics: Europe, 1750-1993, Palgrave Macmillan; 4th edition, 2000.

Nemet-Nejad. Karen Rhea. 1998. Daily Life in Ancient Mesopotamia. The Greenwood Press.

Olmstead, Alan L. and Rhode. Paul W. 2001. Reshaping the Landscape: The Impact and Diffusion of the Tractor in American Agriculture, 1910-1960. *The Journal of Economic History*, Vol. 61, No. 3 (Sep.2001), pp. 663-698

O'Rourke, Kevin H and. Williamson. Jeffrey G. 2005. From Malthus to Ohlin: Trade, Industrialisation and Distribution Since 1500. Journal of Economic Growth, 10, 5–34. http://www.tcd.ie/Economics/staff/orourkek/offprints/JEG%202005.pdf

Perez, Carlota, 2002. Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages, Edward.Elgar Publishing, UK.

Pirenne, Henri, 1937. Economic and Social History of Medieval Europe. HBJ Book.

Pollan, Michael, 2006. The Omnivore's Dilemma: A Natural History of Four Meals. The Penguin Press.
Postan, M. 1973. Essays on Medieval Agriculture and General Problems of Medieval Economy. Cambridge
Rathbone, Dominic. 1997. Prices and Price Formation in Roman Egypt. Economie antique. Prix et formation des prix dans les economies antiques (Saint-Bertrand-de-Comminges: Musee archeologique departmental). pp. 183-244. Cited from Peter Temin. A market Economy in the Early Roman Empire. http://sshi.stanford.edu/Seminars/Papers/classics/temin.pdf
Roberts J.M.. 1989. Europe. 1880-1945: A General History of Europe. Longman Group UK.
Reinhart, Carmen M. *University of Maryland and NBER*, Rogoff, Kenneth S.*Harvard University and NBER.* March 12, 2008. This Time is Different: A Panoramic View of Eight Centuries of Financial Crises. http://www.economics.harvard.edu/faculty/rogoff/files/This_Time_Is_Different.pdf
Schumpeter J. 1939. Business Cycles: A theoretical, historical and statistical analysis of the Capitalist process.
Steinbeck, John. 1997. The Grapes of Wrath. Penguin Books.
Stiglitz, J&Charlton, 2005 *A.* Fair Trade for All. How Trade Can Promote Development. Oxford Univ.Press..
Sousa, Luís de. Hubbert's Peak Mathematics. http://wolf.readinglitho.co.uk/subpages/hubbertmaths/hubbertmaths.html
Stock, Brian 1983. The Implications of Literacy: Written language and Models of Interpretation. Princeton University Press.
Temin, Peter, 2001. A Market economy in the Early Roman Empire. MIT Working Papers. February. http://econ-www.mit.edu/files/1238
Toynbee, A. 1995. A Study of History. Barnes&Noble Books.
Turchin, P. 2003a. Complex Population Dynamics. A theoretical/Empirical Synthesis.
Turchin, P. 2003b. Historic Dynamics. Why States Rise and Fall? Princeton, NJ, Princeton Univercity Press,
Turchin, P, Nefedov, S.A. 2008. Secular Cycles. Princeton, NJ, Princeton Univercity Press (forthcoming),
Tylecote Andrew. 1993.The Long Wave in the World Economy. The present crisis in historical perspective. Routledge. London and New York.
Verhulst, P. F., (1838). 'Notice sur la loi que la population pursuit dans son accroissement. *Correspondance mathématique et physique* 10:113-121.
White, KD. 1970, Roman Farming. Cornell University Press
Whitaker, A.P. 1941. *The Huancavelica Mercury Mine: A Contribution to the History of the Bourbon Renaissance in the Spanish Empire,* Harvard Historical Monographs. Cambridge, MA: Harvard University Press.
Wooley, Leonard. 1995. The Sumerians. Barnes&Noble.
Wrigley, E.A. 2004. Poverty, Progress, and Population, University of Cambridge