# APPLYING NATURAL SCIENCES TO STUDYING HISTORY: REGARDING THE EXAMPLE OF ENGLAND AND THE INDUSTRIAL REVOLUTION PART II

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*In the previous article of this series we presented a bio-ecological approach to studying history. It was shown that societies from the first civilizations to our days are techno-ecosystems (coenoses) and do not differ much from the natural ecosystems of a lake or a forest, which are also restricted by their supplies of food. Historically, a succession of distinctive nestled geo-climatic zones was domesticated as the older ones were exhausted due to growing demographic pressure. In this context, evolution is not synonymous with competition. Cooperation of mutually dependent species is crucial for domesticating a new ecosystem, while at specific moments in its lifecycle, competition intensifies leading to speciation.*

*In this article, we use this concept for analyzing a specific society. We show that the Industrial Revolution was England's specific adaptation to the limitations of its geo-climatic zone. Timber, the main resource of the pre-industrial age, was essential for ship building and metal smelting. It was abundant in its main rival's, France's, geo-climatic habitat, but scarce in deforested England. Using its abundant local resource, coal, in an innovative way, this particular society, just like an emergent biological species, gained an evolutionary edge over its neighbors by opening access to new sources of food. The "workshop of the world" started with export-oriented textile production and ended as the major colonial power of its time. At the start of its rise to supremacy, during the 1805 battle at Trafalgar, Lord Nelson smashed the combined French-Spanish navies using short and light cast-iron cannons. They were much less precise than the long bronze ones favored by Napoleon, but, in the right hands, gave the first taste of industrial might to the England's foes. Under Britain's dominance, the 19th century's Oikumene was completely remade and covered with smokestacks. We show subsequent stages of England's industrialization as related to similar stages in biological ecosystems.*

**Keywords**: evolution, ecosystem, coenosis, technology, history.

## Introduction. The Rising Form of Ownership – Private Property

As a new technology opened a window of opportunity for England, food was literally falling into the niche from outside. From the 1530s, popular, less expensive fabrics of lighter weights, the so-called "New Draperies" or worsted, were made from sturdier English wool as opposed to soft and expensive Spanish wool (Beck 1882), (Radcliffe 1913), (Usher 1954: 304–331). The growth of sheep farming for eager Dutch buyers led to popular practice of *enclosures* marking a complete break with tradition. Previously, within a subsistence economy, there was no way to till land *sans* peasants. Landlords and peasants were mutually dependent, creating a system of mild patronage[1]. According to historic sources, during the troubled late Roman times many of the so-called *coloni* gave up their freedom in exchange for the lord's protection. Allegedly, some were persons of importance.

Now there was a rising alternative to the traditional subsistence-farmers, who paid in kind and relied on communal land – *commons.* Using new technologies of bog draining and land improvement, both arable and non-arable lands could be converted to pastures and thus "liberated" from peasants. The *commons* were enclosed and gradually ceased to exist. The medieval cooperation of landlords and their tenants was thus replaced with a novel, competitive, market-based intensive economy. For the first time in history, we see the rise of true ***private property***, namely, ***land that could be bought and sold regardless of it being populated with peasants***.

The new upper tiers of the forming food chains grew under the protection of Elizabethan isolationist policies, which cultivated domestic merchants and textile manufacturers. The now useless older lower tiers were meticulously and quite mercilessly weeded off. The moral foundation for this shift was provided by the newly created Anglican Church – all the older major religions, including so-called papists, frown on pursuit of wealth and its accumulation.

In the aftermath of these changes, the English, though still dependent on subsistence farming, shifted toward a highly specialized market economy. Small tenants lost their holdings in droves. The *commons* were enclosed and improved for pastureland. The remnants of the older system were cleared off in 1640–1649, during the purification of the Civil War. In 1651–1658, following the earlier sale of the Church's lands, Oliver Cromwell sold off royalist possessions, thus creating a foundation for large, specialized and market-oriented holdings. Note that similar sales in revolutionary France hardly reduced that country's ratio of smallholders further reinforcing the already vast powers of its government. Upon their return, the French royalists and the disowned priests were lavishly recompensed with government bonds for the former and salaries for the latter. This non-productive class of small renters[2] practically drained all private investment sources. To this date, France remains essentially a nation of smaller proprietors.

In England, meanwhile, the pace of adaptation was greatly accelerated[3]. Private land ownership served as the foundation for new hierarchical relationships between different tiers within a market-based technoecosystem. Enclosures gave rise to the intensive agriculture and husbandry of the 17$^{th}$–18$^{th}$ centuries[4].

[1] *The well known horrors of serfdom and slavery represent a later phenomenon of overexploitation within the market economy.*

[2] *After the 1860s, renters appeared in the mature ecosystem of England, showing its loss of vigor.*

[3] *Social adaptation, just as natural selection, rewards the early adopters and punishes the tardy.*

[4] *In 1687 Viscount Charles "Turnips" Townshend 2nd, the Minister of the Exchequer during the reign of George I "the Farmer" supported the 4-field rotation: turnips, clover, wheat, and barley with clover improving the soil. Stall-kept livestock fed with clover and turnips meant all-year husbandry as opposed to earlier mass fall slaughtering. This greatly improved*

England's new food chains grew as a means to further optimize profit taking. The upper tiers of society were nearly obsessed with machines that both "liberated" them from peasants and intensified agriculture with cost-efficient increases in yields. Replacement of peasants with machines was inevitable. Jethro Tull, so-called "gentleman-farmer", achieved fame even though his horse-powered seeder was never really used, due to the insufficient technological level of his times.

Alas, England suffered from shortages in whatever mattered then most: forests, rivers and skilled labor. It seemed to be destined to forever live on margins, a mere supplier for the Dutch, unable to play on a level field against the then leader, the French. But, unnoticed by contemporary observers, the tide was already turning. Most importantly, the food base increased: through the increasingly intensive agriculture and the growth of trade. The English ecosystem gained breathing room to evolve its unique local adaptations, such as the "putting out" of the cottage industry that compensated for its shortages. The wool went to spinners, who passed the thread to weavers, with merchants receiving the end product. There was hardly any overhead – a notable difference with expenses incurred by the royal French manufactures.

The 4-field rotation, drainage of fens and better maintenance of pastures led to bigger herds with sheep that had longer, sturdier wool, preferred for "new draperies" and "worsted". Buoyed by their new wealth, in 1673 the English defeated the Hanseatic League and won Baltic trade rights. In 1699, they forcefully opened markets in Russia and Newfoundland. And, most importantly, from the 1690s the English ran the incredibly profitable *slave trade triangle*. The slaves were acquired in Africa, in exchange for Indian calicos, English beads and metalwork. Brought to the American south, they were exchanged for raw cotton. Liverpool, the capital of slave trade, flourished.

This growing reliance on trade further stressed the importance of timber (ship building and iron smelting), then mostly imported from Northern Europe. England tried to mitigate this uncomfortable strategic dependence through its American colonies[5]. It was thought that ships built in New England could bring back wrought iron in exchange for English-produced nails and other manufactured products. At the same time, the English strived to restrict the development of trade and industries in their colonies so as their raw material suppliers wouldn't grow into competitors, repeating the path that earlier was taken by England, a former supplier for the Netherlands[6]. Things didn't completely work out as planned. However, when France attempted to close continental markets for English textiles, the colonies turned into an important market. From 1744 to 1758 exports to America tripled.

England already had the necessary tonnage. After winning 3 consecutive wars[7] (1640–1686) against their former patron turned main competitor, the Netherlands, the English merchant fleet more than doubled (via shipbuilding and

*the quantity and quality of herds, while cities gained yearlong access to fresh meat. Cited from (Hobsbawm 1968).*

| *Year* | *Sheep weight in lbs* | *Cow weight in lbs* |
|---|---|---|
| *1710* | *28* | *370* |
| *1795* | *80* | *800* |

[5] *"By 1737 it was being argued in England that if, instead of buying from Sweden and – to a much smaller extent – from Russia, pig iron was imported from America a great saving would result because such imports could be paid for by exports of manufactured goods to the colony." (Rolt 1965: 138).*

[6] *Of course, restrictions placed on American industries eventually led to the American Revolution.*

[7] *The 4th war of 1780–1784 was waged separately in order to stop the secret Dutch trade with the colonies during the American Revolution. One of Elizabethan laws stipulated that the dead be buried in domestic woolens.*

capturing war prizes). Meanwhile, no state regulation was deemed improper if it closed England to imports or stimulated domestic demand[8]. The domestic textiles may have been of poorer quality, but, with production subsidized by the so-called *poor taxes* they were also cheaper and enjoyed an essentially captive market. Despite their great popularity with the public, imports of Indian calicos, an affordable replacement to linens, were outlawed. Home-based producers thus gained an opportunity to learn how to spin and weave the poorer quality, short American cotton fibers. At the start, it couldn't be made into a sturdy thread, while the longer Indian cotton was deemed too expensive. This caused a veritable chain reaction of innovations as the manufacturers tried to "open up" the sequential bottlenecks that they encountered. They started up with a compromise – *fustians* were made with woolen or linen thread for warp.

## The Coming of Age or the Fundamental Invention

The coming of age of the specific English adaptation was announced by the birth of its own ideology in the 1776 "The Wealth of Nations" by Adam Smith (Smith 1776). The readers were ecstatic. Far from being a papist-admonished sin (it is easier for a camel to pass through a needle's ear than for the rich to enter Heaven) the pursuit of personal wealth was suddenly elevated to worthy service to community. The new food chains acquired a fully legitimate moral footing. This is an important turning point in the life of every dominant ecosystem. There finally comes a moment, when it must turn away from scavenging bits and scraps at the margins of the then leader and relish instead in its uniqueness, proudly proclaiming its homegrown values. To parallel, this happened to our old friend, the lobe-finned fish. Eventually it stopped caring about its old swamp and applied its energies to its new habitat, the growing land ecosystem. In England too, the all-important personal wealth now served as the fulcrum, the foundation of all the future social relationships and thus its raison d'etre. The new social relationships based on private property worked as the hidden engine behind the future industrial revolution.

Some would insist that the rising food chains based on a new dominant form of private ownership were of no consequence. Simply, England begat the Industrial Revolution thanks to its preeminence in the area of science and technology. To put it mildly, this would be an overstatement. If we were to pick a top technological nation of the times, it would be rather France than England. Of course, the islanders were enchanted with hardware, the more iron laden the better. This turned into an obsession, when they found out that their peasants could be profitably replaced with machines. However, at that time, the process of smelting iron required timber. Trees were plentiful in France, not so in England. To grind ore and fan bellows, one needed rivers, full flowing in France, rather scarce in England. It would hardly hurt if one's country could boast of advanced science and premier learning institutions. The latter were well established in France, unheard of in England. An aspiring English scientist would be well advised to leave for Glasgow, since the Oxfords and Cambridges of the time specialized in gentlemanly pursuits.

In the 17$^{th}$–18$^{th}$ centuries, science in Europe was blooming. England was rather on its outskirts, with Newton a lone star on the backgrounds of a monolithic mass of country gentry in domestic tweeds. Torricelli, Bernoulli, Boyle worked on the theory of gasses starting from 1643. Newcomen's "atmospheric" machine, the precursor to Watt's steam engine, was built to illustrate its principles. The significance of 1785

[8] *The 4th war of 1780–1784 was waged separately in order to stop the secret Dutch trade with the colonies during the American Revolution. One of Elizabethan laws stipulated that the dead be buried in domestic woolens.*

Cartwright's loom for the Industrial Revolution has been well publicized. But few, if any, remember to mention that machines were all the rage of that time. For example, the mechanized loom for ribbon-weaving was well known in the 16th century France[9]. The unlikely prominence of Sweden in 1620–1700 was based on its abundant timber and excellent iron[10]. After the 1753 French-Spanish clashes, even tiny Andorra greatly increased its iron smelting. Abundant rivers and forests were certainly of help.

However, simply having the technology is never enough. It has to be supported by adequate food chains. In the incessant game of give and take that constitutes life, societies differ in their priorities. What for some is vital and must be done regardless of costs and consequences, for others is merely advisable and may be left ignored. The chasm between the rising English and the more traditional French societies can be illustrated by the following story of two inventions.

1. Jacques de Vaucanson was of humble origins. An apprentice to a watchmaker, then to a surgeon, he rose to become an Immortal, a member of the prestigious French Academy of Sciences. Cardinal Fleury, the all-powerful minister of Louis XV, appointed him as the general inspector of the Royal manufactures in Lyons. In 1743 (40 years prior to 1785 Cartwright's loom) he invented a fully programmable loom. In the manner of the 1970s computers, it was operated by ***punch cards*** and powered by a team of oxen. This invention was rejected by the powerful Guild, mindful of preserving their jobs, and sent to collect the dust at the Museum of Arts and Sciences in Paris. In 1751, he also designed a programmable lathe, with about the same outcome[11].

2. Compare this with the luck of his contemporary Robert Peel, whose grandson became the Prime-Minister of England. The first Robert Peel, a common weaver, didn't waste time on futuristic technologies. Instead, in his kitchen, he thought up a cheap way of calico printing. His son, the next Robert Peel, founded a textile mill. Employing the cheap labor of workhouse orphans he grew so wealthy, that he was knighted and became a MP. His son, yet another Robert Peel, studied with Lord Byron and became a MP at 24 – his father gave him a qualifying estate as a reward for good grades. In 1834 he became the Prime-Minister.

The story of *Le Creuset*, currently an upscale French manufacturer of pots and pans, further adds to this pattern. In 1764, Gabriel Jar, yet another French Immortal, visited England. Upon his return, impressed with technologies of iron smelting with inexpensive mineral coal instead of costly charcoal, he recommended opening a

[9] *Records of ribbon-weaving in the Loire region date from early 11th century. After the 1562 Huguenot massacre it has spread to the Netherlands and beyond as a loom for weaving several ribbons at once.*

[10] *Gustavus Adolphus invaded German principalities and Charles XII challenged huge Russia.*

[11] *The story continues. Yet another Frenchman, Joseph Marie Jacquard, simplified Vaucanson's design. His machine used punched cards to weave complex designs and patterns. During the 1801 French Industrial Exhibition (the famous English Exhibition at the Crystal Palace was in 1851), it received the Bronze medal. Napoleon was so impressed as to reward the inventor with a pension and an order of the Honorable Legion. In 1806 the machine was destroyed by the Lyons Guild of Weavers. In 1810 it was imported to England, where it finally started producing instead of receiving medals. 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 errors and reduced the workforce on a loom from 2–3 to 1. These looms, large and expensive, made cottage industry turn factory-based. 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. In 1840s, following its tremendous English success, the machine was finally reintroduced to France. (The Kashmir Shawl, 1973), (Ames 1986), (Clabburn 1996), (Levi-Strauss 1987).*

foundry for the French navy. The site was chosen by William Wilkinson, a colleague of James Watt. *Le Creusot* was a small city in Burgundy close to rich deposits of iron ore and coal and strategically placed between the Atlantic and the Mediterranean, with easy access via the Loire and the Savonne. *La Fonderie Royale* was built in 1782. Due to shortages in both skilled and unskilled labor, it faced difficulties from the start. With France lacking English-style workhouses, its peasants would rather work their land than man foundries for the king. Investors also were in short supply. The foundry became operational only after its nationalization by Napoleon. After producing guns and cannonballs for the French Revolution, it closed in 1815, reopened in 1826, and went bankrupt by 1832. Since the 1840s French industrialization, it worked stably, producing such important inventions as the steam hammer.

This difference between France and England can't be attributed to the lack of scientific learning or even to the shortage of coal and iron ore. France had its share of rich deposits. But, unfortunately for France, the leader of its era[12], it was richly endowed with timber, the main resource of the times. Its people had few incentives for suicidal dashes into mines.

In France, technology was the domain of state-sponsored scientists. Mindful of preserving social accord, the state easily sacrificed technological advance. In England, inventions were made by watchmakers, weavers and other artisans eager to improve their condition in life. The workhouses were made inhuman intentionally, so as not to sponsor "idle" habits of the poor. The investors took Adam Smith's teachings close to the heart and readily served society by stuffing their pockets. They couldn't care less about such intangibles as social concord.

It might seem ironic that "soft-hearted" France exploded in revolutions, while its "hard-nosed" neighbor didn't. As a growing ecosystem, England could channel its social tensions outside. Its people were constantly on the move, both within the country, from villages to cities, and outside of it, to faraway colonies. To the rising leader, the English, just as for the lobe-finned fish of the first article of this series, the world was rich with "swamps" to colonize.

## Exaptation

England's outward push slammed into seemingly insurmountable problems. The French crown's dislike to its growing competitor grew so intense that it would rather support American revolutionaries. The French-English proxy fight on the other side of the Atlantic helped the young US and weakened both adversaries. Severely overextended under the weight of its huge war debt, the fading French *coenosis* exploded in a series of revolutions. The English, meanwhile, lost their prized American possessions, potentially an important source of wood, wrought iron, and ships. When the Americans overtook the lucrative slave trade, the English promptly noticed the great amorality of trading in people and forbade it with an 1807 act of parliament. With a stroke of the pen the slave-trading ships turned into lawful prizes. With American colonies or without, the English fleet still commanded the seas.

The loss of colonies as a potential source of timber around the inflationary peak of the 1780s spurred inventions, especially in metallurgy and the use of fossil coal[13]. The timing was so

[12] *Pointing to France as the leader of the Age of Exploration may seem counterintuitive – while it boasted a good navy, it wasn't the major seafaring power of its times. However, France put to a good use its extensive network of rivers – it built a powerful economy with a budget based on its unified national markets.*

[13]

| | |
|---|---|
| *1709* | *Abrgham Darby uses coking coal for pig iron production in Coalbrooksdale* |
| *1760* | *Boulton's coke run foundry in Birmingham* |
| *1770* | *Iron replaces wood in machine making. First iron bridge. Watt's steam engine.* |
| *1780* | *puddling – "Cort produces wrought iron using coking coal.* |

exact – right before the onset of a severe depression – that one wonders about its serendipity. Was it being caused by a mere chance, or were there inner, not immediately obvious reasons at work? Our guess is that it was triggered by its proximity to the peak of the resource bell-curve. Upon reaching it, the old resource – for pre-industrial England timber and charcoal – stopped growing, while the population still did. In general, as was implied by Malthus (Malthus 1798) and shown by Fischer (Fischer 1996), the demographic bell curve would follow the resource bell curve, with a noticeable, and quite painful, adjustment lag. It was noticed (Brodel 1984) that inflationary prices for inelastic resources caused a deflationary pressure on less critical industries. As people begin to watch their purses, discretionary spending falls. Newer products are hit the hardest. Prices plummet – those who lower their prices faster get a fighting chance; all the others perish. This causes a growing substitution of the older inelastic resource with a whole range of other, more affordable, products. One of those will produce the future winner.

Kondratieff found out that the pace of innovations accelerated about 20–25 years prior to an inflationary peak. This coincides with the slowing of the resource bell curve[14]. The bigger the difference between the inflationary cost of the older resource and the deflationary price of the newer one, the more powerful the rising *coenosis* that consolidates around the latter.

In fact, the most new technologies, including iron casting with coking coal, were known well before the inflationary peak. However, with little outside pressure, they evolved slowly and more often than not were inefficient[15]. Coal mining, while growing admirably, was limited mostly to heating. Cast iron was too brittle compared to wrought iron, which at that time couldn't be produced without charcoal. Thus its uses were restricted. England seemed doomed to either exporting Swedish timber/iron or supporting forest-rich American colonies.

This drastically changed during and after the 2 crises at the end of the century: inflation so severe that it almost immediately turned into deflation. Spurred by these crises, critical inventions in metallurgy and factory-made textiles clustered around the end of the century. For example, the greatest innovations in metallurgyculminated with the 1770 invention of Watt's steam engine and the 1780 invention of Cort's process of "puddling" wrought iron using fossil coal. Simultaneously, the 1779 Spinning Mule produced sturdy, machine-spun cotton thread. The first textile factory powered by steam was built in 1790[16].

*1820 Blast furnace with forced air*
*1850 Steel – Bessemer's catalytic converter*

[14] *At about the midpoint the second derivative turns into zero.*

[15] *Newcomen's "atmospheric machine" that pumped water out of coal mines, was cheap, but wasteful – next to coal deposits cost mattered more than efficiency.*

[16]

*1733 Kay patents the Flying Shuttle*
*1742 Cotton mills are opened at Birmingham and Northampton*
*1743 Lancashire mill owners import East India yarns to improve the quality of textiles*
*1764 Hargreaves designs the Spinning Jenny (patent taken in 1770). Arkwright designs the Water Frame. (patent taken in 1769).*
*1771 Arkwright opens his mill at Cromford.*
*1773 The first all-cotton textiles are produced – before, there were fustians*
*1779 Crompton designs the Spinning Mule, which spun strong cotton thread.*
*1785 Cartwright patents the power loom.*
*1789 Cotton goods production is 10 times more than in 1770.*
*1790 Arkwright's steam powered mill at Masson is opened.*
*1792 Grimshaw's factory in Manchester is destroyed by an angry mob of weavers and spinners. Eli Whitney invents the cotton gin to mechanically remove cotton seeds.*

As the revolutionary wars eliminated the possibility of getting cheap timber from the colonies, the raw new technology was used in military applications, where it produced astounding results. Cheap and light cast iron cannons replaced more precise, but also more expensive and heavy bronze cannons, the preferred weapon of Napoleon. The carronade was adopted by the Admiralty in 1779 on the captain's discretion, but became the mainstay around the Napoleonic wars, when even merchants installed them due to their low weight, half as little use of gunpowder and affordability. By luck and not by design, it perfectly fit the English fighting style – a legacy of its privateering days, when capturing a prize was the main objective. The navy was famous for its seamanship, sailing close to disable the outmaneuvered enemy and inflict maximum punishment through broadsides often aimed at rigging. The new guns proved their worth, when Lord Nelson annihilated the united French-Spanish navy during the 1805 victory at Trafalgar[17]. England was now secure against the threat of French invasion, which was thus channeled to the East.

***Exaptation is the active phase***. Unlike the more passive stage of adaptation, this stage is for the strong, not the weak. At this point, the winning species already passed the trials of two life-changing crises: inflation, and, following it, deflation. Britain survived and, most importantly, found innovative uses for its own unique resource, mineral coal, an affordable substitute for the inelastic resource of timber, now prohibitively expensive. Thanks to this new resource, instead of changing itself, the winning species could now embark on ***changing its surroundings*** in order to better accommodate them to its growing needs. The cottage industry morphed into the new winning format of a steam-driven factory turning the formerly protectionist England into a major textile exporter. The Indian weavers were ruined in the same non-discriminatory manner as the native ones – none of them was a match to English machines[18].

Meanwhile, as it is customary for the inflationary peaks of the odd wave, circa 1815 worldwide inflation reflected shortages of the ***old*** inelastic resource, timber. Even though coal was quite abundant, only the winning species had the smarts to benefit from it – the others suffered from severe scarcities. While England was being covered with steam-driven factories (Watt's steam engine), its neighbors were either ignorant of the change or, as it was the case with *Le Creusot,* couldn't use it to their advantage. This pattern persists within all 6 historic ecosystems.

In England, the new species grew accustomed to its increasingly industrial habitat. It learned to survive in its bleak, soot-covered and pauper filled cities that earned riches unheard of before. The growing wealth and advances in hygiene and nutrition gradually trickled down, causing spurts of demographic growth. The revolutionary and Napoleonic wars almost ruined maritime trade for nearly everyone including France, but except England, well protected by its fleet, despite the continental blockade imposed by Napoleon from

[17] *The Victory at Trafalgar had 2 large 68pdr carronades on her forecastle, one of which devastated a gundeck of the French flagship, the Bucentaure, by firing a 68pdr roundshot with a keg of several hundred musket balls though her stern windows.*

[18] *The following table shows the shift to a new era that traded in textiles, sugar, coffee, tea and tobacco as opposed to the earlier commodities of pepper, spices and gold (Hobsbawm 1968; 52).*

*Main Items of International Trade*

| *Year* | *Part of pepper in East India goods sold in Amsterdam* | *Textiles, Tea and Coffee* |
|---|---|---|
| *1650* | *about 33 %* | *17,5 %* |
| *1780* | *11 %* | *56 %* |

1806. A million pairs of boots for the Grand Army embarking on its 1812 Russian campaign were produced in Northampton[19]. Churning its lemons into lemonade, England also actively traded with its former colonies.

## Implementation – a 2-Step Process

### Forming its Unique Technological Style

This wasn't the last of the English trials and tribulations. As it is usual with rising leaders[20], the country put itself at the mercy of a single industry – textiles[21]. Its growing maturity hit like a hammer. Tremendous growth in productivity caused a precipitous drop in margins and profits[22]. Simultaneously, the move towards large-scale scientific farming caused a rise of rural productivity. Surplus agricultural workers had to move to industrial areas or immigrate[23].

[19] *In 1807, Cockerill, an Englishman, founded a textile factory in Liege, currently in Belgium. Then, he supervised the construction of a foundry. Guns for the French revolution were made at la Fonderie Royale mentioned above.*

[20] *See the concept of a growth pole by Francois Perroux (Darwent 1969).*

[21] *In 1760–1830 Manchester grew tenfold (from 17,000 to 180,000 inhabitants). (Hobsbawm 1968: 56).*

[22] *Costs of raw fiber and selling price of 1 lb of spun cotton (Hobsbawm 1968).*

| *Year* | *Cost of fiber* | *Selling price* | *Profits* |
|---|---|---|---|
| *1784* | *2 sh.* | *10 sh. 11 d.* | *8 sh. 11 d.* |
| *1812* | *1 sh. 6 d.* | *2 sh. 6 d.* | *1 sh.* |
| *1832* | *7,5 d.* | *11,25 d.* | *3,75 d.* |

[23] *In 1830 around 15,000 people sailed from Liverpool to North America. By 1842 this had reached 200,000, which accounted for more than a half of all emigrants leaving from Europe.*

The rising social mobility on the backgrounds of falling margins put an end to easy profits of early industrialization. It is the moment for the Darwinian "Survival of the Fittest". During the following deflation, there was carnage – the older industries unable to drastically lower their prices staying profitable were completely destroyed. At this moment of total restructuring, the technological bundle must be focused on the main resource of the growing ecosystem, in this case coal. Several ruthless depressions ensued, in the 1830s and in 1841–1842, with the latter nicknamed the Great Depression, in parallel to the similar event of the 1930s. The deflation cleared off the ruins of the old and started the "second" industrialization of 1840–1895. In a stark contrast to the narrow-based "first" industrialization centered on textiles, this was all about infrastructure: heavy industries and coal. The textile industry was now fully steam-driven. This period (1840–1895) of building a broad-based infrastructure complete with its mass producent – the worker as opposed to the earlier farmer – corresponds with the deflationary dip and the start of the even K-wave.

Businesses were consolidated. While foreigners were accustomed to family holdings of 10–12 acres, in England, under the conditions of market economy, farms smaller than 100 acres were nonviable (Hobsbawm 1968: 103). In the textile industry, which brought in major profits, the amount of steam-driven looms rose from 2,400 in 1813 to 55,000 in 1829, 85,000 in 1833, and 224,000 in 1850[24]. Simultaneously, the number of weavers first grew, reaching half a million in the 1820s, only to fall to about 100,000 in the 1840s. Marking the end of the restructuring,

[24] *After the Napoleonic wars, cotton industry grew 6–7 % per year for 25 years, providing half of all exports. At its peak, in the 1830s, raw cotton comprised 20 % of all imports. When, at the end of the 19th Century, the pace of growth has slowed (0,7 %) all the industries suffered from contraction, since cotton brought in main profits. In 25 years after 1820 production increased by 40 %, while salaries grew just by 5 %.*

in the 1850s there were barely 50,000 independent workers left. They ferociously reduced their prices in a hopeless competition with machines[25]. Earlier, a fast depletion of surface deposits caused a switch to deep mining, which demanded investments and mechanization, including Newcomen's atmospheric machine, the forerunner of Watt's steam engine[26]. Town gas that lengthened the working day in factories was one among the many side products of coking coal.

Following the customary scenario of fundamental invention, the railroad appeared as a solution to an unrelated storage problem. Foundries, to us the obvious heart of the industrial revolution, started small, depending on military orders. While the state bought in quantities, it didn't do it very often. In 1760, in an attempt to find a cost-efficient way of storing iron between orders, A. Darby, a foundry owner, built an iron-lined road for horse-drawn carts. The cost savings in transport efficiency were so great that this road, the granddaddy of the future railroad, was never dismantled. In the 1820s it was followed by a road with iron rails. Through trial and error, iron manufacturing, the main industry of the epoch, gradually took its shape. Within 20 years, the coal and iron outputs more than tripled, in order to build and service railroads[27].

Steel industry was created later, practically from scratch, causing the second wave of railroad construction. This happened closer to the end of the 19th century, simultaneously with the ironclad steamships. Meanwhile, in the mid-century, railroads replaced insolvent canals of the earlier era en masse[28], creating a brand new ecosystem with dirt cheap transportation, which spurred the growth in regional specialization. The new ecosystem created its own feeding base on the go – low prices increased demand, stimulating employment.

As we see, the mid-century deflation, homological to the massive investments in infrastructure during the New Deal (Hoover dam, TVA etc), is a crucial, though difficult moment that focuses the technological bundle into a unique ***technological style*** of the epoch**.** The latter would remain in posterity forever – an easily-recognizable trademark of its times[29]. First England, then all the other countries of the "civilized" world replaced their bucolic landscapes with smoke-belching factories and railroads. C. Perez (Perez 2002) noticed that the leading technology of an era appears twice, first fueling a short-lived bubble, within a single "leading industry" (Modelsky 1996), then bringing the more lasting prosperity of the so-called "Golden Ages". Prior to its midlife deflation, the industrial revolution in England was on a rather precarious footing, servicing the narrow needs of textiles. Now it was firmly rooted on the broad infrastructure servicing heavy industries.

This was the telltale moment when the shift towards the new inelastic resource became fi-

[25] *Between 1805 and 1833 wages fell from 23 sh. per week to 6 sh.3 d. (Hobsbawm 1968: 93).*

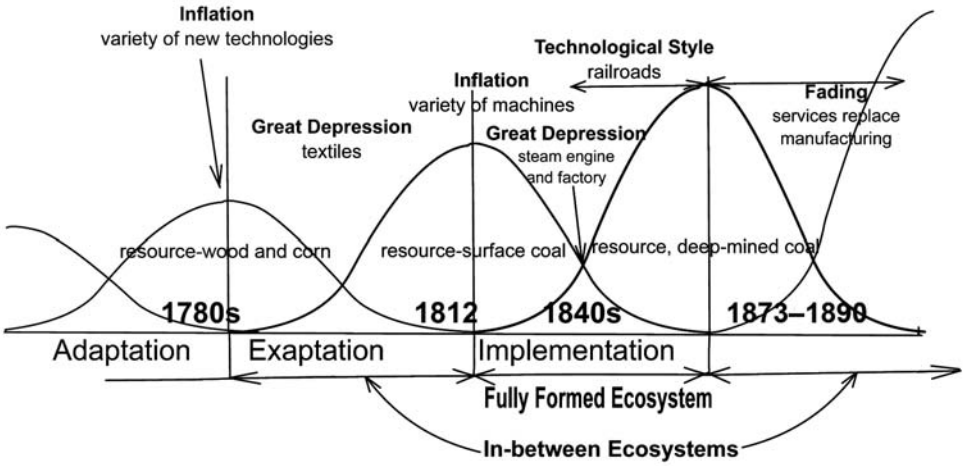
[26] *In the 18th century, coal mines were often shallow and worked by families, with coal taken out in baskets. Coal was mostly a consumer product, used for heating and cooking.*

[27] *Production in thousands of tons (Hobsbawm1968: 47).*

| *Year* | *Coal* | *Iron* |
|---|---|---|
| *1720* | | *50* |
| *1788* | | *100* |
| *1830* | *16,000* | *600* |
| *1850* | *49,000* | *2,000* |

[28] *In the 1790s Britain lived through "canal mania". Circa 1800 it had more than 6000 km of canals. 40 years later, most of them went bankrupt, unable to compete with railroads.*

[29] *For the 19th century it is smokestacks and railways. Highways and supermarkets became the icons of the 20th century. In 1956, after the mid-system crisis of World War II, the building of essential infrastructure, which was started during the New Deal, is concluded by the Eisenhower's Federal Highway Act.*




*The **Coenosis** and Its Lifecycle*

nal. From now on until the mid-wave deflation of the next (oil-based) technoecosystem, the world would depend on coal (Fig). The leader survived the mid-wave depression to become the standard bearer with a fully grown infrastructure[30]. As the top tier species it would replicate, feeding off the zone, remade according to its specifications. Its technological style is fully standardized. Its infrastructure is fully functioning. Its feeding chains are complete. During this fleeting and rare moment of post-struggle balance the entire zone finally enjoys the never before prosperity. The populace expands, following the easy growth of the bell curve of the new inelastic resource, in our case, coal. Even though English industries remained export-oriented, the living conditions improved drastically[31].

[30] *As it was shown above, the first deflation takes place between ecosystems, before the stage of exaptation.*

[31] *This is homologous with the growth of the consumer society in the US circa the 1950–70s on the backgrounds of the Marshall Plan – rebuilding of war-torn Europe on the base of Eurodollars, soon to be supported by Petrodollars.*

## Domesticating the Close Periphery

Meanwhile, ever cheaper transportation significantly broadened England's reach. With its own infrastructure mostly built, the current leader begins to channel its technologies to the outside world. After the mid-*coenosis* deflation of the 1840s, profits from textiles fell steeply, due to ever stiffening competition – both within the country, and increasingly throughout the world. England earned its living by industrializing its neighbors: from the close periphery of Europe and to faraway hostile lands. The majority of industrial era railroads, including those abroad, were built by English professionals using English-made rails, wagons and steam-engines[32]. Calico factories, even as far up as Russia, were built with English-made machinery. This sellout of domestic know-how (formerly expressly

[32] *New railroads, per decade (in thousands of miles) (Hobsbawm 1968: 115).*

| *Year* | *Britain* | *Europe + Britain* | *America* | *Others* |
|---|---|---|---|---|
| *1840-50* | *6,000* | *13,000* | *7,000* | *–* |
| *1850-60* | *4,000* | *17,000* | *24,000* | *1,000* |
| *1860-70* | *5,000* | *31,000* | *24,000* | *7,000* |
| *1870-80* | *2,000* | *39,000* | *51,000* | *12,000* |

prohibited) proved to be extremely lucrative. Besides direct sales and profits from the rising sector of services and maintenance England became the main beneficiary of the immense increase in regional trade[33]. It had developed a ring of far-flung satellites with highly specialized dependent economies servicing specific needs of the England-centered *coenosis*[34].

## Domesticating the Faraway Periphery

The world was divided by a chasm. On the one side, there were underdeveloped suppliers, on the other side, rapidly industrializing countries. The Opium wars of the 1840–1860s hacked into the soft underbelly of China and Japan, opening their markets. The main goal was to force them into taking something else than silver bullion[35] in exchange for their coveted teas and silks. This greatly increased the importance of the Indian[36] colonies, the main exporters of opium to China (50 % of total Chinese imports). Meanwhile, trying to increase sales of its machines, an increasingly important part of its exports, England grudgingly sponsored its future competitors. Among the latter were not only the US and Germany, the next *coenosis*' contenders for the leadership position, but also many former laggards competing on the lower price levels. The Russian and even the Indian textile industries grew.

This is a recurring pattern. It may seem ironic, but the death sentence of the current leader is usually signed at the apex of its might. Since "the end justifies the means", it would spare nothing that could be sold, as long as it prolongs its prosperity. While its fate may thus be sealed, the sentence is never immediate. In fact, the best part of the current leader's life still lay ahead. It doesn't share its technologies with others for nothing. While it remakes its close periphery, its neighbors eagerly pay whatever the costs. Soon, the easy ride would come to an end. The newly industrialized outsiders would begin to innovate too, putting their local assets to good use. The current leader would start lagging behind.

The inflationary peak of the even wave signals the growing exhaustion of this zone's native resource (coal). Following the ensuing depression, the leader has to enter a much wider zone, whose scope is defined by the reach of the newly developed means of transportation, in this case the railroad and the steamship. Here the conditions are much less favorable due to stiff competition from the new upstarts, especially the US and Germany. Just like Britain a century ago, they emerged during the 1870s inflation of the even wave, when the old resource (coal) became too dear[37]. They had to develop their own economies, based on local assets: cheap oil in the US; steel, chemistry and electricity in Germany.

It may seem ironic that the British dutifully followed the path, a *coenosis* earlier taken by the French. The latter could invent machines none the worse than the English, but fell way short when they had to drastically change their society in order to center it around these machines as the prevailing way of life. Being the

[33] *Among many examples were guano from Peru, nitrates and copper from Chili.*

[34] *Agricultural exports came from North American prairies, South American pampas and Russian steppes. Tropical and subtropical countries exported raw materials. Markets in China and Japan were also opened. Tropical and subtropical countries exported raw materials.*

[35] *British monetary system was based on use of three metals: gold for guineas, silver for shillings, and copper for dimes. Differences in global valuations caused an outflow of silver. England was permanently short on silver, practically the only item from Britain that was coveted by the Chinese.*

[36] *In 1876 Queen Victoria became the Empress of India. India gained independence in 1947.*

[37] *Compare this with the growth of, first, Japan, and then, tigers, at the same point after the 1980s inflation.*

leaders of the previous fully grown ecosystem, they weren't ready to sacrifice, for technology's sake, their comfortable social relations. ***No fully grown coenosis would ever allow any serious changes in its power structures/food chains while still alive***.

This time around, this was true regarding the aging British. Maxwell and Faraday, among the first leading names in electricity, were Englishmen. But even while London was still using town gas (inexpensive, with infrastructure already in place)[38], Berlin was illuminated by the electric bulb. Also, the traditional British reliance on export markets started to show its weaknesses. In contrast, the Americans had ample room to grow within their potentially huge inner markets.

These and other cracks had first manifested themselves at the highest point of the first coal-based bell curve (the even wave of the 1850–1890s). American shipping, based on ample timber resources, grew into a formidable competitor[39]. However, to any outside observer, things never looked better. In fact, the all important coal production kept growing well past the peak of this bell curve, as if not noticing its turning point, until it reached its 1913 maximum. After the start of WWI, which marked the apex of the second coal-based bell curve (during the odd wave of the next ecosystem of mass societies, see Fig), we finally see a sharp drop. Meanwhile, even if it wasn't showing on production charts, the prevalence of large deep mines after the 1870s caused a raise in costs and, thus, prices. The resulting depression of 1873–1897 is traditionally referred to as "the Great Depression". An interesting thing is that England weathered it much easier than any of its rapidly industrializing neighbors. However, in the US and Germany the recession was soon replaced by growth, which was not experienced by Britain.

[38] *Compare this with current dependence of US companies on their sales of outdated SUV.*

[39] *Its famed China tea clippers put a noticeable dent on the British trade.*

In the manner of a cancerous growth, the next ecosystem grew hidden in the underbelly of the aging leader. In the same fashion as Britain owed its dominance to coal and the steam engine, the future food chains of the growing American mass society would consolidate around its own resource, cheap oil. The car would become its all-important fundamental invention, put to the service of social novelty – the consumer society. Its rich inner markets grew as a local adaptation, due to high labor costs in a young, resource rich, and population poor country.

Following the tried and true patterns, the car also would come from outside, being of French-German origin. The key to success was not in the device *per se*, but in the right social institutes. Lacking mass markets, the automobile in Europe was a mere toy for the rich. Meanwhile, Germany, continuing the path once taken by the 18th century France, developed its own local adaptation, based on its excellent universities – thus steel, chemistry and electricity. Like the "ancient regime" of the past, it staked its future on the strong state – detailed regulations, deemed the perfect fit for running the so-called "natural" monopolies. This was copied by many, including the young Soviet Union.

Both the American and German ways presented local adaptations, attempts to solve the main problem of the English – namely, the limited capacity of export markets. The newcomers relied on the growing mass classes of the late industrial age[40].

[40] *This* ***coenosis*** *grew on the foundation of mass classes that emerged at the end of the previous one. In the pre-industrial age, both France and England relied on their growing nobility, while differing in their social context. The energies of the French nobility were channeled towards strengthening the state, the product of the previous ecosystem (the Age of Exploration and National Markets). Meanwhile, the English gentry created their own system of social relationships based on pursuit of profit and private ownership. The same dichotomy was true regarding the mass classes. In the US they pursued a new goal, consumption, while in Germany and the USSR they helped to restore the relic of the old, the state.*

## The Technology-Enabler, the Swan Song of the Fading Leader

However, in the late 19th century, writing England off would have been somewhat premature. At the end of its *coenosis,* as it happens with aging leaders, from Assyria (iron plough) to the late Rome and Byzantium (Catafracts and horse) and to the modern US (computers and the Internet), England too had laid the foundation of the future world by producing steel[41].

At the end of the 19th century Britain's leading position was restored thanks to the iron steamship[42], which stimulated the precise machining, the base technology that ***enabled*** the mass societies of the 20th century. Thanks to it, English maritime commerce survived the American challenge and achieved global dominance, readily supported by aggression and imperialism[43]. The worldwide trade routes regardless of the participating parties had to pass through London (Hobhouse 1986). Britain's leadership would stay unquestioned until WWI. Damaged during WWI, it would collapse after WWII.

Thanks to this last hooray of English advanced technologies, the pace of globalization had been rapidly accelerated[44]. After the 1890s, with the end of depression, England started a massive deployment of the iron steamship[45]. It may be argued that, if not for the total British control of the seas, including over critical shipments of guano from Peru and nitrates from Chile, the Germans wouldn't feel threatened and compelled to invest in chemistry. To compensate, German chemists[46] invented the process of fixing nitrogen from air into versatile ammonia: useful both as a fertilizer and for making explosives. It has been suggested that, lacking this technology in German hands, WWI would have been either altogether impossible or much shorter in its duration.

The weaknesses of the English ecosystem became apparent during wars, first and foremost, the 1899–1902 Boer wars. 500,000 English troops crushed 88,000 Boers more by intimidation (concentration camps) than by their military superiority. In fact, the Boer wars were waged (on the Boer side) as the first modern war, where the German observers learned many tactics later used during WWI.

But the most tangible proof of England's advanced age came in its balance sheet. Incredible, but true – "at no time during the 19th century did Britain have an export surplus in goods"[47]. England lacked most natural resources with the only exception of coal. Thus, even during its best years, the "workshop of the world" had to import in order to eat and export. After the 1860s the growth of imports gradually outpaced that of exports.

[41] *Bessemer's 1856 "oxygen converter" produced steel from pig iron. In 1879 Bessemer received a knighthood and a fellowship in the Royal Society for his contribution to the steel industry. Bessemer's process was only suitable for British iron ore. After 1879, the more advanced Gilchrist & Thomas method, suitable for phosphoric ores of Europe, was adopted on the continent, example, A. Krupp in Germany.*

[42] *Even its famed tea clipper Cutty Sark, built in Aberdeen, Scotland in 1869, was a composite ship, a technique that later led to windjammers, iron sailing ships, England's answer to the timber deficiency. The next logical step was putting a steam engine on that. Even though Americans had some of the first steamships, they weren't made of iron.*

[43] *In the previous ecosystem too, France, its aging leader, was its main aggressor until the Napoleon's fall.*

[44] *In another analogue, the Internet enabled the current wave of the US-led globalization via outsourcing.*

[45] *Its naval supremacy was ended in 1922, when the Washington Naval Agreement established "a formula of 5:5:3 for the strength of the US, British and Japanese navies respectively" (Hobsbawm 1996: 36).*

[46] *Fritz Haber received the 1918 Nobel Prize for fixing ammonia from air. He was of Jewish origins.*

[47] *Hobsbawm 1996: 144.*

However, the country more than compensated for its soaring trade deficits. As it is usually the case with the top species of an ecosystem, ***its dynamic productive economy slowly but surely had melted, being replaced by an altogether different economy of global services***. Far from being the oft-touted unique path taken by the modern US but never experienced before, this meltdown took place within every fading leader, from Assyria (specialist-trader) to Rome (outsourced its economy to the empire's outskirts) to Britain.

Global services presented an extremely broad category that included a smorgasbord of different items. In the case of England, starting from the 1860s and intensifying after the 1890s, the country earned its living by controlling global commerce, both through shipping[48] and, most importantly, through financial domination. The financial empire was supported by the real empire which controlled its colonies per force. England had its fingers in all pies. Regardless of the parties in a particular trade it received its "cut"[49].

In 1870–1913, foreshadowing modern Wall Street and the dollar, the City, in London, turned into the financial capital of the world, with the pound sterling as the universal currency. In 1913, at the apex of its financial might, England became the biggest global creditor. It received significant part of its income as interest on its investments abroad. In that it differed from the US, currently the biggest debtor. This can be explained by the special nature of England's relationship with India. Unlike China, a creditor that buys US treasuries in order to compensate for its growing trade surplus, India funded England directly, without requesting any I.O.U. or placing on it any obligations. According to some estimates[50], India covered about two fifths of British deficits. It also supplied opium to China, accounting at least for half of the costs of imports from China.

Unlike the current situation with the United States indebted to China, the deficits of trade with India didn't have to be compensated by any sales of Treasuries, since India, in its turn, had to pay Britain for administering itself as a colony. Note that the US trade deficits are similarly financed by the lower tiers of its global feeding chains – most recently, Saudi Arabia, Japan and China bought Treasuries on a mass scale. This is a recurring pattern. The aging top species loses its industrial might, in the manner of a lion with failing teeth, and increasingly gets its living from the lower tiers.

The latter pay for real services: technology transfer and a place in already established power networks. Meanwhile, as the aging leader's dependence from the lower tiers increases, it also grows more belligerent[51]. After WWI British exports fell in half. Partly, this can be attributed to a contraction of the global economy. But, first and foremost, the British economy had lost its competitiveness. E. Hobsbawm states that, during the 1873–1897 Great Depression, Britain managed to avoid modernization by utilizing its traditional strengths. It built the financial powerhouse around the pound sterling along with the territorial powerhouse of the British Empire, relying on captive markets of its colonies[52]. The price paid for this avoidance of costly investments was high – measured in growing obsolescence of its technologies. After WWI, it was shaken by periodic financial crises.

[48] *Hobsbawm 1968: 152.*

| *Year* | *French cargo carried by UK ships* | *US cargo carried by UK ships* |
|---|---|---|
| *1850* | *30 %* | *30 %* |
| *1900* | *45 %* | *55 %* |

[49] *Hobsbawm 1968; 145–152.*

[50] *(Hobsbawm 1968; 149)..."Before the First World War "the key to Britain's whole payments pattern lay in India, financing as she probably did more than two fifths of Britain's total deficits"." As cited from (Saul 1985: 62) and (Barratt Brown : 85).*

[51] *Note the Crimean and the Boer wars.*

[52] *Hobsbawm 1968: 151.*

Note that other fading leaders, from Assyria to Byzantium, had rarely experienced soft landings of the sort that England was blessed with. This may be attributed to the smaller overall amounts of public wealth accumulated within earlier historic societies. This wealth is important – its cushion or the lack thereof may draw the fine line between a total disaster and a serious disturbance. Populaces may survive or die on a shoestring during the trouble fraught, uncertainty ridden periods that separate 2 successive *coenoses*.

## Conclusion

As we see, human ecosystems play evolutionary games no less wholeheartedly than natural ones. Possibly, we even out-compete our animal brethren, both in the degree of our organization and bloodthirstiness. Meanwhile, technological progress is quite measurable: both in the rising counts of population fed off a given territory and the number of people killed by the increasingly more advanced missiles. Both of these improvements come thanks to the fundamental invention that helps in opening a new niche creating a thriving *coenosis* on the go. Similar teleology in the natural world manifests itself through gradually more sophisticated adaptations that allow exploitation of increasingly more diverse habitats.

The wave patterns are surprisingly stable. Kondratieff was indeed right – K-waves are endogenous, generated within an ecosystem.

However, far from being limited to capitalism's self-corrections, as he surmised, K-waves seem quite universal. They are the side effect of reproduction, which is the main trait of anything alive. As the living things multiply, they enthusiastically overshoot any given niche's limitations. To feed the unsustainable growth in population, the current leader has to first colonize its close periphery, and then spread its people and technologies far and wide. As the dominant social species tries to survive, its representatives, by necessity, enter hostile territories, fertilizing them with the latest technologies. New local adaptations follow, as the newcomers try to compensate for their shortcomings. Thus, the next coenosis would be different, both in its physical location, its main resource and the dominant technology developed for exploiting this resource.

In the next article of this series, we will analyze the current *coenosis* of the US-style mass society.

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# GAMTOS MOKSLŲ TAIKYMAS STUDIJUOJANT ISTORIJĄ: ANGLIJOS INDUSTRINĖS REVOLIUCIJOS PAVYZDYS II DALIS

**Lucy Badalian, Victor Krivorotov**

*Pirmajame straipsnyje istorija tyrinėjama bioekologiniu požiūriu. Bandyta parodyti, kad žmonių visuomenė nuo pirmųjų civilizacijų iki šių dienų yra technologinė-ekologinė sistema, kuri iš esmės nesiskiria nuo natūralios ežero ar miško ekologinės sistemos. Šiame straipsnyje analizuojama tam tikros (Anglijos) visuomenės specifika. Parodoma, kad Anglijos pramoninė revoliucija veikiama šalies geografinės klimatinės zonos. Anglijos visuomenė sugebėjo išnaudoti savo ribotus gamtos išteklius ir tapti pramoninės revoliucijos lyderiu. Anglijos istorijos pavyzdžiai nagrinėjami siekiant pagrįsti tezę, kad industrializacija yra biologinės-ekologinės sistemos dalis.*

**Raktiniai žodžiai**: evoliucija, ekosistema, *coenosis*, technologija, istorija.

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