

# Notes on “The Collapse of Complex Societies” (J. Tainter)

## 1. Introduction to Collapse

**Intro!** The sublime mystery of collapsed civilizations and dark portents (“the possibility that a civilization should die doubles our own mortality”). Comparison of Rome to “future of industrial society”, especially given energy, ecological concerns, nuclear and socio-political concerns – and need to understand this process. Possible for civilization to “be strangled in its own complexities”? Exist millennial trend to more complexity (specialization, energy / info, technology, control, size); but occasionally interrupted by collapse – which is much less studied.

- **What is collapse?** A society collapses when it displays a rapid, significant loss of an established level of sociopolitical complexity (be it empire or chiefdom).
- Signs include less of: stratification, occupational specialization, centralized control, regimentation, investment in epiphenomena of civilization, information flows, trading, coordination, political unit territory.
- **Historical examples.** Western Chou (1122BC-771BC): after decline, barbarian invasions and center losing power. Moved to Eastern Chou but Chinese unity effectively collapsed through Spring and Autumn (770-464BC) and Warring States (463-222BC). Regional states fighting for hegemony, alliances, war, barbarian manipulation until Ch'in. But start of political thought, Hundred Schools and Confucius.
- Harappa (2400BC-1750BC): highly centralized, organized, regimented; granaries, grid streets, fortresses, drainage / sewage, uniformity → less standardization, reuse of bricks, lower quality construction, art simpler, jewelery hoarding, partitioned rooms, unburied corpses in streets, huts amongst ruins.
- Mesopotamia. 1<sup>st</sup> is Akkad, death by rebellions. 2<sup>nd</sup> is Ur: bureaucracy, irrigation, population growth, power maximization → sudden collapse. Babylon Hittites, Assyrians, etc, then incorporated in empires – growth in complexity / density. From 7<sup>th</sup> C, decline and collapse by 10<sup>th</sup>, 11<sup>th</sup> C AD – occupied area to 6% of 500 years earlier and population lowest in 5000 years. 90% tax revenue lost in lifetime, revolts and ungovernable countryside, mostly nomadic until modern era.
- Egypt: from 3100BC, highly centralized, godlike leader, hierarchic bureaucracy. But shift to feudalism in provinces, ruler weaker, wealth of provincials and nobles rose, immense royal construction. From 2181BC, Old Kingdom collapsed, strife, collapse of centralization → independent polities, many rulers with short reigns, looting / killing / burning / anarchy, royal women and bureaucrats disgraced, peasants carried shields as they tilled, trade down, famines, LE down. New 11<sup>th</sup> Dynasty in 2131BC restored order, recentralized by 1870BC.
- Minoans: palaces on islands from 2000BC, science, sanitation, palaces for art / storerooms / control → 1500BC earthquake, Mycenaean competitor + militarism, conquest, 1380BC collapse.
- Mycenaean Greece: from 1650BC, Golden Age in 1400BC, homogeneity in politics / art, independent states centered on palace/citadel complexes (similar to Minoans); 1200BC palaces destroyed, disaster, instability / mass migrations, writing vanished, uniform pottery simpler and local styles, metalwork simpler, fortifications, iron, water supply through bedrock obtained for citadels, 1050BC gone, population down 75%-90% and start of Greek Dark Ages.
- Western Roman Empire: expansion capped under Augustus (27BC-14AD); Pax Romana decline by 2<sup>nd</sup> C, barbarians, plague; 3<sup>rd</sup> C same + civil war / near disintegration; partial restoration of order and further decline to 395 (split), last Emperor deposed in 476AD.

- Olmecs: basalt monuments systematically wrecked in violent paroxysms at the end.
- Maya: lost cities swallowed by jungle chaos (morbid fascination). From Bcs to intensification in 700AD, Mayan cities public works, arts, temples / palaces, plants – rapid onset of collapse soon after and by 900AD prior urban life mostly gone and depopulated.
- MesoAmerican highlands: destruction of monuments (street of the Dead).
- Chacoans and Hohokam: desert peoples underwent collapse + loss of political centralization.
- Kachin of highland Burma – 3 societies, gumlao egalitarian, gumsa stratified, shan feudal higher more complex – continued oscillations between these states.
- Ik of north Uganda – huntergatherers of lowest sociopolitical complexity. Food, water scarce; no advantage to reciprocity, sharing. So fragmented most activities, including subsistence, pursued individually. Families dysfunctional. Children minimally cared for until 3 years, then set loose and they band into age sets for protection. Villages exist but meaningless as concept.
- **After collapse.** According to films, Mad Max Hobbesian war of all against all, Ik world, food / fuel / survival, center doesn't hold, bands of survivors scavenge amidst ruins of grandeur, grass in streets, bandit soldiers / police. E.g. Britain civilized and peaceful 100-400AD, then no public safety, big houses, dwindling townships, all villas / most Roman cities burnt, abandoned, looted, empty.
- Breakdown of authority and central control – revolts, provincial insubordination, revenues decline, foreign / barbarian success, military ineffective, former political center loses power, prominence, can be ransacked and abandoned, small petty states of former union and civil war.
- Prolonged lawlessness, but order will be restored, monumental construction / public art cease, literacy decline and dark age, remaining population in urban reuse existing architecture, little new construction / adaptation of existing buildings; rooms subdivided, flimsy facades, public space to private; depreciation, decay, city drifting to new places.
- Centralized distribution, markets, storages, palaces abandoned, less specialization and long distance trade → local self-sufficiency. Local, simpler styles (scope reduction), as complex machines can no longer be maintained.
- Mass depopulation.
- “In a complex society that has collapsed, it would thus appear, the overarching structure that provides support services to the population loses capability or disappears entirely” (state = monopoly on law, money, violence). No external defence / internal order, public works, big organization. Competition with former economic and political partners. “The world as seen from any locality perceptibly shrinks, and over the horizon lies the unknown”.

## 2. Nature of Complex Societies

- **Nature of complexity.** Measured by inequality (unequal access to resources) and heterogeneity (number of distinctive parts). From rise of civs, inequality fell and heterogeneity fell – more need for info processing. Complex societies are “nearly decomposable systems” - villages – states empires – which can decompose into original building blocks of complexity after collapse.
- Simpler societies: equal, hundreds to thousands, kinship based, power held by charismatic “Big Men” based on giving followers resources with no coercion – but built-in collapse mechanism. Chiefdoms more complex – chieftan is an office, some social structure – but still simple.
- States: territorial / possessive (note: later nationalist reversion), ruling class with depersonalized government with coercive, taxing, legal, drafting powers, ideology, larger so more specialization and stratification, transition in heregeneity from mechanical solidarity to organic solidarity. Needs

legitimacy for survival (coercion is stopgap measure). Official religion for unity, by appealing to supernatural instead of own group - "sacred legitimization", then conflict can begin between secular and sacred. Collapse under "output failure" (political or material) after delegitimization.

- **Levels of Complexity.** Different approaches – is it continuum or discrete? Latter is "structurally stable levels" - bands / tribes / chiefdoms; egalitarian / ranked / stratified. Pertinent to collapse. "Great Divide", supposed, between state and non-state: territorial organization, occupation/class rather than kin differences, force monopoly, mobilization of labor and resources, legalism – but ultimately not absolute divide (conditional states with many characteristics but no monopoly on force, like Anglo-Saxon England).
- States: Inchoate Early State – kinship / community ties dominate politics, little fulltime specialization, ad hoc taxation (pohod / early Rus) and reciprocity / contacts between ruler and ruled. Typical Early State – Kinship ties vs locality; competition and appointment versus heredity; redistribution and reciprocity between strata. Transitional Early State – kinship marginal; admin by appointed officials; market economies, antagonistic classes, private ownership of means of production.
- **Evolution of Complexity.** Purpose of complexity? 1) Managerial – when stress and population increase, integrative requirements must be resolved by managerial hierarchies, like a) labor mobilization for irrigation / hydraulic despotism, b) information processing needs vertical differentiation and horizontal specialization. 2) Internal Conflict – Marxist class conflict to protect privileges of emergent elite. 3) External conflict – in bounded environments, stresses → war and need state apparatus to manage conquered groups, or constant tension leads to value on stable leadership, unity, and conquest of land gives elites resources to create new patron client relations outside kinships.
- Origin of state – "conflict" or "integration"?
- Conflict – Marxist idea that state emerged from needs of individuals in society, to maintain privileged position of ruling class based on exploitation and coercion of the masses – in *Origins of the Family, Private Property and the State*, Engels said differential acquisition of wealth led to hereditary nobility, monarchy, slavery, wars for pillage – state developed to secure new sources of wealth from older, communistic traditions resulting → class antagonism. Material conditions culturally and socially meditates, little room for overpopulation / subsistence stress narratives.
- Conflict symptomatic of complex societies, but are they cause?? Psychological reductions → will of the few – why no states earlier? Contradiction – Marxists say surpluses needed for state, but as material conditions culturally mediated, why can't they be concocted whenever? Strong egalitarian impulses in society – where such cooperation necessary for survival, self-aggrandizement and hoarding aren't tolerated.
- Integration – states not from ambitions of elites, but needs of society – shared consensus not coercive dominance, integrated systems not stages for power struggles. Response to – a) warfare in limited, stressed environment; info management; labor mobilization; regional integration of diverse local economies, etc.
- In integration, admins get differentiated advantages for fulfilling their beneficial roles – a cost of complexity, BUT not all good as compensation of elites doesn't match their real contribution (throughout history they're more overcompensated than reverse) by coercion / authoritarianism (PS. See Marxist wealth inequality explanation). For governing body providing goods / services thus has coercive authority by threat of withholding – but as coercion is costly, emphasis on legitimization.
- Ideologies = the system serves common good (opiate of the masses), but must have real outputs.
- Synthesis of conflict and integration – institutions form from unequal access for resources AND

create benefits for citizens. Integration accounts better for distribution of necessities of life, conflict theory for surpluses. Self-aggrandizement can't account for state development, but helps understand their subsequent history. Complex societies as problem-solving organizations – in conflict to solve problems of class conflict from differential economic success, in integration to secure common wellbeing.

- **Summary.** Growth in complexity is: small, internally homogenous, little differentiated, ephemeral / unstable leadership → large, heterogenous, internally differentiated, class structured, controlled and unequal, needed constant legitimization, reinforcement and coercion.
- Collapse is thus rapid decline in established level of complexity along continuous variable, from one structurally stable level to another (PS. correspondent to new material conditions).

### 3. Study of Collapse

- Why? Roman Empire (Chou China, etc) seen as lost “Golden Age” (leading to iron age, “rust age”?, etc) of wise rule and peace. Attempt to study past, discern future and justify current political philosophy.
- **Discussion on civilization.** From earlier concern with political dynasties and territories, recently concern about civilizations as cultural forms (Spengler, Toynbee, etc) – thus concerned with cultural life-cycles, like fall of Byzantium. But problem of value judgements and cultural continuity (e.g. usually positive about civilization, but Spengler not – they're conclusions, “death following life, rigidity following expansion...they are an end, irrevocable, yet by inward necessity reached again and again”). Civilization is cultural system of complex society – traditions of art, writing, etc, serving socio-economic purposes within complex environment, so discussed.
- **Themes of collapse** exist, 11 major ones (PS. Diamond has 5). 1) Depletion or cessation of vital resources; 2) establishment of new resource base; 3) insurmountable catastrophe; 4) insufficient response to circumstance; 5) other complex societies; 6) intruders; 7) class conflict, societal contradictions, elite mismanagement; 8) social dysfunction; 9) mystical factors; 10) chance concatenation of events; 11) economic factors.
- **Resource depletion.** Depletion of resource base (usually agriculture), often due to mismanagement; and more rapid loss of resources due to environmental fluctuation or climatic shift → collapse. Linkage between economic deterioration → collapse recent, raised during Roman times (but reverse – agricultural yields lowering due to moral decadence in Italy in 1<sup>st</sup> C BC). To late Romans, “the world as a whole...was aging and losing vigor” - decline of mining and agriculture covariable with political weakness. Cyprian in *Ad Demetrianum* (3<sup>rd</sup> C AD) - “the World itself...testifies to its decline by giving manifold concrete evidences of the process of decay”; “the mountains, disembowelled and worn out, yield a lower output of marble”; “there is a decrease and deficiency of farmers in the field, of sailors on the sea, of soldiers in the barracks, of honesty in the marketplace, of justice in court, of concord in friendship, of skill in technique, of strictness in morals...Anything that is near its end, and is verging towards its decline and fall is bound to dwindle...This is the sentence that has been passed upon the World...this loss of strength and loss of stature must end, at last, in annihilation”. Effects of climate on virility and progress; theory that climatic changes makes marginal, buffer areas return to nomadism and chaos, toppling weakened centers of power. Loss of trade and external resources – system fragile when comes to depend on external exchange over which it has little control.
- Maya – soil erosion, land scarcity, encroachment of grasses, silting of lakes / no water transport, less water in dry years, more mosquitoes / malaria. American Southwest – drought, erosion, rainfall

seasonality, lower temps, overhunting of game, more alkalinity of soils. Egypt – variations in Nile floods levels depending on precipitation levels in African interior, e.g. Middle Kingdom (low floods = low yields, high floods = soil crop parasites, destroy dikes, ditches, settlements, food stores, livestock, delay harvesting into dry season) 2035-1668BC was undermined by petty principalities in Delta by 1720BC, well before Hyksos invasion of 1668BC – followed by 1840-1770BC in which 1/3 of Nile floods destructive enough to ruin entire irrigation system → symbiosis with poor leadership, regional factionalism, social stresses / delegitimization of drought (dark ages in 2200-2000, 1200-900). Harappa - “massive extrusions of mud, aided by the pressure of accumulated gases” and damming of Indus downstream from Mohenjo-Daro. Mesopotamia – agricultural intensifications and excessive irrigation raise harvests / prosperity / complexity, then rise of saline groundwater erodes agricultural productivity – when powerful regimes emerged (3<sup>rd</sup> dynasty of Ur, late Sassanians, early Islamic), they maximized resource production / marginal lands, very complex irrigation system requiring state management (fiscal needs), when political weakness they collapsed catastrophically as revenues fell, cost of upkeep remained stable, harsh taxation alienated support population → revolts, coercion, sabotage → civilization around Baghdad, nomadism outside. Roman empire – climate change of coldness / dessication in Asia lead to barbarian migrations; more tree pollen / less crop pollen counts at end of Empire, due to markets / Pax Romana / roads / centralized admin → possibility to alleviate local food shortages, hence opportunities to profit for greater demands for food / surplus production → intensification, population growth, exhaustion, collapse. Deforestation, erosion, food shortages, population decline, sapping of strength. Lead poisoning.

- Problems with resource depletion – different outcomes (England moved to coal after deforestation, Roman Empire collapsed – why?) and fact complex societies have info that their resource base is in decline – why don't they do anything? (PS. Landscape amnesia / creeping normalcy / vested interests, same reason we don't do anything about peak oil).
- **New resources.** Theory that more resources can paradoxically lower complexity – e.g. Pecos River, New Mexico where sedentary horticultural villages abandoned for mobile bison-hunting when moisture at 1250-1350AD led to spread of grasslands / more bison. Unconvincing, can only apply to simple societies.
- **Catastrophes.** Single apocalyptic events like hurricanes, volcanos, earthquakes, floods, major epidemics – simple and appealing. MesoAmerica – Mayas got yellow feverm earthquakes, maize mosaic virus; earthquake at Benque Viejo → social upheaval. Minoans – volcano at Thera led to ash, mud, tsunamis and earthquakes at Crete, receiving an “...irreperable blow, and from then onwards gradually declined and sank into decadence, losing its prosperity and power”. Roman Empire – plagues and malaria. Though obvious / favored, very weak – many societies encounter catastrophes but don't collapse, I.e. can only be the jolt that sends it down (PS. Plagues at end of empires – because of low food per capita and weak immune systems). Finally, Thera exploded in 1500 – but widespread destruction on Crete occurred in 1450.
- **Insufficient response to circumstances.** (PS. Set thinking, ideologies, creeping normalcy / landscape amnesia, etc). Law of Evolutionary Potential: “the more specialized and adapted a form in a given evolutionary stage, the smaller its potential for passing to the next stage” → conservatism, lock in. Interps: Dinosaur (dead end – impressive but maladaptive); Runaway Train (society impelled along path of increasing complexity, unable to stop or change direction); House of Cards (complex societies inherently fragile on low margins of reserves – but societies DO make changes, like Rome after 3<sup>rd</sup> C crisis, mid-dynasty China at times, Tokugawa Japan, etc).
- **Intruders.** Attractive as explanation, but illogical – can only be treated as stress or shock.
- **Elite mismanagement.** Increasing cronyism, indolence, luxury, etc amongst elites, class conflicts,

taxes go up to support them. Particular feature in Chinese (Mandate of Heaven) accounts, where growth and massive construction replaced by corruption, neglect and decadence. More taxes, fewer benefits, social structure favoring overpopulation. Romans = landowners to manorial economies / serfdom – slavery; barbarians to empire; elite luxuries in exchange for precious metals; state authoritarianism; increased taxation, expenditure. Also, regionalism → civil wars.

- **Economic:** Ottoman empire – military burdens, as well as palace, admin, etc, but suppressed by anti commercial leanings and taxes.
- **Mysticism.** Value judgements of vigor and decadence – universal and unscientific (Spengler, Toynbee). Plato *Laws*: “...since all created things must decay, even a social order...cannot last forever, but will decline”. Polybius 2<sup>nd</sup> C BC: “every organism, every state and every activity passes through a natural cycle, first of growth, then of maturity and finally of decay...” Lots of other observers said similar things as Roman Empire declined and fell. Augustine – good inhabitants of City of God would be purified and improved by troubles; wvill who love worldly things would be overwhelmed. Pagan barbarians as punishment (for Rome's sins). Lawler (1970) says history is cyclic, 1470 year cycle, etc (collapse of US slated for 2040 latest). Gibbon: relaxation of military discipline, Christianity, ignorance of dangers, bad emperors, decline of martial spirit with prosperity.
- Danilevsky: *Russia and Europe*, “The course of development of historico-cultural types is similar to the lifecourse of those perennials who period of growth last indefinitely, but whose period of blossoming and fruit bearing is relatively short and then exhausts them once and for all” - civilization is last stage and “...every people is eventually worn out and exhausted creatively...”.
- Spengler: *Decline of the West*, organism; every civ has “...its own idea; its own passions; its own life, will and feeling...its new possibilities of self-expression which arise, ripen, decay and never return”. “Civilizations are the most external and artificial states of which a species of developed humanity is capable”. Intellectuals, cities: “...parasitical...traditionless, utterly matter-of-fact, religionless, clever, unfruitful...”. → “A Culture is born in the moment when a great soul awakens out of the proto-spirituality of ever-childish humanity, and detaches itself, a form from the formless, a bounded and mortal things from the boundless and enduring. Its “living existence...is an inner passionate struggle to maintain the Idea against the powers of Chaos without and the unconscious muttering deep down within” - once Idea attained, hardens into living dead civilization. “A mythic world-consciousness is fighting...against all the dark and daemonic in itself and in Nature, while slowly ripening itself for the pure, day-bright expression of the existence that it will at last achieve and know”, “at last, in the grey dawn of Civilization, the fire in the soul dies down”, “in Romanticism looks back piteously to its childhood; then finally, weary, reluctant, cold, it loses its desire to be, and, as in Imperial Rome, wishes itself out of the overlong daylight and back into the darkness of proto-mysticism, in the womb of the mother, in the grave”.
- Sorokin: Ideational (e.g. Christian) and Sensate (totalitarian) (PS. Gumilev / passionarnost?)
- Main counter-argument – unscientific, etc; but attraction demonstrated even by amount of pages Tainter himself devotes to it!!

#### 4. Understanding Collapse

- **Complex societies** need much greater energy flows for upkeep (US military forces at Casa Blanca = 500,000 artifact types, native peoples of West North America = 3000-6000) than simple ones, by many orders of magnitude. For complexity → more networks between individuals, more hierarchical controls to regulate them, more info processing, more specialists and need for surpluses, etc. So as

society becomes more complex, support costs for every individual rise and larger portion of energy budget is dedicated to maintaining the social structure.

- Complexity solution to problems (managing class struggles in conflict, to satisfy social needs in integration) – but investment in complexity needs to increase, and is subject to laws of diminishing returns. Similar to economic law of *marginal product* and *average product* – eventually, increased investment into sociopolitical complexity becomes costly and unprofitable.
- Main concepts are: 1) human societies are problem-solving organizations, 2) sociopolitical systems need energy to maintain themselves, 3) increased complexity → increased costs per capita, 4) investment in sociopolitical complexity as problem-solving response often reaches point of declining marginal returns.
- **Marginal productivity of increasing complexity.** Analysis broken down into agriculture, resource extraction, information processing, sociopolitical control and specialization, and overall economic productivity (interdependent).
- Agriculture and resource extraction: *Boserup* = increasing agricultural intensity → labor investment > than marginal returns → productivity per unit of land rises, per unit of labor falls. 1) Forest-fallow / slash and burn where clearings in forest made, planting then fallow period of 25 years. 2) Bush-fallow cultivation – shorter fallow of 6-10 years so forest doesn't come back. 3) Short-fallow cultivation – fallow for 1-2 years. 4) Annual cropping – period of few months left between a harvest and next planting. 5) Multi-cropping – most intensive, can only be done in regions with no seasons of extreme cold. Conclusion – as population grows, human labor per unit of agricultural output rises through this sequence → subsistence crises. Mark Cohen – transition from hunter-gathering to agriculture spurred by population density (PS. It was gradual + early farmers poorer, weaker but more numerous than wild men like Enkidu). In subsistence regimes, both marginal and average returns decrease with intensification. Also animal husbandry – between 1850 and 1910, dairying shifted to winter, improvements in feeding, stricted sanitation requirements, but no major tech breakthrough → dairy output / unit of labor fell 17.5% (*Bateman*). Investment in overall nutrition subject to diminishing returns in enhanced life expectancy. Energy / mineral reserves same (best lodes mined first) – common problem now. *Wilkinson* shows that in England major jumps in population, in 1300, 1600, late 18<sup>th</sup> C → intensification of agriculture, industry. Medieval forest cutting → costlier coal → development of transport system for it. For each \$ invested in energy production, marginal thermal units yielded are now falling.
- Information processing. As size of social group increased, communication loan increases faster (PS. interesting calculation: network “cost” i.e. links  $0.5n(n-1)$  / network value by Kurzweil equation  $\sqrt{n} * \text{gross spending on it}$  e.g.  $0.5n(1/2)(n-1) = 0.5n^{3/2} - 0.5n^{1/2} = 0.75n^{1/2} - 0.25/n^{1/2}$ , as  $n \rightarrow \text{inf}$ , “usefulness” of network too but slowly i.e. at  $\sqrt{n}$ ) → greater costs due to increasing redundancy of info as only initial info is easy. Decling returns into investment in R&D, with patent applications per capita and per technical worker in USA falling fast from 1870 to 1950, because of a) declining productivity of inventing, decline in proportion of patentable inventions, c) decline in propensity to patent. More technical workers, patents about constant per year, spending on R&D up from 0.1% of GDP in 1900 to 2.6% in 1960. Medicine: 1930, 3.3% on health for 59.7 years; 1982, 10.5% for 74.5, today, 16% for 78. Between 1870 and 1960, proportion of 18-21 year olds in US in higher education 1.7% → 33.5%; from 0.26% of GDP in 1900 to 1.23% in 1960; # of students per faculty from 12.8 in 1900 to 9.5 in 1958, longer and more specialized courses – but “learning that occurs yields decreased general benefits for greater costs” (most learning is during infancy). (PS. Korotayev insight that key is 4 years and literacy – makes industrial workforce). Decreasing average and marginal returns as those now educated are closer to center of IQ bell curve. Tulchinsky 1967 /

Strumilin – first 2 years of education raise Soviet worker's production skills 14.5% per year, 3<sup>rd</sup> by 8%, 4<sup>th</sup> to 6<sup>th</sup> by 4-5% per year. Specialization serves narrower sector to general social cost (need general education!). IT / communications take up ever larger share of GDP, so shares allocated for other sectors necessarily fall.

- Sociopolitical control / specialization: Parkinson on growth of bureaucracy – from 1914 to 1967, in Royal Navy capital ships fell by 78.9%, # of officers / enlisters by 32.9%, # of dockyard workers by 33.7%; but dockyard officials and clerks rose by 247% and # of Admiralty officials by 769%. Between 1935 and 1964, officials in British Colonial Service rose from 372 to 1661 even as it disintegrated. Taxation: as it goes up → less returns as avoidance up → more bureaucracy or coercion → inflation. But hierarchical specialization common everywhere, including in private sector, since complex organizations need ever more admins because more complexity needs greater quantities of info processing and integration of disparate parts.
- Overall economic productivity. Growth / convergence highest in middle-income countries; at high end, hard to achieve fast growth. (PS. Key is fuel. Practically no bulk output growth per capita from 1970's to 2008 in US).
- **Explaining declining marginal rates in complex societies.** For agriculture – high value / low effort nutritional foods / concentrated ores exploited first; after that comes more intensive cultivation, remoter, dispersed minerals, oil, etc. Info processing – general education most useful and cheapest; specialized costlier, useful for narrow spheres and costs spread across society.
- Same with R&D, constant climb up shoulders of giants and more, harder questions posed than those answered, occasional trackbacks through scientific revolutions (PS. Which are like new economic techniques, like coal); arguments about how despite rise of R&D sector, current costlier work is less important than great original discoveries (PS. Rejoined – but major paradigm shifts occurring much more rapidly); (PS. Tongue in cheek – is Tainter's book unimportant?); “Planck's Principle of Increasing Effort” - “with every advance [in science] the difficulty of the task is increased”, can no longer make discoveries by peering into homemade microscopes or flying a kite in a thunderstorm. (PS. AI, IT, cellular automata). “*Exponential* growth in size and costliness of science, in fact, is necessary simply to maintain a *constant* rate of progress”. Rescher: “In natural science we are involved in a technological arms race: with every 'victory over nature' the difficulty of achieving the breakthroughs which lie ahead is increased”.
- Control and specialization essential to complexity: a) bureaucracy increases, b) more specialization in them, c) cumulative nature of organizational solutions, d) more taxation, e) more costs of legitimization, f) more costs of internal control and external defence. Arms spiral → greater costs in admin/R&D, no benefits – just balance of power. (PS. Hence now addition of still marginally improving electronic systems to hulks / platforms is key multiplier). Exponential growth in complexity, usually (PS. Expectations / legitimization). Taxes, regulation → search for loopholes → more regulation, etc. Summary: growth in complexity self-sustaining → more taxes, energy → declining marginal returns → legitimization demands never decrease (bread and circuses, defence, agriculture, public works). (PS. E.g. see US inability to decrease spending – political capital).
- Growth rates – less for rich countries as all low fruits are picked, must carve new path (PS diffusion increased, education – see notes). But also plight of declining marginal productivity in advanced societies leave less resources for growth? - if less in agriculture, minerals / energy, science / education / info processing, upkeep of capital stock and defence → proportion of budget needed for future growth declines. (PS. See growing energy needed just to maintain industrial civilization, credit explanation how growth is necessary).

**Explaining collapse.** General process: systematic increase in complexity → regulation of



subsistence production → hierarchy, bureaucracy and agricultural facilities investment (irrigation) → agriculture for bureaucrats, more energy / minerals extraction → expanded military for protection → even more food and resources → more resources drained from support population → ever increasing demands on legitimization → if it fails, needs more coercion → more internal policing costs → disillusion / delegitimization as taxes up, corruption up, infrastructure decays, no visible benefits → decomposition becomes optimal option → stresses, fragility, drawdown of reserves → catastrophic event (invasion, climate shift, etc) → collapse to lower, more local and balanced, level of sociopolitical complexity. Peasantry and regional magnates become apathetic to wellbeing of central powers and don't resist invaders (Roman, Byzantine Empires).

- So complexity rises to provide benefits (food security, peace, elite fun, order, defence, public works, etc) and increasing marginal returns, but since it is self-sustaining process is tips over to a point where there are decreasing marginal returns on it, and collapse or sublation (as with England and coal). “At some point in the evolution of a society, continued investment in complexity as a problem solving strategy yields a declining marginal return”.
- Curve for marginal return for complexity is  $\cap$ -shaped. Between declining returns and peak, increased adversity and dissatisfaction – ideological strife (growth and no-growth), system is “scanning” for solutions / alternatives to collapse (new Roman religions, now R&D, education, taxes, inflation, green / efficiency technologies, etc). After peak, you have: serious danger of decomposition (US now?), rebellions / wars weaken it. On downslope, scanning ceases as surplus production for research, etc, disappears; rigid behavioral controls imposed. (PS. Role of Ideology / Religion – growth, complexity, etc was always good before – why is it bad now?)
- Conclusion: Today we have institutionalized technical innovation, unlike in ancient societies, responding to market forces. But it faces declining marginal benefits on investment – societies need a new energy subsidy when marginal productivity starts dropping (or territorial expansion, if old agricultural civilization). Energy subsidy temporarily raises marginal productivity, but will consequently decline again. (PS. Korotayev secular cycles – more prolonged and less severe over all history). Empires follow logistic growth in territorial size (miles of border to defend, internal pacification costs, travel distance between capital and frontier, competitors). Temporary energy subsidy wears off as conquered peoples assimilated – next stage of conquest is more expensive.

## 5. Evaluation: Complexity and Marginal Returns in Collapsing Societies

- Thesis: marginal productivity of complexity curve in action – first, more complexity to relieve stress or seize opportunity is rational with favorable marginal return. Stresses, challenges and costliness of sociopolitical intergration lower the return – embedded spiralling of costs in complexity. As marginal return declines, complexity yields lower benefits at higher costs. Without new energy subsidy or new paradigm, society stagnates and becomes more vulnerable to chaotic / random catastrophes which it is now too weak and impoverished to meet. Collapse becomes ever more certain as it plummets down on curve.
- Thesis to be tested on three cases – Western Roman Empire, Classic Maya and Chacoan Society.
- **Collapse of Western Roman Empire.**
- Early conquests were self-financing – provinces looted of surpluses, Romans didn't have to pay taxes, tributary system; ended with Octavian's conquest of Egypt. Augustus stopped policy of expansion (continued under Principate, to Diocletian) and concentrated on maintaining stable army, restoring prosperity.
- End of geographic expansion → drop in windfalls of conquests; shortages of revenue already under

Augustus, introduced 5% unpopular tax on inheritances and legacies (for military retirement). Major expenses were army (pay, rations, fodder), civil service, state employees (e.g. later workers in Imperial arms factories), public works, postal, education, public dole. Revenue stagnated, but concrete benefits in form of Pax Romana, commerce, public works.

- Agriculture accounted for 90% of economy; trade and industry not important due to prohibitive expense of land-based transport (less costly to ship grain across entire Mediterranean than cart it 120km) – hence key role of Egypt to feeding the Empire (but famines in landlocked places were impossible to relieve). Only long distance trade was in luxury goods.
- Empire supported expenses, but not crises. Little borrowing. Costs rose – Roman revenues from 500,000 sesterces in middle of Augustus reign to 1,200,000 to 1,500,000 under Vespasian; very little budget planning, taxes at fixed rates and hard to raise quickly; from Nero in 64AD, Emperors began debasing the currency (silver denarius) – first from 91.8% under Nero (54-68), went to 80% under Antoninus Pius (138-161) and 58.3% under Septimius Severus (193-211) – see graph. Trajan's conquests unprofitable; Hadrian retrenched; Antininus Pius spent wisely; Marcus plague / Germanic wars depleted all previous surplus. Military growth – from 25 legions under Augustus, to 30 under Vespasian, to 33 legions at end of Severan dynasty in 235 (PS. check size of Roman military). Soldiers pay increased from 225 denarii under Augustus to 300 under Domitian and to 750 denarii in 235 at end of Severus Alexander – Matting “The expenses of government were steadily increasing out of proportion to any increase in receipts and the State was moving steadily in the direction of bankruptcy”. Roman dole increased, including oil under Septimius Severus. Massive inflation; bands of military deserters by Severans (180-235).
- 235-284 was unparalleled crisis. Foreign / civil wars, barbarian incursions, devastation of provinces, growing bureaucracy and army, financial exigencies, more taxes, currency debasement, inflation – MacMullen, “So extensive and complex was the unraveling of the empire's power to defend itself, it strained every power of comprehension”. Literacy / science fell (as did detailed records, censuses, etc) to be replaced by “increase in mysticism, and knowledge by revelation” as well as “increased propaganda about patriotism, ancient Roman values, and superiority over the barbarians”. Emperors ruled for months at a time / usurpers, regicides. *Emperor's rule required support of the military*, so needed legitimization and money; in 260's, 270's subsidized food and Egyptian cities added to the dole. Periods of regional independence and revolts; lawlessness and banditry; brigands, Bagaudae. Government costs rose for dole, cities, army, storage / roads / palaces; despite more spending, civil services declined and buildings fell into disrepair → further taxes and currency debasement.
- Inflation: hurt fixed incomes (government); currency debasement → State needed forced labor (Aurelian's conscription of craft associations to build walls around Rome) and economy in kind (form of supplies directly used by the military / government, or in bullion). Barbarian incursions, esp 248-268; rural plight; Roman armies sapped by inflation and reduced to pillage themselves. Abandonment of frontier provinces. Wall and fortresses.
- Plague 166-180 depopulation, no recovery due to invasions, inflation and instability; further plague 250-270. Commerce declined. Aurelian reformed coinage, reattached lost provinces and repelled barbarians (270-275); order obligatory farming of land by drafting nearby villages and towns into agricultural forces. Further chaos, then sweeping, stopgap reforms under Diocletian (284-305).
- New Empire of Diocletian and Constantine had larger, more complex, organized government with bigger, more powerful military forces; more taxes, conscription and regulation; coercive, omnipresent, organization subduing individual interests and “levied all resources to one overarching goal: the survival of the state” (PS. Russia! - 3<sup>rd</sup> Rome).
- 1: Army at 300,000 under Severans; 400,000 under start of Diocletian; 500,000-600,000 under

Diocletian and Constantine; 650,000 at end of 4<sup>th</sup> C. Diocletian built networks of strategic roads and fortresses along frontiers; Constantine focused more on central, mobile striking force with more cavalry. Better quality as most now professionals, rather than civilians with commissions. (NATO, Russia today, etc).

- 2: Admin. Under Diocletian, Tetrarchy of separate Emperors with subordinates called Caesars. More bureaucracy, smaller provincial units (to dissuade revolt), state military factories, state transport, segmented and specialized bureaucracy. Continued dole and public works; and Constantinople. Constantine embraced Christianity for legitimization; Emperor divine-sanctioned, focus on symbols of power (diadem, mantle, scepter, orb) not personality, to disguise increased authoritarianism of Imperium now called Dominate.
- Salaries for bureaucrats remained lower than in 2<sup>nd</sup> C, even accounting for new practice of payments in kind; not big burden. Military spending is heavy burden, esp with shift to cavalry. Taxes and very high inflation continued increasing (Diocletian – innovation of gearing tax rates to estimated expenditure), despite price controls (301 Edict on Prices – set them too low, rigged in favor of creditors and the government). Population remained depressed after plagues and chaos of 2<sup>nd</sup>, 3<sup>rd</sup> centuries → supporting more military / bureaucrats. Agricultural labor scarce so landowners (still influential) bribed vagabonds to enlist instead. Height requirements lowered, barbarians enlisted, by late 4<sup>th</sup> C even slaves enlisted. In 315 Constantine ordered assistance to poor children and orphans in attempt to reverse demographic trend (PS. Modern Europe, Russia).
- Trends. Conscription, and soldier's sons frozen into father's occupations as well as amongst civil servants, government factories. Distinction between private and public blurred as State directed persons into occupations and levied their output. As very wealth had by now fled towns to country villas or obtained exemptions, this burden fell mostly on middle income segment. Agricultural labor tied to soil – serfdom, tenants bound to large estates / colonate, a boon to large land owners in time of labor shortage. Abandonment of arable land and concern about it.
- Why abandonment? Expls – soil exhaustion, labor deficiency, barbarian raids (not satisfactory as Nile soil renewed annually by Nile but declined as elsewhere). **Taxes** → high before Dominate, doubled from 324 to 364. Flat, unresponsive rates and rigid; not progressive penalizing poor and large families; wealthy bribed to get their land under-assessed and passed on costs → peasants have no reserves, so if shock like droughts, barbarians or locusts, they borrow or starve → dispossession by creditors, tenancy, serfdom → had to sell crops for taxes → farmers suffered first from famine and flocked to cities for relief (PS. Hence movement controls?).
- Very high taxes; unvarying taxes however poor the harvest; couldn't meet taxes → jail, old children into slavery, left the land; no large families → farm abandonment and concentration in richer areas. Appropriation of landed endowments of cities. Rigid control of individuals and their output – each citizen / guild / locality expected to produce essentials for imperial survival. It survived a cost of abandonment of land, declining agricultural yields, depopulation of country and impoverishment of city. Different occupations fought for personnel, so military declined until barbarians were relied upon entirely to staff the army – Attila defeated in Gaul in 451 by federation of local Germanic kingdoms.
- Taxes continued to be crushing – especially in the West; forced to increase them despite knowing that they would be devastating. After 395 agricultural breakdown in the West. Records indicate both rich and poor apathetic or sympathetic to barbarians (378, Balkan miners en masse went over to Visigoths); gov't forced to make up grain deficits in frontier provinces. RM Adams: “By the fifth century, men were ready to abandon civilization itself in order to escape the fearful load of taxes”. Dwindling tax revenues, barbarians more successful – in 439 Vandals took Carthage, supplying

grain to Rome → breakdown in civil services). After Valentinian III (455), Roman Army dwindled to nothing – only Italians and barbarians; couldn't pay them, refused settlement in Italy, so they mutinied, elected Odoacer King and deposed Romulus Augustus, last Western Emperor, in 476.

- **Assessment of Roman collapse.** (PS. Like Civilization game). Roman conquests highly successful and self-financing – from middle of 3<sup>rd</sup> C BC. Yet high marginal return not sustained – Persia too powerful (Trajan's successes abandoned by Hadrian) and poor regions (Germans). Furthermore, logistics and transport power sea-based (mare nostrum) and impotent beyond the capital and Mediterranean regions. Under Augustus size capped: Claudius Britain and Dacia Trajan conquest didn't pay for themselves. Third, for one time transfer of accumulated surpluses costs of administrating, garrisoning and defending permanently incurred – Spain and Macedonia took more than gave. Under Principate
- From Augustus, Empire faces fiscal problems at times of stress surges – response was selling capita, debasing currency (deferring costs) and raising taxes. Devastating effects on support populations to support expanded bureaucracy and army. By 4<sup>th</sup> and 5<sup>th</sup> C, Empire sustained itself by consuming its capital resources – land (barbarians, depopulation) and people (demographics) → “Where under the Principate the strategy had been to tax the future to pay for the present, the Dominate paid for the present by undermining the future's ability to pay taxes”. Marginal returns, decreasing average, terminally hurt by stress surges, some overtaxed peasantry welcomed barbarians – the end as people fight over shrinking economic pie. Replacement by them → (venerated Rome, tried to carry on few traditions for few decades), lower admin / military costs, Africa prosperity improved under the Vandals until Justinian's reconquest. West weaker, poorer, more vulnerable than the East. Gov't attempts at renewal, growth (aid to children), reclaim abandoned land, etc, unsuccessful → dark age in complexity, art, etc. (PS. Digital dark age; comparisons to late USSR, current USA, North Korea (lots of coercion; transition to feudalism)).
- **Assessment of Mayan collapse.** Maya – high density, stressed, intensive agriculture, living in political centers, elite class, public works and war. Low topography / no economic diversification and opportunities for symbiosis / “energy averaging”, so war / conflict – raids on fields and storage facilities → military hierarchy, economic stratification → intensification of agriculture for easier defence → population growth for manpower, spiral to oblivion. Centers feature art showing torture of prisoners for propaganda (in absence of real military strength, unlike Romans) – signs of strength for attracting minor centers, monuments to display power. Subsistence crisis by the Classical period; females not as affected as males, presumably because of emphasis on population growth.

## 6. Summary and Implications

- summary. Decreasing returns to complexity; need to invest more into it just to preserve status quo (see runaway costs); stresses that a younger, expanding society could brush off (Rome during Punic wars) can permanently main older society; late 3<sup>rd</sup> century barbarian invasions actually more dangerous than those of first decade of 4<sup>th</sup> C. “At some point along the declining portion of a marginal return curve, a society reaches a state where the benefits available for a level of investment are no higher than those available for some lower level” → potential gap, collapse.
- **Collapse and declining productivity of complexity.** Loss of art, literature, protection, peace, etc often seen as catastrophic; but it is *economizing* process (Romans aiding barbarians). Population collapse ambiguous, but usually actually preceded collapse (Rome: in mid 2<sup>nd</sup> C). (PS. Modern empires solve problems not through territorial expansion, but through energy subsidies – what happens when they run out?). But bad for bourgeois elite, historians, etc – those who can't produce

primary food surpluses.

- **Further implications of declining marginal returns.** “In competitive, or potentially competitive, peer polity situations the options to collapse to a lower level of complexity is an invasion to be dominated by some other member of the cluster...investment in organizational complexity must be maintained at a level comparable to one's competitors, even if marginal returns become unfavorable” (Maya states, European states). For Renfrew: “The specific state is legitimized in the eyes of its citizens by the existence of other states which patently do function along comparable lines”.
- More on peer competitors: peasant political actions aims at *reformation*, not *decomposition* → democracy for better return on organizational investment (participatory government); but in Warring States China, led to ideology of good government and protection of populace to receive Mandate of Heaven.
- “Collapse occurs, and can only occur, in a power vacuum”. Also why Byzantine Empire didn't collapse – presence of Sassanian Empire, but why Mayans and Mycenaeans collapsed so comprehensively.
- **Suggestions for further applications.** Analysis extended to other collapse cases: Chou China – barbarians, increasing costs of integration and containing stress surges typical for all Chinese dynasties. Old Babylon – loss of dependencies under Samsuiluna, but attempt to retain former level of administration; marginal returns decline automatically when smaller land area / population governed with former bureaucracy (its own vested interests). Note: though collapsed, new empires can build up on the bones of fallen ones to get higher complexities. Ik – huntergatherers → minimal foraging units, like families, when stress makes large gathering impossible (150).
- **Declining marginal returns and other theories of collapse.** Resource depletion – choice between decomposition and further intensification (English coal); if latter too apparently costly, then former. Catastrophes = irrecoverable shocks that deligitimize and demonstrate that lowering complexity is good idea. Intruders = more powerful, complex state can't prevail against simpler ones if complex one is at / beyond peak of marginal returns on complexity and fragile, and simple ones invest only in high-return military ventures. Mysticism / elite mismanagement – rulers look good when empire is good, vice versa, whatever they do; circumstance-induced perceptions of vigor and decadence.
- **Contemporary conditions.** (PS. US imperium; armies; inflation / taxes / spending and entrenched thoughts, ideologies). Scanning behavior – survivalism. Decline in marginal returns in – agriculture, minerals, energy, health and education investment, education, gov't / military / industrial management, productivity of GDP for producing new growth, some elements of technical design + current practice, budget deficits tax future and emissions undermine ability of future to pay taxes (BUT, info techs are subject to law of *accelerating* returns and are present in ever more products – this is our opportunity for intensification, PERHAPS).
- More R&D? Itself subject to diminishing returns, as is substitution and environmental. BUT we are peers, so deindustrialization will lead to takeover (US should be example – nuclear forces and small, mobile military). Paul Valéry: “...nothing can ever happen again without the whole world's taking a hand”. (PS. Today more and more failed states, burden; predicted to continue). Also, today evolutionary processes / collapse take place much quicker. Marginal pattern for overall investment began in early 20<sup>th</sup> C – Peter Sorokin; I think it was 1970's discontinuity. Lack of power vacuum postpones collapse but makes it more brutal.
- Recommends massive investment shift into new energy sources, shared by all (fusion!). (PS. Though discontinuity in 1970's, since has been mitigated by energy efficiency, credit and freeing up of economies)

### Comparison – cleaning a room.

Buildup of layers and parasites and organization falls apart. Clear out the trash in paroxysm of despair after struggle to keep it orderly. Start over. Laws of Thermodynamics suck etc.

### Comparisons with Soviet collapse

Dependence on foreign grain, and oil exports for investment, capital, debt service. Unsustainable increase in complexity, and ability of central planning to set so many prices despite all innovations in linear algebra. Delegitimization of the system, spiralling spending on arms; relaxation on internal security (North Korea remained intact! since they're cultlike, totalitarian – though anecdotally, a demoralized nation). Once freed up, fell sharply to lower equilibrium level – I.e. hyperdepression and 40% fall in Russian GDP. Depopulation, collapse, crime and anarchy, fall of empire, banditized police and military,

### Comparison with North Korea

Industrialization complete by 1970's; then military spiral, dependence on foreign aid. Reversion in 1990's to lower level; transition to more stable system of feudalism, albeit huge spending on legitimization (helped by peer system) and coercion.

### Comparisons with USA

Growth slowed down in 1970's after oil shocks. Prison population exploded, continuing spirals in finance, bureaucracy, healthcare, etc. Legitimization through more overt imperial symbology. Growth driven by credit, and now will tax future to support present through inflation. Undercutting future by resource depletion and pollution (the entire world that is). Declining returns to complexity, average peaked in 2000's? (incomes that is). Slowdown in marginal returns in 1900, peak marginal returns in 1970 – since then declined. Rising inequality, elite parasitism.