Tolerating Waste in the Innovation Economy

William H. Janeway

Cambridge University/Warburg Pincus

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WARBURG PINCUS

Economic Development through Technological Transformation

- From ~1750, waves of innovative technology have driven increases in productivity and living standards
- Transformational innovations are embodied in networks of infrastructure that create new economic space
- The process is discontinuous and disruptive, inefficient and wasteful : resources cannot be optimally allocated *in principle*
- It takes place at the intersection of the “real” economy with financial markets and institutions
- It is often sponsored and/or mediated by the state
- It expresses the essence of capitalism

Five Technological Revolutions, 1770s to 2000s

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

Technological revolution	*Popular name for the period*	*Core country or countries*	*Big-bang initiating the revolution*	*Year*
FIRST	The 'Industrial Revolution'	Britain	Arkwright's mill opens in Cromford	1771
SECOND	Age of Steam and Railways	Britain (spreading to Continent and USA)	Test of the 'Rocket' steam engine for the Liverpool-Manchester railway	1829
THIRD	Age of Steel, Electricity and Heavy Engineering	USA and Germany forging ahead and overtaking Britain	The Carnegie Bessemer steel plant opens in Pittsburgh, Pennsylvania	1875
FOURTH	Age of Oil, the Automobile and Mass Production	USA (with Germany at first vying for world leadership), later spreading to Europe	First Model-T comes out of the Ford plant in Detroit Michigan	1908
FIFTH	Age of Information and Telecommunications	USA (spreading to Europe and Asia)	The Intel microprocessor is announced in Santa Clara, California	1971

The Process of Innovation

- The Three Phases
  - Phase 1: Discovery and Invention (dependent on scientific research)
  - Phase 2: Deployment
  - Phase 3: Exploration of New Economic Space
- Phases 1 and 3 executed by trial and error
- Phase 2 may be centrally planned or not
- All require financing under conditions of uncertainty
- All require sources of funding decoupled from economic return

Types of Economic Waste

- "Keynesian Waste" = under-utilized resources
- "Schumpeterian Waste" = essential to innovation
  - scientific discovery
  - technological development
  - discovery of what to do with the technology
- The market economy on its own
  - Generates too much Keynesian Waste
  - Has limited capacity to generate Schumpeterian Waste
- Feedback: inadequate aggregate demand inhibits innovation on the supply side of the economy

Market Failure in the Innovation Economy

- Nelson, 1959. “The Simple Economics of Basic Scientific Research”: limited ability to estimate returns to innovation
- Arrow, 1971. “Economic Welfare and the Allocation of Resources to R&D”: limited ability to appropriate returns to innovation
- “The Failure of Market Failure”: *limited ability to legitimize state intervention*
- State investment in innovation needs non-economic legitimation
  - National development
  - National security
  - Conquest of disease

Discovery and Invention: Sources of Funding

- "Angel" rentiers
  - Robert Darwin
  - 7th Duke of Devonshire
  - Alfred Loomis
- Monopoly rents of great corporations
  - Return to customers through lower prices?
  - Return to stockholders through higher dividends/stock buybacks?
  - Fund scientific research?
- The state
- All (relatively) unconcerned with economic return

Discovery and Invention: from Mechanical Tinkering to Scientific Research

- The 19th Century U.S. “market in patents”
- Industry discovers science:

  “What fools we had been! But then there was this consolation: we were not as great fools as our competitors....Years after we had taken chemistry to guide us [they] said they could not afford to employ a chemist. Had they known the truth then, they would have known they could not afford to be without one.” [Andrew Carnegie]
- The 20th Century “central research lab”

Discovery and Invention: Science in the Nation's Service

- World War II: U.S. Office of Scientific Research and Development
- 1945: Vannevar Bush, "Science: The Endless Frontier"
- 1950: Korean War induces
  - National Science Foundation
  - Massive increase in Defense Department support of R&D
  - Federal Government
    - Funds >50% of U.S. R&D 1953-1978
    - Exceeds 2% of GDP in 1960s
- NIH: from $8 million (1947) to $1 billion (1966)
- 1980: Platform constructed for ICT and BioTech revolutions

Discovery and Invention: Dangers of Efficiency

- Easier to tolerate waste when operating at the innovative frontier, unchallenged competitively
- Benefits of “loose” IP regime: patent pools, second sources, low-cost licenses
- “Pasteur’s Quadrant”
- When competitive position threatened, retreat to efficiency:
  - UK: from the Haldane Principle (1904) to the Rothschild Report (1971)
  - US: from *The Endless Frontier* (1945) to “Star Metrics” (2010) =

  “Science and Technology for America’s Reinvestment: Measuring the Effect of Research on Innovation, Competitiveness and Science”
- Post-1980:Central research retreats to applications at GE, ATT, IBM, Xerox

Deployment

- Alternatives: speculation or the state
  - Railroads, electrification, telephony, highways, internet
  - How calculate the return on an innovative network before it is built?
  - What is the value of one railroad station or one fax machine?
- Who plans?
- Who funds?
- Who underwrites the financial consequences of network economics?

Deployment: Network Economics

- High capital cost; minimal marginal cost
- Under competition, all lose money
- Alternatives:
  - State ownership: national/regional/local
  - State-sanctioned cartel or monopoly
  - Bail-outs and bankruptcies = consolidation “the hard way”

Deployment: The Railroads

- UK:
  - Unplanned duplication of routes
  - Financed by unsubsidized speculation
  - Role of state: eminent domain and sanction of defensive cartels
- France:
  - State planning and control and underwriting
  - Funded by speculation
- US:
  - Unplanned duplication of routes
  - Funded by subsidized speculation
  - Endless struggle to defend returns against network economics
- China: State planning and funding can be as wasteful as private sector

Exploring New Economic Space: The Necessity of Bubbles

- Bubbles are endogenous to financial capitalism
  - Momentum investing inevitable in an uncertain world with incomplete markets
  - Even before index investing institutionalized the practice
  - Invert Schleifer & Vishny: “How long can you afford to be wrong?”
- Bubbles always burst
  - Bubbles in the equity market do relatively little harm (2001)
  - Bubbles in the credit markets compromise the banking system and paralyze the real economy (2008)
- Focus of a bubble can by *anything*: tulip bulbs, gold mines, real estate
  - Occasionally the focus of a bubble is fundamental new technology
  - Bubbles fund the build out of the network
  - Bubbles fund the search for what to do with the network

Exploring New Economic Space: The Search for the Killer App(s)

"…British investors in the U.S. railroads during the late 19th century got their pockets picked twice: first as waves of over-enthusiasm led to over-building, ruinous competition and unbelievable…burn rates, and second as sharp financial operators stripped investors of control and ownership during bankruptcy workouts. Yet Americans and the American economy benefited enormously from the resulting network of railroad tracks….For a curious thing happened as railroad bankruptcies and price wars put steady downward pressure on shipping prices…New industries sprang up.

"Mail a catalog to every household in the country. Offer them big-city goods at near big-city discounts. Rake in the money from satisfied customers. For two generations this business model – call it the 'railroad services' business model – was a license to print money, made possible only by the gross over-building of railroads, the resulting collapse of freight rates, and the fact that railroad investors had to kiss nearly all their money good-buy"

"The same thing will happen with the froth that the bubble put on our 1990s boom. Investors lost their money. We will now get to use their stuff." [Brad DeLong, 2003]

Exploring New Economic Space: Financial Assets *versus* Physical Assets

- What *is* the "fundamental" (net present value of expected cash flow from innovation)?
- "…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 (1936) 151]
- Q is "the ratio between two valuations of the same physical asset. One, the numerator, is the market valuation: the going price in the market for exchanging existing assets. The other, the denominator, is the replacement or reproduction cost: the price in the market for newly produced commodities." [Tobin and Brainard (1977) 235]

Exploring New Economic Space: How to Value Innovations?

"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 (2011) 41-2]

"By conveying a positive signal about profitability, higher aggregate investment…increases asset prices, which in turn raises the incentives to invest. This two-way feedback between real and financial activity makes economic decisions sensitive to higher-order expectations and amplifies the impact of noise on equilibrium outcomes. As a result, economic agents may behave *as if* they were engaged in a Keynesian "beauty contest" and the economy may exhibit fluctuations that may appear in the eyes of an external observer *as if* they were the product of "irrational exuberance" [Angelotos, et. al. (2010) 31-2]

Exploring New Economic Space: Latency

- Railroads: U.S. regional networks built 1830-1860
  - Montgomery Ward founded 1872
  - Sears Roebuck founded 1886
- Electrification: Edison's Pearl Street Station constructed in 1882
  - Replace steam engine with generator and motor
  - Street lighting, trams, amusement parks
  - 50+ years to build out the grid
  - 1920s: flexible manufacturing and home appliances
- ICT: Robert Solow, 1983: "You can see the computer age everywhere but in the productivity statistics…."

Exploring New Economic Space: Schumpeter's 1st Error

"This [entrepreneurial] function is already losing importance and is bound to lose it at an accelerating rate in the future even if the economic process itself of which entrepreneurship was the prime mover went on unabated. For, on the one hand, it is much easier now than it has been in the past to do things that lie outside familiar routine – innovation itself is being reduced to routine….

"On the other hand, personality and will power must count for less in environments which have become accustomed to economic change….

The perfectly bureaucratized giant industrial unit not only ousts the small or medium-sized firms…, but in the end it also ousts the entrepreneur…" [Schumpeter (1943), 132-4]

Exploring New Economic Space: The Innovator's Dilemma

- Two different modes
- New technology directly attacks existing products
  - IBM: RS6000 *versus* AS400
- New business unattractive relative to established business
  - Xerox: Alto *versus* Copiers
- Innovation within an established business only possible if *not* "reduced to routine": e.g., skunk works
  - BEA: WebLogic *versus* Tuxedo

Exploring New Economic Space: Is Venture Capital the Answer?

- Venture capital returns show extreme skew: a small number of firms account for all of the excess return versus the public equity markets
- Venture capital returns show persistence: unlike other asset classes, the return on one venture fund is predictive of the return on the next fund of the same firm
- **Venture capital returns are highly dependent upon the performance of the public equity markets, especially the market for Initial Public Offerings**
- **Venture capitalists have invested successfully in a narrow band of the spectrum of technological innovation: ICT and Biotech**

Venture Fund Performance Relative to the NASDAQ

Fund Multiple and IRR measures of performance are estimated for a hypothetical set of funds that are created assuming that each terminated fund in the database made an equivalent investment in the NASDAQ. The Public Market Equivalent (PME) is a measure of the total disbursements to a fund expressed relative to the total distributions to the hypothetical fund. This data is also summarised excluding the top decile and quintile of funds.

	Mean	Med.	St. Dev.	Skew	25th Percent	75th Percent	Max.	Min.
Nasdaq Multiple	2.42	2.38	0.83	0.39	1.96	2.82	5.05	0.63
- Excluding top decile	2.23	2.27	0.63	-0.69	1.92	2.71	3.27	0.63
- Excluding top quintile	2.12	2.21	0.58	-0.90	1.86	2.58	2.92	0.63
Nasdaq IRR	16%	15%	10%	-0.24	11%	21%	45%	-24%
- Excluding top decile	14%	14%	8%	-1.50	11%	19%	28%	-24%
- Excluding top quintile	13%	13%	7%	-2.02	11%	17%	23%	-24%
Nasdaq PME	1.59	1.00	3.67	10.33	0.57	1.68	42.36	0.14
- Excluding top decile	1.02	0.93	0.57	0.66	0.57	1.33	2.48	0.14
- Excluding top quintile	0.88	0.83	0.43	0.44	0.54	1.19	1.85	0.14

The Bubble and Venture Fund Performance: 1998 – 2002

The following table summarises the performance of funds that were active during the bubble and post bubble periods. To be considered active during the bubble period, a fund had to have made more than 50% of its distributions during the 1999Q2 – 2000Q3 period. To be considered active during the post-bubble period, a fund had to have made more than 50% of its distributions after 2000Q4.

		Bubble Funds			Post-Bubble Funds			
	Full Sample		Excluding	Top Decile	Full Sample		Excluding	Top Decile
	IRR	Multiple	IRR	Multiple	IRR	Multiple	IRR	Multiple
Average	111%	7.94	85%	5.05	8%	2.37	-3%	1.21
Median	91%	4.66	78%	4.14	-3%	0.89	-7%	0.85
Stdev	100%	13.15	61%	3.73	38%	3.83	20%	1.18
Skewness	1.68	5.71	0.51	1.41	1.82	2.78	0.79	1.15
25th Percentile	39%	2.73	33%	2.12	-15%	0.64	-16%	0.58
75th Percentile	146%	7.73	131%	6.47	11%	1.70	7%	1.33
Max	515%	96.10	237%	16.69	116%	14.85	42%	6.13
Min	-2%	0.97	-2%	0.97	-34%	0.18	-34%	0.18
No. Obs.	56	56	50	50	28	28	25	25

Venture Fund Performance (IRR) Relative to the IPO Market

The performance of the sample of venture funds, as measured by the IRR, is summarised by market and exit conditions indicators.

	Mean	Med.	St. Dev.	Skew	25th Percent	75th Percent	Max	Min
- Market Conditions < -1	22%	4%	52%	1.28	-15%	39%	141%	-30%
- Market Conditions = -1 to 1	51%	27%	77%	2.75	9%	65%	515%	-94%
- Market Conditions > 1	41%	20%	60%	2.52	10%	32%	256%	-10%
- Exit Conditions <2	19%	9%	42%	1.60	-7%	29%	155%	-34%
- Exit Conditions = 2 to 3	33%	24%	42%	1.93	11%	40%	237%	-94%
- Exit Conditions >3	106%	76%	110%	1.56	22%	167%	515%	-6%

Venture-Backed IPOs: Key Statistics by Year 1980-2007

Year	Number of IPOs	Average 1st Day Return (%)	Offer Amount (U.S. $ MM)	Med Age at IPO (Years)	Med Offer Amount (U.S. $)
1980	59	49.53	664	9.43	9
1981	97	16.76	1,068	6.05	8
1982	39	15.24	577	3.95	8
1983	196	23.59	3,770	4.00	12
1984	84	11.68	1,028	4.63	9
1985	76	13.20	1,293	3.80	13
1986	366	10.87	3,461	5.57	15
1987	127	9.97	2,361	5.35	15
1988	54	9.49	846	5.29	14
1989	65	13.70	1,223	6.39	15
1990	70	13.55	1,396	5.96	20
1991	157	17.95	4,923	6.66	25
1992	196	12.25	7,280v	5.88	24
1993	221	15.33	6,688	6.73	22
1994	167	13.73	4,671	7.53	23
1995	205	20.04	8,147	7.47	33
1996	272	17.01	11,482	5.66	32
1997	138	13.57	4,826	6.37	30
1998	78	27.01	3,782	5.24	41
1999	270	72.98	20,871	4.31	63
2000	264	49.59	25,499	4.93	73
2001	41	13.35	3,490	6.05	71
2002	22	8.48	2,109	7.47	71
2003	29	12.70	2,023	7.83	66
2004	93	12.72	11,015	6.75	69
2005	56	10.69	4,461	6.13	66
2006	57	9.92	5,117	8.10	76
2007	44	N/A	6,463	7.68	88

Source: Venture Expert; Thomson Financial; Jay Ritter http://bear.cba.ufl.edu/ritter/ipodata.htm
Note: $1.00 1980 = $2.50 2007

Venture-Backed Liquidity Events by Year/Quarter 2005:1-2011:2

Quarter / Year	Total M&A Deals	M&A Deals with Disclosed Values	*Total Disclosed M&A Value ($ MM)	*Average M&A Deal Size ($ MM)	**Number of IPOs	Total Offer Amount ($ MM)	Average IPO Offer Amount ($ MM)
2005	**350**	**163**	**17,324.7**	**106.3**	**57**	**4,482.4**	**78.6**
2006	**377**	**164**	**19,034.8**	**116.1**	**57**	**5,117.1**	**89.8**
2007-1	88	31	4,640.3	149.7	18	2,190.6	121.7
2007-2	90	37	3,912.1	105.7	25	4,146.8	165.9
2007-3	108	55	11,261.7	204.8	12	945.2	78.8
2007-4	93	45	9,645.8	214.4	31	3,043.8	98.2
2007	**379**	**168**	**29,460.0**	**175.4**	**86**	**10,326.3**	**120.1**
2008-1	109	42	4,983.2	118.7	5	282.7	56.6
2008-2	87	27	3,321.2	123.0	0	0.0	0.0
2008-3	89	32	3,080.2	96.3	1	187.5	187.5
2008-4	66	18	2,390..9	132.8	0	0.0	0.0
2008	**260**	**96**	**13,915.4**	**145.0**	**6**	**470.2**	**78.4**
2009-1	65	15	666.0	44.4	0	0.0	0.0
2009-2	65	13	2,570.1	197.7	5	720.7	144.1
2009-3	69	23	1,392.4	60.5	3	572.1	190.7
2009-4	74	41	8,924.3	217.7	4	349.3	87.3
2009	**273**	**92**	**13,552.7**	**147.3**	**12**	**1,642.1**	**136.8**
2010-1	121	31	5,586.6	180.2	9	936.2	104.0
2010-2	97	22	2,932.2	133.3	17	1,274.9	75.0
2010-3	104	27	3,843.0	142.3	14	1,249.1	89.2
2010-4	88	36	5,675.7	157.7	***34	3,557.3	111.2
2010	**420**	**120**	**18,307.2**	**152.6**	***72**	7,017.5	97.5
2011-1	109	45	5,891.2	130.9	****14	1,375.8	98.3
2011-2	79	36	5,410.3	150.3	*****22	5,454.2	247.9

*Only accounts for deals with disclosed values **Includes all companies with at least one U.S. VC investor that trade on U.S. exchanges *** Includes 17 Chinese companies ****Includes 4 non-US companies, of which 3 Chinese *****Includes 8 non-US companies, of which 5 Chinese; 2 non-US companies raised aggregate proceeds of $2 billion.

Source: Thomson Reuters and National Venture Capital Association

Table X: U. S. VC Index Returns

For the period ending 3/31/2011

1 year	3 years	5 years	10 years	15 years
18.5%	2.0%	5.9%	-0.1%	34.3%

NASDAQ Composite

1 year	3 years	5 years	10 years	15 years
16.0%	6.9%	3.5%	4.2%	6.4%

Source: Cambridge Associates LLC.

Table IX: VC Fund-raising 1980-2010

	# of Funds	$B raised	$B managed
• 1980	52	2.0	2.1
• 1885	121	4.0	11.2
• 1990	87	3.2	22.1
• 1995	172	9.9	33.5
• 2000	653	105.0	184.4
• 2005	235	28.8	229.2
• 2009	120	15.2	176.7
• 2010	157	12.3	NA

Source: National Venture Capital Association

Limited Scope of VC Investments

- VCs dance on platform built by state investment in research:
  - Information and Communications Technology = Primary Focus
  - Biotechnology/Healthcare = Secondary Focus
  - All Other <20% of Investments

Amount ($million)	1980	1985	1990	1995	2000	2005	2009
ICT	**231.5 (44.3%)**	**1,851.2 (70.3%)**	**1,366.5 (53.3%)**	**4,020.2 (54.5%)**	**75,373.7 (75.0%)**	**13,642.6 (59.5%)**	**8,052.2 (45.5%)**
Healthcare/ Biotech	**87.3 (16.7%)**	**362.6 (13.8%)**	**674.1 (26.3%)**	**1,744.6 (23.7%)**	**7,574.6 (7.5%)**	**6,624.2 (28.9%)**	**6,116.3 (34.6%)**
Other	**204.3 (39.1%)**	**417.7 (15.9%)**	**525.5 (20.5%)**	**1,605.2 (21.8%)**	**17,576.2 (17.5%)**	**2,674.2 (11.7%)**	**3,522.1 (19.9%)**
Total	***523.0***	***2,631.5***	***2,566.1***	***7,370.1***	***100.524.6***	***22,941.0***	***17,690.7***

(Source: NVCA Yearbook, 2010)

Exploring New Economic Space: Cleantech/GreenTech

- Two fundamental risks
  - Science immature/technology nascent
  - Exposure to commodity markets
- Plus political risk: dependent on government policies
  - Investment in R&D
  - Procurement programs
  - Carbon price
  - Subsidies
- At deployment, 1 unit = $1 billion
- Investment in “clean energy” technologies 2010
  - China $54 billion
  - U.S. $34 billion

The Macroeconomics of the Innovation Economy: Schumpeter's 2nd Error

"…Schumpeter emphasized the long-run efficiency enhancing aspects of economic downturns. We argue here that by ignoring the deleterious effects on R&D he underestimated the negative effects of recessions, and that on balance macro-economic policies that stabilized the economy are more likely to be conducive to long run growth." [Stiglitz (1993) 5]

"…Schumpeterian policies *potentially* foster economic growth, but they do not appear to be able alone to yield sustained long-run growth….By the same token, demand shocks…bear persistent effects upon output *levels, rates of growth* and *rates of innovation*. Keynesian policies not only have a strong impact on output volatility, but seem to be a necessary condition for long-run economic growth." [Dosi et. al., (2010 1750]

Tolerating Waste: an Ironic Conundrum

- Developed world:
  - High tolerance for Keynesian Waste
  - Low tolerance for Schumpeterian Waste
- Market failure NOT adequate rationale for state action
  - National security and human health have legitimized state investment in research
  - Climate change/global warming not (yet) effective rationale
- **Higher degree of Keynesian waste makes Schumpeterian process *less "Creative"*/*more* "Destructive"**

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