

# APPLYING NATURAL SCIENCES TO STUDYING HISTORY: THE KONDRATIEFF-WAVE AS LIFECYCLE OF A RESOURCE- DEPENDENT INFRASTRUCTURE

## Part III

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*In the first two articles of this series we introduced a model of evolutionary history, based on biological concepts, such as **coenosis**, geo-climatic zone, feeding chains etc. We showed that, historically, civilization evolved by gradually domesticating 6 distinct geo-climatic zones – corresponding to 6 traditional historic eras: from the first civilizations to the mass society of the 20th Century.*

*We conclude the series with the study of economics within a zone. We show that each specific historic society evolved in order to take the best advantage of its unique resource, such as light loess soil of the first civilizations or oil of our days. The necessity of building a specific resource-dependent infrastructure, such as canals of antiquity, railways of the 19th century or highways of the 20th century, influenced every facet of life of the related society, from its leading technological style to the dominant form of ownership. The switch to a new resource was usually violent and could start well before the physical exhaustion of the older one – the latter's growing scarcity and rising price generated a flurry of substitutes. In fierce competition between contenders the victory came on the basis of resource superiority. We show that the regular rhythms of K-waves, first noticed by Kondratieff on the example of prices in the 19th and the early 20th Centuries, correspond to the lifecycle of a resource-dependent infrastructure of an era.*

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### The Disappearing Act. Do Kondratieff-Waves Even Exist?

In the early 1920s, a Russian economist, Nikolai Kondratieff (Kondratieff 1987) discovered 3 cyclic “long” or K-waves of prices, each 50+ years long. The amazingly regular peaks and troughs caused, in their wake, devastating recessions

and wars on the background of rapid technological changes. Today, despite the deathly accurate prediction of deflation in the 1930s followed by the World War II (WWII), the debate about the nature of K-waves or even their existence is unsettled, with the majority view turning rather against them. Recurring movements of prices don't seem discernible anymore, possibly due

to a heavy-handed government intervention in the financial market<sup>1</sup>.

And, even if the K-wave did exist, no one was as yet able to explain the cause of its amazing regularity. Science abhors mysteries and things that rather belong to the foggy area of magic than its levelheaded domain – that this controversy remains unresolved isn't for the lack of trying. As to this date, several competing hypotheses have been offered – including such as solar flares, which tend to repeat regularly with dire economic consequences – none of these quite satisfying.

Some suggested that K-waves are about innovations and undertook lengthy research aimed at counting those, one by one, in a chronological order, in an attempt to find clustering. We need not say that no such regularities were found – obviously, inventions arise more or less on random. Instead, this research led to more unanswered questions. Like what would constitute an innovation as opposed to a mere incremental improvement? Assuming an unlikely consensus on a technique of winnowing “wheat” from “chaff”, no one can say how to count the selected innovations – should we weigh them by importance or not, and if yes, then how? Also, where to place them – at the exact moment someone thought them up or at the moment of their implementation, possibly differing by decades if not centuries?

If K-waves were instead caused by self-corrections of capitalism, as many, including Kondratieff himself have suggested, then why do these corrections must occur with such unbending regularity? Also, are they limited to capitalist societies or can they be observed farther back into our past as some have suggested, slowing their pace, but still exhibiting the same amazing regularity? Fischer, for example, proposed a competing, in his opinion, concept of the so-called Great Waves extending back up

to the 13<sup>th</sup> century. Following the Malthusian line of thought, he saw them as caused by correction of overoptimistic demographic trends. Again, it isn't clear if his concept applies only to the past societies. Could it be that today, when grain shortages don't seem to govern human reproduction anymore, the cause for such waves has finally disappeared<sup>2</sup>? Fischer seems to not think so, offering the 1980s as the most recent peak. Also, what caused the “long 16<sup>th</sup> century” of Braudel and the much shorter but felt as if it were sort of “long” “19<sup>th</sup> century” of Hobsbawm as opposed to the “short 20<sup>th</sup> century” of the same author? Questions are many, while answers few and far between.

### **Lifecycle of an Infrastructure as a Cause of K-Waves**

Meanwhile, things don't seem quite hopeless – there are many hints as to the possible nature of K-waves. It may be more than a pure coincidence that the first K-wave waned along with the use of timber closer to the end of the Industrial Revolution of 1760–1830. At the first glance, this statement seems missing the point – shouldn't we equate the Industrial Revolution with the rise in use of coal, not of timber?

Even if counterintuitive, the start of the Industrial Revolution does seem concurrent with the rise in demand for timber. In no way should we confuse the early stages of steam with widespread global use of coal, a brand new energy resource of Britain. In the same way, the start of the 20<sup>th</sup> century of the mass car coincided with the run up both in prices and strategic relevance not of oil, but rather of coal, the main resource of the previous era. Not only did coal shape the 19<sup>th</sup> century, it

<sup>1</sup> *Though the overnight rates tend to move with an intriguing regularity and display the familiar pattern.*

<sup>2</sup> *The current technology is capable of producing sufficient amounts of grain for every man, woman and child. However, distributing the plenty to the starving exceeds the range of a purely technological problem.*

also put its indelible mark on the first half of the 20<sup>th</sup> century. Only later it slowly relinquished its strategic position to oil. Currently, the latter is the lifeblood of our economy, to the point of waging wars for it, even as we enter a new century, which probably would find its own strategic resource.

So, as these and similar historic examples show, technological eras seem to pave the way for the related resource-based eras by appearing a full phase earlier. Translating a chance technological innovation, however significant, into the foundation of an economy, as it was the case with the 19<sup>th</sup> century's railway or the 20<sup>th</sup> century's mass car seems not that easy. It leads to changes in all facets of a society's life, as an adequate infrastructure for its optimum utilization must be built. From the pioneer society it will then radiate throughout the Oikoumene. Consider, for example, a seemingly minor act of switching from firewood to coal within a household. It would require a new range, with the implication that the old one must be discarded; a new technology of cooking etc. The family in question may go without a dinner, if there is no adequate infrastructure of coal procurement and distribution. The older infrastructure would lose a customer, cutting the livelihood of entire groups of people employed within it.

Also, a seemingly small and insignificant detail caused much chagrin at the time, namely, the foul odor of untreated coal. It isn't for nothing that a new resource, such as coal, wasn't known in this quality before. Adequate technologies had to be developed for its utilization. In the case of coal, the odor problem was so bad that most considered coal-cooked food repugnant. In an effort of getting rid of the offending smell, the *coking coal* was invented by beer brewers. Their product would be taken on by one Abraham Darby, a onetime brewer's apprentice, and used in a drastically new functionality for iron smelting. This shift in functionality would cause a veritable technological revolution, greatly increasing both the coal usage and its strategic importance with a commensurate increase in demand. The need

to pump water out of deeper mines, along with wider availability of cast iron, would eventually jumpstart the Industrial Revolution.

This is a fairly typical pattern. A seemingly minor invention introduces a new and much needed resource, a cheaper substitute to an increasingly dear older one. This may start a technological revolution along with a social one. This applies not only to coal (coking – steam engine – industrial society) and oil (refinery – internal combustion engine – mass society), but even to less obvious products, such as olive oil (lever of the press – phalanx, trireme, Roman engineering – classic society) that provided an edge to the rising world of Greek-Roman antiquity. As a calorically superior source of food olive oil allowed to greatly stretch insufficient stores of grain.

The benefits of a society growing around a newer resource seem pretty obvious. But, as the case of Britain shows, the growth of prosperity may start at a much earlier date<sup>3</sup>, in this case conventionally related to the Agrarian Revolution of the 17<sup>th</sup> century (the “Norfolk system” of land management from the Low Countries). There can hardly be a doubt that a concerted attempt to improve the land could indeed be beneficial. One is left wondering though about the scale of its economic impact, considering the near absence of mechanization, still well in the future, which would be needed to increase the labor productivity.

As convincingly shown by G. Clark for the case of coal, the British raise in prosperity didn't come through building anything new, but rather through dismantling the old. According to his calculations, the growing substitution of coal for wood for everyday needs brought in huge initial costs savings by dismissing the expensive infrastructure of timber procurement. The arable under the so-called coppice woods, a renewable source

<sup>3</sup> According to archaeological data, there is a marked increase in silver plate starting from the 17<sup>th</sup> century.

of timber, could now be freed for other productive uses. This was not a small matter, since, at that time, the demand for timber for heating, cooking, beer brewing, pottery firing, metal smelting etc accounted for at least a third of all British arable. Further on into the Industrial Revolution, the need in thermal energy only grew. According to Clark, soon it exceeded the timber producing capacity of all British arable combined (Clark 2002).

Similarly, after introducing oil, the first substantial savings came from dismantling the older costly infrastructure of coal procurement and distribution. In the first half of the 20<sup>th</sup> century, coal still reigned supreme. However, between WWI and WWII, railways and steamboats were gradually switched to diesel burning boilers, an economical substitution for coal, while preserving its old functionality (Roberts 1989: 380). Thus, the ascent to the next historic era is usually accompanied by a switch to a new dominant inelastic resource, which, in its turn, requires its own infrastructure and leads to gains through dismantling of the older one.

Closer to the first inflationary peak of a new era, the older resource's growing scarcity and skyrocketing price stimulate a flurry of its substitutes. During the following turmoil, homologous to WWI, one of these would beget a winning technology for its pioneer. For example, the internal combustion engine showed its potential during WWI<sup>4</sup>. With economic considerations rendered nil and void by realities of war, several generations of aircraft were rapidly developed, a feat impossible in peacetime. The British army

entered the war with 100 trucks, finished it with 60 000. After being refined during WWI, the diesel technology was sufficiently mature to gradually displace the severely damaged old coal infrastructure. As it was the case with coal replacing timber, this first stage of using the new resource was well within the old functionality and led to considerable cost savings (Roberts 1989: 380).

In order to facilitate a better use of the new resource, a brand new infrastructure, tailored to fit its specifics, had to be built instead of the older one. Historically, this led to a quantum leap both in labor productivity and resource availability – consider, for example, that a carload of timber holds about the same amount of thermal energy as a basket of coal or a bottle of oil. This change is neither cheap nor fast. Not only are new infrastructures expensive to build, they also lead to wholesale changes in everything held dear, igniting fierce resistance.

### **The Inelasticity of the Dominant Resource and the Hubbert's Curve**

That a new inelastic resource does indeed shape its era is acknowledged in such accepted terminology as Coal Age or Oil Age. This also showcases the fact that each era depended on its unique inelastic resource. Of course, today, within the Oil Age, other sources of energy are also being widely used, as substitutes. More such substitutes would turn economical as oil price breaches yet another record. Some countries, such as Brazil, Iceland etc strive to reach oil independence on the base of their substitutes. Nevertheless, as to this date, not a single one or even a group of substitutes can fully replace oil – the global infrastructure of mass transportation generally depends on it and may grind to a stop, if deliveries were interrupted. In the same way, coal reigned supreme in the 19<sup>th</sup> century. Its preeminence was breached not by gasoline we are addicted to, but by diesel used

<sup>4</sup> *This pattern held regarding the homologous period for the 19th century, the Napoleonic wars. In the deflationary dip between centuries on the background of growing French-British conflict the cast iron gun has been tested and refined. Technologies developed for boring it would prove crucial for Watts' steam engine that, in its first widespread use, powered the textile factories mushrooming after the end of the war.*

in boilers of newer steam engines, firmly within the old functionality. Thus, a historic era can be usually defined by its chief inelastic resource.

Building an infrastructure around it is a costly and life-altering act lasting the lifetime of its *coenosis* – historically, no two competing infrastructures could peacefully function side by side. The infrastructure of the older fading resource usually dominates the first half of a new *coenosis*, when only early adopter countries can take an advantage of their substitutes, pursuing several alternatives related to different zones. Thus, there is a sizeable lag between an invention per se – a technology for using a new material as one of acceptable cheap substitutes to an older inelastic resource – and a social revolution, when one of the newer resources matures to become the foundation of the next society. This lag reflects the time span needed for building and refining the newer infrastructure in its early adopter country. After a competition, homologous to WWII, sufficiently well packaged, this infrastructure would be ready for radiation, as others too start switching to a cheaper and calorically superior resource.

At the beginning of the Industrial Revolution, only Britain staked its future on coal. Other countries, even in Europe, accepted industrialization as the predominant way of life in the aftermath of the 1848 European revolutions, with the technological package of railroads already fully refined. During the K-wave of the first half of the 20<sup>th</sup> century, coal reigned supreme. Only the fourth K-wave, the last discernible one, from the 1950s to the Oil Shock of the 1970–80s<sup>5</sup>, announced the true start of the Oil Age.

One might suspect this wasn't random. The opinion that a K-wave marks a dependence on a single resource and fades as this resource is exhausted seems corroborated by the existence of the so-called Hubbert's curve. As early as in the 1950s the latter predicted that, in about 20 years, the US oil deposits would be exhausted.

<sup>5</sup> See Fig below.

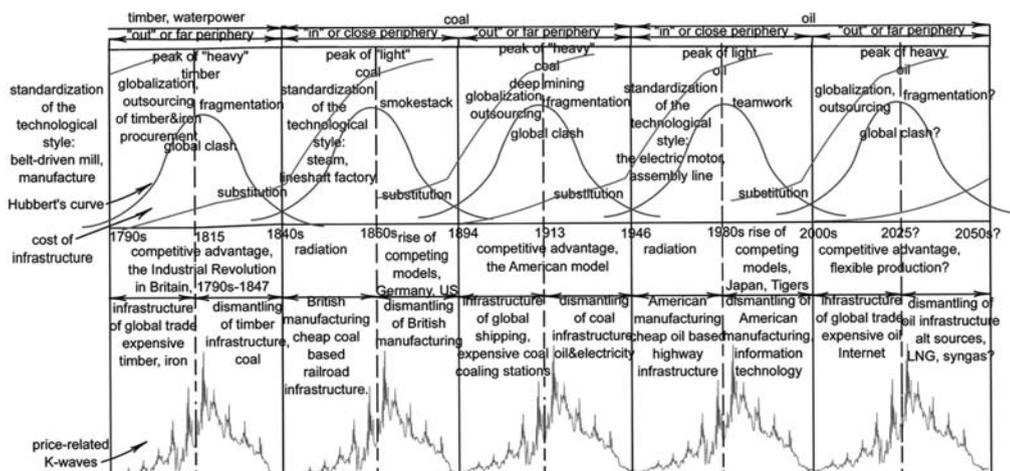
This prediction materialized to the “Z”. There was also a second Hubbert's curve, with similarly dire predictions for the resources of global oil in our near future.

However, even while people die in wars fought for oil, many would insist that oil is far from being exhausted and would dispute the curve's implications forecasting global oil shortages, as close to our time as the 2000s. And it isn't just politicians and oil executives, who try to soothe both their and public's emotions, which, in the era of \$3+ gas have grown a tad too intense. While the price for oil is shooting through the ceiling, many would argue that in no way is this related to any shortages. These just didn't materialize, defying alarmist predictions. And, technically speaking, this opinion is absolutely correct. Oil is still plentiful around the world, as far as the eye can see, in tar sands, oil shale etc. This stays true even though it grew more expensive to pump, refine and distribute, more because of political risks than purely technological reasons. In this sense, it would seem pointless to tie together any resource-based curves and K-waves at all. Instead, we can relax, as both of these seem to not exist.

Meanwhile, this soothing notion may be a bit premature. One needs to keep in mind that, far from being peculiar for oil, this situation of skyrocketing prices despite plentiful resources has been repeated many times before with predominant resources of their eras, such as timber and coal. Far from signaling abundance, it is rather a typical sign of the coming end gambit of a particular era, which used to depend on the said resource.

### **The Costs of Infrastructure-Building: Local versus Global**

Fig depicts five major infrastructure building periods related to specific resource-based economies, ranging from the “heavy” timber of the 1790s–1840s and up to the “heavy” oil of our imminent future. A sequence of 2 stages: “light” and



*Structure of the Kondratieff Cycle (1790s–2050s)*

“heavy”, meaning procured locally versus globally, is fairly representative for a major resource of its era. Historically, the easier phase of the “light” resource is exhausted all too soon. This pushes prices up in order to finance the global “heavy” infrastructure for its retrieval and delivery from all over the Oikoumene. Soon thereafter, a drop in prices provides a welcome respite. Usually, it is not caused by a technological breakthrough, but rather by finding new global resources that cover the extant demand.

For example, a shift to the “heavy” oil of global deliveries was caused by the 1970–80s oil shock. The subsequent 1990s drop in oil prices came from hitting a jackpot – the former Soviet oil, previously out of reach for the global economy, flooded world markets. Alas, as it is usually the case, this was just a temporary relief. The huge costs of building a new global “heavy” oil infrastructure eventually led to price increases. This reflected the related political risks and technological difficulties as opposed to the earlier reliance on easily accessible US controlled oil deposits. That

is why, currently, we find ourselves on a rapidly rising upward price curve of the “heavy” oil.

As a rule, the rise in costs of the “heavy” resource-related infrastructure leads to anxiety and desperation. After it reaches the inflationary peak, it may be increasingly replaced by its affordable substitutes. As it was the case with the medieval European forests, hastily cleared off only to be left untilled, and, later, with coal that ceased being the main inelastic resource it once was, this happened many times before and, undoubtedly, would happen again. This didn’t happen because the corresponding resource, be it cleared land or coal, was lacking. At some point, the costs of supporting the related infrastructure<sup>6</sup> become so prohibitive that eventually it may end abandoned as not worth the trouble.

Historically, during each and every run-up in the inelastic resource’s price during its “heavy” stage, huge investments were pumped into the development of cheaper substitutes<sup>7</sup>. Ultimately, this led to the total diversion of investment flows into competing resources along with a catastroph-

<sup>6</sup> *In the deforested Europe, a laborer’s costs of living rapidly shot up. Food and fuel, which previously were collected from the forest, now had to be bought on the market. And they cost a pretty penny too.*

<sup>7</sup> *In the case of the twilight of the medieval Europe, surplus of agrarian labor was shifted towards industry.*

hic drop in prices. This helped the newcomers, yet unencumbered by large infrastructures (see, for example, the young US, which skipped the Coal Age altogether). There is one notable exception. The fading dominant is totally unable to abandon its extensive infrastructure, an unalienable part of its identity. Undermining of its leading resource thus also means the loss of competitive advantage by its champion along with the growing obsolescence of its carefully built and tended infrastructure. This, for example, happened to Britain between two world wars.

Indeed, the story of coal presents a good illustration for this sequence of events. It isn't a secret that coal is still plentiful as to this date. If we disregard energy efficiencies, brought by via using oil as opposed to the bulkier, more polluting and less calorically rich coal, it wasn't for the lack of coal's availability or even its cost<sup>8</sup> per se that the economic model of coal-run smokestacks had collapsed.

In fact, there were two clearly dissimilar periods of using coal. As mentioned above, up to the 1860s coal used to be rather cheap and mostly used in Britain. The other European countries joined in after the 1840s. Meanwhile, in Britain, after the 1860s, the local deposits accessible with the then technology were pretty much exhausted. The subsequent 1870s drop of prices was not caused by technological advance, which, albeit substantial, didn't compensate for the increase in demand. Instead, it came from new global supplies, with the start of coal mining in faraway places, such as Argentina and Australia. They provided replacement for the British coal, which used to be brought in to run the local railroads. Long-term, such a drop was unsustainable. Soon, the costs of building a new global infrastructure, with a network of coaling stations and navies patrolling the world, would outweigh any cost savings, marking a

switch to the era of expensive "heavy" globally mined coal.

This threshold between the cheaper local and costlier global coal infrastructures also marked the end of the unchallenged British leadership and the appearance of eager competitors, the US and Germany. Both of the newcomers, including Germany that rose relying on its extensive coal fields, were developing rival energy use approaches: based on oil in the case of the US or electric power in the case of Germany. Britain, meanwhile, was weighed down by its extant immense investments into coal industry. Thus, it was much more restricted in its attempts to modernize. It had to proceed cautiously lest its extensive coal based infrastructure grinds to standstill and be rendered obsolete<sup>9</sup>. When it managed, at the end of the 1890s, modernize, it did so by remaining faithful to its old friend, coal.

In its "second lease on life", Britain handily outran its competitors. By investing in a new round of distinctly coal-based global infrastructure it once again proved its status of the major country of its era. Of course, its new infrastructure of "heavy" coal was much more expensive than the previous one used to be. Also, Britain's reliance on maintaining extensive global networks of coaling stations along with local railroad and mining operations all over the world was much more vulnerable in the context of global instability, when compared to the older one of domestic British railroads. This point would be brought home by the German U-boats right after the start of WWI.

The new infrastructure also depended on the extensive financial support of global commercial operations ran from the City. The British pound sterling, its backbone, had to be shored up with new sources of gold, for example, from Africa. This might've been one of the

<sup>8</sup> According to the British Energy Department, the price hike of the 1860s was seemingly caused by a switch to deep mining, but they have no such explanation regarding the peak of 1913.

<sup>9</sup> London was illuminated with town gas, when Berlin switched to the electric bulb.

causes of the bloody 1890s Anglo-Boer wars, with the first mass use of concentration camps to “pacify” civilians. A tad earlier (1876), India became an official colony, eventually providing about two fifths of the state budget needs.

Each of the two dissimilar periods of the “light” and “heavy” coal corresponded to a single K-wave. Thus, the first K-wave marked the era of the easier to procure local coal along with a relatively cheap infrastructure of the close periphery (1842–1894). It was quite different from the next K-wave of the harder to acquire “heavy” coal along with an expensive global infrastructure for its procurement and distribution (1894–1946).

If we turn our attention back to oil, it is easy to notice a similar pair. Up to the Oil Shock of the 1980s, the US lived in the age of “light sweet crude”, either pumped locally or controlled by national distributors. From the 1980s up, things were much harder. Following the temporary relief of the 1990s with the resources of the former USSR sent outside, we are entering the stage of “heavy sour” oil. Along with the increase in worldwide demand, in no small part caused by the ongoing globalization, procuring, refining and distributing it entails significantly higher costs, both for technical and political reasons. It provides some relief, albeit not a substantial one, that the share of oil in the national economy is generally decreasing, while, if anything, the US economy grows even more dependent on oil.

It is easy to see that the burden of building and maintaining the substantially more expensive global infrastructure mainly falls on the leading country of its *coenosis*. While others, with less extensively developed oil infrastructures, have a room to diversify and even switch to alternative sources<sup>10</sup>, the US, in the manner of Britain a century earlier, is

weighed down by its oil-based infrastructure. That is why the temporary new lease on life in Detroit didn’t come from developing fuel-efficient or alternative fuel cars, all the rage in Europe and Asia, but rather from the Detroit SUVs, including such behemoths as the Hammer. No wonder, it was short-lived.

Repeating the earlier pattern of coal introduced by the British, the stage of “light” oil was indisputably led by its pioneer, the US. It gained a competitive advantage thanks to its early investments in oil infrastructure and grew fast on immense cost savings when its oil was dirt cheap. As it was the case with the coppice woods, with the introduction of tractors, about 160 million acres, previously used for growing horse and mule feed, became available for other productive uses.

However, the resource-based leadership causes specialization. In the future, regardless of the related expenses, the leader remains stuck with its extensive infrastructure dependent on a single inelastic resource, while the others may pursue alternative fuels. During the early modern era, the use of timber, an essential resource both for heating and, more importantly, for ship building and iron smelting, also conformed to these patterns. It had two stages: of “light” and “heavy” timber, respectively. During the first stage, a country’s domestic timber resources were paramount – in a sequence of dominants, the early adopters, a number of forest-rich countries such as Portugal, the Netherlands, Sweden and France developed a competitive advantage. As their domestic resources of timber dwindled, while the costs of procuring it globally rose, in a series of wars they tried to secure their hold on colonies, rich both in timber and other resources.

In the deflationary trough between the “light” and “heavy” timber (the 1780s) France imploded under its heavy financial load. The huge debt amassed by its kings included the costs of the French assistance of the American Revolution (1775–83) after a sequence of lost

<sup>10</sup> A whole range of countries announced their ongoing switch to alternative sources of fuel, at least, to cover their generation needs. Among them are: Holland (wind power), Brazil (agricultural ethanol), Portugal (tidal power) etc.

colonial wars with Britain in North America and a number of earlier war loans. In the blur of swiftly rising prices the causes can be easily mistaken with consequences. Indeed, it isn't altogether clear, what had caused the American Revolution: tax rises to cover huge British colonial expenses or the growth of colonial expenses leading to a hike in prices or, possibly, even both?

Even in hindsight it is hard to gauge the chance of success or the lack of thereof regarding the British policy of procuring timber from the American colonies. But there is no denying that such a policy was in fact stated. That is why, despite the traditionally accepted date of the start of the Industrial Revolution at the 1760s, it, in fact, started in earnest full two decades later, when the loss of the American colonies finally liberated Britain from its hopeless quest of procuring more "heavy" timber abroad.

After the 1780s, Britain, an early adopter, could redirect its funds towards building a massive, brand-new and super-efficient coal-based economy. France, in contrast, after its revolutionary implosion at the switch to the "heavy" timber stage<sup>11</sup>, could recover neither its former leading status nor its reproductive rates. The existence of other paired periods for still earlier eras exceeds the scope of this article, but is argued in other works of the authors. Even though they unfolded at a much more leisurely pace, reflecting the slower deployment of a new infrastructure in the past, the same 2 stage pattern has been repeated with stubborn regularity.

Amazingly, within each of specific resource-related historic eras, three seemingly unrelated curves behave in a fairly synchronized manner. These include the logistic curve of investments into a specific resource-dependent infrastructure; the Hubbert's curve of resource production;

and the K-wave of prices (see Fig). We can see no way of dismissing this mind-boggling coincidence as purely random.

## The End-Game

### The Early Adopter and the Eventual Loss of Its Evolutionary Advantage

The eventual switch to the next era is pioneered by an early adopter of the next inelastic resource. While everyone else is pursuing the dwindling "heavy" supplies of the previous era's dominant resource by investing into the related global infrastructure, it has its own agenda. Indeed, it builds up its eventual competitive advantage by relying on an altogether new and per calorie much cheaper resource, abundant in its geoclimatic zone. From the start, the refining of the needed technology (fundamental invention) and investing in a related infrastructure brings in early adopter's advantages. All alone, the future leader gorges on its dirt cheap resource, for all outward appearances one of many substitutes to the inelastic resource of the fading era. The others, with no abundant native supplies to push them towards developing technologies for utilizing it, mostly ignore it. Instead, they are either pursuing their own substitutes or, in the worst case scenario, especially applying to the older leader, are weighed down by their older resource-dependent infrastructure. In the future, its growing dearth would shortchange their chances for growth.

Examples abound. At the time of the Napoleonic wars, the battle of Trafalgar was won by Britain, an early adopter of coal, at least in part thanks to the increased firepower of its navies, armed with the new cast iron gun, the carronade. France, meanwhile, held firm in its reliance on bronze cannons and the related timber-based infrastructure. Note that the technique developed for boring the carronade was later used for Watt's steam engine, giving Britain a leg up as it led in the Industrial Revolution. A century

<sup>11</sup> *The fuel required to cook a dinner in Paris costs nearly as much as the dinner itself. Fuel is very scarce, and the American is surprised to find shops [selling sticks of] wood... done in bundles like asparagus.* First published in *Scientific American*, February 1856, cited from a reprint in February 2006, p. 16.

later, the US garnered enormous savings as it skipped the coal age altogether and started its industrialization on the base of oil, calorically a better fuel. The Model T, the first mass car, led to the rise of Detroit, enabling the American Dream of owning a single family house and a car. The US retained its status as the major industrial producer up to the Oil Shock of the 1980s, supplying the world first with consumer products, then with advanced technologies.

Of course, because of the limits implied in the Hubbert's curve, sooner or later the party of a cheap resource is bound to end. As supplies become increasingly inelastic, the leader has to act. First, it moves locally, to the close periphery, with a higher cost of its resource's procurement. As shown by many historic examples, including the deforestation of medieval Europe, an advance to the less productive marginal "wastelands" signals the exhaustion of the related domestic economy within its own geographic area. The end of this "in" stage usually means the start of an "out" stage of globalization, with a marked increase in imperialistic wars. For example, concurrently with the rise in forest clearings, the Latin Christendom embarked on a number of Crusades, ranging from those traditionally known under this name and directed against the "Saracen", to those aimed at Slavic lands and against other westerners, including the Albigensian "heretics" of the southern France. The overpopulation at the end of the "light" stage, when people couldn't live off land, could've been among the causes of the devastating 1348 Black Death at the inflationary peak.

During the "heavy" stage starting in earnest from the end of the 15<sup>th</sup> century, political risks and costs grew due to globalization of resource procurement which pushed to colonies. It isn't a secret that Spain fell under the burden of its gold/silver producing colonies exploited using the older manor-like charters as opposed to the more modern British model of "agrarian" colonization, with introduction of marketable plants from elsewhere. The stage of imperialistic globalization is evident in the modern US.

Note that the global infrastructure of the "out" stage depends on a corresponding buildup in financial might. To work as a universal foundation of the global trade, the leader's currency has to hold adequate tangible content. To support its gold-backed pound of sterling Britain fought the Anglo-Boer wars of the 1890s. The same applies to the US currently mired in the Mid-East in order to support the oil-trade backed dollar. Note that both of these functionally similar wars were homologous within the dominants' respective life cycles.

During the shift to the "heavy" K-wave the dominant's finances are weighed down by the cost of building and supporting an extensive global infrastructure, be it coal-based for Britain or oil-based for the US. While it can't in fact cover its obligations, the global infrastructure would hum uninterrupted as long as the leader's currency is accepted by other players. The British pound was supported by infusions of African gold and its Indian and other colonial possessions. In the case of the US, the dollar's content comes from something that formally doesn't even belong to this country. The petrodollar is backed by oil, the current black "gold". Oil fills the role of a tangible foundation of this country's currency – in order to buy dollar-denominated oil one must first sell something of value for the said dollars. The growing US current account and budget deficits can thus be taken care of, as long as there are still buyers for its treasuries.

Fig models the interrelation between the logistic curves of investments into an infrastructure, bell-shaped Hubbert's curves and distinctly double-peaked K-waves. The latter are presented using a typical pattern of the so-called Federal Funds. By implementing overnight rates of the Federal Reserve Board through the open market the latter present the cost of money borrowing in the US, which we found to be an agreeable way of gauging prices. We also used it as a proxy for depicting the earlier K-waves that followed a fairly similar pattern. It may seem intriguing to

those mathematically inclined that bell-curves present the first derivative of the logistic curve, while the K-wave contains, at least as its component, the double-peaked curve of its second derivative. The mathematical model can be found at (Badalian, Krivorotov 2006).

### **Passing the Command: the Rise of the Next Leader as the Fading Dominant Seeds the World with Its Advanced Technologies**

Massive money and technology infusions into faraway places in exchange for badly needed resources lead to the *commoditization* of the leader's advanced technologies. Previously jealously guarded know-how becomes portable and spreads all over the world, seeding new areas with "outsourced" industries. This stage was played in history at about this point of the respective lifecycle, from Rome to Britain and now is being repeated in the US.

In its twilight hours, a fading leader suffers from the rise of costs of living within the zone, as its producers turn into quasi consumers, controlling the flows of global goods. Pricey investments into a new global infrastructure of its inelastic resource procurement and distribution push ahead yet another Hubbert's curve along with the related K-wave. Overall prices increase, borne up by the rising costs of inelastic resource from global "wastelands". Meanwhile, it remains indispensable for every facet of the then life. As estimated, oil amounts to up to 90 % of costs of milk, lettuce and other seemingly unrelated items.

In fact, the Hubbert's curve reflects not the availability of a resource per se, but rather its availability with a given technology and at a given price level. Obviously enough, at a higher price, more supplies can be retrieved. Consequently, if the consumption increases – the price must increase as well bringing more supplies within the reach. Each successively breached price level reflects the cost of pro-

urement and delivery of the last irreplaceable nit the society can't do without, lest its vital infrastructure grinds to a standstill. As costs rise, the marginal utility drops. At some point, the margins from using this extra expensive energy are so low that, eventually, supporting its extra expensive infrastructure stops making any sense.

As the prices rise higher, money is pumped into substitutes. The cost of building and supporting alternative infrastructures for their use becomes more attractive. For example, \$70 a barrel makes solar energy commercially feasible, to say nothing about cheaper wind and tidal sources of power. Price differences can pay both for wind and solar farms and electric grids extended their way, to wilderness. Even a shift towards ethanol and natural gas-run cars along with alternative means of transportation, including public buses and metrorail, may become attractive justifying significant investments into the related infrastructure of fuel stations. Such processes already are evident today. Brazil (sugarcane ethanol) is on the way to fuel independence, as is Iceland (thermal and hydrogen) and Malaysia (palm oil diesel). The authors' home jurisdictions in the Fairfax County, suburbs of Washington DC, lobby for a metrorail worth billions of dollars, previously an anathema for suburbanites scared off by ease of public access. How the times have changed.

Historically, the next leader gets a competitive advantage (which may be either long-lasting or short-lived depending on the related infrastructure) from its access to a virginal energy resource as it finds an appropriate technology for its use along with a fitting business model. Surprisingly enough, the technology itself (fundamental invention) is rarely truly revolutionary. More often than not, it is based on a preexisting technology developed by the previous dominant.

However, to be used in a novel quality, it has to be significantly simplified, sometimes beyond recognition, in order to fit both the

needs of a new zone and the specifics of its virginal resource. Its basic economics changes dramatically. What was dear and used by a chosen few must become affordable to masses. For example, in the US, the Model T presented a simplification of a better and more expensive European product aimed at the rich.

Detroit happened due to a combination of a ground-breaking technological paradigm of the assembly line and a social novelty, the substantial US market. It grew on cheap oil, the main American competitive advantage and the foundation of its affluent consumer society. The car was used for domesticating the rich US territory, which turned productive as its farthest points became accessible to the market. The other countries of the 20<sup>th</sup> century, which had no commensurate geo-climatic zones, failed to develop a full-fledged oil-based economy.

While the young society advances, largely unnoticed by anyone, the fading dominant approaches its end gambit. Today, the dollar-based oil market becomes increasingly precarious as competitors, such as the euro, make inroads. To resist the loss of its lucrative franchise, along with a precipitous fall in the dollar, which would curtail its buying power, the US expends significant efforts<sup>12</sup>. This leads to costlier military and political outlays. The related global infrastructure becomes pricier, eventually, to the point of becoming unsupportable. It remains to be seen if a parallel loss of American manufacturing wouldn't also erode the US military preparedness, while nimble groups of technologically savvy terrorists confront it at the hot spots of the planet.

<sup>12</sup> *The demise of the dollar may cause a global disaster as countries hold huge dollar-denominated assets. Balzac depicted the marvelous life of pampered aristocrats, perpetually in debt. The more was owed to tailors, barbers etc, the easier it was to extend their credits. They hoped that the debt would be made good upon getting a courtier's job, finding a rich bride or receiving an inheritance.*

## The Looming “Write-off” at the End of the Oil-Based Economy

So, while the discovery of a new, more efficient energy resource gives its pioneer an evolutionary advantage, it also starts a time bomb portending its future waning. During the global “out” stage it must reach outward, seeding the birthplace of its future successor with its advanced technologies. Simplified and transformed beyond recognition, these technologies would enable the use of the next resource becoming the foundation of the future winning adaptation. The up and coming zone would eventually surpass the older dominant, riding on its higher energy efficiency.

In no way should we think that the older society is doomed and must disappear physically, such as, for example, the Mayans. Things are rarely that dire – most past societies stabilize, shrink to their initial zone of competitive advantage, and stop growing. Usually, they stay around as a foundation and gene pool for the future. The new dominants pile up on the top of their predecessors forming an intertwined structure, in the manner of an archaeological “tell”, where the living city grows up on the top of the older layers.

Thus the primordial clan survived to this date in the guise of the nuclear family, the basis of the modern society. Nations were shrunk to form ethnic enclaves within a foreign city. The relics of the first civilizations can be still seen today around the Euphrates – the peasant waters his plot with an ancient-looking lever – oftentimes motor powered. We burn wood in fireplaces and run emissions-spewing generating plants on coal. The older layers of society retain their functions along with the ingrained lifestyle, while turning into *producents* for the newly risen *consument* in the ever more complex social order. Thus Rome was fed with Egyptian grain. The US obtained its technologies from Europe, while also selling its products to Europe starting from the Marshall Plan.

Alas, this passage from a zone to a zone is far from being peaceful<sup>13</sup>. Historically, the shift between eras has been marked by wars and famines: from the 12<sup>th</sup> century BC Catastrophe of the Bronze Age to the 1348 Black Death to the two world wars of the 20<sup>th</sup> century.

Usually, a global confrontation signals the end of the old leader's dominance, be it during the waning days of the first civilizations that crumbled under the wave of *Völkerwanderung* or the Roman Empire that fell to the Germanic barbarians or even the British, the singular historically most successful dominant that lost its importance between two world wars. The old leader may still tower over its rivals. In 1913 it didn't matter much that, after the 1860s, Britain lost its manufacturing edge and failed to recover it. What did matter was that, at the end of the 19<sup>th</sup> century, it regained its superpower status, through a global monopoly on shipping and financial services.

The challengers, such as Germany, were kept at bay – Britain controlled deliveries of their vital supplies, such as nitrates and rubber and outmatched the Boers in a war. However, during WWI and then between two world wars, there was a catastrophic “write-off” of the coal-based economy in the favor of the oil-ran one. This led to the loss of British competitive advantage. The suddenly “freed” and still warm “throne” of the former dominant was the ultimate prize for a frenzied tangle of contenders. The fierce confrontation of differing models offered by the US, Germany, Japan and the USSR culminated with WWII.

This stresses the point that a shift from one resource-based economy to another is an

incredibly painful process. It implies wholesale changes in the society needed to build a completely new infrastructure for procurement, distribution and exploitation of the up and coming resource. As a rule, transportation is the most critical and telltale part, indispensable for domesticating the zone, and a future important character of the evolving lifestyle. Even today, Britain is basically a railroad country, while the US, in contrast, grew on its highway. Rome stretched as far as its excellent roads, with the future European cities at the sites of its military camps.

Meanwhile, as the earlier economy is being dismissed in a painful process of a total “write-off”, living breathing people are destroyed along with the world they lived in. The transitional period usually lasts an entire generation – new ways of living pretty much require new people. Such generation-long shifts provide a hint that the K-wave depends on the inner logic of biological reproduction, which dictates the minimum length of its stages. One generation must go in flames freeing room for the other, so it may build a totally new world order.

The sad story of WWI thus acquires a special poignancy for our times. We seem approaching that very chronological spot within the lifecycle of “heavy” oil. Homologically, a century earlier, it produced WWI and, another century earlier, the Napoleonic wars. Today we covet oil as opposed to coal (which used to be the inelastic resource at the start of the 20<sup>th</sup> century), or timber (the main inelastic resource at the dawn of the 19<sup>th</sup> century). If our conjectures are even remotely accurate, we might be moving full speed ahead towards a comparable period of destabilization. By totally “writing-off” everything we used to hold dear, it would accomplish nothing more and nothing less than a switch to a next resource-based economy. This seems way too trivial and absolutely unworthy of the possible human suffering, and there may be still a way to alleviate if not avoid it.

<sup>13</sup> Paul Fussell, a historian, wrote of the famous truce on the West Front during the 1914 Christmas: “The Christmas truce was the last twitch of the 19th century. It was the last public moment in which it was assumed that people were nice, and that the Dickens view of the world was a credible view... Nobody could believe that after the First World War and certainly not after the Second” (Fussell 2000).

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# GAMTOS MOKSLŲ TAIKYMAS STUDIJUOJANT ISTORIJĄ: KONDRATJEVO BANGOS IR IŠTEKLIAMS IMLIOS INFRASTRUKTŪROS CIKLAI. III DALIS

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*Ankstesniuose šios serijos straipsniuose istorijos raida tyrinėjama bioekologinių požūrių. Bandyta parodyti, kad civilizacijos raida priklauso nuo klimatinė zonų. Straipsnių serija baigiama tokios zonos ekonominiiais tyrimais. Parodoma, kad kiekviena istorinė visuomenė plėtojosi išnaudodama savo unikalius išteklius. Pasak autorių, visuomenės gyvenimas persmelktas būtinybe sukurti specifinę ištekliams imlių infrastruktūrą. Perėjimą prie naujų išteklių paprastai lydi smurtas, jis prasideda išsekus seniesiems ištekliams. Nuožmi konkurencinė kova – tai varžymasis dėl išteklių. Autorių teigimu, imlių ištekliams gyvenimo ciklai gali būti apibūdinti Kondratjevo bangomis.*

**Raktiniai žodžiai:** evoliucija, istorija, technologija, ištekliai, Kondratjevas.

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