

# **Venture Capital and the Economics of Innovation**

Lecture 1:

Investing at the Technological Frontier

# Theme of this Course...NOT!

**“The only thing that matters is the future,”** he told me after the civil trial was settled. “I don’t even know why we study history. It’s entertaining, I guess—the dinosaurs and the Neanderthals and the Industrial Revolution, and stuff like that. But what already happened doesn’t really matter. You don’t need to know that history to build on what they made. **In technology, all that matters is tomorrow.”**

Anthony Levandowski, quoted by Charles Duhigg. “Stop, Thief,” *New Yorker*, October 22, 2018.

# Economic Growth as an Evolutionary Process: I

“Different abilities to innovate and imitate are central aspects and drivers of industrial evolution, shaping the patterns of growth, decline and exit over populations of competing firms, as well as the opportunities of entry of new firms....evolutionary processes driven by the twin forces of (**often mistake-ridden**) idiosyncratic learning by persistently heterogeneous firms...and (**imperfect**) market selection delivering prices and penalties – in terms of profits, possibilities of growth, and survival probabilities – across such heterogeneous corporate populations....”

(G. Dosi and Nelson, R.R., “Technical Change and Industrial Dynamics as Evolutionary Processes,” in B. Hall and Rosenberg, N. (eds.) *Handbook of the Economics of Innovation* (Amsterdam, Elsevier, 2010) p. 113)

# Economic Growth as an Evolutionary Process: II

**“We have...here the basic ingredients of an evolutionary interpretation of economic growth and development.** Such an evolutionary account...would highlight the significant differences in the rates of progress at any time across different technologies and industries....[A]n important underlying variable seems to be the strength of the scientific fields that illuminate the technologies used in an area of practice....[P]rogress within a field of technology tends to become more narrowly focused and to slow down as the technology matures. **While repressed in neoclassical growth theory, the process of economic growth as we have historically experienced it has been driven by the continuing introduction of new products and new technologies, and the continuing shifting of resources from older industries where the rate of advance has slowed down to new industries....”**

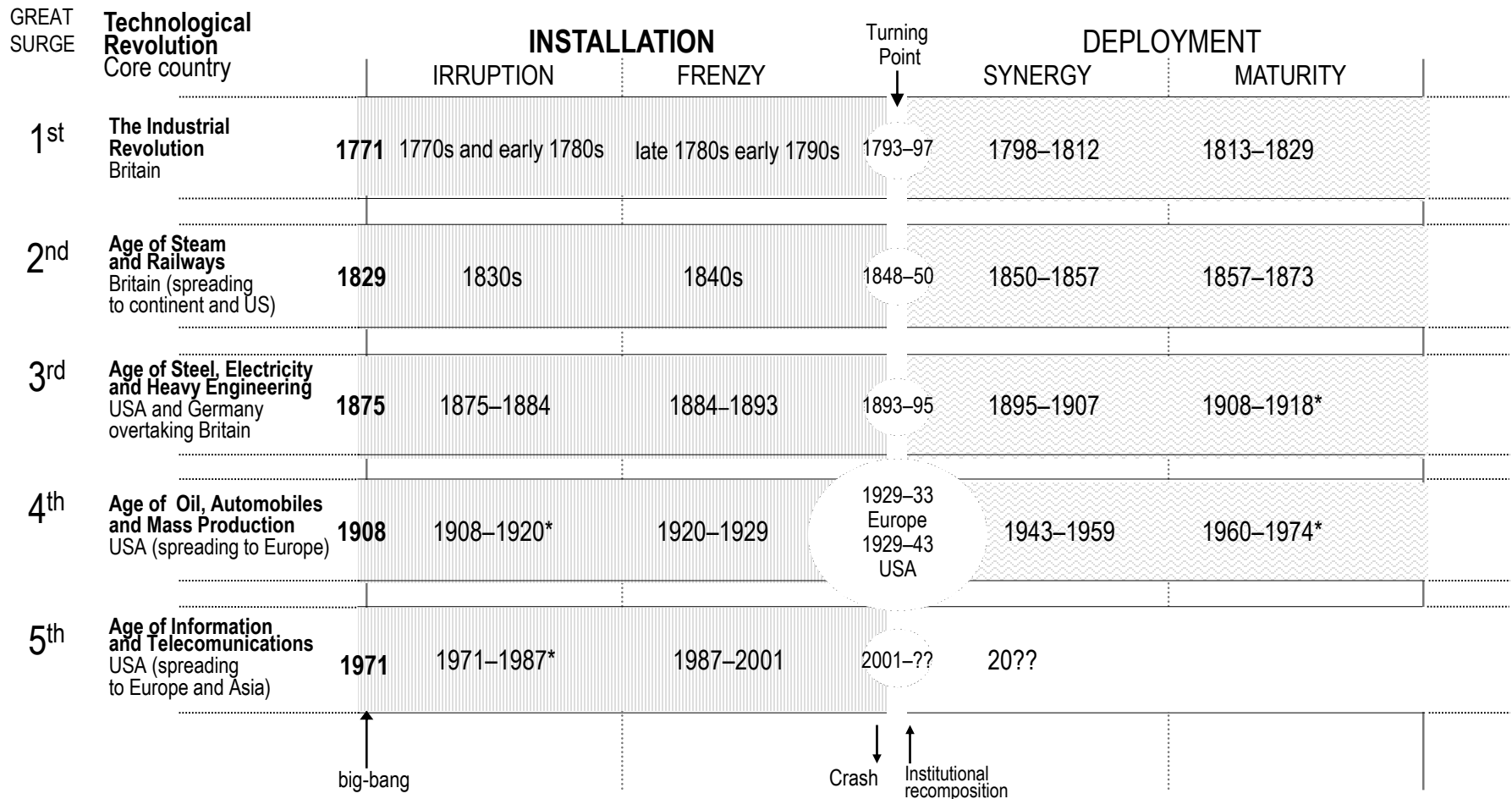
(Dosi and Nelson, p. 112)

# Technology Paradigms and New Economies

“A full evolutionary account of economic growth would also take into account that **the historical time path of growth tends to be punctuated by “eras” characterized by the development and diffusion of specific constellations of “general-purpose” technologies, that is broad techno-economic paradigms....** During a particular economic era , much of the economic growth is accounted for by innovation and productivity growth in the industries that produce the goods that directly incorporate the driving technological paradigms and also in the downstream industries that are able to use these goods as inputs (historically this was the case of **steam power**, later **electricity** and the **internal combustion engine** today it is the case of **ICT technologies**.)”

(Dosi and Nelson, p. 113)

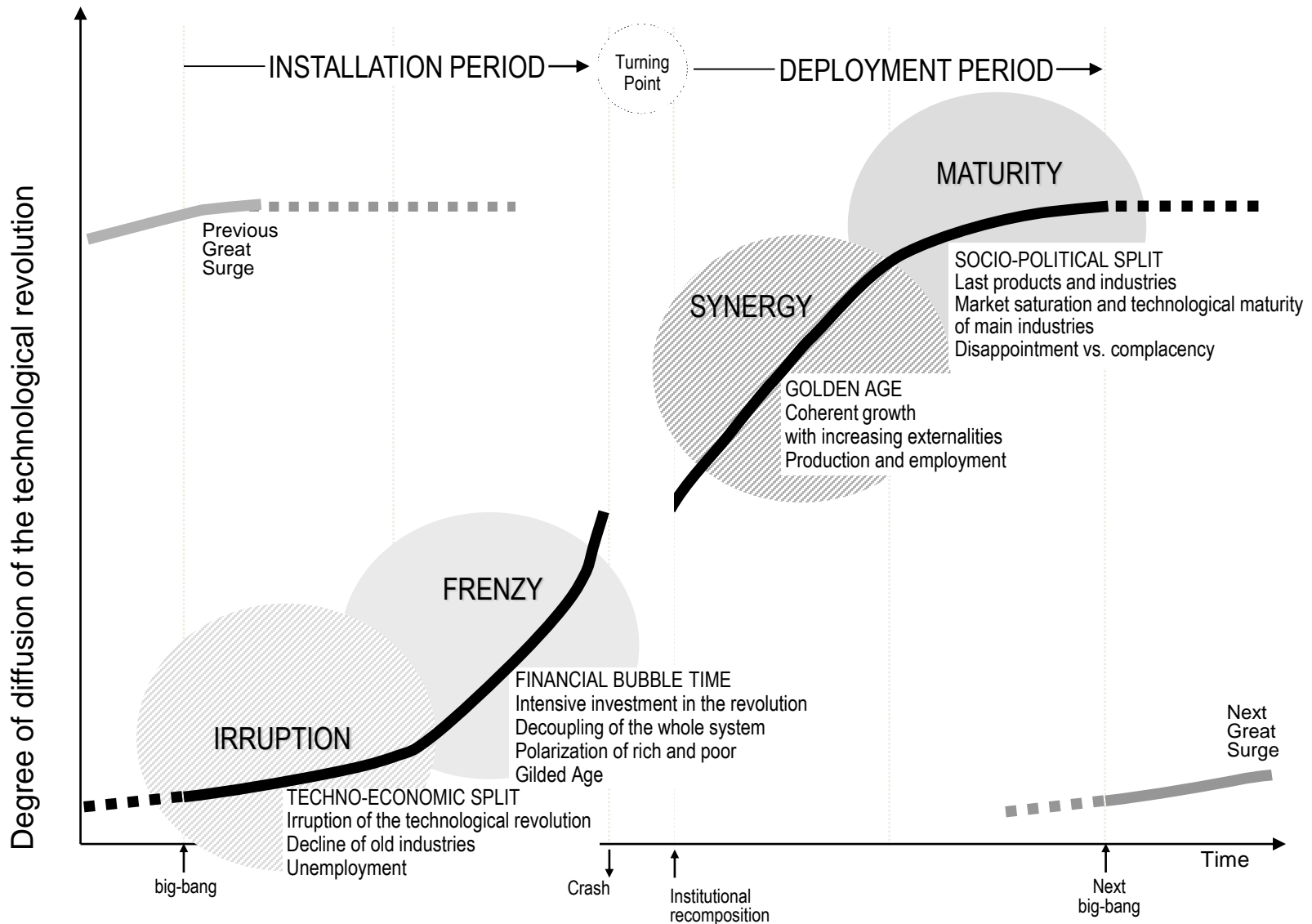
**Figure 5.2** *Approximate dates of the installation and deployment periods of each great surge of development*



Note: \* Observe phase overlaps between successive surges.

# Recurring Phases of Each Great Surge

(C. Perez, *Technological Revolutions and Financial Capital*, Table 2.1)



# Keynes on Uncertainty

**“By ‘uncertain’ knowledge’...I do not mean merely to distinguish what is known from what is merely probable....**The sense in which I am using the term is that in which the prospect of a European war is uncertain, or the price of copper and the rate of interest twenty years hence, or the obsolescence of a new invention, or the position of private wealth owners in the social system in 1970. About these matters there is no scientific basis on which to form any calculable probability whatever. **We simply do not know....”**

(J. M. Keynes, “The General Theory of Employment,” *Quarterly Journal of Economics*, February 1937 in E. Johnson and D. Moggridge (eds.), *The Collected Writings of John Maynard Keynes*, vol. XIV, pp. 112-3.)



# Gaddis on Continuity and Contingency

**“The trouble with the future is that it so much less knowable than the past. Because it lies on the other side of the singularity that is the present, all we can count on is that certain continuities from the past will extend into it, and that they will encounter uncertain contingencies.** Some continuities will be sufficiently robust that contingencies will not deflect them: time will continue to pass; gravity will continue to keep us from flying off into space; people will still be born, grow old, and die. **When it comes to the actions people themselves choose to take, though – when consciousness itself becomes a contingency - forecasting becomes a far more problematic exercise.”**

(J. L. Gaddis, *The Landscape of History: How Historians Map the Past* (New York: Oxford University Press, 2004), p. 56.)

# Uncertainty and “The Convention”

- “The outstanding fact is the extreme precariousness of the basis of knowledge on which our estimates of prospective yield have to be made . . .** If we speak frankly, we have to admit that our basis of knowledge for estimating the yield ten years hence of a railway, a copper mine, a textile factory, the goodwill of a patent medicine, an Atlantic liner, a building in the City of London amounts to little and sometimes to nothing; or even five years hence....
- “In practice we have tacitly agreed , as a rule, to fall back on what is, in truth, a convention. The essence of our convention...lies in assuming that the existing state of affairs will continue indefinitely, except in so far as we have specific reasons to expect a change.** This does not mean that we really expect the existing state of affairs to continue indefinitely. We know from extensive experience that this is most unlikely. The actual results of an investment over a long period of time seldom agree with the initial expectation....
- “Nevertheless the above conventional method of calculation will be compatible with a considerable measure of continuity and stability in our affairs, so long as we can rely on the maintenance of the convention.”** (Keynes, *The General Theory*, pp. 149-50, 152)

# Risk, Uncertainty and Ignorance

	<b>Knowledge of States of the World</b>	<b>Investment Environment</b>	<b>Skills Needed</b>
<b>Risk</b>	Probabilities known	Distributions of returns known	Portfolio optimization
<b>Uncertainty U</b>	Probabilities unknown	Distributions of returns conjectured	Portfolio optimization, Decision theory
<b>Ignorance UU</b>	States of the world unknown	Distributions of returns conjectured, often from deductions about other's behavior. Complementary skills often rewarded along side investment	Portfolio optimization. Decision theory. Complementary skills (ideal) Strategic inference.

(R. Zeckhauser, "Investing in the Unknown and Unknowable," *Capitalism and Society*, Vol. 1: Issue 2, Article 5 (2006), p. 3)

# Unknown, Unknowable and Unique

- “Many UU situations deserve a third U, for unique.** If they do, arbitrageurs – who like to have considerable past experience to guide them – will steer clear. So too will anybody who would be severely penalized for a poor decision after the fact. An absence of competition from sophisticated and well-monied others spells the opportunity to buy underpriced securities.
- “Most great investors, from David Ricardo to Warren Buffett, have made most of their fortunes by betting on UUU situations.** Ricardo allegedly made 1 million pounds (over \$50 million today) – roughly half of his fortune at death – on his Waterloo bonds. Buffett has made dozens of equivalent investments.”

(Zeckhauser, p. 7.)

# Schumpeter: The Process of Creative Destruction

**“The essential point to grasp is that in dealing with capitalism we are dealing with an evolutionary process....**

“...The fundamental impulse that sets and keeps the capitalist process engine in motion comes from the new consumer goods, the new methods of production and transportation, the new markets, the new forms of industrial organization that capitalist enterprise creates.

**“...This process of Creative Destruction is the essential fact about capitalism.** It is what capitalism consists in and what every capitalist concern has got to live with....”

(Schumpeter, *Capitalism, Socialism and Democracy*, pp. 82-3)

# Schumpeter: The Nature of Competition

“Even when ‘price competition’ is supplemented by ‘quality competition and sales effort’, ...it is still competition within a rigid pattern of invariant conditions, methods of production and forms of industrial organization...But in capitalist reality as distinguished from its textbook picture, it is not that kind of competition that counts but **the competition from the new commodity, the new technology, the new source of supply, the new type of organization**...- competition which commands a decisive cost or quality advantage and **which strikes not at the margins of the profits and the outputs of existing firms but at their foundations and their very lives.**”

(Schumpeter, *Capitalism, Socialism and Democracy*, p. 84)

# Schumpeter Mark I

**“We visualize new production functions as intruding into the system through the action of new firms founded for the purpose,** while the existing or ‘old’ firms for a time work on as before, and then react – with various characteristic lags and in various characteristic ways – adaptively to the new state of things under **this pressure of competition from downward shifting cost curves.**”

**“...We will assume that innovations are always associated with the rise to the leadership of New Men.”**

(Schumpeter, *Business Cycles*, vol. I, pp. 95-6)

# Schumpeter Mark II

**“Technological progress is increasingly becoming the business of teams of trained specialists** who turn out what is required and make it work in predictable ways....

“...[P]ersonality and will power must count for less in environments which have become accustomed to economic change...and which, instead of resisting accept it as a matter of course....

**“The perfectly bureaucratized giant industrial unit not only ousts the small or medium-sized firm and ‘expropriates’ its owners, but in the end it also ousts the entrepreneur....”**

(Schumpeter, *Capitalism, Socialism and Democracy*, pp. 133-4)



# Schumpeter and the State

**“What we know from experience is not the working of capitalism as such, but of a distorted capitalism which is covered with the scars of past injuries inflicted on its organism.... Everywhere we find industries which would not exist at all but for protection, subsidies and other political stimuli....**Such industries are assets of doubtful value, in any case a source of weakness and often the immediate cause of breakdowns or depressive symptoms. This type of economic waste and maladjustment may well be more important than any other.”

(Schumpeter, *Business Cycles*, vol. I, p. 13)

# The Post-WW II US Innovation Economy

“In summary, **the innovation ecosystem that emerged after World War II saw a sustained growth of the research university sector, spurred by the infusion of federal funding. Throughout this period, corporate labs maintained high-caliber scientific personnel and made complementary investments in instrumentation and experimental equipment.** This helped firms to readily absorb the newest scientific developments and accommodate university scientists in their labs. During this time, corporations were also, perhaps unfairly, often blamed for failing to exploit the many inventions created in their labs. **As research universities continued to expand, corporations' ability to source inventions from outside also grew. These changes made it increasingly difficult for firms to justify large investments in internal research.** A drastic transformation of the American innovation ecosystem ensued, beginning in the last quarter of the twentieth century.”

(Ashish Arora, Sharon Belenzon, Sharon, Patacconi, Andrea, and Suh, Jungkyu , “The changing structure of American innovation: Some cautionary remarks for economic growth,” NBER Working Paper 25893, August 2019, p. 19)

# Schumpeter Mark III?

**“The new innovation ecosystem is characterized by a deepening division of innovative labor between universities and corporations, with the former focusing on research and the latter dedicating their efforts to development....**

“The withdrawal from science by large corporations resulted from the confluence of several factors. **As competition intensified and the interval between invention and commercialization narrowed, it became increasingly difficult for corporations to profit from their in-house research....**This intuition is supported by the results in Arora et al. (2017) who further document that spillovers to rivals have greatly increased between 1980 and 2015.

“Large firms also started to invest less in internal research...because **tapping into external sources of knowledge and invention became increasingly easy. Historically, many large labs were set up partly because antitrust pressures constrained large firms’ ability to grow through mergers and acquisitions....The more relaxed antitrust environment in the 1980s, however, changed this status quo.** Growth through acquisitions became a more viable alternative to internal research, and hence the need to invest in internal research was reduced.

**“The growth of university research likely also contributed to the ease of external knowledge acquisition.** Corporate labs historically operated in an environment where university research and start-up inventions were scarce. To generate a steady flow of high-quality inventions, large firms had to develop them in-house, typically by setting up a large lab. As discussed above, however, universities and small firms became over time more reliable sources of invention.”

(Arora, et al., “Changing Structure,” pp. 19, 32-3)

# Schumpeter Mark I and II Revisited

“[W]e make a distinction between **two types of R&D that firms undertake: exploration and exploitation**. Firms undertake exploration R&D to create new products and capture leadership in markets. On the other hand, firms undertake exploitation R&D to improve product lines that they are currently serving...

“We show that our model matches many known empirical facts regarding the firm size distribution such as the high skewness of the distribution. Moreover, our model has sharp predictions on some long-standing debates: It predicts that small firms grow faster and that their R&D to sales ratio is higher than large firms on average. These two predictions are strongly supported by our data for the recent US economy. ...[W]e show that the relative rate of major inventions is higher in small firms and that the exploitation innovation share is higher in large firms. We demonstrate that these distributional differences are not due to differences in research capabilities or technologies, but are instead an outcome of R&D investment choices by firms.

“[W]e find that **growth spillover effects are larger from exploration R&D than exploitation R&D...Our model identifies a comparative advantage for new entrepreneurs and small firms in undertaking exploration innovation due to increased managerial attention of large firms on refining their existing product lines....[S]mall firms and new entrants also yield greater spillovers, in a relative sense, into economic growth due to these forces.**”

(U. Akcigit and Kerr, W. R., “Growth through Heterogeneous Innovations,” NBER Working Paper No. 16443, November 2010, p. 2, 3)

# “Exploration” Innovation and Small Firms

“One important implication of the model is that **small firms, and especially new entrants, have a comparative advantage for undertaking exploration R&D**. This is very natural as large firms have many product lines to concentrate on. This framework rationalizes why small, entrepreneurial firms contribute disproportionate numbers of major innovations. Moreover, the predicted distributional patterns line up with the data.

“Another important implication emerges from patent citations. By incorporating patent citations behavior into our model, **we derive a simple test as to whether the growth spillover effects across firms are higher for exploration or exploitation innovation. For the recent US economy, we find that the external impacts of exploration innovation on other firms exceed exploitation innovation**. This in turn suggests that small, innovative firms and new entrants play a special role in economic growth due to these spillovers.”

(Akcigit and Kerr, p. 33)

# Follower *versus* Frontier

“[A] country that starts far behind the world technology frontier can grow faster than one close to the frontier because the former country will make a larger technological advance every time one of its sectors catches up to the global frontier. **In Gerschenkron’s terms, countries far from the frontier enjoy an ‘advantage of backwardness’.** This advantage implies that in the long run a country with a low rate of innovation will fall behind the frontier, but will grow at the same rate as the frontier; as they fall further behind, the advantage of backwardness eventually stabilizes the gap that separates them from the frontier.

**“These same considerations imply that policies and institutions that are appropriate for countries close to the global technology frontier are often different from those that are appropriate for non-frontier countries,** because those policies and institutions that help a country to copy, adapt and implement leading-edge technologies are not necessarily the same as those that help it to make leading-edge innovations.”

(P. Aghion, Akcigit, U. and P. Howitt, “What Do We Learn from Schumpeterian Growth Theory,” NBER Working Paper No. 188824, February 2013, p. 20)

(SEE: A. Gerschenkron, *Economic Backwardness in Historical Perspective: A Book of Essays*, (Belknap Press of Harvard University Press, Cambridge MA: 1962).

# New Opportunities for Followers

- “The ICT revolution unleashed, and in turn has been shaped by, a constant revolution in social and market organization....Two dramatic shifts occurred: the decomposition of production and the transformation of services....**
- “Production is no longer organized in vertically integrated companies focused on home locations....**The ICT industry has been at the forefront of this transformation of the organization of work, while also producing the tools that facilitated [it]....For our purposes , decomposition refers to the geographic and organizational recasting of operations that run from actual manufacturing to research and development and strategy....
- “Services are transformed when they are converted into formalizable , codifiable, information-based processes with clearly rules and algorithms for their execution. **The algorithmic transformation of services permits routine and manual functions to be automated which...permits the unbundling of the many activities and tasks that constitute a service...**As in production, these changes facilitate outsourcing and the easy relocation of services.”

(D. Breznitz and Zysman, J. (eds.) *The Third Globalization: Can Wealthy Nations Stay Rich in the Twenty-First Century?* (Oxford University Press, 2013), pp. 4-5, 8.)

# Schumpeter and Finance

**“[R]isk bearing is no part of the entrepreneurial function. It is the capitalist who bears the risk.** The entrepreneur does so only to the extent to which, besides being an entrepreneur, he is also a capitalist but **qua entrepreneur, he loses other people’s money....**”

“...[S]ince [financial] failure primarily shows in dealing with novel propositions – where judgment is most difficult and temptation strongest – an association has developed between financing innovation and miscarriage or misconduct.”

(Schumpeter, *Business Cycles*, vol. I, pp. 104, 116)



# Share Prices and Economic Fundamentals

“[O]n average over the past century, U.S. stock prices have been three times more volatile than fundamentals . . . But the trend in the degree of excess volatility is also telling. **Up until the 1960s, prices were around twice as volatile as fundamentals. Since 1990, they have been anywhere from six to ten times more volatile.** Excess volatility in equity prices has risen as financial innovation has taken off.”

(A. Haldane, “Patience and Finance,” paper presented to Oxford China Business Forum, Beijing, September 9, 2010, p. 15, [www.bis.org/review/r100909e.pdf](http://www.bis.org/review/r100909e.pdf).)

# What is the Fundamental?

“In the vast majority of cases, the prospects of investment projects—the stream of future returns—cannot be understood in standard probabilistic terms . . . This is obviously true for investments in innovative products and processes for which estimates of returns cannot be based solely on the profit history of existing products and processes.”

(Frydman and Goldberg, *Beyond Mechanical Markets: Asset Price Swings, Risk, and the Role of the State* (Princeton University Press, 2011), pp. 41-2)

# Procedural *versus* Substantive Rationality

**“Reasonable men’ reach ‘reasonable’ conclusions in circumstances where they have no prospect of applying classical models of substantive rationality.** We know only imperfectly how they do it. We know even less whether the procedures they use in place of the inapplicable models have any merit—although most of us would choose them in preference to drawing lots. **The study of procedural rationality in circumstances where attention is scarce, where problems are immensely complex, and where crucial information is absent presents a host of challenging and fundamental research problems to anyone who is interested in the rational allocation of scarce resources.”** (H. Simon, “Rationality as Process and as Product of Thought,” *AER*, 68, no. 2 (1978), p. 14)

# The Beauty Contest

**“Professional investment may be likened to those newspaper competitions in which the competitors have to pick out the six prettiest faces from a hundred photographs, the prize being awarded to the competitor whose choice most nearly corresponds to the average preferences of the competitors as a whole; so that each competitor has to pick, not those faces which he himself finds prettiest, but those which he thinks likeliest to catch the fancy of the other competitors, all of whom are looking at the problem from the same point of view. It is not a case of choosing those which, to the best of one’s judgment, are really the prettiest, nor even those which average opinion genuinely thinks the prettiest. We have reached the third degree where we devote our intelligences to anticipating what average opinion expects the average opinion to be.”**  
(Keynes, *The General Theory*, p. 156)

# Keynes' Bridge

“The daily revaluations of the Stock Exchange . . . inevitably exert a decisive influence on the rate of current investment. For **there is no sense in building a new enterprise at a cost greater than that at which a similar existing enterprise can be purchased; while there is an inducement to spend on a new project what may seem an extravagant sum, if it can be floated off on the Stock Exchange at an immediate profit.** Thus certain classes of investment are governed by the average expectation of those who deal on the Stock Exchange as revealed in the price of shares, rather than by the genuine expectation of the professional entrepreneur.” (Keynes, *General Theory*, p. 151)

# Long Term Consequences of Recessions

“Thus, economic downturns have long run consequences. With lower expenditures on R&D and lower levels of investment and production resulting in less learning, the growth path of the economy is shifted down....”

(J. Stiglitz (1993), “Endogenous Growth and Cycles”, NBER Working paper No., 4286, reprinted in Y. Shionnoya and Perlman, M. (eds.), *Innovation in Technology, Industries and Institutions*, Studies in Schumpeterian Perspectives, Ann Arbor MI: The University of Michigan Press. )

# Social Costs of Recessions

- “**The social costs of reducing waste in the midst of a recession are greater than the private costs.** Firms see their costs reduced. But it is not as if the workers that are fired are immediately redeployed to more productive uses. To a large extent, they redeployed to a less productive use—they join the unemployment pool.
- “By contrast, **the social benefit of R&D expenditures typically exceed the private benefits:** firms seldom capture all the returns from their inventive activity. Indeed, when many firms engage in R&D activity, say enhancing the productivity of labor, wages are bid up, and much of the gain is appropriated by workers. Thus the social costs of cutting back R&D expenditures typically exceed the private costs.” (Stiglitz, p. 18)

# A Vision of the Innovation Process

**“The Innovation Economy begins with discovery and culminates in speculation.** Over some 250 years, **economic growth has been driven by successive processes of trial and error and error and error:** upstream exercises in research and invention, and downstream experiments in exploiting the new economic space opened by innovation. **Each of these activities necessarily generates much waste along the way:** dead-end research programs, useless inventions and failed commercial ventures. In between, **the innovations that have repeatedly transformed the architecture of the market economy, from canals to the internet, have required massive investments to construct networks** whose value in use could not be imagined at the outset of deployment. **And so at each stage, the Innovation Economy depends on sources of funding that are decoupled from concern for economic return.”**

(Janeway, *Doing Capitalism*, 2<sup>nd</sup> ed., P. 1)



# Financing Upstream Science

**“Upstream, when mechanical tinkering yielded to scientific discovery as the basis for economically meaningful innovation, funding initially was supplied by the great corporations...spawned by the Second Industrial Revolution toward the end of the nineteenth century. These corporations, variously supported or at least tolerated by the state, channeled a portion of their profits into central research laboratories. By the time over the past generation that their seemingly unassailable market positions were lost to competition or deregulation,.”** **a cadre of American political entrepreneurs had successfully invented national security and human health as legitimizing rationales for direct state investment in science.”**

(Janeway, *Doing Capitalism*, 2<sup>nd</sup> ed., pp. 1-2.)

# Financing Transformational Networks

**“The transformational networks of infrastructure that implement the Innovation Economy can be planned, built and funded by the state:** the US interstate highway system is an outstanding example. **They can also be planned, built and funded by the willing collaboration of promoters and speculators:** the original British railways system is the exemplar. **In each case, the calculus of expected economic return was a secondary consideration.** Hence the endless miles of superhighway crossing the empty wastes and wilderness of the American West, and the multiplication of competing routes and the destructive competition that followed hard on the British railway mania of the 1840s.”

(Janeway, *Doing Capitalism*, 2<sup>nd</sup> ed., pp. 2)

# Financing Downstream Exploration

**“Downstream, the Innovation Economy is driven by financial speculation. Throughout the history of capitalism, financial bubbles have emerged and exploded wherever markets in assets exist.** The objects of speculation have ranged across a spectrum that challenges the imagination: from tulip bulbs, to gold and silver mines, to the debt of newly established countries...and - again and again – by way of real estate and the shares that represent ownership of corporations....

**“Occasionally, decisively, the object of speculation is the financial representation of one of those fundamental technological innovations – canals, railroads, electrification, automobiles, airplanes, computers, the internet – the deployment of which at scale transforms the market economy, indeed creates a ‘new economy’ from the wreckage of the financial bubble that attended its birth.”**

(Janeway, *Doing Capitalism*, 2<sup>nd</sup>. ed., p. 2)

# The Three-Player Game

“I have come to read this history as driven by **three sets of continuous, reciprocal, interdependent games played between the state, the market economy and financial capitalism**. Through the centuries, the state and the market economy have variously collaborated and competed in the allocation of resources and the distribution of income and wealth: those who are *losers* in one arena seek opportunity for redress in the other and (not *or*) the *winners* in one seek opportunities for the extraction of economic rents in the other. And **financial capitalism stands ever ready to exploit discontinuities in market and political processes, while it depends on those same processes for its prosperity and even at times for its survival.**”

(Janeway, “What I Learned by Doing Capitalism,” pp. 5-6)