9 THE NECESSITY OF BUBBLES

Why do bubbles matter, aside from the crashes that their excesses engender? They matter because they not only transfer wealth from greater to less-great fools, and to the knaves who prey on the former. Occasionally – critically – they transfer wealth to fortunate opportunists and insightful entrepreneurs in the market economy who are granted access to cash on favorable terms and put it to work with astounding consequences. Bubbles matter because, as Keynes put it so characteristically well,

> 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.[1]

A generation later, James Tobin and William Brainard explicitly extended and operationalized Keynes's insight by defining the ratio *q*:

[1] J. M. Keynes, *The General Theory of Employment, Interest and Money*, in E. Johnson and D. Moggridge (eds.), *The Collected Writings of John Maynard Keynes*, vol. 7 (Cambridge University Press and Macmillan for the Royal Economic Society, 1976 [1936]), p. 151.

> 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.[2]

Tobin's *q*, as it has come to be known, quantifies the apparent arbitrage opportunity created by a disparity between the valuation of corporate assets in the financial markets and the cost of investing in new ones. In yet another instance of the informational inefficiency inherent in the financial markets, the continuous flux of such arbitrage opportunities offers the ability to beat the market with persistence to those who are tuned in, as Edward Chancellor has documented with respect to one London-based asset manager.[3]

Tobin's *q* may be greater than 1, if monopoly rents of a dominant firm are capitalized, or less than 1, when new technology renders existing assets obsolete. Either way, it quantifies in rough order the most crucial relation in the dynamics of the Innovation Economy: Keynes's bridge between speculation and enterprise. Thus, it expresses the dimension of the Three-Player Game along which I have lived my life as a practitioner: the dimension played between financial capitalists and the market economy.[4]

Keynes's meditation on speculation versus enterprise stops short before he considers precisely those "classes of investment" for which no "genuine expectation" about the return can be well established, by the professional investor or by anyone else. Indeed, although it is true that "the energies and skill of the professional investor and

[2] J. Tobin and W. C. Brainard, "Asset Markets and the Cost of Capital," in R. Nelson and B. Balassa (eds.), *Economic Progress: Private Values and Public Policy, Essays in Honor of William Fellner* (Amsterdam: North-Holland, 1977), p. 235.

[3] E. Chancellor (ed.), *Capital Account: A Money Manager's Reports from a Turbulent Decade, 1993–2002* (New York: Thomson Texere, 2004), especially pp. 7–41.

[4] A demonstration of how far from reality neoclassical financial economics had evolved is that a working paper for the National Bureau of Economic Research published in January 2012 begins by asking: "How can one explain the attention devoted to secondary financial markets? Why does the press so frequently report the developments in the stock market? Can this be rationalized in a world where secondary market prices are passive . . . in that they merely reflect expectations and do not affect them, as in many economic models, *including most of those used in the asset-pricing literature*?": P. Bond, A. Edmans and I. Goldstein, "The Real Effects of Financial Markets," National Bureau of Economic Research Working Paper 17719 (2012), p. 3 (emphasis added).

speculator are mainly occupied . . . not with making superior long-term forecasts of the probable yield of an investment over its whole life,"[5] from time to time they have been focused on investments with enormous economic significance, for they embody innovative, transformational technology. And it is these investments that are the most uncertain.

That is precisely why their deployment depends so often on the forces of speculation, not those of enterprise. Roman Frydman and Michael Goldberg put it nicely:

> 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.[6]

Academic Rediscovery of Keynes's Bridge

Following on the most recent world-class bubble in the financing of transformational technology, academic economists finally woke up to the significance of Keynes's insight as applied to innovation. Three papers are indicative. The first, by George-Marios Angeletos and Guido Lorenzoni of MIT and Alessandro Pavan of Northwestern University, builds a theoretical link between the dynamics of the financial markets and the economics of technological innovation. The authors extend the mainstream paradigm to demonstrate how rational entrepreneurs and traders – all of whom know that they do not know enough – observe each other's behavior and construct "higher-order beliefs" to rationalize respectively their own overinvestment in physical assets and overpricing of the corresponding financial assets.[7]

Angeletos, Lorenzoni and Pavan summarize their formal analysis of "the interaction between the real and the financial sectors of

[5] Keynes, *General Theory*, p.154.

[6] R. Frydman and M. Goldberg, *Beyond Mechanical Markets: Asset Price Swings, Risk, and the Role of the State* (Princeton University Press, 2011), pp. 41–42.

[7] G.-M. Angeletos, G. Lorenzoni and A. Pavan, "Beauty Contests and Irrational Exuberances: A Neoclassical Approach," National Bureau of Economic Research Working Paper 15883 (2010).

a[n] . . . economy with dispersed information about the profitability of a new investment opportunity" thus:

> 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." Importantly, these effects are symptoms of inefficiency, are driven purely by the dispersion of information, and obtain in an otherwise conventional neoclassical setting.[8]

One may suppose that the authors' repeated resort to the italicized "*as if* " and their insistence on the "conventional neoclassical setting" in which their "rational" agents operate are necessary acts of obeisance to the still dominant neoclassical gods. But their use of the phrase "dispersion of information" cannot conceal that they are, in fact, exploring the consequences of decisions made in the face of ontological uncertainty, the unavoidable circumstance at the core of Keynes's economics. The authors are all but transparent when they recognize explicitly that "the effects analyzed in this paper are likely to be stronger during periods of intense technological change, when the information about the profitability of new investment opportunities is likely to be highly dispersed."[9] Of course, the missing information is not "dispersed" at all: its bits are not scattered out there, available to be assembled in order thereby to render the market efficient. It does not exist. It can be discovered only in retrospect, as a consequence of the decisions made in its absence by entrepreneurs and traders doing the best they can.

The two other papers are mirror images of each other. James R. Brown, Steven Fazzari and Bruce Petersen provide an empirical analysis of the dependence of young high-tech firms on access to external equity capital to fund research and development. Analyzing data from the decade 1994–2004, they tracked the correlation between the extraordinary increase in new equity issues for young firms and the

[8] *Ibid.* 31–32 (emphasis in original). [9] *Ibid.* 32.

growth in research and development (R&D) spending far above trend. They found that "the financial cycles for young high-tech firms alone can explain about 75 percent of the *aggregate* R&D boom and subsequent decline" associated with the tech bubble.[10] Here is a well-defined signal of the necessity of bubbles to relieve financial constraints and to fund extension of the frontier of innovation.

These empirical findings confirm the characteristically insightful theoretical intuition of Joseph Stiglitz. Some fifteen years earlier, Stiglitz extended his exploration of the effects of information asymmetries to include "capital market imperfections," noting in particular how the riskiest corporate expenditures (those devoted to funding research and development) by the most vulnerable firms ("young" ones) are likely to be the most volatile: reduced disproportionately in economic downturns and increased disproportionately in booms.[11] In counterpoint, Ramana Nanda and Matthew Rhodes-Kropf explore the fates of start-ups funded in the context of bubbles versus those launched in normal times:

> We find that startups receiving their initial funding in more active investment periods were significantly more likely to go bankrupt than those founded in periods when fewer startup firms were funded. However, conditional on being successful, and controlling for the year they exit, startups funded in more active periods were valued higher at IPO or acquisition, filed more patents in the years subsequent to their funding (controlling for capital received), and had more highly-cited patents than startups funded in less active investment periods. That is, startups funded in hot markets were more likely to be in the "tails" of the distribution of outcomes than startups funded in cold markets: they were both more likely to fail completely and more likely to be extremely successful and innovative.[12]

A precisely similar phenomenon has been identified among public companies. The authors find that "overvaluation" of a company's

[10] J. R. Brown, S. M. Fazzari and B. C. Petersen, "Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom," *Journal of Finance*, 64(1) (2009), p. 152 (emphasis in original).

[11] J. Stiglitz, "Endogenous Growth and Cycles," in Y. Shionnoya and M. Perlman (eds.), *Innovation in Technology, Industries and Institutions: Studies in Schumpeterian Perspectives* (Ann Arbor: University of Michigan Press, 1994).

[12] R. Nanda and M. Rhodes-Kropf, "Investment Cycles and Startup Innovation," *Journal of Financial Economics*, 110(2) (November 2013), p. 2.

shares is reflected in increased spending on R&D and on fixed capital with the former being some 4-8 times as sensitive.[13] While the measurement of overvaluation is necessarily somewhat problematic, reliant in part on stock price performance relative to investment analysts' forecasts of future cash flows, the effect is highly – and unsurprisingly – nonlinear. The authors suggest that the most overvalued firms, the top 20 percent:

> are more prone to engage in "moon shot" projects that have very high inventiveness and expected innovative output. This strong convexity also suggests that misvaluation effects do not just average out. The possibility of either under- or overvaluation may on average increase innovative activity and inventiveness, potentially increasing welfare.[14]

Thus, bubbles are the environment in which technological revolutions can reach commercially and economically significant scale. John Eatwell has neatly summarized the useful role bubbles can play in the equity markets. Considering how rational investors may be inhibited from funding major innovations by the challenge of scale, by their inability to capture positive externalities and by the very long-term nature of the potential returns, Eatwell writes:

> The usefulness of bubbles derives from their effect in alleviating social inefficiencies that derive from rational individual actions. In other words, I suggest that, in the absence of bubbles, rational individual actions result in a socially irrational outcome, and that the bubble, by inducing irrational acts in individuals, may (and only, may) shift the economy toward a more socially rational position.[15]

That Eatwell plays with the loaded term *rational* should not obscure the positive, if messy, conclusion: bubbles can overcome a potential coordination failure to generate a new and more productive economy. The seemingly perverse opportunity to make money by speculating in risky financial assets regardless of the fate of the real investments so funded is – precisely – the vehicle of economic progress.

[13] M. Dong, D. Hirshleifer and S. H. Teoh, "Stock Market Overvaluation, Moon Shots and Corporate Innovation," National Bureau of Economic Research Working Paper 24142 (2017), p. 7.

[14] *Ibid.* 8.

[15] J. Eatwell, "Useful Bubbles," in J. Eatwell and Milgate (eds.), *The Fall and Rise of Keynesian Economics* (Oxford University Press, 2011), p. 88.

All of this work, theoretical and empirical, was motivated by the great tech bubble of the late 1990s. But its significance transcends ad hoc explanation and rationalization of that singular event. These scholars are reconstructing the reciprocal interdependence of investment in financial and real assets, of financiers and entrepreneurs, of the financial system and the real economy. In their rediscovery of Keynes's economics at this fundamental level, whether acknowledged or not, they have demonstrated as much insight as those who have rediscovered the relevance of Keynes's macroeconomic policy response to the failure of private-sector demand, and they will, I expect, have at least as much impact in the long run.

Financing New Networks

A decade ago, at the turn of the millennium, I was living and working in the middle of the dotcom/telecom bubble, which was composed of two overlapping but quite distinct ingredients. First, like the nineteenth-century railroad booms and the electrification boom of the 1920s, the bubble funded the build-out of physical infrastructure to support the global deployment of the internet and the World Wide Web riding on top of it. Second, it funded an accelerated exploration – a quasi-Darwinian exercise in trial and error – to discover what to do with this new economic environment that, for the first time ever, integrated reciprocal flows of information and transactions over arbitrarily long distances and complex networks.

In the first of these aspects, there was a clear echo of previous waves of financial mania whose economic consequences had been the pioneering deployment of new networks: physical infrastructure to revolutionize transportation, communication and the distribution of electric power. The economic value of such networks is notoriously difficult to evaluate. One line of argument derives from Metcalfe's Law, which asserts that the value of a network grows proportionately with the square of the number of connected devices or users.[16] But a network's value is not only a function of the number of nodes. It is

[16] See S. Simeonov, "Metcalfe's Law: More Misunderstood than Wrong?" *HighContrast* (blog) (July 26, 2006): http://blog.simeonov.com/2006/07/26.

also a function of the uses to which the network is devoted, the applications that ride on it.

The transformational transportation networks – the turnpikes, canals and railroads of the eighteenth and nineteenth centuries – served as more efficient channels for the physical movement of goods and people between established centers of production and consumption. As links between densely populated nodes were completed, however, railways became engines of economic development, opening up new territories to settlement and simultaneously forcing the re-architecting of production and consumption across the entire domain served. With respect to the communications networks, the application of the telegraph may have been obvious, as a near-instantaneous means of transmitting abstracts of messages that were alternatively delivered slowly by post. Even so, the reduction it caused in the latency of communications revolutionized financial trading as the lag in reporting prices between geographically distant markets – first Chicago and New York, then New York and London – disappeared.

An informative uncertainty attended the initial deployment of telephony and wireless. In the case of the telephone, in an inversion of what would become its standard use for direct communication between individuals, the broadcast of entertainment to the home was an early application: by the first years of the 1890s, the Electrophone Company in London was offering concerts, opera, music hall variety and even church services by subscription; the entertainments were delivered to homes, hospitals and other venues via telephone.[17] Conversely, point-to-point communication by wireless telegraphy, especially between ships at sea after the *Titanic* disaster, served as the principal application of radio communications until the introduction of public broadcasting after World War I.

Electrification offers an even more relevant historical analogy to the past generation's revolution in information and communications technology. Joseph Nye explores at length the search over forty years for commercially rewarding applications of electric power: from municipal lighting and streetcars through the electrification of manufacturing to the proliferation of domestic appliances.[18] To an extent even greater

[17] BBC News, "The 19th Century iPhone," May 17, 2010: http://news.bbc. co.uk/1/hi/technology/8668311.stm.

[18] J. Nye, *Electrifying America: Social Meanings of a New Technology* (Cambridge, MA: MIT Press, 1992), pp. 85–97, 111–132, 185–206, 238–277.

than was the case with the growth of electrical grids, the deployment of the internet created a space of possible applications of a dimensionality that transcended simplistic analogies such as the information superhighway. It took the wastage of a bubble to fund the exploration that would yield Amazon and eBay and Google.

The commercial development first of steam power and then of electricity presages that of information and communications technology. Each of these is a general- purpose technology (GPT) whose development and deployment demonstrate the nonlinear nature of the innovation process. Timothy Bresnehan offers a basic definition:

> A GPT (1) is widely used, (2) is capable of ongoing technical improvement, and (3) enables innovation in application sectors (AS). The combination of assumptions (2) and (3) is called "innovation complementarities" (IC).
>
> More precisely, IC means that innovations in the GPT raise the returns to innovation in each AS and *vice versa*.[19]

The key factor is the positive feedback between innovations in the core body of the GPT and the various domains of application – from cotton mills to railways in the case of steam power, from residential lighting to manufacturing in the case of electricity, from supply-chain management to social media in the case of the internet. The consequence can be sustained innovation over an extended period of time as the GPT improves along multiple dimensions in response to demands from those engaged in discovering what it is good for. If the scope of the GPT is broad enough, "the relevant increasing returns also matter at the aggregate level."[20]

Given the radical uncertainty about future economic returns, it is impossible to overemphasize this salient historical fact: two modes of financing have prevailed to fund the initial, pioneering construction of networks. Each of them is decoupled from the rational calculation of gain from the project over its economic life. One has been state investment in pursuit of national development or national security; the other, financial speculation. Bonds guaranteed by the State of New York funded DeWitt Clinton's Erie Canal in the 1820s, and the National

[19] T. Bresnehan, "General Purpose Technologies," in B. H. Hall and N. Rosenberg (eds.), *Handbook of the Economics of Innovation*, 2 vols. (Amsterdam: North-Holland, 2010), vol. 2, p. 764.

[20] *Ibid*. 765.

Interstate and Defense Highways Act of 1956 launched the interstate highway system. Of course, the US Defense Department's ARPAnet was the precursor of the internet, whose extraordinarily robust packet-switching architecture was designed to survive thermo-nuclear war.

The manner in which France's railroad system was engineered had demonstrated long before that agents of the state can plan and implement the construction of a novel, transformational network infrastructure. The French system was from the beginning far more economically efficient in its layout of routes and in their construction than were the systems in Britain and the United States, where the alternative mode was dominant: recurrent bubbles of speculation financed uncoordinated projects that were redundantly proposed and built by competing promoters.[21] But no matter how networks are deployed, discovering what they are economically good for requires the sort of trial-and-error experimentation that both feeds on and feeds speculation.

Within the Dotcom/telecom Bubble

In the midst of the whirlwind of the late 1990s, there was little time to reflect on the economic significance of the bubble in the long sweep of history. From that time, however, I can extract an illustrative example of the link between frenzy in the financial markets and real investment in physical assets, yet another narrative of contingency and chance at the interface of financial speculation and technological innovation.

Covad was a child of the Telecommunications Act of 1996, which required that the incumbent local telephone monopolies – the "Baby Bells" – open their central switching offices to accommodate new Competitive Local Exchange Carriers (CLECs). A year before, Netscape's IPO in August 1995 had heralded the promise of the internet as a new medium: its "web browser" made the internet potentially accessible to all. But physical access for more than the most constrained uses would be a function of the availability of high-speed, broadband data channels with capacity that would be multiples of that of the minimal and expensive dial-up connections allowed by "POTS," the plain old telephone service delivered by the Bells. While other start-ups,

[21] F. Dobbin, *Forging Industrial Policy: The United States, Britain and France in the Railway Age* (Cambridge University Press, 1994), pp. 25, 95–157.

such as Level 3 and Global Crossing, set about laying fiber optic cables for broadband backbone networks in competition with AT&T and the other long-distance carriers, Covad was the first of a number of CLECs launched to deliver broadband access over the copper wires of the local loop.

Two members of our tech team at Warburg Pincus discovered Covad in the summer of 1997. Henry Kressel is among the most distinguished venture capitalists of his or any generation.[22] His role with respect to Covad was strikingly appropriate. By the early 1980s, Henry had already completed a successful career as a physicist, having risen to lead solid state research at RCA's Sarnoff Laboratories. There, he had been responsible for developing the reliable semiconductor lasers that, complemented by Corning's development of glass fiber technology, enabled fiber optic communications. Henry had uprooted himself professionally as he saw RCA lose its way in the early 1980s, had earned an MBA at Wharton, and had joined Warburg Pincus. There he established an extraordinarily productive partnership with another Wharton alumnus a generation younger. Joe Landy carried the venture capitalist's equivalent of a field marshal's baton in his knapsack. Covad was among a succession of rewarding steps on Joe's path to becoming co-CEO of Warburg Pincus.

Before they met Covad, Henry and Joe had already collaborated on a relevant and successful start-up called Level One, yet another of those successful investments that needed to be restarted along the way. Level One's initial launch had taken place before I joined Warburg Pincus, when Henry and Joe led the firm to follow some marginal venture capitalists in backing a former Sarnoff colleague of Henry's named Bob Pepper. The first effort to design specialized semiconductor devices for digital data communications had failed when IBM acquired and effectively smothered Level One's initial customer. Unusually for Warburg Pincus, but in a way all too familiar to me, we were in the back seat of the car as it headed over the cliff and into bankruptcy and liquidation.

Pepper and Henry were convinced that the company's core technology could be repurposed into a nascent but promising

[22] Henry documents his experience of the three investments discussed below in H. Kressel and T. V. Lento, *Investing in Dynamic Markets: Venture Capital in the Digital Age* (Cambridge University Press, 2010), pp. 113–121, 143–148.

application known as Digital Subscriber Line (DSL), which could deliver broadband access for the "last mile" over the copper wires that connected the phone company's central office to the home. Exploiting that opportunity, as usual, required new money to buy the necessary time to reposition the venture: Cash, that is, could be effectively deployed only if it purchased Control. And that, in turn, required that the other investors get out of the way. With some encouragement from me, Henry and Joe supported Pepper in a successful game of chicken with his original investors, and Level One was relaunched. By the summer of 1997, the company had both achieved a position of leadership in its new market and uniquely equipped Henry and Joe to appreciate the technical feasibility of what Covad proposed to do.

The only cash investment Warburg Pincus ever made in Covad was $6 million to lead its first round. The goal was to prove both the technology and market demand for it in the San Francisco Bay Area and then, stepwise, to expand geographically, securing funding at progressively lower cost as the model was proved out, in emulation of the successful deployment of cable television and mobile telephony. The initial application was supposed to be telecommuting so employees in the new knowledge economy could work from home.

But any such mundane consideration of what economic activity the new technology would support swiftly became irrelevant. Less than nine months after our investment, Bear Stearns approached us with a proposal to sell $300 million of junk bonds to enable full-bore acceleration of the plan – this for a company that in 1997 recorded just $26,000 (that is correct: twenty-six thousand dollars) of revenue. All that was required was a promise by Warburg Pincus to inject additional equity in twelve months if the company had not raised it away from us. Together with the common stock warrants that we received as payment for the promise, Warburg Pincus owned about 20 percent of Covad when it went public in January 1999. In a year and half, this raw start-up raised half a billion dollars of financial capital and had a market value of some $5 billion. Of course, this was one small component of the estimated $4 trillion of equity and debt raised and invested in broadband networks – backbone and local access – by start-ups and incumbents before the bubble burst.

Covad did indeed burst with the bubble, passing through Chapter 11 bankruptcy on its way to a renewed, post-bubble life. By then, however, Warburg Pincus had been the contingent beneficiary

of Henry and Joe's discovery of another, even more compelling investment opportunity generated by the Telecommunications Act of 1996. Lockheed Martin was the source. One of its systems development units had won the contract to deliver the local-number portability mandated by the Act. This was a critical condition of competition in communications services, as it would allow customers to switch local carriers without having to change their telephone numbers. But the technical requirements were fearsome: specifically, the system would have to be able to change the relevant database in every single central office in North America in order to complete each transaction, or roll back all the changes made if even just one were not completed. The provider of such a system would own an exclusive franchise and would be responsible for managing the North American Numbering Plan, the foundation of telephone service in the United States and Canada.

Having demonstrated its ability to execute the demanding specifications, Lockheed Martin proceeded to compromise its ownership of the contract. Strict neutrality among the growing horde of competing carriers, legacy and new, was an absolute requirement. But Lockheed Martin had separately decided to buy the communications satellite company ComSat, a common carrier, and therefore had to divest itself of its no-longer-neutral business unit.

Joe and Henry engaged in a year-long process, the first half of which involved negotiations of the terms and conditions of our purchase from Lockheed Martin, and the latter half negotiations with the Federal Communications Commission to confirm *our* neutrality as an owner of what was to be called – cutely – "Neustar." It was necessary to establish a firewall of independent trustee-directors to ensure Neustar's autonomy. In a consequence both fortuitous and fortunate, our new investment required and rationalized acceleration of the liquidation of our investment in Covad, a process that had begun in the summer of 1999. Since Henry and Joe had been required to leave Covad's board, a rapid series of distributions and public sales of shares was not inhibited by any taint of insider information. Altogether, thanks to Neustar, our thirty-month engagement with Covad was completed in December 1999, with more than a year to spare before the bubble burst. And so a $6 million investment resulted in proceeds of just over $1 billion. In its turn, our $77 million investment in Neustar's much more robust and defensible business carried beyond the bubble and generated its own $1 billion return some five years later.

Waves of Innovation

Covad exemplified the most obvious economic consequence of the bubble of 1999–2000: the deployment of network infrastructure on a scale not rationally imaginable by any investor other than the state, which had turned the internet over to private enterprise precisely to shift responsibility for its financing and for exploration of its potential uses. It thus carried forward a line of comparable exercises that began with the double wave of Britain's Canal Mania, first in the 1770s and again in the 1790s.

By the late eighteenth century, England's economy was generating a sufficient financial surplus and its capital markets were sufficiently mature to enable the private financing of the canals and the turnpikes that constituted the new transportation network literally underlying the First Industrial Revolution. The only legislation required was to endow the "projectors" with needed powers of eminent domain. Financing was so forthcoming that by 1824 more than sixty canal companies had been created, disposing of more than £12 million of capital.[23] By contrast, in the United States, as with DeWitt Clinton's pioneering Erie Canal,

> the new canal systems of Pennsylvania, Maryland, Virginia and Ohio were financed almost wholly by the states and the port cities . . . Only a government had the credit rating needed to raise the required funds; for their ability to pay interest on their bonds was based on the power to tax, as opposed to private companies, which depended merely on anticipated profits from providing rights-of-way.[24]

But to finance the second network of innovative transportation infrastructure, the United States emulated Great Britain to the extent that it could, while supplementing speculative private finance with state subsidies.

The installation of the railways in Britain also came in two principal waves. The first, the "little" Railway Mania of the 1830s, is distinctive not only because it demonstrated the technical feasibility of the technology that, more than any other, would enable the new

[23] C. Haacke, *Frenzy: Bubbles, Busts and How to Come Out Ahead* (New York: Palgrave Macmillan, 2004), p. 18.

[24] A. D. Chandler, *The Visible Hand: The Managerial Revolution in American Business* (Cambridge, MA: Harvard University Press; Belknap Press, 1977), p. 34.

economy of the latter nineteenth century. Also, for once, a financial bubble was validated by the economic returns from the projects it financed. As Andrew Odlyzko has shown, speculative commitments in 1835–1836 led to real investments in railway construction that approximated 2 percent of gross domestic product (GDP) in each of 1838 and 1839.[25] The part-paid structure of share subscriptions deferred the flow of financing to match expenditure on construction: typically, a £2 deposit on a £50 share underwrote application for parliamentary approval. If such sanction were received, investors would receive repeated calls, to be met on pain of sacrifice of the shares (not unlike the case with commitments to a venture capital fund today). It was not at all unusual for cost overruns to exceed the initial nominal amount of committed capital, requiring follow-on rights issues.

In the case of the first Railway Mania, construction and capital calls proceeded through the economic depression at the end of the 1830s, with the market price of shares often falling well below book value. However, Odlyzko provides examples of projects whose investors came out ahead, notably four of the most prominent lines: the London and South Western, the Liverpool and Manchester, the Grand Junction, and the London and Birmingham. Beyond the financial rewards, of the 2,200 miles of railways approved by Parliament during the mania, no fewer than 2,000 were in service by 1843.[26]

This success was the basis for the second wave of Railway Mania. As *The Economist* recorded in 1848:

> Prior to the commencement of the recent railway mania in 1844 this species of property had acquired a reputation for security and profit greater than any other similar speculations which had preceded them: while nearly every other class of joint stock speculations from 1824 downward, in which the accumulating capital of the country had been invested, had ended in ruin to the parties engaged, railways, as they then existed, appeared to promise a permanent security for very large dividends.[27]

[25] A. Odlyzko, "This Time is Different: An Example of a Giant, Wildly Speculative, and Successful Investment Mania" (2010). Available at www.dtc. umn.edu/~odlyzko/doc/mania01.pdf.

[26] A. Odlyzko, "Collective Hallucinations and Inefficient Markets: The British Railway Mania of the 1840s" (2010). Available at www.dtc.umn. edu/~odlyzko/doc/hallucinations.pdf.

[27] Quoted *ibid*. 73.

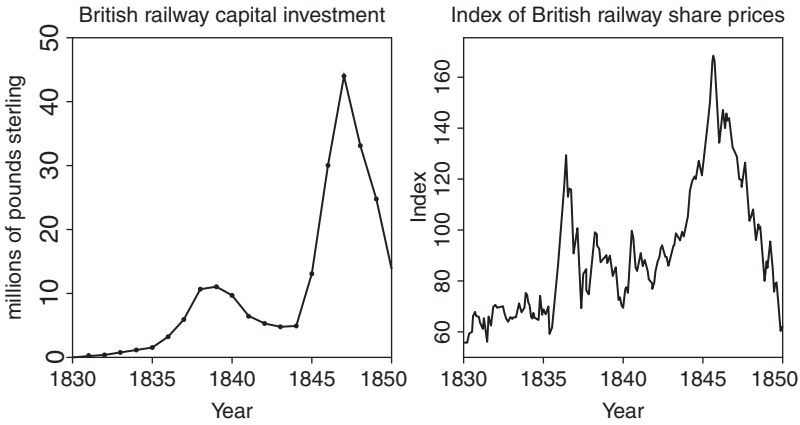

Figure 9.1 Infrastructure investment / financial speculation
Source: A. Odlyzko, "Collective Hallucinations and Inefficient Markets: The British Railway Mania of the 1840s." Available at http://papers.ssm.com/sol3/papers.cfm?abstract_id=1537338.

Compared with the mere 2,000 miles of railways in service in 1843, some 12,000 additional miles were approved by Parliament in 1844–1848, entailing planned investment of some £100 million per year in an economy whose aggregate annual income has been estimated at perhaps £600 million. Actual investments averaged only £33 million in the late 1840s, and returns fell far short of expectations: construction costs were typically 50 percent above plan, operating expenses ran at 50 percent of revenues rather than the forecast 40 percent, and revenues themselves were 30–40 percent below projections.[28] An index of railway shares that peaked at 168 in July 1845 collapsed to 60 in October 1849.[29] Odlyzko charts this supreme example of a "productive bubble," as shown in Figure 9.1: the volume of investment in the real assets – rights of way and rail lines and the equipment to ride upon them – exactly matches spikes in the valuation of the shares issued to pay for them.

In the United States, the railroad boom that began in the late 1840s likewise consumed capital on an unprecedented scale. Compared with the $188 million invested in canals from 1815 to 1860, 73 percent of which was supplied by state and local governments, by 1859, Chandler reports, "The investment in the securities of private railroad corporations had passed the $1,100 million mark; and of this amount

[28] *Ibid.* 76–78, 94–95. [29] *Ibid.*table 3 (pp. 7 and 77).

$700 million had been raised in the previous ten years."[30] Capital on this scale "could no longer be raised ... from farmers, merchants and manufacturers living along the line of the road." By the start of the Civil War, New York had emerged as the centralizing financial node through which capital from Europe flowed to the burgeoning array of railroad projects. The explosion in railway securities during the 1850s

> brought trading and speculation on the New York Stock Exchange in its modern form ... The new volume of business brought modern speculative techniques to the buying and selling of securities. Traders sold "long" and "short" for future delivery. The use of puts and calls was perfected. Trading came to be done on margin. Indeed, the modern call loan market began in the 1850s, as New York banks began to loan [*sic*] to speculators ... In the 1850s skillful securities manipulators were becoming nationally known figures. Jacob Barker, Daniel Drew, Jim Fiske, and Jay Gould all made their dubious reputations by dealing in railroad securities.[31]

The Crash of 1857 ended the speculation, but by the start of the Civil War, the United States had more than 30,000 miles of track in service, compared to 9,000 miles a decade earlier.[32]

Chandler explores in detail the interaction of speculators, investors and managers that determined the course of the American railroad industry. As in all industries characterized by high fixed costs – represented by the interest and repayments required to service the debt that financed construction – and marginal costs approaching zero, competition among railroads was inherently unstable this side of monopoly or cartel. Exactly the same dynamics would dominate the commercial airline industry before and after the fare-setting authority of the Civil Aeronautics Board was first established and then abolished, and the telecommunications industry, before and after the three generations of stabilization delivered by AT&T's legislated monopoly.

While the managers and investors sought good-faith agreements to limit competition, "it was ... the speculators who shattered the old strategies ... were the first to disrupt the existing alliances ... [and] precipitated system-building in American transportation." The second great wave of American railway construction, driven by the search for scale by the competing systems and funded by enormous speculation,

[30] Chandler, *The Visible Hand*, p. 90. [31] *Ibid*. 92.
[32] See www.answers.com/railroads.

came in the 1880s: "75,000 miles of track [were] laid down, . . . by far the greatest amount of railway mileage ever built in any decade in any part of the world." No fewer than five trunk lines ran between Chicago and New York, ensuring that none could make money. And between 1894 and 1898 foreclosure sales alone aggregated over 40,000 miles of track, with a capitalization of over $2.5 billion, "the most massive set of receiverships in American history."[33]

As the investment bankers led by J. P. Morgan set about cleaning up the financial mess and rationalizing the economics of the industry, in the country at large a new economy had definitively arrived. Brad DeLong, economist at Berkeley, captured the essence of the case and linked it to the most recent equivalent experience in a casual note published in *Wired* magazine (a bible of the NASDAQ bubble that has managed to survive) in April 2003, just three years after the bubble's peak. "Let us now praise famous men, the wild-eyed enthusiasts who begat the bubble-boom," DeLong begins.

> Today's party line is that the gold rush brought both pain and gain. Fortunes were poured into over-flowing snake pits of fiber-optic cables which, like Web-ordered groceries, proved to be profit-free zones . . . On the flip side, public markets paid for a build-out of the network infrastructure, and burn rates pushed the envelope of the culture.
>
> In fact, history will look back and see gain and gain . . . 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 (for that time) 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 and slashed rail freight and passenger rates . . . New industries sprang up.[34]

DeLong identifies the iconic example of transformational business innovation – the "killer app" that exemplified the economic significance of the railroads – in the mail order businesses of Montgomery Ward and Sears Roebuck:

[33] Chandler, *The Visible Hand*, p. 171.
[34] J. B. DeLong, "Profits of Doom," *Wired*, 11(4) April (2003).

> 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 overbuilding of railroads, the resulting collapse of freight rates, and the fact that railroad investors had to kiss nearly all their money good-bye.

Even as Amazon and eBay were demonstrating their post-bubble momentum and even before Google's IPO, DeLong correctly anticipated the rhyming of history: "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."[35]

Despite the evident transformation they wrought, the economic significance of the great railroad booms has been a subject of controversy among economic historians for more than forty years, ever since Robert Fogel's pioneering exercise in cliometrics, the application of econometrics to historical data.[36] Fogel's purpose was to extract the US railroad network from the statistical economy of 1890 in order to calculate the "social saving," or incremental reduction in transportation costs, that the railroads provided versus the hypothetical alternative of extended canals and improved roads. His debunking conclusion was that the benefit of lower costs attributable to the interregional railroads amounted only to some 0.6 percent of 1890 national income: "The absence of the interregional railroads would have retarded the development of the economy by about three months."[37] The intraregional social saving was modestly more significant, 1.8 percent to 2.5 percent of national income.[38] To take account of the impact of railroad construction on the nation's manufacturing industries, Fogel calculates the "value added in manufacturing attributable to railroad consumption of manufactured goods" at no more than 4 percent in 1859, the end of the first wave of construction, and notes that "in the absence of the railroads there would have been a considerable increase in the consumption of wagon and water services."[39]

[35] *Ibid*.

[36] R. Fogel, *Railroads and American Economic Growth: Essays in Econometric History* (Baltimore, MD: Johns Hopkins University Press, 1964).

[37] *Ibid*. 46–47. [38] *Ibid*. 84–85. [39] *Ibid*. table 14.2 (p. 145).

Fogel gives the game away stealthily in an extended footnote:

> The treatment of the differential in transportation costs as a differential in levels of national income is based on the assumption that there would have been no obstacle to a non-rail situation. More specifically, it is based on the assumption that national income would have fallen *only* because more productive resources were required to provide a given amount of transportation services and *that all productive resources not used in transportation would have remained fully employed*.[40]

This bedrock, neoclassical presumption both underlies and undermines Fogel's entire approach. It is what mandates him, in another footnote, to dismiss "Keynesian issues of insufficient demand" from consideration.[41] Yet in the peak years of the first US railroad boom, during the mid-1850s, expenditures on the construction of railroads amounted to approximately $100 million per year, or some 20 percent of all capital formation in the United States, on the order of 3 percent of estimated gross national product.[42] In contemporary terms, this is greater than the annual expenditures under the American Recovery and Reinvestment Act of 2009, the stimulus program enacted in the first year of the Obama Administration that put a floor under the Great Recession. A grace note to the inappropriateness of Fogel's abstraction from the macroeconomic consequences of the railroad boom and bust is this: the economic aftermath of the Crash of 1857 is what induced Stephen Foster to write his classic dirge, "Hard Times Come Again No More."

Recent academic work contributes to putting Fogel's labors into appropriate perspective. Donaldsen and Hornbeck consider the role of the railroads in transforming "market access" for agricultural producers, with very large, cumulative impact on the value of agricultural land and, even more consequentially, on consumer welfare and the growth in US population. Moreover, they explicitly acknowledge that their analysis must understate the impact of the railroads as it does not consider the impact on the manufacturing sector or the dynamic feedback onto technological innovation itself:

[40] *Ibid*. 21 n. 10 (emphasis added). [41] *Ibid*. 47 n. 58.

[42] Historical Statistics of the United States Millennium Edition Online, tables Df865–873, "Railroad Investment by Region: 1828–1860" and Ca219–232, "Gross National Product: 1834–1859 (Gallman)." Available at http://hsus.cambridge.org/HSUSWeb/index.do.

> In summary, revisiting the historical impact of railroads on the U.S. economy suggests a larger aggregate economic impact from railroads and market integration. Fogel (1964) calculates the impact of railroads based on willingness to pay for the transportation of agricultural goods, and our methodology is based on a similar willingness to pay for agricultural land. Beyond the substantial effects on agricultural land value, however, our analysis anticipates substantial declines in consumer welfare and total population in the absence of the railroads. Our estimates neglect further potential impacts on other sectors and technological growth, yet we hope our ability to measure and analyze impacts of "market access" will spur further research on the aggregate impacts of railroads throughout the U.S. economy.[43]

Beyond econometrics, DeLong caricatures and Chandler documents in detail the transformation that the railroads engendered in the United States, transcending their direct macroeconomic and sectoral effects. They drove the westward movement of population and property development, the re-architecting of industrial organization, the evolution of accounting practice and principles, the emergence of nationally branded goods, and the creation of liquid exchanges for securities – in short, they transformed the core commercial and industrial and financial structures of the nation. To focus only on the marginal cost of transporting commodities as the measure of the railroad's economic significance does not trivialize Fogel's heroic efforts at data collection and analysis. Rather, it exposes the irrelevance of the framing neoclassical economic theory that specifies the problem Fogel addresses.

Of the new and expanded industries that accompanied the build-out and consolidation of the railroads, none required capital on the scale of the railroads or was as dependent on financial speculation. The telegraph system largely followed and was partly funded by the railroads, and local capital did the rest, as it did for the host of local telephone companies that sprang up in the last two decades of the nineteenth century. The Boston railroad financiers who funded the organization of the American Bell Company in 1880 eventually did have to turn to J. P. Morgan and Wall Street for capital, obtaining $100 million even as the financial crisis of 1907 pushed the banking

[43] D. Donaldsen and R. Hornbeck, "Railroads and American Economic Growth," *Quarterly Journal of Economics* (2016), p. 803.

system almost to collapse, hardly a time of speculative excess.[44] The iconic manufacturing and distribution companies of the new economy that emerged from the Second Industrial Revolution, in turn, relied on local businesspeople and commercial banks for both short-term and long-term loans. None, however, needed to go to the capital markets to finance the expansion that so quickly placed them among the largest business enterprises in the world.[45]

Nonetheless, the evolution of the US capital market that made it a welcome venue for the industrial and utility issues of the trust bubble at the start of the twentieth century proved its value to the Innovation Economy in the gathering boom of the 1920s. In this, Wall Street represents the mirror image of the City of London, the latter immunized against investing in technological innovation by the Brush Boom and the automobile financing frauds of the previous generation. Even before US entry into World War I, nineteen new auto companies went public in 1915–1917 during a stock boom that raised $100 million in some fifty new issues. Thirteen of them had died by 1924, but one of the survivors was Chevrolet. In the two years that followed the motor stock boom, the market for securities in the United States was vastly expanded by the Wilson Administration's mobilization of Wall Street and Hollywood to market war bonds to the mass public.[46]

The stock market's continued interest in funding the iconic industry of the age of mass production was illustrated by the repeated efforts in 1924 by the then leading brokerage firm of Hornblower & Weeks to convince Henry Ford to sell out in exchange for $1 billion in cash, to be financed by public market issues. Even without what would have been the largest industrial financing deal of the age, Mary O'Sullivan calculates, corporate stock issues in the late 1920s represented by far the greatest amount, proportionate to national income, ever: they reached about 7 percent of national income in 1929, whereas even at the peak of the tech bubble at the end of the twentieth century they amounted to barely 1.5 percent, slightly above the mean for the entire period from 1897.

[44] Chandler, *The Visible Hand*, pp. 199–201. [45] *Ibid*. 298.

[46] M. O'Sullivan, "Funding New Industries: A Historical Perspective on the Financing Role of the US Stock Market in the Twentieth Century," in N. R. Lamoreaux and K. L. Sokoloff (eds.), *Financing Innovation in the United States: 1870 to Present* (Cambridge, MA: MIT Press, 2007), pp. 198–199.

During the 1920s, the public equity and debt markets played the critical role in funding the build-out of the systems that delivered electricity to industry and to households, regionally and, at length, nationally. The public utility holding companies, initially created to transfer technical expertise to local generating and distribution companies, evolved into vehicles for providing the necessary finance for an industry whose capital intensity rivaled that of the railroads.[47]

> The dominant *economic* fact of the electric utility industry, determined by technology, was extreme capital intensity. This had two major implications. First, the industry had high fixed costs that had to be met in order for a utility to be profitable, and relatively low operating or variable costs . . . A substantial amount of capital had to be raised before any electricity could be produced.
>
> A second economic effect . . . was that production was subject to significant economies of scale . . . This meant that for most relevant output levels, marginal costs were below average costs . . . If firms set a price equal to marginal cost (the point to which competition would drive prices under "normal" circumstances), they would be making economic losses.[48]

So electrification evolved through a dynamic feedback process that delivered both speculative capital and governmental regulation, generally at the state and local levels, the latter invoked to protect the prospective returns on the former. Once again, a collaborative game between the state and the market economy created an opportunity for financial capitalism. As the level of electrification for manufacturing industry and (nonrural) residential uses passed 50 percent in the early 1920s, consolidation of the industry into regional and even national holding companies was enabled by a frenzy on Wall Street terminated only by the Crash of 1929.[49] Before the frenzy ended, installed generating capacity in the United States had risen from 13 million to 33 million kilowatts.[50]

Two additional new industries were midwived by the stock market in the 1920s. Charles Lindbergh's flight in May 1927 ignited

[47] Chandler, *The Visible Hand*, p. 393.

[48] W. J. Hausman, *The Historical Antecedents of Restructuring: Mergers and Concentration in the US Electric Utility Industry, 1879–1935*, report prepared for the American Power Association (1937), pp.2–3.

[49] *Ibid*. 7. [50] *Ibid*. fig. 8 (p. 42).

a speculative frenzy for aviation-related shares. Wright Aeronautical was the only publicly traded aviation company at the time. Its shares traded from 25 in April 1927 to 94¾ by the end of that year. From mid-1928 through mid-1930, no fewer than 124 public issues raised $300 million, of which more than half had been raised prior to the Crash of 1929.[51]

Finally, to return to the source of my abiding sensitivity to the emergence of a bubble: radio is a classic example of the Three-Player Game in action. The pioneers of wireless technology on both sides of the Atlantic had found sufficient funding from angel investors. It was the discovery in 1920 of the "killer app" for wireless communications – broadcast entertainment – that triggered speculative interest, a development that was accompanied by the creation of RCA, under the direct sponsorship of the US Navy and War Departments, to pool ownership of the patents held by American Marconi, General Electric, AT&T and Westinghouse. Through early 1925, new companies and new offerings proliferated – some 258 in 1925 alone, the most prominent of which traded on the Curb Exchange. The inevitable collapse took radio stocks, excluding RCA, down by 92 percent from December 1924 to May 1926. Thereafter, RCA's successful enforcement of its patents limited new entry, but its own soaring stock price, from (split-adjusted) 7 at the bottom of the correction to 103 just before the Crash, induced a second wave of entrants beginning in March 1928.[52]

Notwithstanding the long hiatus of financial capitalism through the Depression, World War II and the immediate postwar period, by 1929 the American public equity markets had already evolved into the engine for

> turning long-term financing into assets that could be realized through sale on the market at short notice ... Thus, through the magic of financial intermediation by investment banks, the productive sector received permanent equity financing while investors believed they had liquid assets.[53]

When the post-World War II golden age of broad-based economic growth unfolded under the new regime of big-state capitalism, the

[51] O'Sullivan, "Funding New Industries," pp. 186–187. [52] *Ibid*. 173–174.
[53] J. Kregel, "Financial Experimentation, Technological Paradigm Revolutions and Financial Crises," in W. Drechsler, R. Kattel and E. S. Reinert (eds.), *Techno-Economic Paradigms: Essays in Honour of Carlota Perez* (London: Anthem, 2009), p. 208.

equity markets responded. They would be there to finance commercialization of the digital technologies spawned by the American military in its role as investor in research and lead consumer of digital products.

Speculation and Innovation: an Explanatory Schema

This chronicle of the interdependence between epochal waves of financial speculation and the deployment of innovative technological infrastructure whose economic significance reveals itself only over decades invites construction of a systematic, explanatory narrative. I began my own search for such a narrative in 2000, as my generation's bubble was reaching its apogee. I had recognized that the literature on technology and technology-driven industrial development was much farther along than the literature on how that evolution had been financed. In response, I initiated a research project sponsored by the Social Science Research Council and led by two distinguished economic historians, Naomi Lamoreaux and the late Ken Sokoloff, whose output was a range of case studies, published in 2007 as *Financing Innovation in the United States, 1870 to the Present*.[54] In parallel, in 2003 I discovered the work of Carlota Perez and her book *Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages*.[55] In an appropriately recursive movement, that discovery was a function of Amazon's ability to work out that I would be interested in a book with such a title.

Perez applies her schema to five successive technological revolutions, as laid out in Table 9.1. In each case, the technological revolution begins with an "installation" period that climaxes in a frenzy of speculation, which is followed by a crash and an extended turning point, as that which was once innovative – even revolutionary – and not amenable to rational calculus becomes recognized as routine. Finally, the technology's deployment constitutes the construction of a previously unimaginable new economy. Figure 9.2 illustrates the process.

[54] Lamoreaux and Sokoloff (eds.), *Financing Innovation in the United States, 1870 to the Present*.

[55] C. Perez, *Technological Revolutions and Financial Capital: The Dynamics of Bubbles and Golden Ages* (Cheltenham: Edward Elgar, 2002).

Table 9.1 *Five Successive Technological Revolutions, 1770s–2000s*

Technological revolution	Popular name for the period	Core country or countries	Big bang initiating the revolution	Year
First	Industrial Revolution	Britain	Arkwright's mill opens in Cromford	1771
Second	Age of Steam and Railways	Britain, then spreading to Europe and the United States	Test of the "Rocket" steam engine for the Liverpool and Manchester Railway	1829
Third	Age of Steel, Electricity and Heavy Engineering	United States 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	United States at first vying with Germany 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	United States, then spreading to Europe and Asia	The Intel microprocessor is announced in Santa Clara, California	1971

Source: C. Perez, *Technological Revolutions and Financial Capital*: *The Dynamics of Bubbles and Golden Ages* (Cheltenham: Edward Elgar, 2002), table 2.1 (p. 11).

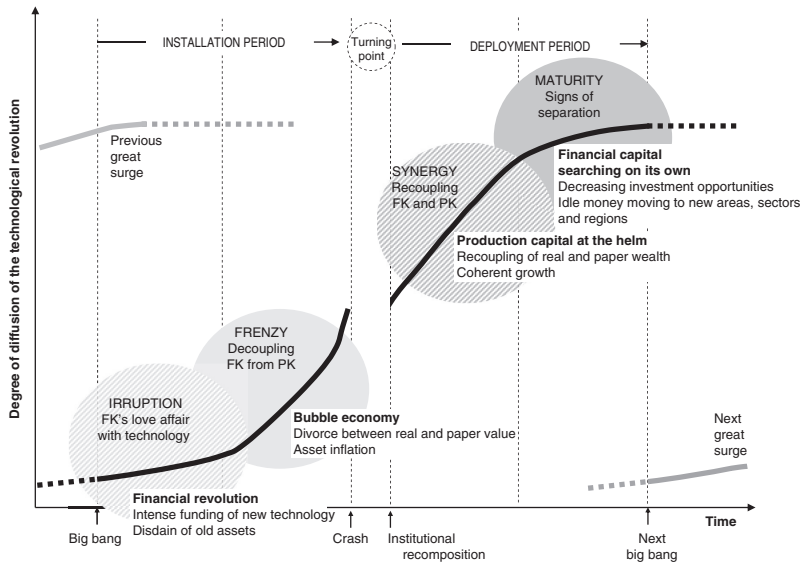

Figure 9.2 The recurring sequence in the relationship between financial capital (FK) and production capital (PK)
Source: adapted from C. Perez, *Technological Revolutions and Financial Capital*: *The Dynamics of Bubbles and Golden Ages* (Cheltenham: Edward Elgar, 2002), fig. 4.1 (p. 37).

Throughout her analysis, Perez distinguishes financial capital, the agent of speculation in Keynes's formulation, from production capital, which is embedded in Keynes's "enterprise." Thus, in her explicitly neo-Schumpeterian characterization of the recurrent waves of creative destruction, Perez too has revitalized the approach to reading the world that I had inherited from my Cambridge mentors, Keynes's own students. In doing so, she has constructed a framework for understanding the necessity of bubbles and the prospective cost of eliminating them from our economic life.

The process of moving from technical invention to funded innovation is messy and wasteful; the extreme skew in the returns of venture capital, within individual portfolios and across the multitude of funds and firms, testifies to this. So, too, do the bubbles of speculation in the financial markets that fund the deployment of innovations significant enough to make a broad economic difference, along with the detritus of scams and no-hopers that get swept along with them. Efficiency in the allocation of resources to satisfy current demands at a given moment of time – the hallmark of well-behaved markets in neoclassical theory – hardly captures the process through which

conditions of life have been transformed by Perez's five great waves over more than 200 years. But can the ability to tolerate such waste be enhanced? Can the costs incurred when the speculative bubble bursts be limited in advance?

Certainly, there is no a priori set of economic principles that will yield an efficient outcome. Frank Dobbin observes that Britain, France and the United States all "produced rapid, dependable and cost-effective transport systems in relatively short order," although in each country the process of planning, funding and regulating the railways was radically different.[56] The one common element shared by British speculators, French state planners and the entrepreneurial American sources and seekers of subsidies is that rational calculation of economic returns was not a primary motivator. France from the 1820s with respect to the railways, and the United States since World War II with respect to digital electronic technology, demonstrate that the state can play a decisively catalytic, and not merely a supportive, role. But to explore the new space for innovative applications thereby created remains the realm of entrepreneurial finance, the world of bubbles and crashes.

Productive Bubbles, Destructive Bubbles

The history of financial capitalism demonstrates the need to distinguish between bubbles along two different dimensions. One dimension is defined by the object of speculation. Only occasionally have speculators focused on fundamental technology instead of such assets as gold mines or houses, neither of which contributes to system-wide increases in productivity. The second dimension concerns the locus of speculative activity, distinguishing between bubbles that remain confined to the capital markets and those that transcend the capital markets to suck in the institutions that accept deposits and provide the credit that fuels the ordinary workings of the market economy. A crucial distinguishing factor is the degree of leverage, the relative magnitude of debt mobilized to finance the unsustainable rise in asset prices. In the trading markets for equities and bonds, it is limited: on the order of 1:1 at most. In the banking system as of 2007, it ranged upwards from reported levels of

[56] Dobbin, *Forging Industrial Policy*, p. 223.

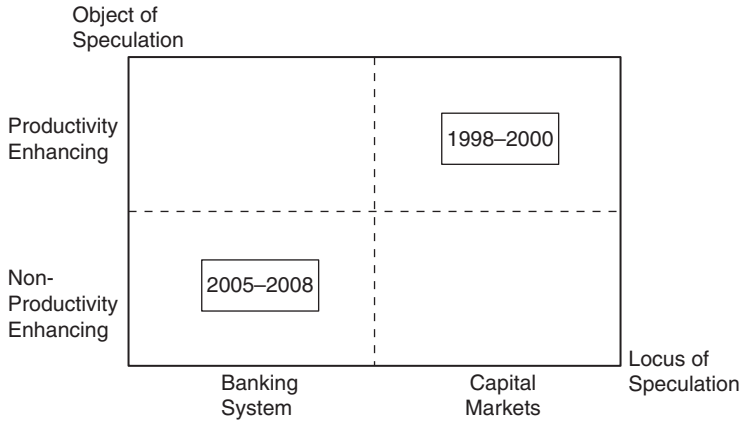

Figure 9.3 Bubbles: a typology.

30:1 and beyond – in reality, far beyond: marginal declines in the value of assets rendered the institutions at the core of the financial economy insolvent. And these reported capital ratios substantially overstated the robustness of the banks' balance sheets. Figure 9.3 provides a simple chart to illustrate the crucial distinction.

In the immediate past, the contrast is instructive between the respective consequences, positive and negative, of the dotcom/telecom bubble of 1998–2000 and the credit bubble of 2005–2007. When the $6 trillion of nominal financial wealth created in the former and concentrated in equity securities and junk bonds was liquidated, the economic consequences were within the bounds of postwar experience, leaving the technological foundations and business models in place for the newest new economy. The great credit bubble will be remembered precisely for its destructive economic consequences and not for any physical legacy, least of all the abandoned tract houses scattered along the coastal regions of the United States and from Ireland and Spain to the emerging lands of Central and Eastern Europe. The dichotomy echoes that between the limited economic consequences of the stock market Crash of 1929 and the overwhelming impact of the international banking crises of 1931–1933.

Over the course of the past generation, rationalized and enabled by theory, the practice of finance was both deregulated and transformed. Credit was securitized both directly and through the superstructure of derivatives, and it was decoupled from the

cash flows of the underlying economic assets. To the extent that the banks that constructed and distributed those claims held on to a portion of them, they imagined that, like their customers, they could lean on the insurance supposedly provided by credit default swaps: the ultimate instrument of self-deception constructed by modern finance.

Re-regulation: Incomplete and Threatened

The process of re-regulating the financial system in response has been a haphazard one at best. The one seemingly unequivocal gain has been in the increased capital and reduced leverage of the "global systemically important banks" (G-SIBs): the leverage ratio, defined as Tier 1 capital divided by total assets, increased from 3.1 percent to 5.9 percent on average for G-SIBs between 2007 and 2015. But these numbers mask a double source of continuing concern.

The international regulatory regime introduced post-Crisis, known as Basel III, mandates an increase in total common equity to 4.5 percent of assets with an additional 2.5 percent "capital conservation buffer" in normal times, to be rebuilt when depleted under stress. The new rules include additional capital requirements for the largest, "systemically important" banks, backstopped with limits on total leverage and a range of additional prudential regulations.[57] Is the increase in required capital enough? No, strongly argues Anat Admati of Stanford; she is joined in this by no less than Sir John Vickers, the distinguished Oxford economist who chaired the British Independent Commission on Banking in 2011.[58]

Noting that, historically, levels of bank equity capital "were commonly 20 or 30 percent of total assets in the early 20th century," Admati proposes a return to such levels, even if she not does suggest bringing back "the double, triple or unlimited liability" that faced bank stockholders before the introduction of deposit insurance by the Glass–Steagall Act.

[57] Basel Committee on Banking Supervision, "Basel III: International Regulatory Framework for Banks." Available at http://www.bis.org/bcbs/basel3.htm.

[58] A. R. Admati, "The Missed Opportunity and Challenge of Capital Regulation," *National Institute Economic Review*, 235 February (2016). Vickers has stated that banks need to double the amount of capital they use to back their activities. See M. Sandbu, "Banking Systems Remain Unsafe," *Financial Times*, October 2, 2017. Available at https://www.ft.com/content/b13dc90c-a75a-11e7-ab55-27219df83c97.

Paul Tucker, former Deputy Governor of the Bank of England, has emphasized the first underlying concern with the headline ratio of balance sheet strength. "Equity" is an accounting construct: pre-Crisis banks were allowed to count in its calculation such assets as acquired goodwill that are utterly unavailable as cash reserves in times of stress. Even post-Crisis, tighter definitions of equity do not equate to the sort of unconditional access to cash I learned was the sole hedge against radical uncertainty. A further concern is the continued use of "risk-weighted assets" as the numerator for calculating equity ratios, with large banks empowered to use their own internal models for assessing their required capital. Not only does this allow for aggressive self-assessment, it can distort bank provision of credit toward lower-risk sovereign borrowers versus lending to business.[59]

The world's banking system as a whole may be somewhat more robust than the fragile construct of a decade ago. But Minsky's warning that bailing out the bankers without more radical and intrusive regulatory reform is relevant:

> Unless the regulatory apparatus is extended to control, constrain and perhaps even forbid the financing practices that caused the need for lender-of-last-resort activity, the success enjoyed by this intervention in preventing a deep depression will be transitory; with a lag, another situation requiring intervention will occur.[60]

The Dodd–Frank legislation of 2010 in response to the Global Financial Crisis enacted a panoply of regulatory reforms and initiatives. One of the most salient of these is the hotly contested "Volcker Rule" that limits the ability of depository institutions to use their own capital in trading securities versus acting as agents for customers: the consequent potential for reducing the liquidity of the securities markets that depend on market making by banks has made this perhaps the most problematic of the reforms. Altogether, the direct and indirect costs of regulatory compliance, taken together with the substantial increase in required capital, mean that banks are less profitable: return on equity for major American and European banks has fallen from the high-teens prior to the Crisis to the mid-single digits today.

Barely a decade after the start of the Crisis, however, intense pressure has been mobilized to ease the regulatory constraints, including

[59] Sandbu, "Banking Systems Remain Unsafe."

[60] H. P. Minsky, *Stabilizing an Unstable Economy* (New Haven, CT: Yale University Press, 1986), p. 52.

even the stress tests that proved crucial to the restoration of confidence in the banking system in 2009. Stanley Fischer, former Vice Chair of the Federal Reserve, is the dean of active central bankers. His comments to the *Financial Times* in August 2017 are compelling and deeply worrying:

> It took almost 80 years after 1930 to have another financial crisis that could have been of that magnitude. And now after 10 years everybody wants to go back to a status quo before the great financial crisis. And I find that really, extremely dangerous and extremely short-sighted. One can understand the political dynamics of this thing, but one cannot understand why grown intelligent people reach the conclusion that [you should] get rid of all the things you have put in place in the last 10 years.[61]

Beyond the amendments to the regulatory structure, one crucial component of an effective attack on the "moral hazard" that arises whenever the state saves market participants from the consequences of their own actions has been shocking by its absence. In striking contrast with the aftermath of the Savings and Loan Crisis of the early 1980s, when approximately one-third of mortgage-financing thrift institutions went bankrupt,[62] criminal prosecutions and convictions have been few.[63] Despite revelations of criminal behavior across the entire spectrum of subprime mortgage origination, securitization and distribution, those responsible for the institutions that participated have been effectively exonerated. In a perverse substitute for justice, the institutions have been the targets of investigation, indictment and settlement. The big banks have paid out well more than $150 billion in fines, with a nice demonstration of the agency issues that arise between owners and managers. Of course, it is the shareholders of the banks that have borne the penalties, not the executives.

Limit leverage in the banking system, make banking boring again: that is the central policy of prudence. But what is to be done to limit the range of objects to which the speculative appetites of equity investors are recurrently drawn? Should anything be done at all?

[61] S. Fleming, "Fred Fischer Attacks Moves to Unwind Regulation," *Financial Times*, August 16, 2017.

[62] Federal Deposit Insurance Corporation, "S&L Crisis: A Chrono-Bibliography." Available at https://www.fdic.gov/bank/historical/sandl.

[63] Jesse Eisinger, "Why Only One Top Banker Went to Jail for the Financial Crisis," *New York Times Magazine*, April 30, 2014. Available at https://www.nytimes.com/2014/05/04/magazine/only-one-top-banker-jail-financial-crisis.html.

The negative reason for caution in enacting regulations in this sphere is the limited damage done to the market economy when money games on the stock exchange end in tears. The positive reason is the challenge of preemptively adjudicating which apparent folly will morph into the foundation of the next new economy.

The most powerful enabler of risk-taking at the frontier of innovation is the possibility of winning financially even if the funded project fails. The much-derided greater fools of the stock market, the "noise traders," are the essential constituency that makes possible the process of trial and error and error and error through which our technologically driven economy evolves. Eliminate equity bubbles from our financial economy? The thought puts me in mind of Sir John Falstaff, a personage devoid of control either of his cash or of himself, when he was first threatened with banishment by Prince Hal in *1 Henry IV*: "Banish plump Jack, and banish all the world."