Industrial Society's Natural Future

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Article Outline

Major Terms

Unisex life expectancy life insurer's disaster-corrected national averages after birth.

Industrial evolution long-term envelope above all disasters of the leading nation's gross domestic products (GDPs), the real (inflation-corrected) value of goods and services produced per capita p.a.

National recoveries optimal paths with asymptotic convergence into the industrial evolution.

Human capacity individual combination of inherited and educated capacities; its average per capita value follows from equilibrium between all main variables.

Annual working time the official paid working time as part of the natural flow of time; a similar part is used for unpaid homework including reproduction; both yield with Sundays and 8 h of sleep per day the inevitable annual part of spare time required for enjoying affluence far above biologic needs.

Systems engineering optimizes annual working time for the GDP in line with technical progress.

Physical capital real per capita value of technical infrastructure; different for production and housing.

Synergetics understanding complex systems by deriving constructive relations between their subsystems; this chapter unites four academic disciplines with a unique family of six analytic solutions.

Introduction

The Cold War secured the world's longest time of relative peace and, on average, the best existential conditions. Yet the richest nations developed a precarious combination of new problems: population relevant increase of the life expectancy and decreasing endemic birth rates, diverging national and international distributions of incomes and wealth, coexistence of the largest private assets and public debts, loss of stable employment, saturation of economic growth, unemployed youth, and decreasing financial and political stability.

A civilization capable of visiting its moon should be able to understand and shape its planetary future. But the industrial society's four dynamic subsystems industry, economy, human nature, and finance seem to be too complex for understanding any one of them with quantitative forecasting quality.

On the other hand, macro-systems can acquire long-term stability by combining constructive properties of their subsystems. Fauna and flora exemplify this since primeval times. Self-organizing systems were generally treated by Hermann Haken. He coined the term synergetics for constructively interacting subsystems (Haken 1983). According to this theory, the macroscopic dynamics of a complex system can be captured by few characteristic variables obeying simple equations even when it operates close to instability.

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The homonymous Springer Series published extensions and applications quantifying order-disorder transitions from lasers in physics to networks in city planning. So far, most examples quantified a macro-system with two subsystems connected by the same academic discipline. In this chapter, we complete the natural theory of mankind's largest possible macro-system by unifying four subsystems that were separated by four academic disciplines. This explains why understanding the industrial society's nature with forecasting quality comes now so late compared with the natural sciences.

When four subsystems determine the dynamic success of their macro-system, there must exist at least four constructive relations between them. They must follow from the existing data. In 1987, we began collecting long-term data series without academic bounds from the eighteenth-century UK to the current G7 level nations. In 1991, we formed a small group of chief technical officers in the new PICMET community (Portland International Center for Management of Engineering and Technology) and organized an international research project for future business policy with Hitachi, Siemens, and other companies. It was jointly supported including staff participation by the European Commission and MITI (Japan's former Ministry of International Trade and Industry).

At first, we derived the dynamics of national recoveries from World War II and their convergence into a collective industrial evolution. This chapter includes all relevant data on the industrial society and completes its theoretical basis. Our analytic solutions for recovery from national disasters were new and relevant for national and business planning since no globally active company could neglect the world's largest and fastest growing national market. In particular, we predicted China's current change from fast exponential to slow linear growth and the currently observed saturation of G7 level growth to an asymptotically approached final state (Danielmeyer and Airaghi 1999).

For discussion and wider understanding, we supported a working group (Kümmel et al. 2000) that developed into the German Physical Society's current division "Physics of Socio-Economic Systems" (SOE). In its tenth year, we discovered the industrial society's intrinsic order with the identical time-dependence of the G7 level lifestyle's unisex life expectancy and the industrial evolution. The latter appeared for the first time as upper envelope of the best gross domestic products (GDPs), the national annual outputs of goods and services above all disasters since the eighteenth-century UK (Danielmeyer and Martinetz 2010). This bio-economic time-dependence was the final proof of our natural theory. It resolved immediately three mysteries of three disciplines: the current linearity of G7 level economic growth, the life insurer's current success with linear extrapolation of G7 level life expectancies, and the partial heritability of human longevity (Herskind et al. 1996).

In 2014, we adopted the so far newest results on national annual working times (Hubermann and Minns 2007). Their smooth decrease since 1800 from 96 to 39 h per week showed that systems engineering generates not only the technical infrastructure but implicitly also the annual spare time required for enjoying life far above biologic needs. Without it G7 level affluence would neither be demanded nor produced. As shown with the section on human nature, this spare time completed the theoretically required minimum number of six long-term variables for quantifying the industrial society's peaceful evolution. The latter's existence defines also every optimal recovery from unpredictable disasters. All variables and their corresponding data are plotted in the following sections.

We derived six simple constructive relations in and between the four subsystems. They have one unique family of six irreversible analytic solutions. Since individuals are biologically limited systems, the family saturates inevitably per capita. This excludes unlimited exponential growth per capita. The appendix offers an extension for small population growth or decline. As shown with all following plots, the solutions reproduce the industrial society's data from its start in the eighteenth-century UK to its current state without any fitting parameter.

This agreement will continue into the industrial society's asymptotic final state because all time constants are inherited as directly measured constants of the human species. Such solutions are even without genetic stabilization very rare in nature and new to economy and finance. Their derivatives and analytic integrals are also valid solutions for the macro-system. This allows many cross-checks that lead to additional discoveries and explain details that were clearly observed but not understood to date. Not knowing the collective dynamics while managing the subsystems separately caused some of the new problems identified in this introduction's first paragraph. The other problems will turn out to be natural and inevitable.

All data shown are 5 to 10 year's averages of the annual data published by the national statistical offices or by specifically cited sources. Short-term fluctuations are hereby reduced to the plotted size of the data because we showed earlier that instabilities associated with the northern hemisphere's theoretical phenomenon of business cycles have a base period of 2Pi years but are damped down to half a cycle (Danielmeyer and Martinetz 2009). Thus, the following agreement with theory may give the impression that the data show simulations of the theory. This is definitely not the case. Finding and processing an order of magnitude higher volume of original data and converting inflation and exchange rates to US$ of 1991 or 2010 through two centuries with different national reference times took about half of this chapter's development time.

The entire database will be published in due time together with the Mathematica programs for all plots. The analytic solutions are plotted into their data. Only one data point per nation is required for locating every successful national recovery completely with respect to the industrial evolution. The appendix lists the natural and all national constants used for the plots.

The main text follows the subsystem's contribution to the natural theory. Industrial engineers do exactly what the theory describes. The economy is physically caught between human demand and industrial supply. Since these three subsystems are controlled by the laws of nature, the financial subsystem must follow them, not vice versa. The conclusion proposes a pragmatic solution for the problems associated with the financial subsystem's saturating or even negative interest rates because time runs out especially for Europe with half a billion individuals lacking a cohesive constitution.

The outlook offers a timely example for using all figures as benchmarks for long-term national planning. The latter is now possible in spite of unpredictable disasters because the industrial evolution is immune to them as long as innovation continues challenging human adaptability as the slowest and, therefore, dynamically decisive process.

Industry

Industrial engineers are renowned for the development, quality, efficiency, and reliability of the industrial society's technical infrastructure termed physical capital by economists. Less known but equally important is the fact that systems engineers design the annual working time required for producing the GDP with technical progress optimally and irreversibly into every production line. Machines are not just input factors. They organize and amplify annual working time with respect to human power, speed, and/or precision for producing the GDP.

That optimizing annual working time generates simultaneously the annual spare time was so far neglected because the latter has no direct economic value. But without this spare time, the G7 level affluence far above biologic needs could neither be enjoyed nor demanded and produced. The maximum sum of weekly working time w(t) and weekly spare time s(t) equals the agricultural 16 h 6 days per week without vacation. We use this maximum available active time of 96 h per week now as unit and dimension of $\epsilon = 1$ p. a. for measuring annual working and spare time. Then systems engineers split the flow of active time according to

$$w + s = \epsilon \equiv 1 \text{ p.a.} \qquad (1)$$

Using this natural unit makes sense because the GDP contains the same unit and all real values are in the end created by human work, including natural resources and physical capital. Figure 1 shows this inevitable tradeoff for the maximum available active time of 96 h per week:

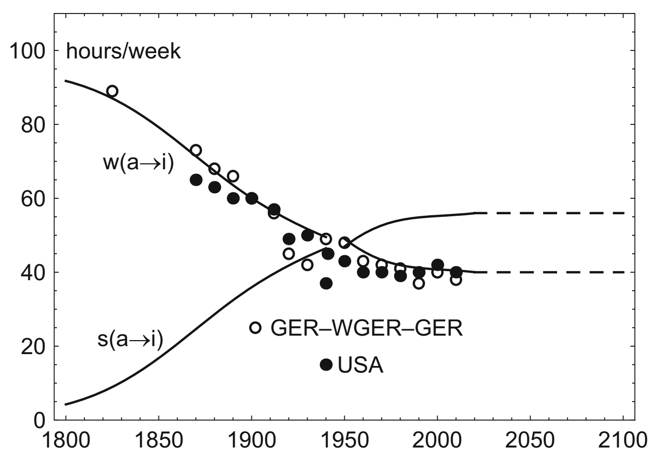
We selected the data of the USA and Germany-West Germany-Germany from the comprehensive work of Hubermann and Minns as examples of the most stable and unstable industrial nation concerning political and territorial integrity. Strawe reported nearly the same data but contributed also the earliest official working time of 1823. It is still close to the agricultural and physical maximum of 96 h per week. The lowest annual working time is due to the Great Depression. Its decennium of declining employment ended for the USA with a nearly vertical step in 1941 due to its entry into World War II. In order to resolve this, we dropped our 5- to 10-year averaging for 1930 and the transition 1941/42. But even such a disruption left no long-term trace. This means technical progress is quite immune to disasters. Since there is no superior force providing such regularity over two centuries, there must exist some "invisible hand" as proposed already by the moral philosopher and customs officer Adam Smith in 1776 for his early vision of a self-stabilizing free market. The following sections show that this hand is generally provided with every individual's inherited and educated capacities.

Business administration measures labor with its cost or employment on the microeconomic level. But on the macroeconomic level, the cost of labor is a bad variable because as income it must essentially buy the GDP, and employment is no variable at all since nations try to keep it high. The section on details links this problem to macroeconomics' neoclassical paradigm.

Fortunately, systems engineers design the annual working time $w(\mathrm{t})$ optimally into the technical infrastructure $k_w(t)$ of every production line. A priori there is no reason for assuming any nonlinearity beyond their product. Then an industrial nation's GDP per capita is generated with the simplest possible relation

$$y = wk_w. \tag{2}$$

The other part k_s is designed for housing and reproduction with a trade-off corresponding to Eq. 1 between generally unpaid homework and spare time. Their sum $k(\mathrm{t})$ is the entire real (inflation corrected) per capita value of the national technical infrastructure. National statistics list all three parts as physical capital:



Industrial Society's Natural Future, Fig. 1 Systems engineers divide the flow of time into weekly working time (plot with data) and the spare time required for enjoying G7 level affluence. Sunday and sleeping time are neglected. $(a \rightarrow i)$ indicates that the observed working time is actually a superposition of the agricultural and industrial working times as quantified with Eq. 4. Original data source: Strawe (1994) and Hubermann and Minns (2007)

$$k_w = \lambda\, k(t) = k - k_s. \tag{3}$$

The appendix' Table 2 shows $\lambda = 0.45 \pm 0.02$ for Germany's recovery from World War II.

Initially, industry left agriculture in its poor state $y_o = \epsilon k_o$ with the maximum working time from Eq. 1 and, including crafts enterprise, up to 1.000 US$ in their present value for Germany's preindustrial GDP per capita. For the first time, their linear superposition

$$w_{a\to i}(t) = (y_o + y)/(k_o + k_w) \tag{4}$$

is quantified for the entire transition from the agricultural to the industrial society as shown in Fig. 1. Considering today's G7 level contribution to the GDP of industrial food generation, processing, and distribution, the industrial society just absorbed agriculture as expressed with Eq. 4. The following section on the economy derives the analytic solutions for the industrial GDP and the physical capital needed for Eq. 4. Thus, the agreement seen in Fig. 1 without any fitting parameter between the data and Eqs. 2, 3, and 4 confirms using the simple product in Eq. 2 and the sum $\epsilon \equiv 1$ p.a. as natural unit for measuring working and spare time.

That systems engineers created not only technical progress but implicitly also the spare time required for enjoying and demanding affluence, and education far beyond biologic needs is decisive since these extensions allow mankind for the first time to reach its genetic limits. Asking systems engineers to be less successful with achieving technical progress, generating four of the industrial society's six main quantities, and optimizing the trade-off between working and spare time would jeopardize their professional ethics and the industrial society's physical sustainability.

Annual working time and physical capital generate the GDP with Eq. 2. The fourth quantity, annual spare time, could connect the GDP's supply with its demand when a real counterpart of k_w would exist for life at home that could amplify spare time for generating demand like k_w amplifies working time for supply. The next sections show that biology found a genetically safe and orders of magnitude cheaper solution for generating demand.

Economy

Production data are measured at the microeconomic level with the detailed costs of taxable added value tasks. Business administration integrates them to the company level. National statistical offices integrate them to the macroeconomic level, correct them for inflation to get the real (inflation-corrected) values, and reduce them to internationally comparable data for the real per capita values of the national GDP, physical capital, and labor. Then the data can be corrected for foreign trade imbalance and converted to the lead currencies US dollar and Euro. The new theory agrees with all data through two centuries for all successful recoveries, and the collective industrial evolution is the first quality proof of economic data collection and processing. Systematic mistakes of one per cent p.a. would have added up to unacceptable discrepancies between data and a new theory that has no fitting parameters.

Full agreement between theory and data requires also quantifying the economic equilibrium between national supply and demand, both to be independently determined. But for G7 level affluence, there are no added value parts for measuring and integrating demands. Individual demands overlap in time, with different and changing satisfaction, and without money's property of additivity. As already suspected by Jean-Baptiste Say in 1803, national demand and its theoretical equilibrium with supply cannot be quantified within the discipline of economics. The next section recalls how nature resolved this bio-economic problem.

This section must yield the industrial production variables for Eq. 4 with $k_w = \lambda k$ from Eq. 3. So far, macroeconomics used the fiscal depreciation rate γ_k for the physical decay rate. Then the annual maintenance cost is given by $\gamma_k k = \mu_k\, y$. This depreciation is tax deductible and immediately useable for new investment. In Japan, equipment bought for research and development could be completely written off in its year of purchase. When bought at year's end, this equipment was a tax- and maintenance-free Christmas bonus. Depreciation is generally used by national tax authorities for stimulating investment, employment, and economic growth. Then the effective physical lifetime G of physical capital against technical obsolescence and aging through wear and tear is much larger than the fiscal lifetime $1/\gamma_k$. Even more important is the fact that G provides a memory for the level of technical progress at the year the annual addition $\dot{k}$ to k(t) is produced. Then the annual cost of maintaining its original purchase value is given by

$$k/G = \mu\, y. \quad (5)$$

It identifies the required part $\mu(t)$ of the GDP y(t). We named it capital function. G will be directly measured with Fig. 3. It yields for the USA, Germany, and Japan the same constant result $G = 25$ years. Due to its proximity to the generation gap, we named it generation constant.

Solving a problem with three unknowns requires three independent equations. Equation 5 excludes exponential growth because economies can only grow with an increasing capital coefficient $k/y = \mu\, G$, i.e., with $\dot{\mu} > 0$. This follows from the fact that technical progress can only be designed into the annual addition $\dot{k} = \mu G\dot{y} + \dot{\mu}Gy$ of new physical capital, not into the GDP of finished products nor into the already accumulated physical capital. Since the latter must be maintained simultaneously, economic growth requires the annual flow

$$\dot{k} + k/G = \mu\, y + \mu G\dot{y} + \dot{\mu}Gy \equiv \overline{\mu}y + \dot{\mu}Gy \quad (6)$$

from the GDP. The fastest recovery from loss of $k(t)$ results when the maximum affordable value $\overline{\mu}$ of $\mu(t)$ is used throughout as "saving constant" for $k(t)$. Then the identity has with one equation

$$\mu(1 + G\dot{y}/y) = \overline{\mu} \quad (6a)$$

for two variables $\mu(t)$ and $y(t)$ still no general solution. But the initial and final states $k_o = \mu_o G y_o$ and $\overline{k} = \overline{\mu}G\overline{y}$ are now defined with the measurable and reported initial growth rate

$$\beta = (\overline{\mu}/\mu_o - 1)/G. \quad (7)$$

For the nations used as examples, all three parameters are listed in Table 1 of the appendix. Successful recovery and the initial growth rate depend on the level of technical progress given by μ_o at the time of the decision to recover with $\overline{\mu}$. Obtaining the latter from national statistics is explained in the appendix. Generally, it follows from β and $0.08 \le \mu_o \le 0.11$.

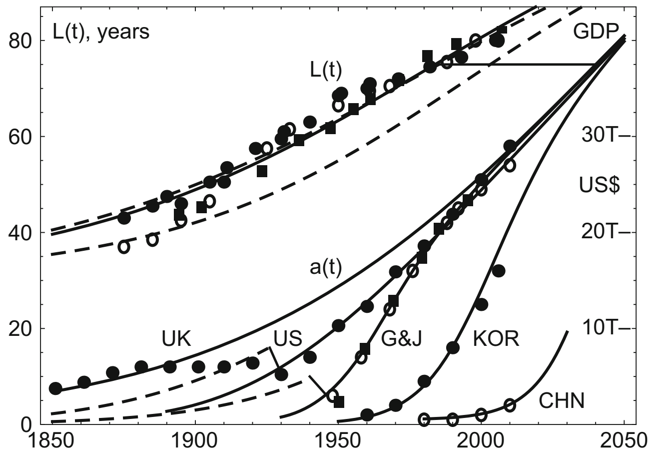
Equation 6a quantifies the continuous decrease of the growth rate with increasing capital coefficient $\mu_o G \le k/y \le \overline{\mu}G$. The industrial society's growth saturates inevitably because of the limited trade-off between saving for growth of physical capital and maintaining its accumulated level. When the capital function's increase $\dot{\mu} > 0$ is neglected, Eq. 7 is a solution of Eq. 6a, but exponential growth is just one of the ideal pure cases that are physically impossible.

The GDPs in Fig. 2 help now in discovering the natural solution for Eqs. 6 and 6a. The GDPs show two overlapping dynamics: one quantifies recovery from disasters, the other the ideal peaceful industrial evolution. Two interrupted recovery paths are dashed. The first shows how the USA caught up with the UK due to the Monroe Doctrine's separation of American and European global ambitions.

European global ambitions. The second shows that the first World War prevented Germany and Japan from catching up with the USA. This changed dramatically with their cooperation after World War II during the Cold War's peace on G7 soil.

Industrial Society's Natural Future, Table 1 National constants for recovery from national disasters

Nation range	GER <1938	GER and JAP >1949	KOR >1970	USA >1940	PR CHN >1980
$\overline{\mu}$	0.15	0.25	0.26	0.18	0.38
μ_o	0.08	0.08	0.08	0.08	0.11
β *p. a.*	0.035	0.09	0.09	0.05	0.10
Halftime τ	2005	1971	2010	1965	2045



Industrial Society's Natural Future, Fig. 2 Average life expectancies after birth (upper left) and recoveries (lower right) of the USA (points), West Germany/Germany (squares), and Japan (circles). Successful recoveries converged into the industrial evolution a(t) established initially by the UK as only world power before its stagnation after 1880; South Korea's convergence is beyond halftime; China enters its long nearly linear path after its Cultural Revolution. Their scale in US$ 1000 of 1991 is adjusted to show both theoretical inflection points at the horizontal bar's ends from L(t) to a(t). Its constant length and their identical shape relative to their industrial change yield the industrial society's mean maximum life expectancy L(t). The dashed paths are explained in the text. Updated from Danielmeyer and Martinetz (2009). The early GDP data are from Mitchell's international tables (Mitchell 1988)

All successful recoveries of the general GDP y(t) converge into the collective industrial evolution $a(t)$ defined as envelope of the best per capita GDPs above all disasters. Although $a(t)$ represents the peaceful existential conditions, the suspected parallelism of a(t) and L(t) after their normalization to the same industrial increase suggests, and the next section confirms, that $a(t)$ is already dominated by demand because the mean life expectancy measures progress toward mankind's all-inclusive demand for longevity.

Since there exists no superior authority controlling five recoveries on three continents for five generations, the convergence must proceed without a parameter specifying the division of annual working time between recovery and evolution. Figure 2 shows a smooth transition from recovery into the evolution without overshoot. The only process that achieves this is the growth rate's linear division in proportion to the future gaps $a - y$ and $\overline{a} - a$ to be closed for recovery and evolution:

$$\dot{y}/y = \beta(1 - y/a) + (\dot{a}/a)(y/a). \qquad (8)$$

Then linearity must apply also to approaching asymptotically the final GDP $\overline{y} \equiv \overline{a} = 75.000$ US$ of 1991 (or, due to inflation, 110.000 US$ of 2010) p.a. per capita. This means for the industrial evolution's growth rate

$$\dot{a}/a = (1 - a/\overline{a})/E. \qquad (9)$$

Its solution

$$a = \overline{a}/\left(1 + e^{(T-t)/E}\right) \qquad (9a)$$

is known as logistic function. It is plotted in Fig. 2 as envelope of the best national GDPs above all disasters from the eighteenth-century UK to the G7 nations. We named $a(t)$ industrial evolution and its growth parameter $E = 62$ years evolution constant (Danielmeyer and Martinetz 2009). Its inflection point is at halftime in $T = 2040$ where $a = \overline{a}/2$. The fit is exact to one calendar year because of UK's early exponential path and the much later nearly constant slope at G7 level convergence. E follows according to Eq. 9 from the directly measured initial growth rate $1/E = 0.016$ p.a. Other properties of the logistic function will be discussed in the next section.

Equation 8 has with Eqs. 9 and 9a the simple solution $1/y = 1/a + (1/\overline{a})e^{\beta(\tau-t)}$ so that

$$y = \overline{a}/\left(1 + e^{(T-t)/E} + e^{\beta(\tau-t)}\right). \quad (10)$$

A fast check is possible by inserting Eqs. 9a and 10 into this simple solution where both exponential terms of the same kind cancel separately. τ is the halftime of national recovery listed in the appendix' Table 1. $y(t)$ converges into a(t) for $t > \tau + 1/\beta$.

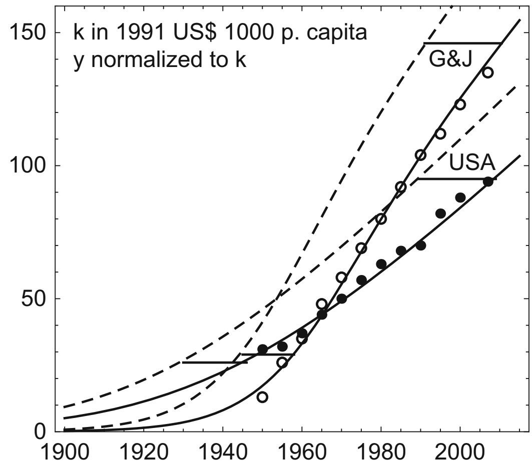
The GDP grows when the exponential terms in the denominator decrease. There is no alternative since every nominator of Eq. 10 consists of a component of the asymptotic final state. According to Eq. 7, the recovery term removes technical limits and obstacles. The next section shows that the slower evolutionary term removes human limits and obstacles. It follows that Adam Smith's accumulation of wealth introduced in 1776 is not the industrial society's goal. Its real goal is reaching the given human limits with technical and human cooperation by removing both kinds of obstacles as they appear after earlier obstacles are removed.

"As they appear" is for more than one kind of obstacle only possible with the unique structure of Eq. 10 where the exponential terms compete in the denominator. Financial wealth grows exponentially with the nominator. There the faster process would always win, and human maturation will be missed. Not knowing this fundamental difference caused the Great Depression after 1930 and the financial disaster after 2007. The next section shows why industrial engineering and human nature dominate the economy and finance.

Inserting the solution Eq. 10 and its time derivative into Eq. 6a yields with some patience and the identity $ce^{\gamma t} \equiv e^{\gamma(t+\Delta t)}$ for $\Delta t = \gamma^{-1} \ln c$ the solution

$$\mu = \overline{\mu} y_k / y \quad (11)$$

for the capital functions plotted in Fig. 4. They agree automatically with their data because the original data shown for y(t) and k(t) agree with their data in Figs. 2 and 3. Discrepancies between the measured values of $\overline{\mu}$ from Eqs. 7 and 11 and the officially published values (see the appendix) disclose central planning and/or irregular reporting practices. They destroy also the parallelism expected theoretically between $\overline{\mu}Gy$ and k(t) in Fig. 3 for recovery and evolution.



Industrial Society's Natural Future, Fig. 3 Time-shifts between GDP (dashed, taken from Fig. 2, normalized with the factor $\overline{\mu}G$) and physical capital (plots in data) for the USA and Germany and Japan disclose the generation and evolution constants G and E

The auxiliary function $y_k(t)$ is the direct result of the above patience. Its only difference to the GDP y(t) is that its exponential terms are delayed by

$$\Delta\tau_k = \beta^{-1} ln(1 + \beta G) \quad (12)$$

and

$$\Delta T_k = E\, ln(1 + G/E) = 21 \text{ years}. \quad (13)$$

Inserting Eqs. 11, 12, and 13 into Eq. 5 yields finally

$$k = \overline{\mu} G y_k = \overline{\mu} G \overline{a}/\left(1 + e^{(T+\Delta T_k - t)/E} + e^{\beta(\tau+\Delta\tau_k - t)}\right). \quad (14)$$

Both time-shifts are measured with the length of the four bars in Fig. 3. The normalizing factor for comparing y(t) with k(t) is $\overline{\mu}G$. Well below halftime of recovery, the time-shifts for Eq. 12 are different (13 years with $\beta = 0.09$ p.a. for Germany, 16 years with $\beta = 0.05$ p.a. for the USA) but yield the same effective physical lifetime

$G = 25$ years for $k(t)$. This was the first measurement of this important time constant (compare its introduction with Eq. 5). Its proximity with the generation gap means that the industrial society respects implicitly the fairest intergenerational contract for maintaining the value of the inherited physical capital: Every generation renews it on average once during its time of responsibility.

The time-shifts observed here between the charging flow and the stored result k(t) are the analogue for irreversible processes of the phase shifts known from periodic processes. This essential information on the industrial society's reaction times was always hidden in the data. It was just not detectable with the exponential approximation because of the exponential function's physically impossible property of unlimited exchangeability between value and time.

The slight bends seen for Germany and Japan after 1980 are due to the convergence of y(t) into a(t) in Fig. 2. Beyond convergence the time-shifts are constant for 21 years (upper lines) and yield with G from Eq. 13, again the evolution constant $E = 62$ years known from UK's eighteenth-century growth rate.

Measuring the constancy of E through two centuries required patience beyond 2010 until the length of the upper lines in Fig. 3 was clear. The decisive role of systems engineers for creating and maintaining the industrial society's technical infrastructure could not have been confirmed earlier than 240 years after Boulton and Watt's first steam engine with acceptable efficiency for production lines.

Our first analytic solutions for the macroeconomic production variables show that real growth per capita requires removing two kinds of obstacles as they appear in recovering from disasters and the industrial evolution. Both reaction times are directly measured with the time delay of physical capital with respect to the GDP. Industrial engineering determines the supply of goods and services completely. The only parameter that can and must be nationally fixed is the saving constant $\overline{\mu}$ for physical capital. It determines time and speed of recovery and the technical infrastructure's final level. "As they appear" specifies one unique family of analytic solutions where the removal of both kinds of obstacles competes in the denominator. This structure favors the early innovators like the UK because the gap to be closed for catching up with industrial evolution was in the eighteenth century much smaller than China's and India's gap in the twenty-first century.

Human Nature

The preceding section described the first measurements of the industrial society's physical lifetimes and/or reaction times. They are measured in situ and are here to stay as effective time constants for every human civilization. This section shows that they are heritable, i.e., stabilized by the human genome, and that the industrial society's long-term future is predictable in spite of unpredictable disasters, as long as innovation challenges human adaptability as the slowest and dynamically decisive process. Then optimal medium-term recoveries from unpredictable disasters are also predictable because of the "optimality condition" of Eq. 8.

For long-term equilibrium, the supplied GDP must equal the demanded GDP. Annual spare time is the compatible and exactly known counterpart of annual working time. Then symmetry with the supply of Eq. 2 would require just a counterpart on the side of demand for physical capital on the side of supply.

In search of a permanently measurable quantity with the shape of a(t), we found in 2009 the mean G7 life expectancies L(t) at birth shown in Fig. 2. The lowest circles are caused by higher infant mortality due to Japan's later industrialization. The plot is the visually best fit through all other data assuming the simplest possible logistic dynamics with the industrial evolution's growth parameter E:

$$L - L_o = \left(\overline{L} - L_o\right) / \left(1 + e^{(T_L - t)/E}\right). \qquad (15)$$

Its parameters are $L_o = 30$ years, the life expectancy known as the medieval minimum for stable populations with average harvests, and the asymptotically approached maximum mean life expectancy $\overline{L} = 118$ years. Since antiquity it was expected near 120 years. After two orders of magnitude growth of the GDP per capita, the G7 passed the inflection and halftime point of the mean life expectancy in $T_L = 1981$. Rainer Ansorge found a robust numerical convergence to these parameters (Ansorge 2010).

Only a factor of 2.4 in the GDP is required for reaching on average the maximum mean life expectancy for the G7 level lifestyle. The life expectancy measures progress toward longevity, the all-inclusive top demand. Longevity is to a relevant extent heritable (Herskind et al. 1996). Life insurers eliminate all deaths due to identifiable national disasters, extrapolate the resulting mortalities and existential conditions, and obtain the insurable life expectancies $L(t)$ currently up to 115 years. With a(t) from Eq. 9a, the disaster-corrected existential conditions were for the first time quantitatively known. This allows replacing the life insurer's very complicated numerical approach with the simple analytic integral named bio-economic relation:

$$L = L_o + \left(\left(\overline{L} - L_o\right)/\overline{L}\overline{a}\right)\int_t^{t+\overline{L}} a(t)dt$$
$$\cong L_o + \left(\overline{L} - L_o\right)/\left(1 + e^{\left(T - \overline{L}/2 - t\right)/E}\right). \quad (16)$$

Since $\overline{L} < 2E$, the approximation of the exact logarithmic integral with the logistic function is as good as observed in Fig. 2. The shift between both inflection points shown with the bar in Fig. 2 is theoretically given by the identity and measured as the bar's length with the result

$$T - T_L \equiv \overline{L}/2 = 59 \text{ years}. \quad (17)$$

Its extrapolated value $\overline{L} = 118$ years is now directly measured with its time-shift. This first measurement of the maximum unisex life expectancy will be reached in the twenty-second century.

The bio-economic relation Eq. 16 resolved three mysteries of three disciplines (Danielmeyer and Martinetz 2010): the current linearity of G7 level growth, the life insurer's success with linear extrapolation of the disaster-corrected mortality, and the fractional heritability of the life expectancy, because only the part adapted to within the generation gap can be heritable.

The lower dashed path for *L(t)* in Fig. 2 would theoretically result when integration and averaging would proceed over the life insurer's predicted mean life expectancy $L(t)$. But predictions cannot be embodied. Naturally embodied is the inherited maturation program from birth to the genetic limit $\overline{L}$ with the proportionality of Eq. 9 between the current growth rate and the future gap to be closed. Equation 9 includes what Eq. 16 quantifies: the human capacity to monitor, integrate, and average over the existential conditions, adapt to them with the partially inherited gains of the life expectancy, and report the final result with death. This master plan protects the genome from external manipulation because it allows maturation without external monitoring and control. The logistic function represents life's condition sine qua non.

Since only the part of longevity acquired within the generation gap can be passed on to the offspring, the industrial evolution extends over 16 generations instead of the one to four generations experienced individually during the industrial evolution. Now the industrial society can be quantitatively understood as the largest possible extension of the human maturation program for reaching mankind's given limits through social and technical cooperation. This natural goal explains why the industrial society can be developed at all, defended against unnatural goals, and quantified with the rigor of the natural sciences.

The mean life expectancy is already the integrated result of satisfying the relevant demands. A counterpart of physical capital, which amplifies spare time for generating demand like k_w amplifies working time for generating supply, is obviously not required for long-term equilibrium between demand and supply. In fact, biologic processes are subconsciously regulated on the molecular level with enzymes, hormones, and proteins. Conscious actions are controlled with only100 bits per second and electric signals that are synthesized with the brain's inherited and educated capacities.

This architecture for generating demand requires less than 100 Watts and comes by heritage for free. It is orders of magnitude more effective than the 6 kilowatts per capita required for generating and maintaining the G7 level lifestyle with the industrial society's technical infrastructure worth 10^5 US$ per capita.

On the other hand, the natural theory's data for spare time and the evolution constant E open a classical way for quantifying equilibrium between demand and supply. Figure 4 collects the operating costs as parts of the GDP of per capita leading nations during their so far best time:

The law and order costs (upper data) exclude all transfers but include all costs from the legislative to defense. They are proportional to the national population but beyond this not just proportional to the GDP but to the accumulated physical capital. The next section explains this result with the increasing social stress due to the nationally and internationally diverging distributions of incomes and wealth.

The educational data in Fig. 4 contain all national costs from kindergarten to university. Their doubling within 15 years was capitalism's answer to the "Sputnik Shock" caused in 1956 when socialism orbited the first satellites. The next section continues this track with the social consequences. Here we assume there exists an indestructible but appreciating combination h(t) named human capacity of educated and inherited capacities. We assume they organize and amplify annual spare time for enjoying and demanding G7 level affluence like $k_w(t)$ amplifies annual working time for supplying that affluence. With human capacity for demand, we avoid confusion with Gary Becker's human capital used in 1964 for quantifying the economic value of the work force. The human capacities' educated component can now be estimated with

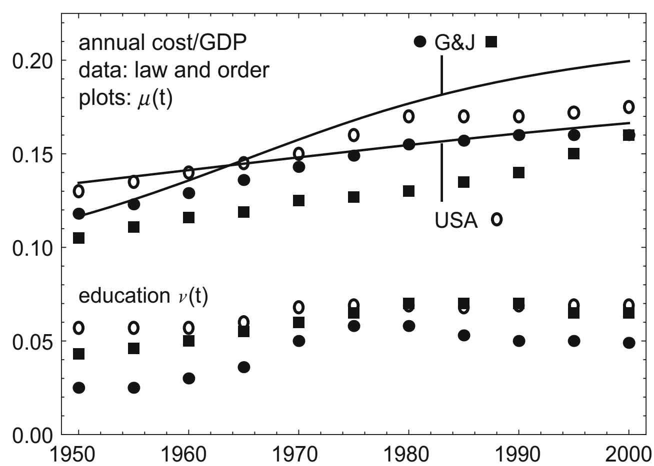
$$h_e/E = va. \tag{18}$$

This defines in analogy to Eq. 5 a national parameter $v(t)$ named capacity function for maintaining the educational level. Accepting $\overline{v} = 0.07$ from Fig. 4 as final level yields $\overline{h}_e = \overline{v}E\overline{a} = 4.3\overline{a}/\epsilon$. This is a minimum because it does not include the parent's priceless education. The evolution constant E is the effective reaction time of the actually needed human capacity h_s that combines h_e and the inherited capacity.

Both capacities are per capita indestructible and, like knowledge, nonadditive since their contents can compete for making decisions. For long-term equilibrium between the evolutionary demand and supply, the formal value of h_s follows with the generation of a(t) according to Eq. 2 from

$$sh_s = a = wk_w. \tag{19}$$

Eliminating both times with Eq. 1 yields a form with all exponential terms in the nominator:



Industrial Society's Natural Future, Fig. 4 The costs of keeping Germany, Japan, and the USA just operational exceed one third of their GDPs. The plots are the capital functions of Eq. 11

$$\epsilon/a = 1/h_s + 1/k_w. \quad (20)$$

This relation has again the property that the obstacles can and must be removed as they appear because the value a/ϵ of the annual national output cannot be larger than the smaller of both storable quantities. For long-term equilibrium, $k_w/h_s = s/w$. Inserting $k_w = \lambda\mu Ga$ from Eqs. 2 and 5 yields finally for the evolutionary level

$$h_s = a/(\epsilon - 1/\lambda\mu G). \quad (21)$$

With $\lambda = 0.47$ from the appendix and $\overline{\mu} = 0.26$, Germany and Japan require $\overline{h}_s = 1.7\overline{a}/\epsilon$ for final equilibrium. The USA need a little more due to smaller saving and larger consumption. But even that is well below the final educational level $\overline{h}_e = 4.3\overline{a}/\epsilon$ from Eq. 18.

This first comparison between educated and required human capacity shows that G7 level nations installed implicitly a sufficient safety buffer against a limiting role of education for the industrial society's evolution except for Germany, as Fig. 4 and the Pisa Tests showed. It follows that human capacity's inherited part dominates and limits the industrial evolution. This agrees with the role of the bio-economic relation $L(a)$ of Eq. 16.

Equation 20 allows deriving the maximum part of the GDP left for education and consumption. $a(t)$ saturates with increasing k_w, whereas the sum $b(t) = 2k/G \cong 4k_w/G$ of maintaining physical capital and law and order increases continuously as shown in Fig. 4. Differentiating $a(t) - b(t)$ with respect to k_w yields the maximum difference for $\hat{k}_w = (3/2)h_s$. The integers result from the square root 2/5 of $4/G$. Eliminating $s(t)$ in Eq. 19 with its trade-off Eq. 1 yields $w = \epsilon/\left(1 + \widehat{k}_w/h_s\right) = 0.4\epsilon$. Thereafter $w(t)$ saturates as shown in Fig. 1 because the evolution's optimal industrialization must implicitly wait for the adaptation of h_s. Explicitly this means waiting for human demand, a situation that was experienced already in China when a nationwide housing project benefitted more speculators than tenants in 2010.

Since h_s is indestructible and $w(t)$ fixed by technical progress, destruction of the technical infrastructure down to $k_w \ll h_s$ destroys long-term equilibrium and reduces the GDP of Eq. 19 to the recovery GDP $y = wk_w$ of Eq. 3. Annual pay necessarily follows the national GDPs, but recovery can be much faster than starting from agriculture because h_s maintains its evolutionary level when $\overline{v}$ keeps its relative level. This explains the fast recoveries of West Germany, Japan, and South Korea in Fig. 2. China invited foreign experts and required joint ventures.

Human nature and industry dominate the economy with the division of time of Eq. 1, the bio-economic relation of Eq. 16, the optimality condition of Eq. 8, and the genetic constants G, E, and $\overline{L}$. The per capita saturation of G7 level growth observed with all four figures is theoretically confirmed against any defense. The theoretically prominent complications caused since 1923 with the neoclassical paradigm's fractional exponents are discussed in the section on details.

Finance

During the Cold War's best time of peaceful growth on G7 soil, the financial sector acquired a dominating influence over business, human life, and politics. The mission of the European and all national central banks is stabilizing the currency and, as supporting goal, stabilizing the growth and inflation rates near 2% each. This banking paradigm means stabilizing exponential growth forever. It is based on an empirical relation between inflation and employment called Phillips curve. Believing in it as a natural growth law (which it is not), central banks and national governments injected since 1980 trillions of US dollars into their economies for stopping saturation and recovering exponential growth per capita.

General banks take care of the people's savings, investments, and loans. For the banking paradigm's exponential growth, an interest rate of 4% p.a. would maintain saving competitive with investing into business. But since 2010 the interest on G7 level saving accounts is practically zero. This rate cannot be due to the generally quoted subprime mortgage disaster of 2007 because the following section on the outlook for Europe shows with Fig. 6 that this disaster left hardly a trace in the medium-term growth of European nations.

Quoted are now external and internal risks from terrorism, refugees, tax havens, and protecting the Euro to rescuing banks, high bank leverages, interbank confidence, compliance, and consolidation pressure. But zero interest must have a deeper cause than management problems of a subsystem that depends on non-zero interest. After all, the business policy of the most powerful financial institution is fundamentally challenged by the total failure of the largest experiment carried out under this policy for nearly 40 years.

This failure follows with the rigor of the natural sciences from the constructive relations between the natural subsystems. The real cause of zero interest is that all main variables saturate per capita because individuals are limited systems per unit of time flow ϵ (Eq. 1), per annual supply due to $\overline{\mu}$ (Eqs. 6 and 6a) and law and order, and per annual demand due to $\overline{L}$. Saturation would also follow for education from pursuing the analogy to $\overline{\mu}$ for $\overline{v}$ introduced after Eq. 18. For peace on their soil, the average real per capita growth rates of G7 level GDPs will fall from now 0.9% p.a. to 0.4% in 2100. For the lower half of families with most of the children, the effective growth rate is already negative.

Since money is not subject to the laws of nature, it can theoretically grow exponentially with the principal in the nominator. This is perfectly fine for regular credits, but not for long-term policy. Not knowing this fundamental difference caused the financial problems listed in the introduction: financial instability, diverging distributions of incomes and wealth, coexistence of the largest public debts and private fortunes in history, and also zero interest. A recollection of the financial decisions made during the industrial society's best time for accumulating wealth helps understanding how the inequality problems came about and how they can be resolved.

Capitalism's answer to the Sputnik Shock shown in Fig. 4 consisted essentially of improving top education and research in the natural and engineering sciences. Together with the industrial reaction, the 15-year effort created the industrial society's largest technology push to date. This was a unique time of commitment, confidence, and optimism mainly in the USA, Japan, and Western Europe. Many high technology parks were built in the 1960s for direct cooperation between academia and industry. Some industrial labs followed AT&T Bell Labs' Area 1 policy of selecting worldwide postdocs for individual research hoping for discoveries that open new markets. Information theory and coding, solid-state electronics, optical communication, and software systems were invented there and developed in a cooperative spirit. In the end socialism lost its competitive power due to this technology push.

The courage of giving fresh postdocs 3 years of individual free research (no teams) with industrial effectiveness and without any other obligation requires a locus genii that takes time to develop with a steady flow of international top-level postdocs, on-the-job language and writing courses, free links to government and university labs, good library and laboratory services, direct relation to one permanently assigned patent attorney who applied within 2 weeks before conferences, tenure only for primus inter pares management having their own labs, an individual scientific career path to the associate executive director level, and ideally also a safe monopoly market of the parent company like national telecommunications for AT&T called "Ma Bell" by the people. 30,000 of a million AT&T employees worked at Bell Labs. ABB, Alcatel, GE, GM, Hitachi, IBM, Nokia, Philips, Siemens, Toshiba, and many other global companies followed suit and built new laboratories in technology parks far from the pressure of immediate manufacturing needs.

The contrast between great advances in science and engineering and a weak economy prompted the USA's first decision to end the US dollar's gold backing in 1971 in the hope of recovering exponential per capita growth. That was just-in-time because the second move came with printing money against the fourfold oil price hike of 1973–1975. Since the growth rate continued its decrease, the final move came in 1981 with cutting the top tax rate for the rich to 28% with the immediately criticized argument that the freed money would "trickle down" to the poor. With due delay the UK, Japan, Germany, and many other nations followed suit.

Yet even such a tax cut could not increase the growth rate. Instead, pension funds and financial analysts discovered the opportunity to stimulate profit instead of growth by innovating managerial and financial processes. This started the divergence of executive incomes. Pension fund managers and financial analysts demanded fast return on investment and increasing shareholder value as top criteria for corporate policy. Cash-strapped communities were convinced to selling their infrastructure and leasing it back. Banks created unlimited derivatives just by different packaging and called them products. Hedge funds were invented and speculations against the Euro allowed. Bank leverages exceeded the factor 10.

This concerted effort prepared the stage for an uncontrolled monetarism. Finally, the subprime mortgage crisis culminated in the global banking disaster after the US government refused the Lehman Brother's bailout in 2007. With the expression "house poor," a new kind of poverty emerged. Since 1981 trillions of dollars or Euros were injected into G7 level nations for stimulating growth, after 2008 also for stabilizing the Euro and many European banks. The final coup was creating "bad banks" just for sweeping junk papers under the carpet.

As short-term result, the technology push had not enough time to materialize. Central sales and just completed research divisions were closed because their corporate mission prevented buying and selling manufacturing divisions. MBAs and lawyers replaced engineers and scientists in management and supervisory boards. This required a booming management consultant business because boards were professionally too narrow for a global market where technology became a commodity for locating factories in regions with cheap labor. Streamlining until every company looked simple enough for lean top management became a goal for management consulting also because it extended relations, sometimes ending with an attractive position.

The divergence of incomes was also driven by the consolidation of business from independent crafts and groceries to global industry and supermarket chains. This silent social revolution created the most powerful hierarchy in business. The shift from political to global business power is highly visible. Transnational trade agreements are the logic consequence. Some professionals had the chance of starting with the research boom in the USA and experiencing the full revolution during their careers by finishing in a streamlined European board.

But G7 level growth continued saturating, and instead of trickling down, the injected money found its way into the top decile's accounts. From 1942 to 1981, its share of the USA's annual income was stable at 34%, and then it grew nearly linearly to 51% in 2012 (Saez 2014). The worst consequence is that pension funds dry out fast with negligible growth and interest. Assuming the entire pension system consists of one big fund, its required per capita volume is

$$k^* = \sigma(p/z)y \tag{22}$$

(Danielmeyer and Martinetz 2009). Compared with the national physical capital of Eq. 5, this pension fund must be maintained with a capital coefficient of

$$\mu^* G^* = k^*/y = \sigma p/z. \tag{23}$$

For estimating the fund's required volume, assume it pays an interest rate of $z = 1\%$ p.a. above the rate of inflation for a really minimum pension level per individual of $\sigma = 0.1$ relative to the real GDP per capita. The retired fraction $p(t)$ of the population depends on its age distribution. A not too simple model calculation with a logistic tail for L(t) from Eq. 16 yields for this century $p = 0.6$ and 0.4 for an effective retirement age of 60 and for an increase in proportion to L(t) from 60 to 85 in 2100, respectively, when the mean life expectancy will be 107 years (Danielmeyer and Martinetz 2009). Taking the average value $p = 0.5$ yields in 2100 toward the end of this century a capital coefficient $\mu^* G^* = 5$ years for the required pension fund. For a real fund with $G^* = 25$ years, the capital function's value must be $\mu^* = 0.2$.

There is only one such fund per G7 level nation, namely, the total value of its physical capital. But that is already owned by the rich. For the USA, the top quintile owns 80 ± 5% of total wealth (Saez 2014). This means that even for a 1% growth rate above inflation and increasing retirement age, there will be no alternative to returning to a fair distribution of incomes and wealth and reviving the classical tax-based pension system. This example shows how simple and useful analytic solutions are compared to numerical approximations.

Now the highly profitable time of fast recovery is over and with it the main social ordering power for the first two generations after World War II. The social situation disclosed by Emmanuel Saez and Thomas Piketty in 2014 is quantitatively confirmed with an analytic theory that unites all dynamic subsystems of the industrial society for this century. So far, the consequence was the electorate's observed split into an international top class and a disappointed national majority.

The responsible governments allowed this social splitting consciously but without knowing the so far hidden fundamental cause. The resulting disorder can and must be corrected. The enormous subsidies for recovering exponential growth and rescuing banks were especially critical for the European Union because it lacks the uniting power of a common constitution.

Details

This natural theory could only be developed for per capita quantities because reproduction and immigration rates are unpredictable. In the long run, even very small monotonic changes spoil analytic solutions. However, by replacing G with $G_\pi = G/(1 + \gamma_\pi G)$, the theory accepts small and slowly changing population growth with rate γ_π. The impact of this approximation follows from three examples.

For poor nations, a population growth rate of γ_π= 4% p.a. all but excludes catching up with the G7 because that rate will exactly double the cost of just maintaining physical capital's value per capita. This can already be seen with Eq. 5 and its physical lifetime of $G = 25$ years. The PR of China knew why it stabilized its population with a tough but successful one child per family policy, but it must already correct it for preventing the projected decrease to 0.75 of the female to male ratio in the relevant age for reproduction.

Japan's population is expected to decrease for the foreseeable future with rate $\gamma_\pi \approx -1\%$ p.a. This will save with $G_\pi = 33$ years about 25% of the maintenance cost of physical capital compared to the case of constant population. Fortunately, the natural theory allows controlled retreat from untenable levels of affluence. The capital function must be reduced from 0.21 to 0.17. As observed, the real GDP decreases in spite of subsidizing growth with building.

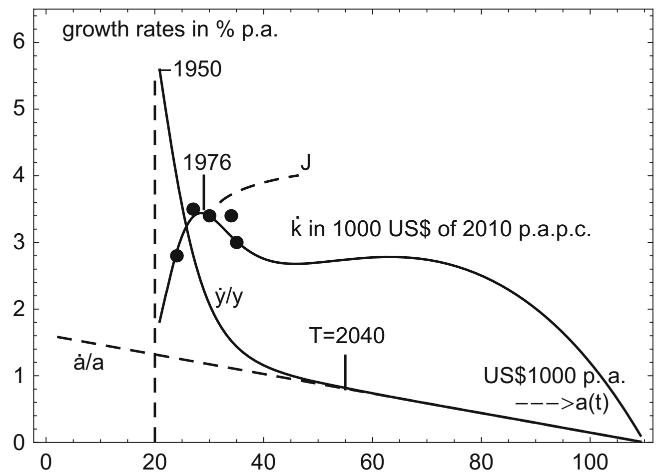
The natural theory's second long-term requirement is using the annual working time with the unit of Eq. 1 as macroeconomic labor variable. So far economics used employment or cost of the work force. This lead in 1923 to the neoclassical production function $y = A(t)\ell^{\varphi}k^{1-\varphi}$ as theoretical workhorse. Since this is unlike Eq. 2 a static equation, all variables were assumed to grow with the same constant exponential growth rate except for the technical progress function A(t) with an estimated growth rate near 2% p.a. But no original producer can separate technical progress from the price of physical capital. Equation 2 leads to $\dot{w}/w = -\dot{k}/k$ for constant GDP. The relative value of new industrial physical capital increases in proportion to its saving of relative working time. This is the natural pricing rule for physical capital.

The sum of neoclassical exponents must be 1 because of dimensional coherence and scaling with population. Another so far silent reason for fractional exponents is that housing is included although it is designed for reproduction at home. Such exponents are physically wrong, and neoclassical production functions are underdetermined in spite of two fitting possibilities. The natural production function of Eq. 2 is completely determined without any fitting. This is one of the best examples for synergetics: finding simple solutions for seemingly insoluble problems by accepting that macro-systems exist only because they are stronger than the sum of its subsystems. Keeping micro- and macroeconomics together in one academic discipline is easy when their natural differences are understood and accepted as inevitable.

Figure 5 shows Germany's predicted GDP with a parametric plot over the entire evolution. Its first 250 years before 1950 are now irrelevant. The predicted wide maximum is due to the industrial evolution's smooth dynamics. According to Eq. 13, it peaks 21 years after the industrial evolution's halftime in 2040. The evolution's definition with Eq. 9 can be directly read from the axis intersections of the dashed line for $\dot{a}/a$. Since $\dot{y}/y$ converges into it without overshoot, Eq. 10 describes the optimal path from the deepest level of destruction to the final level $\overline{a}$ without fitting parameter. This excludes the existence of a third kind of obstacle for the industrial society. The natural theory is complete.

The small detail's data are collected for Germany in Table 2 of the appendix. Their agreement with the investment peak of $\dot{k} = k(\dot{y}/y + \dot{\mu}/\mu)$ from Eq. 5 shows the advantage of analytic solutions. All derivatives and analytic integrals are also valid solutions for the system. We named the new phenomenon convergence crisis. The peak and economic growth are physically due to the term $\dot{\mu}Gy$ in Eq. 6. Just this term was neglected to date. The USA's smooth development was short of showing a peak because that appears only for $\beta > 0.05$ p.a.

Without having the real explanation, Japan coined the term "hollowing out" for its convergence crisis. Assuming that due to cheaper imports from China about 4% of its manufacturing was lost, Japan began immediately with injecting money into new housing and Tokyo office towers (dashed). By now it is clear that this classical policy could only deepen and extend the crisis. In Germany, employment collapsed



Industrial Society's Natural Future, Fig. 5 Parametric plots over the industrial evolution (Eq. 10) of its growth rate $\dot{a}/a$, West Germany's annual addition of physical capital (with data during its convergence crisis' peak from Table 2 in the appendix), and its rapidly decreasing growth rate after 1950 from Eq. 8. Both continue into Germany's evolutionary saturation

Industrial Society's Natural Future, Table 2 Data processing for West Germany's convergence crisis

Page	Quantity, unit	1960	1970	1980	1990	1993
46	Population P, millions	55.4	60.7	61.5	63.3	65.5
678	K, 10^9 DM of 1991	3291	5719	8479	10,989	11,975
678	K_w/K	0.42	0.44	0.45	0.45	0.46
678	ΔK_{in}	245	362	418	502	487
678	ΔK_{out}	38	73	131	188	210
$\dot{K}$	$\epsilon(\Delta K_{in} - \Delta K_{out})$	207	289	287	314	277
$\dot{k}$	$\dot{K}/P$ in 10^3 US$ of 2010	2.8	3.5	3.4	3.6	3.0

Source: Statistical Yearbook of Germany 1995, Metzger-Poeschl 1996 initially by 4%, but thereafter West Germany's 63 million people were saved by well-timed unification with 18 million East Germans and their huge demand for renewing their entire infrastructure with G7 level standards.

Table 1 of the appendix predicts the PR of China's convergence crisis from 2045 to 2055. Due to its longer linear path, China's peak will top Germany and Japan's peak by a factor 2 to 3. With a population of 1.6 billion instead of West Germany's 63 million, China's convergence crisis will cause the industrial society's largest imaginable financial and social disaster.

Outlook

Figure 6 shows the change Δk of net physical capital over the change Δy of the GDP between 2006 and 2014 for European nations. Both quantities were obtained from Eurostat's tables (eurostat.eu) for 2006 and 2014. Luxembourg and Norway grew exceptionally because they are dominated by finance and offshore oil, respectively. Such sectors have no special influence on the life expectancy because the latter requires balanced educational, medical, social, and technical progress. All other nations follow the natural theory's course (dashed) surprisingly well, not only the European G7 level nations. The UK's departure from industry started already with the oil price hike in 1973. Except for Ireland (ie), Spain (es), and Greece (gr), the subprime mortgage crisis left in the critical 8 years hardly a trace.

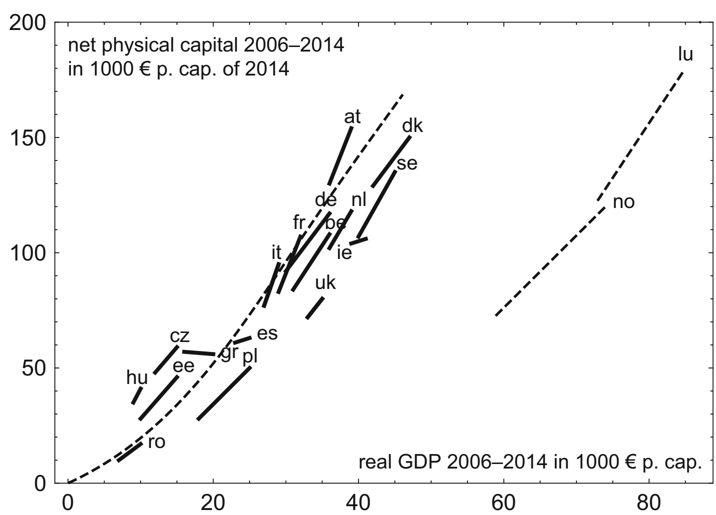
The top positions are occupied by Austria (at), Denmark (dk), and Sweden (se). These countries profited from Europe's recovery because their technical infrastructure survived World War II. The central G7 level group is quite homogeneous. The lower group consists mainly of nations that are still recovering from World War II because in the socialist block they could not benefit from the Cold War's Western boom.

Longer $\Delta k/\Delta y$-lines for the top nations should not be mistaken for stronger growth. Their average levels are in the denominator of both growth rates (besides the factor of 8) so that for equal growth rates, the top lines should have three times the length of the low group. Since the top lengths are much shorter, the entire continent's growth rate saturates.

Europe's future depends essentially on a functioning common market for a dozen G7 level nations, another dozen relatively poor and/or politically critical nations, and the Russian Federation. The latter is geographically invincible, has again global ambitions, and is with 150 million people the natural enemy of a strong European Union with 500 million people. The USA and China have also increasing internal problems, but they can defend themselves.

The European Union can no longer afford fighting the laws of nature by injecting tens of

Industrial Society's Natural Future, Fig. 6 Full growth through the mortgage crisis of European nations identified by their e-mail code



billions of Euros per year without any possible success for increasing the growth rate. That money doesn't trickle down but ends up in top accounts and tax havens. Asking the most successful nations to be less successful would impede Europe's physical sustainability without solving the problems of the other nations and offend the professional ethics of systems engineers especially in Central Europe where the "ingenieur" derives from genius instead of engine.

All national media know that the European Union redistributes 90% of its budget also for integrating the poorer member states. The media must stop criticizing the 10% used for administrative tasks that all members would need separately with altogether much higher costs. Not the young but national media, languages, and governments are the obstacles to unification.

Reversing the divergence of incomes and wealth requires much more time than legislative periods permit. The evolution constant $E = 62$ years is the natural time horizon for sustainable planning because it is the reaction time for human maturation, mean life expectancy, and industrial evolution. This coincidence and proximity to $2L_o$ suggests that aging is due to a well-defined process involving parents and grandparents. Investing this time now with dedicated patience is Europe's last chance and challenge for survival in China's and North America's world.

Conclusion

The industrial society's theoretical base is now complete. Six simple constructive relations unite four subsystems and their associated academic disciplines with a unique family of six analytic solutions. They are completely determined by three inherited time constants of the human species and two national constants for the educational and technical infrastructure.

This progress was possible with the discovery of two directly correlated pairs of variables evolving from the eighteenth-century UK to the current G7 level nations nearly without a trace of financial and political disasters: the life insurer's disaster-corrected national predictions of the unisex life expectancy after birth and the envelope of the best real (inflation-corrected) GDPs per capita above all disasters named industrial evolution and the engineer's division of the annual flow of active time into annual spare time and paid and unpaid annual working time. Initially, agricultural and industrial annual working times overlap. Physical capital for paid work in production and housing for unpaid work in reproduction must be separated. The latter may allow quantifying the average home evolution. Then Gary Becker's pioneering work of 1964 could also be completed after half a century with quantitative forecasting power.

The best time for global development was the Cold War's peace on G7 soil. After 1950 the annual spare time became implicitly the main driver of growth into affluence far beyond biologic needs. After 1980 writing and copying software for robot manufacturing became so easy and cheap that employment shifted to stand-by jobs known from supervising chemical production. The cost of hard labor in classical disciplines became the cost of time across disciplines. School and university teaching adapted too late, especially in Europe.

Due to the Great Depression in the USA and the destruction of Germany and Japan in World War II, the per capita destructible physical capital showed two constant time delays relative to the normalized GDPs. Before the transition in the 1980s, three observed delays allowed the first measurement of the physical lifetime (25 years) of physical capital against technical obsolescence. After the transition, the delay allowed measuring the superposition of the physical capital's lifetime and the human reaction time (62 years) to improving existential conditions.

The corresponding effect between the industrial evolution's existential conditions and the industrial increase of the mean unisex life expectancy at birth resulted in the latter's constant precedence (59 years). Human life integrates and averages linearly over the existential conditions from life to death. This leads to a life expectancy whose relation to the industrial evolution is an invariant of the macro-system named bio-economic relation. This precedence equals half the final average life expectancy of 118 years.

All three time constants are encoded with the heritable human maturation program. They fix and limit the dynamics of all variables so that all data are reproduced without any fitting parameter. The implicit assumption that the industrial society's evolution can be optimized by any subsystem's independent reasoning or paradigm is refuted against any defense by the genetic power of human nature. The saving constant for physical capital is the dominant national parameter; it fixes the speed of recovery and the G7 level lifestyle. The national effort for education must just be large enough for challenging human adaptability to affluence to its inherited limit. These conditions provide forecasting power.

As overall result, the industrial evolution survived all unnatural policies nearly without a trace and became implicitly an extended projection of the individual maturation program. This formed the largest possible and sufficiently diversified macro-system. Longevity is the industrial society's uniting natural goal; Adam Smith's accumulation of wealth was a dividing spin-off. Reaching the genetic limits takes half a millennium instead of the maximum unisex life expectancy because only the part adapted to within the generation gap can be heritable. Without this projection and the partial heritability of longevity, the majority cannot reach the genetic limits of the human species.

Theoretically this natural goal is embodied in the unique structure of the analytic solutions. It allows the technical and human infrastructures to contribute independently to longevity by competing with different time constants in the denominator. Physically, economic growth is achieved by removal of technical and human obstacles as they appear during the industrial evolution.

When two competing exponential terms compete in the nominator, the faster will win, and human maturation is missed. Money can be exponentially printed in the nominator; it is not subject to and, therefore, not controlled by the laws of nature. Optimizing the financial subsystem without knowing its structural incompatibility with the natural subsystems caused the new financial and political problems of the G7 level nations listed in the introduction and explained in the section on finance. Realizing and respecting this difference is the key to surviving this century's saturation of G7 level economic growth.

The top demand's data come with the life expectancy free house. Everyone's learned capacity is individually entangled with human nature's priceless inherited capacity. The latter comes also free house. Together they allow discriminating positive, neutral, and negative contributions to longevity. Hereby billions of daily decisions achieve long-term equilibrium between demand and supply. No human institution has the power and diligence to mastermind the industrial evolution above all disasters in three continents with different cultures for half a millennium. Society's master plan is the human maturation program, and this is installed in every individual.

The seamless agreement without fitting parameter between data and theory in Figs. 1, 2, 3, 4, and 5 suggests that forcing different master plans onto society will fail like communism. Subsidizing the financial utopia of exponential growth per capita at G7 level must stop immediately because fighting the laws of nature is futile even for mankind's most powerful institutions. The currently available money should be saved from inflation by century projects that stabilize Europe and its relation with Africa. The same applies to North and South America. China agreed recently to its change from exponential to linear growth, but it must also agree to contain its convergence crisis immediately by reducing its growth rate even faster than predicted by the natural theory.

The natural theory's forecasting power reduces the macro-system's apparent complexity and the risk of long-term social planning decisively. The divergence of the distributions of wealth and income can and must be reversed. The national pension systems can and must be stabilized not for the next election but for the life insurer's predicted life expectancy. The section on finance showed against any defense that returning to tax-based pension systems is inevitable.

Jobs must be created for the young and for the lusty seniors because both groups are powerful voters. Reproducing couples need stable jobs. The G7 level employment challenge requires a level of social innovation that is only comparable to the level of technical innovation. There can be no political stability without success on the job front with fair pay.

All nations have nearly the same final problems because (with the XY-difference) they are subject to the same maturation program. Beyond that, the new possibility of long-term planning raises the question what governments and their national and international institutions can actually contribute to the industrial society's long-term success. Most of their creative time was probably spent with preventing national and international disasters and repairing the damages when that failed. Finding socially uniting goals before mankind's biologic limits are practically reached is this century's top challenge.

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Appendix

Natural Constants of the Human Species

$\epsilon = 1$ p.a, the calendar year's unit for measuring the annual flow of working and spare time

$E = 62$ years, evolution constant, effective reaction time of L(t), a(t), and $h(t)$

$G = 25$ years, generation constant, effective physical lifetime of $k(t)$

$L_o = 30$ years, mean minimum life expectancy for maintaining the medieval population

$\overline{L} = 118$ years, mean maximum life expectancy at time of birth for the G7 level life style

Main Variables of the Industrial Society

$y(t)$, gross domestic product (GDP) per capita, after recovery $\rightarrow a(t)$, industrial evolution

$k_w(t)$, national physical capital per capita in production; $k(t)$ includes the housing part

$h_e(t)$, educated part of human capacity h(t) per capita; $h_s(t)$ includes the inherited part

$L(t)$, mean G7 level life expectancy

$s(t)$, annual spare time

$w(t)$, annual working time

Evaluating National Policy

The fastest way is inserting the recent data of the nation to be tested into Figs. 1, 2, 3, 4, 5, and 6. This should yield the halftime τ and the initial growth rate β of the last recovery. National statistics show the total annual support $\dot{k} + k/G$ of Eq. 6 for physical capital as gross fixed capital formation (*GFCF*). Then the saving constant is given by $\overline{\mu} = GFCF(t)/y(t)$. When this ratio is not fairly constant, the economy is centrally planned (like China's). Starting central planning means endless central planning or a veritable revolution for a free (nearly self-ordering) society.

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