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THE ENTREPRENEURIAL MULTIPLIER EFFECT

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The authors of this paper are studying entrepreneurship because we believe that innovation is the central dynamic of capitalism; that it is largely responsible over the long-term for the economic expansion of the system; that it is the primary source of the system's opportunities as well as its instability; that it inevitably produces an unequal distribution of income and wealth; and that it also occasions the expansion in all democratic societies of public sector efforts to achieve more stable and equitable systems. These efforts clash over the long-term with an entrepreneurial economy, culture and politics that stress innovation and economic efficiency.[1] The struggles between these two visions of the good society continue today, with somewhat different results in every society that experiences modern economic development.[2]

Our approach to a subject that many economists avoided for decades nevertheless draws upon economics for its central concept.[3] Since the Keynesian revolution in economics, a standard part of the profession's analytical framework and a forceful argument for government support for investment has been the multiplier concept. The multiplier has helped generations of students understand why additional investments can, through re-spending, have a greater impact on national income than the amount of the investments. If a society's multiplier is three, for instance, the national income will be increased by a factor of three when government spending or a new technology prompts investment. The re-spending and thus the multiplier works through consumption in an equilibrium model.[4]

Our contention is that there is also an Entrepreneurial Multiplier that works directly through investment by forcing or incentivizing new investments in innovation in a dynamic, disequilibrium model.[5] These investments have been researched and analyzed in various contexts without synthesizing them as a multiplier.[6] Thus, historians of public as well as private entrepreneurship have described and discussed “spill-overs.”[7] Similarly, historians of technology have found many examples of “bottlenecks” produced by successful innovators; the bottlenecks raised the premium on further technical advances in a particular industry.[8] There is a substantial body of literature on backward and forward linkages in economic development.[9] Joseph A. Schumpeter, the father of modern entrepreneurial studies, emphasized emulation of the entrepreneur as a source of growth and competition as high entrepreneurial profits attracted competitors and drove economies ahead in great surges.[10]

The general concept of an Entrepreneurial Multiplier unifies these several approaches to innovation and focuses attention on the sequences of entrepreneurship launched by changes, large and small, in the capitalist economy. The Multiplier enables us to bring together the two types of entrepreneurship most common in recent work in economics, business and economic history, and managerial studies. One branch involves startups which are small, most often unsuccessful, and seemingly insignificant; the other focuses on entrepreneurship within existing firms, which frequently are large, complex, and bureaucratic. Like Schumpeter, our focus is upon innovation, whether by individuals or teams.[11] Our entrepreneurs are risk-takers, but we do not limit them to the heroic giants of Schumpeterian lore. We consider all startup firms to be inherently entrepreneurial even though they seldom have a widespread impact on the national, regional, and often not even on the local economy; nor, until they develop further, are they likely to launch a sequence of additional acts of entrepreneurship. We include them because in toto, a series of these seemingly insignificant innovations can have a significant impact upon a local economy and also upon the society's culture and politics in ways that favor entrepreneurship over the long-term.[12]

The heart of the Entrepreneurial Multiplier is the sequence of innovations and startup firms are more likely to be a response to other innovations than the source of an additional entrepreneurial sequence. Most startups fail within a few years. As the successful startup matures, however, its capacity to promote further entrepreneurial activity can increase sharply; it may never reshape a national economy, but it can encourage others to establish new firms to take advantage of newly perceived opportunities. As you can see, the sequence of innovations is the key aspect of this analysis: the sequence or series of innovations is what is being multiplied.

Entrepreneurship also takes place within established firms that are, for instance, improving processes or developing new products or services that enhance the business's competitive position without necessarily creating new markets or upsetting an industry's basic structure. This type of entrepreneurship can, however, prompt the creation of new businesses – starting a short entrepreneurial sequence -- and can even create the competitive pressure that prompts larger, well-established firms to innovate or exit the market in the manner described by Clayton M. Christensen in The Innovator's Dilemma and Andy Grove in Only the Paranoid Survive.[13] These sequences -- and all of the others we describe -- thus inherently and importantly are characterized by numerous failures as well as successes.

Schumpeterian entrepreneurship involves the types of innovation that reach across industries, sectors, regions and nations and bring about dramatic economic changes. This type of innovation has been studied as a "general purpose technology," such as the water- or steam-powered, factory-based machinery of the first industrial revolution. Because of the multiple sequences they launch, these innovations have significant economic effects that are likely to show up in national income accounting. We do not limit our analysis to technological innovations, but they have clearly been dramatic sources of entrepreneurial sequences in the developed nations since the late eighteenth century. These innovations are frequently associated with the social, cultural and political ramifications we label as an industrial revolution. They cause the type of structural changes Joseph A. Schumpeter memorably called "creative destruction:" an evolutionary process in which entrepreneurs drive out of business those organizations and individuals unable to adjust to competition from the innovator and fail (unless of course they can be shielded publically or privately from competition). This type of entrepreneurial sequence will be very long and the impact on the economy very significant. The path of these sequences resembles a great tree with many branches, rather than a single, linear trace.

The Entrepreneurial Multiplier and the First Industrial Revolution:

In New England

For illustrations of the Entrepreneurial Multiplier at work, we can look to the familiar ground of the first industrial revolution. In cotton textiles during the late eighteenth and early nineteenth centuries, the first major innovation involved the application of water-powered machines to the spinning of yarn; this early development of the factory movement prompted British entrepreneurs to develop new water-powered looms to weave the cloth.[14] While the British government tried to prevent other nations from stealing the central ideas of the factory movement, Samuel Slater learned the secrets of the factory production of cotton yarn, immigrated to America, and put the ideas into practice in a mill in Pawtucket, Rhode Island, in the early 1790s.[15] The Entrepreneurial Multiplier has seldom respected national frontiers, lending to innovation a transnational dimension long before the British Parliament looked to free trade rather than mercantilism as a national policy. Slater's success attracted a wave of imitators, à la Schumpeter, as "cotton mill fever" hit New England. These entrepreneurial sequences were important to New England and to the entire American economy of that era. Soon, there were many new businesses making cotton yarn and the industry continued to expand and change.

The Multiplier process generated entrepreneurial sequences in several different ways. Profits from innovation encouraged emulation. Growing businesses and work forces also created local opportunities to establish new retail stores, boarding houses, and taverns -- opportunities that had not existed before. Meanwhile, the mills were developing new mechanical capabilities and knowledge that spilled over into other enterprises, and successful innovation generated capital that begat further innovations, large and small. The Multiplier process was cumulative, broad, and powerful.[16] The length of the sequences was primarily a product of the economic applicability of the technologies, business systems, and patterns of demand in a market-oriented society.

Some of the most important changes were introduced by firms like the Boston Manufacturing Company (BMC), which produced both yarn and cloth in Waltham, Massachusetts. Water-powered weaving as well as spinning gave the new enterprise an advantage over its American competitors. Unlike most of the young firms in the industry, the Boston Manufacturing Company was unusually successful in the years immediately following 1815, when competition from Britain cut into U.S. markets. The firm's sales increased from slightly under $2,000 that year to $345,000 by 1822. By the following year, the firm's assets were up nearly twenty-fold over the first year of operations. Profitable in good times and bad, the BMC was a model entrepreneurial firm.

The Boston Manufacturing Company spawned a number of other entrepreneurial ventures – large and small – that did not attract much attention at the time and have often not been able to win a place in our general economic and business histories. Some of these ventures were retail businesses that serviced the mill workers, handled the products of the mills, and that provided special services to firms like the BMC.[17] That famous mill innovated in labor relations by employing "mill girls," who were housed in dorms or boarding houses and were paid in cash. Between 1810 and 1820, Waltham's population increased by 65% and new stores were attracted by the cash flowing into the local economy.[18] In 1820, the local economy was also strengthened when the Boston Associates established the Waltham Bleachery and Dye Works, a company that would remain in business for 131 years.[19] Another ancillary business was the Newton Chemical Company, which was led by one of the BMC founders.[20] BMC was either directly or indirectly responsible for the development of these new enterprises, all of which strengthened the local and regional economy, fostered a culture friendly to innovation, and nurtured a political environment conducive to entrepreneurship.

Another innovation on the creative side of “creative destruction” was the early development of the machine-tool industry, a sequence that would have long-term implications for the national economy. Cotton textile producers needed machines – at first wood and then metal – and most of them initially built their own in rudimentary machine shops on site. Individual craftsmen began to build equipment and then created firms to supply the rapidly expanding industry. Luther Metcalf of Medway, Massachusetts, a cabinet-maker and later retailer of “spirituous lyquors,” was typical of the lot.[21] He caught the “cotton-mill fever” and then founded a machinery business, which supplied spinning machines and related equipment to the Boston Manufacturing Company as it got started in business in 1814.[22] BMC went on to build its own water-powered looms and to finance a well-equipped, basement machine shop. As BMC got fully into operation, the firm began to look for additional work for the machine shop. In 1817, the shop started to provide machinery for other mills, and within a few years was a profitable business. Under Paul Moody’s direction, the machine shop was able to draw upon the resources of the Boston area, including its iron foundries and other machine shops.[23] In the meantime, it became a training ground for future mechanics – much as Slater’s mill had been in previous decades and much as the railroad shops would be in the future.[24]

The BMC machine shop became a potent source of innovations in textile production and in other sectors of the economy. Fortunately for students and historians, George Sweet Gibb studied this history in detail and we can draw upon his account – as well as Thomas Navin's book on the Whitin Machine Works – for more information on how the Entrepreneurial Multiplier worked in those years.[25] Between 1814 and 1824, the BMC's shop matured into a leading source of machinery for one of the fastest growing industries in the United States. Improvements in the machinery – a series of process innovations – gradually increased the productivity of the BMC mills.[26]

The mills and machinery businesses were so successful between 1821 and 1824 that the Boston leaders of the enterprise looked to the Merrimack River and Lowell, Massachusetts, for a new and larger opportunity to expand their mills and their machinery enterprise.[27] Successful in the new site, the machine shop was employing almost 300 men by 1835.[28] New mills and a thriving machine shop brought a sharp increase in population in Lowell and in new startup businesses.[29] By 1832, a complex, local economy had replaced the farm land along the Merrimack.

In a manner that would later be incorporated in business-cycle theory, however, the cotton-mill business inevitably leveled off and then declined after the Lowell mills were built.[30] By the time that happened, the machine shops were already developing new capabilities that would sustain a profitable business and foster entirely new sequences. One of their special talents was in the use of water power and the transmission of energy to a manufacturing operation. Major changes were taking place in the efficiency of water wheels and the shop developed new skills in using water turbines. Now organized as one part of the Locks and Canals Company, the shops had – as their name indicates – also become significant contributors to the engineering of canals and their locks. In 1834, they moved into another major field when they took on locomotive construction for a new steam line, the Boston and Lowell Railroad. Drawing upon British models, the shop turned locomotives into a large part of its business. By 1838, it was the third largest producer in the country and had 32 locomotives in operation, most of them in New England.[31] By this time – despite the depression that had begun the previous year – the machine shops were important contributors to three of the essential elements of American industrialization and economic growth: manufacturing; canal transportation, and the railroad.

Like the mills, the shops were contributing to additional entrepreneurial sequences on the local level, especially in Lowell, Massachusetts, a new urban center. The new enterprises included thirty-four boarding houses, bakers, bars, hardware stores, a bank, dress makers, a hotel, a shoe store, a livery stable, etc., etc.[32] None of these tiny enterprises were economically significant above the local level, but their combined effect was to create an entrepreneurial culture attuned to market relationships and the transitions fostered by innovation.[33] Insofar as they were successful, these micro-entrepreneurs enjoyed the positive, material sanctions that gave heft, political resonance, and lasting power to that culture. The enterprisers who started these little businesses needed to look no further than their own experiences to understand entrepreneurship.

Where do these entrepreneurial undertakings belong in history? Schumpeter ignored them, as do most economic and business historians. The late Alfred D. Chandler – long the world's premier business historian -- focused scholarly attention on the largest, most profitable businesses of the nineteenth and twentieth centuries. The Chandler paradigm certainly helps us understand some of the most dynamic institutions of the first and second industrial revolutions. But what neither Chandler's nor Schumpeter's history provides is a grasp of the broad, ideological and cultural impact of rapid industrialization.

Looked at individually, the network of startup enterprises in Lowell and elsewhere were of vital importance only to the men and women who started the businesses and to their customers. Looked at collectively, these businesses were important to the local, state, and regional society because they helped to shape and sustain the distinctive economy, culture and politics of early nineteenth-century Massachusetts.[34] Collectively, they strengthened what Max Weber called "the spirit of capitalism."[35]

The culture of entrepreneurship was embedded within a broader culture that favored social, geographical, and economic mobility as well as innovation. That very diffuse set of values helped Americans deal with the fact that most entrepreneurial ventures fail and most of the successful ones appear to become less innovative over the long-run. The entrepreneurial culture allowed the society to handle conflicting experiences: subsidies to enterprises and the myth of the self-made man, for instance; cooperation and competition, for another; and there were many more, including of course slavery and democracy. The culture of innovation was durable but not impenetrable. It was wide-spread in early America, but certainly not universal.

Not everyone benefitted from the impressive record of the Entrepreneurial Multiplier at work, and of course those who did benefit received very unequal shares of the income and wealth being generated by the Boston Manufacturing Company, the mills in Lowell, and the machine shops in Waltham and Lowell.[36] Investors who caught the "cotton-mill fever" propelled the industry ahead in surges that were always followed by depressions that brought down employment and income in the working class.[37] While the budding machine-tool industry was less vulnerable after it diversified its product line, it too experienced sharp fluctuations that brought cuts in employment on the shop floor.

Businessmen of that era would have thought it strange to contemplate any other arrangement or questions about the unequal distribution of misery. There were, nevertheless, questions raised in 1819, when the mill girls went on strike over a wage cut.[38] But the recovery that followed and the influx of immigrants looking for factory wages soon erased or suppressed the immediate social discontent over the insecurity of industrial work. So too with the routine use of the blacklist to prevent discontented employees from moving from one job to another.

For much of the nineteenth century, these conditions would continue, creating a counterpoint to the entrepreneurial culture and ultimately to the politics of capitalism. The tension between these cultures and their associated ideologies would become a central issue in the politics of America and all of the other industrializing nations.[39] The resolutions would ultimately produce the "varieties of capitalism," which were in reality the varieties of the political half of political economy.[40] While the political and cultural ramifications of innovation should not be analyzed using a multiplier, they should certainly not be left out of a long-term perspective on this aspect of the history of capitalism. That is true even though for many decades, America's unfolding economic opportunities and mobility trumped the desire for social and political change in what was one of the world's fastest growing industrial economies.

Political change was particularly difficult to achieve in a society in which the new industrialists and the established commercial class had so much power. That control was reflected in the ease with which the Boston Associates were able to get state charters passed for their new enterprises. Incorporation had previously been used largely for infrastructure improvements in which the social interest loomed very large. Bridges and piers were advantageous to the many, not just a small coterie of businessmen. But a charter or the tariff protection won in 1816 was another thing entirely. The social benefits were indirect and in the future; the economic return was direct and of overwhelming benefit to the industry's investors. A glimmer of the balance of power could be seen when the state authorized the railroad from Boston to Fitchburg: the BMC investors' agent specified the exact route of the line when it passed through Waltham.[41]

There were thus political grumblings and caveats about the mills and machine shops, but none of these interrupted the flow of profits and dividends from the operations of the shops at Lowell. The company had land and water power to sell, as well as growing markets for its textile machines and locomotives. The entrepreneurial sequence in machine tools appears to have provided the major source of income to the Locks and Canals firm, even during the deep downturn after the Panic of 1837. When the machine-tool operations were finally sold in 1845, the company's founders could reflect on its contributions to the region's economic advances: the solid establishment of a successful regional cotton-textile industry; the expansion of Waltham's local economy and the creation *ab ovo* of the city of Lowell; and the manufacture of many of the locomotives for a growing rail network in New England.

More difficult to total are the social and political outcomes from this sequence: the balance sheet in this case clearly included liabilities as well as assets. There were surges of socio-economic discontent with each economic downturn and the depressions appeared to be getting longer and deeper. They produced periodic efforts to find some means of ensuring a greater measure of economic security for the working classes and some glimmers of an anti-capitalist movement that would continue to develop with every downturn of the business cycle. As these problems became more severe, it would get harder to drown out the voices calling for change. But as the nation's transportation and communication improvements continued and growth in the manufacturing and service sectors carried America into a second industrial revolution, the culture and polity were still primarily amenable to change and supportive of entrepreneurship.

In Lombardy

Although the economic and political settings in Lombardy were very different than those of New England, the Entrepreneurial Multiplier was at work in northern Italy, producing sequences similar to those in nineteenth-century America. Unlike New England, Lombardy had a very significant textile industry before water-powered spinning and weaving transformed the industry. The silk industry was well-established and had long been selling its goods in upper-class markets in Italy and the rest of Europe. Capital was available for investment, and there were no significant guild impediments to production in the countryside where abundant sources of water-power were available. The region had a flourishing agriculture and an expanding manufacturing sector rooted in several districts within the countryside, scattered in a number of small towns, in the suburbs and in the city of Milan. What's more, the industry was deeply embedded in international trade networks and Lombardy's businesses were intentionally trying to keep pace with European economic progress.[42]

Beginning in the late 18th century, a growing number of local merchants and entrepreneurs of the textile sector – in both silk and cotton -- gradually expanded their volume of sales on a regional level and extended their transnational connections. The wars of the French Revolution and Napoleon's campaigns impinged upon trade and the local economy, but after the Restoration (1815) of Austrian rule, the traders and merchants of Lombardy began to explore aggressively the new technologies of textile manufacturing.[43] Enlarged domestic and international markets encouraged innovations in both production and commerce. From then on, economic growth in Lombardy was increasingly due to investments in silk and cotton, which in turn forced further innovations and offered incentives for new investments across industries and sectors throughout the region.

Increasing investments in textiles gave birth to a long series of entrepreneurial sequences across the century, much as they did in New England.[44] Under the pressure of international competition, Lombard entrepreneurs invested in technological innovations that involved local carpenters, artisans and hydraulic mechanics, some of whom created small family firms in Milan, Como, Lecco, and Bergamo.[45] These companies specialized in essential pieces of machinery, including reels, thrown silk mills, and steam-heated boilers, as well as essential pieces of machines and various iron and wood tools. The firms were decisive for the further evolution of the mechanical sector. The mechanical enterprises founded in the first part of the nineteenth century became extremely skilled at producing more efficient hydraulic wheels, agriculture machines, and advanced mechanisms for silk production processes.

The major differences between New England and Lombardy stemmed from the breadth of the market. There was no shortage of entrepreneurial talent in Northern Italy, and finances were available. But the domestic market was smaller than it was in America. As a result, the Italian machine tool industry was still unable to construct high quality cotton-textile machinery at competitive prices. Cotton textiles represented a sharp break with the past in Lombardy because the goods were cheaper and the profit margins tighter in middle- and lower-income markets. New England and Lombardy both followed the normal industrialization pattern of gradually moving up the value chain from low-cost to higher-cost fabrics. But until the First World War, Lombard cotton entrepreneurs continued to import their technology from the well-recognized mechanical centers abroad. In that sense, the sequences in northern Italy were for a time more truncated and less productive than those in America of ancillary innovations.

Nevertheless, the Lombard cotton factories laid a foundation for further technical innovation. They each built workshops and employed a combination of foreign, skilled "instructors" and local mechanics, carpenters and lathe turners. Some of the indigenous mechanics became key figures in the organization of new firms. Their family workshops came to be the crucial vehicles of new technologies coming from England and Northern Europe. They were later responsible for technological "spillovers" in other industries.[46]

The leading silk and cotton firms were controlled by a handful of influential entrepreneurs based in Milan. Their financial resources and links to the commercial networks enabled them to keep in their hands the biggest part of the business – including its financing, production and trade. Often they coordinated operations in several plants across the elevated plains and hills, wherever they could find hydraulic power and relatively cheap labor. As they gained economic strength and accumulated wealth, some of those involved in silk commerce became bankers, on the lookout for additional remunerative investments and ways to diversify their holdings.[47] In this and other regards, the silk industry built upon Lombardy's traditional strength in upper-class markets for relatively fine goods, while cotton textiles moved the region into new modes of production, labor relations, and patterns of distribution. The contrast between Lombardy and New England was thus in part a function of the contrasting business traditions and institutions of the two economic regions, as well as the relative size of their markets.[48]

Capital from silk and to a lesser extent from cotton production began near mid-century to flow to other economic sectors. In 1846, textile resources helped to finance "Elvetica," which took on a role in the building of the region's first railways (the Milan-Monza and Lombard-Venetian lines) and whose production included boilers and fireboxes, locomotives and freight cars. The main partners of the company were part of the local business élite, including distinguished silk "merchants" transformed into bankers (men like Enrico Mylius, Giovanni Esengrini, and Francesco Decio), cotton industrialists (including Francesco Amman), and noblemen-entrepreneurs like Emanuele Kevenhuller, a shareolder of the lighting and gas company of Milan. A year later, in 1847, Giovanni Noseda, a wealthy and renowned silk banker, was the main financier of a new company, "Grondona," which made coaches, freight cars, and wagons. Noseda supplied both capital and loans to the enterprise.[49]

Entrepreneurship in Lombardy fostered conflicts as well as economic growth, along lines initially similar to those that developed in New England. The textile entrepreneurs had political as well as economic power, and they exercised that power in ways that had both negative and positive effects on the region. The positive side was their role in the lengthy struggle against Austrian authority. What they sought and eventually achieved was a relatively conservative "revolution" that pushed out the

Austrians but left the region's social and economic relations largely unchanged. They were already struggling to maintain their control of their workers. In some cases they had built mill villages in an effort to promote entrepreneurial paternalism, stymie class conflict, and keep the legitimacy of private property off the political agenda. For a time they succeeded but would give ground later in the nineteenth century.

After the unification of Italy in 1870, the capital accumulated in Lombardy spurred the establishment of new financial institutions and limited companies. This process began with a great fervour: twenty-one new banks were established in Milan in 1871-73, and while some failed in a short time, others survived and deepened the region's financial resources. Among the administrators and financiers were the well-known names of the wealthiest industrialists: for silk, De Vecchi, Gavazzi, Gnecchi, Pedroni, and Ronchetti; for cotton, Cantoni, Turati, and Ponti. Many of them invested capital in a series of new enterprises: "Pirelli & C.," an innovative rubber firm;[50] Lanificio Rossi, in wool; Società Richard in porcelain china; and Cotonificio Canapificio Nazionale, and Cotonificio Cantoni in cotton and hemp.[51]

The Cantoni family enterprise was typical of the firms of this era. Costanzo Cantoni, one of the first cotton merchant-entrepreneurs, shifted to the factory system in the 1830s. During the following decade, he expanded his factory in Legnano (reaching 3,546 spindles by 1845), established weaving and bleaching divisions as well as a dyeing plant, and built, together with his son, Eugenio, and the financial help of Ponti and Turati, a big factory in Castellanza that was vertically integrated and supplied with all the advanced technology then available. Eugenio – like Samuel Slater – took advantage of the foreign technology he had studied in Switzerland, Austria, Germany, France and England.[52]

In the 1850s, Costanzo transferred the direction of the firm to his son. By that time, Eugenio (1824-88) had access to ample capital to invest in other economic sectors beyond cotton. In 1854-56 he took part in the business group that acquired the Lombardo-Veneto railways, after the Austrian government decided to sell the line. After the Italian unification, Eugenio made two crucial decisions: first, he transformed the family enterprise into a limited company (1872); then, he supported the organization of several other firms: Banca di Busto Arsizio (1872), Lanificio Rossi (1872), Reiser (1873), and Linificio e canapificio nazionale (when?).[53] In 1874 he built up a workshop whose first objective was to assure speedy repairs for cotton factory machinery. In 1875 this undertaking evolved into “Cantoni-Krumm e C:” with Luigi Krumm, a technician with experience in Lombardy’s cotton sector. The following year Cantoni invited Franco Tosi to join the venture and, in a couple of years, the company became an important mechanical enterprise and an innovative entity in the industrial structure of Lombardy.

Tosi (1850- 1898) was a young engineer who had studied at Zurich’s Polytech and worked for a short time in German mechanical businesses. He had solid technical expertise and a strong business instinct. He put his knowledge and his money into the business and steadily grew the firm’s output to include mechanical looms, many other items of textile equipment (for cotton, wool, linen – and the full industrial plant if needed), agricultural machinery, hydraulic engines, illuminating gas plants and industrial boilers and steam engines. The production of steam engines – in many models – was particularly successful.[54] In 1881, the firm was renamed “Franco Tosi.”[55]

In Italy, as in America, the machine tool industry spawned by textile production using water and then steam power had significant entrepreneurial multiplier effects on the local, regional, and then national economies. Here too the multiplier was generating opportunities for further innovation, new capabilities, and the capital to sustain addional investments. Here as well there was a vibrant entrepreneurial culture and politics. The major differences between New England and Lombardy continued to flow from the size of their markets. Nevertheless, by the end of the 1870s, Italy's strength in luxury goods had been supplemented – although certainly not replaced – by important investments and technical capabilities in mass-production industries such as cotton textiles. Eugenio had founded a new and larger "Cotonificio Cantoni S.p.A." with the involvement of 29 major Lombard businessmen.[1] His efforts and those of other Lombard businessmen and technicians had laid a foundation for a new wave of innovations in communications, transportation, and manufacturing. On balance, the Italian and American experiences with the first industrial revolution followed similar patterns.

The Second Industrial Revolution

In America's Middle West

In the latter half of the nineteenth century, a distinctive new wave of innovation transformed the developed economies. Changes in transportation and communications opened new national and international markets. New electrical, chemical and electro-chemical industries arose, as did giant firms attuned to the growing markets and the opportunities for mass-production and mass-distribution of standardized goods and

[1] P. MACCHIONE 1987; R. ROMANO 1990.

services.[56] Urbanization fostered further specialization, much as Adam Smith had predicted. Growth across a broad front in America and Europe spawned increasingly complex and elongated sequences of entrepreneurship.[57]

One of the new industries was aluminum. Like cotton-textiles in the first industrial revolution, aluminum was a major innovation that launched numerous entrepreneurial sequences in the years following its introduction as a commercial product in the United States and France.[58] Charles Martin Hall discovered his new and inexpensive way to recover the metal in 1886, and two years later, he and a team of American investors founded The Pittsburgh Reduction Company.[59] Unlike the BMC, the aluminum venture did not start with adequate, commercially generated financial resources. The "Three Fs" (family, friends, and fools) did not provide Hall and his partner, Alfred E. Hunt, a metallurgist, with the capital they needed, but they were able to interest three Pittsburgh businessmen and a local chemist in their new company.[60] The firm started with $20,000. Additional financing came from other local businessmen, including the Mellon brothers, well-to-do Pittsburgh bankers who had acquired substantial capital by investing in local real estate.[61]

After fighting off two patent challenges and settling out of court after a third decision, the new firm solved a series of technical problems and invested and reinvested enough capital to make the company a profitable mass-production enterprise with tightly controlled markets. Renamed the Aluminum Company of America (Alcoa) in 1907, the firm was by the end of World War I, a large and successful producer of a metal that had been transformed from a laboratory curiosity to an industrial product with substantial potential for further development.[62]

As this new industrial firm emerged, it soon began to foster additional entrepreneurial sequences, much as the Boston Manufacturing Company (BMC) had in the early 19th century. Seeking space for expansion, the aluminum company also followed the BMC model by creating a town at New Kensington, Pennsylvania, on the Allegheny River to the north of Pittsburgh. New sequences of innovation in and near that location followed quickly: in addition to the usual retail establishments, there was a new Braeburn Alloy Steel company.[63] The search for new applications for aluminum reached out to Wisconsin, where there were several aluminum cookware firms; to Ohio, where there was a new aluminum sign-lettering business; and also to Illinois, where there was a new Illinois Pure Aluminum Company.[64] Many of the early ventures in aluminum products failed – as many startups did and still do – but the enthusiasm for the potential of a metal that was lighter than steel and a good conductor of heat and electricity did not wane.

As the Pittsburgh Reduction Company expanded output and lowered costs and prices, the business sought additional production sites. The next big move was to Niagara Falls, where cheap electricity was the attraction. Shortly, there was a second plant at Niagara Falls and then a third, as well as a plant at Massena, New York.[65] The Tennessee River was next, and here the firm, now Alcoa, established dams, power plants, and smelters and founded the town of Alcoa, Tennessee. Upstream vertical integration into bauxite, the firm's major raw material, took the business further westward to another new town, Bauxite, Arkansas.[66] The ore from Arkansas was refined into "alumina" in another new plant in East St. Louis, Illinois.[67]

Through its early history, the enterprise was protected by its patents, by a stiff tariff on imported aluminum, and by its membership in an international cartel that left the U.S. market to Alcoa's control. At the end of World War I, Alcoa was the sole producer in America of aluminum ingots. Alcoa's response to that large and growing market was to emphasize mass-production rather than improvement in the quality of their product.[68] Without acquiring significant scientific prowess, the firm had nevertheless steadily improved its production processes and achieved the greater efficiency and lower costs that further buttressed its monopoly position. Alcoa's process improvements were a credit to good engineering rather than good science.

As this suggests, the firm – again, like the Boston Manufacturing Company – had substantial power to shape its environment. It had fiercely resisted unionization of its plants. In the legal and political environment of that era, it had no real difficulty in establishing its particular combination of a holding company and an operating company structure. It exercised near absolute authority in its company towns.

Like other prominent monopolists and oligopolists in America during the second industrial revolution, however, Alcoa's relations with the federal government were unstable. A surge of agrarian unrest and a progressive reform movement created demands for more active governments at the local, state, and federal levels in America. As a new regulatory administrative state took hold, the political environment for entrepreneurship became more complex and negative; new questions were asked of business and new constraints imposed on business behavior. The entrepreneurial politics and culture were under serious attack in this first great surge of reform in American political economy. The federal and state antitrust laws properly reflected the attitudes of many Americans toward large concentrations of economic power. The public had become suspicious of the so-called "trusts" without being particularly attracted to radical ideologies that looked to the demise of big business and the capitalist system.[69] In 1911, the U.S. Department of Justice issued an antitrust complaint against Alcoa, but the firm's leaders were not interested in fighting national authority. They quickly reached an agreement with the government, signed a consent decree, and protected their monopoly.[70]

Meanwhile, Alcoa's contributions to the entrepreneurial multiplier across a wide expanse of America was fostering innovation in a new basic metal, feeding the American hunger for material progress, modulating the fear of "creative destruction," and building a new series of great fortunes that further exacerbated the nation's skewed distribution of income, wealth, and power. The firm's environmental footprint would eventually prompt political responses, but in these early years of the second industrial revolution, there was far more interest in the nation's rise to global industrial leadership than there was in the rise of industrial pollutants. Soon, however, that too would change, and local, state, federal power would be exercised in an effort to protect the environment.[71]

While the progressive reform movement challenged entrepreneurial authority on several fronts, the culture and politics of innovation still had broad appeal in America. They were actually bolstered in this same era by the rise of the professions in urban America. The professions were themselves sites of transformation. All of them lauded change and developed social systems that rewarded creativity. Science and engineering in America were transformed, as were the institutions of higher education that provided professional training and began to generate research. Although the United States at first lagged far behind Germany in developing university-based technical research, American schools began to close the gap in the twentieth century and then to move ahead in many fields after World War II.

Alcoa took advantage of this surge in science and engineering to improve its production processes and to develop new uses for aluminum.[72] Like most American manufacturing firms, it first tried to use consultants instead of developing in-house technical capabilities. But the company needed its own technicians just to deal effectively with consultants. Shortly, Alcoa started to build its own staff, first with engineers. Next came chemists and metallugists. Soon Alcoa had a central laboratory capable of generating new products and processes and also able to guide the business of buying innovations. This task became all the more important after the company's patents expired in 1909. European competition had pushed ahead of the United States in aluminum quality and in the diversity of its products. Following World War I, as Alcoa's Technical Department attempted to catch up, the Department became a major source of new products, improved processes, and fundamental research.[73] It also became a source of the opportunities that brought new firms into the business of using aluminum to make everything from airplanes to automobile parts, from window castings to cooking ware and aluminum foil.[74] The process was multiplying entrepreneurial opportunities, knowledge, and capital across a broad front.

In France

The virtually simultaneous discovery in France (1886) and the United States of the modern electrolytic method of producing aluminium made it possible to start production of the metal on a large scale in both nations. In both countries, this technological innovation launched an impressive array of entrepreneurial sequences in subsequent years. In France, unlike the United States, the new process was picked up and promoted by existing chemical enterprises. These businesses had developed to serve the glass industry and the regional textile districts in the first half of the century. One of the important firms was Pechiney, which would become the major French producer of aluminium in the 1920s. The engineer Henri Merle had launched the firm (at first Société Henri Merle et C.ie) in 1855 as a caustic-soda Leblanc factory to supply the Lyon textile district. Merle raised the capital he needed locally: J.-B. Guimet (a pigment producer in Lyon) invested, as did the private 'Banque Dugas' (among the founders in 1835 of the 'Banque de Lyon', from 1848 a branch of the 'Banque de France'), and a local notary, Piaton from Lyon. Merle built his first soda factory in Salindre (Languedoc-Roussillon), near coal and limestone mines and a new railroad, Paris-Lyon-Mediterranée, that could supply salt from the Mediterranean.[75]

Very soon, H. Merle began to diversify beyond soda. He manufactured sulphuric acid, chlorine, and chlorates; from 1860 until 1890, the business produced aluminium using a chemical process discovered in 1855 by the French scientist Henri Sainte-Claire Deville. The Deville process permitted the company to obtain pure aluminium from its compounds by treating them with sodium instead of the expensive potassium. As a result, aluminium became a commercial metal in France for the first time.[76]

This chemical process cut down the cost for producing the metal from bauxite, but the aluminum was still too expensive to permit widespread use. Although enough was then known about the properties of aluminium to indicate a promising future, the enterprise, which in 1860 became the unique aluminium producer on industrial scale in the world, still only produced around 2 tons per year until 1889. By that time, Merle had died and A.R. Pechiney was running the firm, renamed Société des Produits Chimiques d'Alais et de la Camargue in 1897. Later, the company changed its name to Pechiney, which is the name we will use now to avoid confusion.

Although Pechiney had been the first enterprise to attempt large-scale production of aluminium, it was not the first in Europe to adopt Héroult's innovative process. In 1886 the 23- year-old Héroult offered his new method to Pechiney. Héroult was a close friend of Louis Merle, young son of Henri, the former director of the company. But Pechiney and his son-in-law, Alfred Rangod, who was managing the firm at that time, made a conservative and expensive decision to stick with the company's chemical process. A.R. Pechiny said he "did not like electricity."[77] This decision – comparable to the decision by America's Western Union Company not to buy the Bell telephone patents for $100,000 – had unfortunate consequences for Pechiney. Héroult sold his patent to a Swiss enterprise which started aluminium production on a large scale and soon internationalized its business. In France the Swiss firm operated as the 'Société Électrométallurgique Française,'called 'Froges' after the place where it founded its first plant, near Grenoble, about 1888.[78] Froges was thus the first in France to adopt the new technology and it quickly surpassed Pechiney. The Swiss business became the leading French producer of aluminium.

Near the end of the century, Pechiney and his son-in-law realized they had made a serious mistake. Unlike Western Union, they were able to recover from their blunder. In 1897, they acquired 'Calypso', an electrolysis factory using the Hall process, and also incorporated their business. The Bernard brothers had founded Calypso in 1890, at Saint-Martin-la-Porte in the Mourraine Valley. From that time on, the Pechiney strategy gave aluminium first place in both production and investments. In 1907 Pechiney founded a second aluminium plant using the Hall process in the Mourraine Valley (later called "la Vallée de l'Aluminium"), at Plans de Saint-Jean. The company began at the same time to look to international markets.

On the eve of World War I, Pechiney transformed all of its aluminium plants from the Hall to the Héroult process. By that time, the enterprise's capital had increased from 3.6 million (1896) to 17 million F. It still was a medium firm by European standards – especially when compared to Saint-Gobain or to the big French metallury companies. It was significantly smaller than the German chemical firms Bayer, Hoesch or BASF, or the Belgic Solvay. It was, however, a profitable business, in part due to the successful combination of extensive resources of bauxite (abundantly available in Provence and Bas Languedoc) and hydro-electrical power, concentrated in the Pyrenees and along the Alps.[79]

The industry thus became concentrated in the South-East of France. The Société Électrométallurgique Française also built two new aluminium factories, at La Praz in 1893 and La Saussax in 1905. Together with the plant at Prémont (1907) owned by a third chemical company, Henry Gall et de la Montlaur, five of the nation's eight aluminium plants were concentrated in the same area. Outside of the Mourraine Valley, there were three other factories: at Chedde (1906) , Auzat (1907) – both owned by Bergès-Bouchayer - and at L'Argentiere (1910).[80] That was where Pechiney built a great hydroelectric plant which serviced its production of aluminium.[81]

Although achieving economies of scale and integration, the French firms, like those of Germany, emphasized the high quality of their products substantially more than

Alcoa did. This was an adjustment both to their domestic markets and their human resources, much as Alcoa was doing in the early phase of its operations.[82]

The new industry, with its huge investments in hydropower constructions and in aluminium plants and equipment transformed the economic and social environment of these mountains areas. The entrepreneurial multiplier was at work. Several new hydroelectric centrals were built to supply the industry and soon every factory had its own water fall, electrical source, and surrounding small enterprises. Industry pumped money into the communities to the benefit of their local businesses after Pechiney acquired and founded new electrical plants at Saint-Felix (1902) and Pontamafrey (1910). Little by little, every water fall was exploited.

For a long time, the companies had to deal with the regular fluctuations in the supply of water, energy, and labor. The water supply expanded in the summer and shrank in the winter and spring. That was not the industry's only problem. While industrial work gave additional income to local peasants, they continued to desert the factories and go back to agricultural work when they were needed, usually in the summer. This was when production was normally growing and factory hands were most needed. The firms responded by bringing in seasonal workers from Italy (the Piedmont) and Africa (the Maghreb). To facilitate this addition to the workforce, the businesses began to provide welfare services, houses, and other accommodations to the workforce. The firms, as a result, became deeply involved with their local communities and exercised significant local authority, as was the case in early New England.

Their authority was tested but not overcome as it became clear that the production of aluminium caused dangerous pollution in the air and in the water of the valley. This affected the workers inside the factories and outside of them, impacting the local communities and their economy based on forests, livestock and cereals. Since the very beginning of the 20th century, inspectors of water and forests and municipal councils had begun to protest the pollution.[83] But there is little evidence that these protests brought about significant changes in the industry until after World War II when a surging environmental movement in France, throughout Europe and the United States forced the businesses to change. This pattern was similar in France and the United States.

In both countries, demand for aluminium was increasing and new uses were being found for this relatively light, malleable, and corrosion-resistant metal.[84] French output between 1900 and 1914, experienced significant expansion even though it lagged the growth in world output.[85] The 'golden age' of this new product would take place after WWII, especially for Duralumin alloy (first patented in 1910) in cars and airplanes. Research and development contributed to this growth, particularly in the laboratories closely tied to the factories. That alignment favoured improvements in process. Especially important were innovations that saved energy and coal: the cistern of Héroult, which in 1888 had a single anode, used 3,000 amperes and consumed from 80 to 90,000 kw per ton. By 1914 the French factories had cisterns with anodes of 10,000 amperes that consumed only 30,000 Kw per ton.[86] Other science-based innovations followed – particularly in aluminium alloys.[87]

In France the early industry was less concentrated than it was in the United States, but the enormous set-up costs and large energy requirements fostered both vertical and horizontal integration. Up-stream integration brought control of the different stages of the process, from mining bauxite, to refining alumina, to producing aluminium. The

French approach to competition differed from that of the United States, but the long-term results were much the same: oligopoly based on cartels and then a trend toward monopoly.[88]

In the case of Pechiney, these developments accelerated after Adrien Badin succeeded A.R. Pechiney as head of the company in 1906. Badin helped manage the creation of aluminum's domestic and international cartels, internationalized Pechiney's distribution, and finally, launched a merger strategy that made his company once again the top French producer. Badin led the successful effort (1910) to establish the "Comptoir de vent de l'Aluminium Française," which divided the French market as follows: 44% to Froges, 33% to Pechiney, 15% to the group Bergès-Bouchayer, 8% to Ugine. The French cartel was in turn part of an international agreement which stabilized market shares for the world.

Already cooperating under the Comptoir, Pechiney and Froges launched two new branches in Norway and North Carolina (1911/12). The Banque Franco-Americaine, the Crèdit Lyonnais, and the Banque Dreyfus all supported this venture into the large American market.[89] But the last two banks left the business during World War I, and the lack of financial support led to a decision to sell the U.S. plant to Alcoa.[90]

Pechiney was more successful in France. The aggressive Badin led Pechiney's 1914 acquisition of Bergès-Bouchayer's plant at Auzat and absorbed the rest of the group in 1916. In the wake of World War I and the Versailles peace treaty, he completed his grand strategy of merger by acquiring (1921) the Société Électrométallurgique Française and organizing the new Compagnie de Produits Chimique et Electrochimiques Alais, Froges et Camargue. For the second time in its history and for a long time thereafter, Pechiney was the dominant French producer of aluminum.

Although the markets for the new metal in France and the United States were significantly different, as were the politics and the industry's scientific resources, the entrepreneurial multiplier worked in France much as it did in the United States. The successful enterprises that gradually won for aluminium a growing role in their respective national economies fostered new sequences of innovation. Concentration and the cartels doubtless slowed the process but they certainly did not stop it in either country. By the end of the interwar era, aluminium was one of the success stories of the second industrial revolution and of the entrepreneurial multiplier in Europe and in America .

The Third Industrial Revolution

In the years following the Second World War, America's Bell System developed the innovation that would launch a third industrial revolution in the United States and soon after in the rest of the world. The Bell System's switching innovation, the transistor, set in motion the single most far-reaching entrepreneurial sequence in modern history.[91] The digital revolution can be traced from the transistor, to the integrated circuit, to the internet and to a multitude of related innovations that are still today remaking political economies, societies, and cultures worldwide.[92] The Entrepreneurial Multiplier in this case is very long, very complex and continuing to grow. The path of these sequences – charted by numerous historians and economists – is certainly tree-like. In manufacturing, distribution, and financial services, new enterprises continue to develop in the wake of the digital transformation. So too do smaller retail firms down to the level of the internet cafes. Even in some of the poorest and least developed societies in the world, wireless communications and the internet are changing the way people communicate, carry on economic activity, and engage with the world outside of their families, communities, and nations.[93]

This recent burst of innovation has had important cultural, social, and political, as well as economic effects on the United States. In the aftermath of the New Deal of the 1930s and the wartime expansion of government controls in the 1940s, it appeared to Schumpeter and other sagacious intellectuals that the drift toward socialism and away from market-oriented capitalism and the entrepreneurial culture was inevitable.[94] America's European allies were headed down that path in the aftermath of the war. But then a formidable political and intellectual "re-formation" in America revived entrepreneurial values and again transformed the nation's political setting.[95] That context continued to be characterized however, by formidable tensions between those in quest of equity and economic security and those Americans who emphasized the search for efficiency and for what Michael Lewis memorably labeled "the new new thing."[96] These tensions came to the surface and roiled American society in the years following the Great Recession of 2008.

While this latest episode political and cultural struggle was underway, the digital revolution decisively reinforced with new opportunities, profits, jobs, services and goods an entrepreneurial culture which now began to play a larger role in the United States and the global economy. It is beyond our capabilities to follow the millions of digital sequences from the initial innovation at Bell Labs to the more recent entrepreneurial experiences in the United States, Asia, Latin America, and Europe. Others have tracked some but not all of these major sequences, as indicated in the materials cited in our endnotes. Instead, we will leap over the multitude of sequences stemming from the transistor and look at one sequence, a very recent development that we believe provides a good illustration of what has happened and is continuing to happen in the information age. We will briefly examine 3D printing, an innovation that could well become a general purpose technology and is today continuing to evolve in the United States, in Asia, and in several countries in Europe. As we do so, we are jumping into Wiki-History Land, where the factual base is skin-thin and the perspective stunted. After applying a simple "Media-Hype Discount" of 50%, we can at least chart some of the outlines of this sequence.

Those who have not been following 3D printing in the press and other publications can turn to Chris Anderson's recent book, *Makers: The New Industrial Revolution*, for a simple, non-technical explanation of the technology.[97] As Anderson aptly observes, you can start by thinking about the laser jet printer that you probably use in your home or office. That machine is a two-dimensional printer. You put computer instructions in the printer, and it applies ink to the page as instructed. Your letter, chapter, or lecture comes out (one hopes) in finished form. Now imagine that you add a third dimension to the instructions and the machine extrudes plastic or metal instead of ink. You now have a 3D Printer. This is also called "additive manufacturing." These machines are currently available in a variety of sizes, forms, and capabilities.

Charles W. "Chuck" Hull invented and patented the original machine in 1986, using an ultraviolet light beam to harden a light-sensitive liquid as it was applied, layer by layer, to make the product specified by the software. Hull founded 3D Systems to produce the machines and today it is one of the two largest companies in the industry.[98] There are now various different techniques for shaping either plastic or metal (laser sintering and laser melting, for example) and all have taken computer assisted design (CAD) and computer assisted manufacturing (CAM) to a new level in which the printer actually makes the object you want to produce. It makes them one at a time. It makes them just as complex as your software design is. Some of the printers build up the object, layer by layer, from the plastic or metal they extrude. Others cut the object from the material. If you do not want to develop software instructions, you can put the object you want to copy in a 3D scanner that will produce the instructions you need.

Where is 3D printing being used? One of its most important uses is in producing prototypes for further development in other forms of manufacturing. It is also being used in making dental products, medical devices, architectural models, electrical circuits, and the tools and molds used in mass-production. To those who see manufacturing moving away from standardized products toward personalized, individualized products, 3D has great appeal. In its current form it favors customization, but that too may change with further technical development. New firms are entering the industry, including General Electric (GE), which now has a "Rapid Prototyping Center." By 2020, GE plans to be producing more than 100,000 aviation parts using 3D Printing.[99] Even after applying our hype discount, it is significant that firms like GE and Hewlett Packard (HP) have moved into the industry. HP announced (October 2014) that it would soon have available a 3D industrial printer that it claimed could cut costs by fifty percent while working ten times faster than existing machines.[100] Like the early textile industry, 3D printing has produced a new system of manufacturing and a new machine-tool industry with substantial capabilities for further entrepreneurial development. There is currently interest in creating machines large enough to produce 3D automobiles.

As befits a relatively new industry in a new digital age in a very large, capital-rich America, funding for 3D entrepreneurial ventures has taken on new forms.[101] In addition to the traditional ways of funding entrepreneurship – mortgages, credit cards, the 3 Fs, and the post-WWII venture capital companies – businesses making 3D printers have turned to campaigns of so-called "crowdfunding." This is a way of using the internet to collect small amounts of capital from a relatively large number of people who do not know each other. One of the "platforms" for crowdfunding is Kickstarter, which has been in business in the United States since 2009. Forty-one producers of 3D printers have gathered pledges of $18 million through Kickstarter and the amount of capital raised in this way is continuing to grow. Large firms such as GE and HP can depend on internal financing, but the startup producers have turned with apparent success to public campaigns to promote their innovations.[102]

Will 3D Printing be a disruptive technology, à la Clayton Christensen?[103] According to Lyndsey Gilpin, writing in TechRepublic, 3D will have a revolutionary impact on manufacturing in electronics, automobiles, jewelry, and military equipment, on medicine, and on many other aspects of production in the developed and the developing worlds. McKinsey Global Institute predicts that it will be a major factor in the global economy by 2025.[104] The global market for printers and services has been estimated at $2.2 billion in 2012 (the growth rate was 29% over the previous year).[105] In a report entitled *The Search for Creative Destruction*, investment firm Goldman Sachs focuses on three transforming technologies: big data solutions; software-defined networking; and

3D printing, which "is expected to continue on its path of rapid acceleration."[106] Projections vary, but the historical trend for the years 2007-2011 is impressive: there were 66 3D printers sold in 2007 and 23,265 sold in the latter year, a dramatic increase.[107]

Recent developments in bioengineering are especially interesting. As Professor Jerome Groopman observed in a recent issue of the *The New Yorker*, cell biologists using 3D printing are making progress toward the goal of printing functional body parts that can be used to replace failing organs.[108] Researchers at Cornell University have already printed aortic heart valve conduits, and the Wake Forest Institute for Regenerative Medicine has implanted lab-grown bladders in patients.[109] Work is currently being done to develop human tissue that could be used by pharmaceutical companies to cut the costs of safety and clinical tests for new drugs.[110] Patenting has been vigorous in this field, and there are currently a number of relatively new companies exploring commercial applications. They include Materialise, a Belgian firm with offices around the world, EnvisionTEC, 3D Printsmith, and Organovo Holdings, Inc., which is listed on the New York Stock Exchange and recently raised $24.7 million in equity.

As Steven Leckart reported in 2013, Organovo was now able to print liver tissue. "Three factors," he said, "are driving the trend: more sophisticated printers, advances in regenerative medicine, and refined CAD software. To print the liver tissue at Organovo," Leckart said, "Vivian Gorgen, a 25-year-old systems engineer, simply had to click 'run program' with a mouse." That product leaves Organovo a long way from making a fully functioning organ, but it is an astonishing step forward.[111]

The extended, incredibly varied entrepreneurial sequences leading to these developments in bioengineering and the millions of other similar innovations in the third industrial revolution were taking place in a political and cultural environment that very recently appeared to be loaded against the entrepreneur. Despite the late twentieth-century rise of neo-liberalism, a mature American regulatory state was scrutinizing many forms of business behavior that had one hundred years ago been free of political control. In the wake of the Great Recession, a very active federal government and a very active array of non-governmental organizations now have available and are prepared to use vast amounts of information on the economy and the actions of particular businesses and individuals. There is a mounting interest in squeezing risk out of the financial system that funds the American brand of capitalism.[112] Class action lawsuits, opposition from environmental organizations, and an aggressive media impinge on private sector decisions that had once been easy to make on the basis of economic factors alone.[113] Entrepreneurial profits and inequality of income, wealth, and opportunity are central issues on America's political agenda. A society nervous about the economic future seems on the surface less concerned about the opportunity to build wealth by developing new products and services, new sources of raw materials, new markets, and new styles of organization.

And yet, the rise of 3D printing and, indeed, the entire digital revolution indicate that entrepreneurship has not been choked off by a hostile culture and polity -- the *Wall Street Journal*'s litany of laments notwithstanding.[114] To the contrary, the adaptable entrepreneurs of 3D printing and all of the other digital innovations seem to be just as enthusiastic about change as were the early nineteenth-century founders of cotton-textile mills and machinery firms and the inventors and investors who built up the aluminum business in the early twentieth century. In the United States the incentives for entrepreneurship – an inherently risky undertaking in finance and industry – still apparently outweigh a cultural, media, and political environment increasingly focused on reducing risk in the aftermath of the Great Recession of 2007-2009 and its global aftermath.[115]

So too in the European Union, where neither the Great Recession nor the recent problems with mass immigration have deterred 3D entrepreneurs. In a case of near-perfect historical symmetry, the United States has sparked a 3D movement in Europe two centuries after Britain provided America with the essential ideas it needed to start its first industrial revolution. In Italy, where a well-established and talented array of designers exists, 3D caught on quickly. Milan, the current style center of Europe, became for a time the leading 3D city in the world. The highly specialized manufacturing enterprises of Northern Italy had been troubled for years by competition from China. The new 3D mode of production pumped new life into many of Italy's small and medium-sized businesses. Exports are increasing. Entrepreneurial sequences are beginning to multiply: in addition to producing the machines and the raw materials (plastic filaments, for instance) used in 3D production, Italian businesses are making products ranging from furniture to shoes to eye glasses to medical materials and to automobile and airplane parts.[116]

Other European Union members are quickly catching up with the leaders: as one might expect, Germany has made strides in machine tools; and both German and British companies have partnered with firms from other nations in efforts to advance the technology and find new applications for 3D production.[117] In Britain, public-private alliances have been popular. Renishaw, a British precision-measuring firm, has developed a 3D business in products ranging from aerospace to medical care.[118] If there is, indeed, going to be a 3D revolution in manufacturing, it will certainly have global dimensions.

Conclusion: So What?

By focusing on three industrial revolutions, we have stressed technological, rather than institutional change and emphasized endogenous rather than exogenous factors in shaping the entrepreneurial aspects of capitalism.[119] Many of the major innovations since the late eighteenth century have not been technological. Changes in the organization of firms (the unitary-form, the multidivisional-form, for instance; and later the network-form of business) encouraged innovation in many sectors of the industrial economies, as did the rise of management consulting since World War II. New sources of supply and of labor had similar effects. Nevertheless, from the perspective of the entrepreneurial multiplier, technological change has been the most productive of the long, highly varied sequences of innovation that we have examined.

These entrepreneurial sequences in America and Europe help us improve our ability to estimate the total impact on society of innovations like those associated with early textile and textile machinery development, with the expansion of aluminum production, and in the recent past with the digital revolution and such innovations as 3D printing. The changes were revolutionary in part because they spread through the economy and fostered new opportunities, new capabilities, and new sequences of innovation long after the initial acts of entrepreneurship. They continued to promote growth and also to shape and reshape the society's culture and polity. The resulting changes easily crossed national frontiers. The nation state was still all-powerful in the military realm, but it could not contain the powerful force of entrepreneurial change.

For economic and business historians, the multiplier seems to us to suggest that we should look beyond the firm and trace the sequences of innovation that will give us a deeper historical understanding of how and why capitalism has evolved over the past three centuries.[120] These sequences will as well give us a better understanding of the economic, political, and cultural resilience of capitalism. The Entrepreneurial Multiplier will force business and economic historians (as it has the authors of this article) to look again to social, urban, and cultural history for a better understanding of the capitalist process. The Multiplier might also provide a new intellectual avenue between industrial and financial history and between history and the related behavioral sciences. Scholars in sociology, political science, management and anthropology – as well as economics – are exploring, to good effect, the history of capitalism. An elaboration and discussion of the Entrepreneurial Multiplier will, we believe, facilitate further work in all of these disciplines and in business history.

While there are many varieties of capitalism and differing patterns of entrepreneurship, there are as well some central aspects of the innovative process.[121] It has, above all, promoted economic growth. "Crowding out" functions as a limiting factor, as does the destructive side of the creative destruction that normally accompanies innovation. But the dual impact of the classical multiplier and the entrepreneurial multiplier has normally yielded the positive economic effects over the long-term that distinguish modern capitalism from all of its predecessors and recent competitors.[122] The adaptable entrepreneur has played and continues to play the lead role in that historical process.

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[1] The authors have been helped a great deal by several earnest, imaginative, thoughtful research associates. They include Nathanial Mark, Jim Ashton, Rebecca Stoil, and Silvia Conca. We appreciate their efforts on our behalf and on behalf of The Multiplier.

[2] We recognize that the two "visions" are merely central tendencies in vast bodies of thought and political action that include many variations within and between nations. Advocates of economic security and equity would, of course, also like to share the benefits of innovation and efficiency; those who stress efficiency and innovation would like to have full measures of security and equity as well. One of the tasks of politicians is to develop and implement compromises that somehow balance these goals, compromises that perhaps favor innovation without appearing to endanger equity. Sometimes the politicians succeed.

[3] In recent years there has been a sudden burst of attention to the entrepreneur in economics. See, for example, some of the following sources: Mark Casson, Entrepreneurship: Theory, Networks, History (Cheltenham: Edward Elgar, 2010); and a series of publications by William J. Baumol: "Entrepreneurship: Productive, Unproductive, and Destructive, The Journal of Political Economy, 98, 5, Part 1 (October 1990), 893-921; "Formal entrepreneurship theory in economics: Existence and bounds, Journal of Business Venturing, 8, 3 (May 1993), 197-210; and "Entrepreneurship and Innovation: The (Micro) Theory of Price and Profit," available at https://www.aeaweb.org. See also the entire issue of Industrial and Corporate Change, 22, 1 (February 2013); and Mümtaz Keklik, Schumpeter, Innovation and Growth: Long-cycle dynamics in the post-WWII American manufacturing industries (Aldershot: Ashgate Publishing Limited, 2003). As J. S. Metcalfe notes, there is still significant tension between a neoclassical approach and an entrepreneurial approach to economic change. "Entrepreneurship an Evolutionary Perspective," in Mark Casson, Bernard Yeung, Anuradha Basu, and Nigel Wadeson, eds., The Oxford Handbook of Entrepreneurship (Oxford: Oxford University Press, 2006), 59-90.

[4] The basic concept of the multiplier has changed very little in the past half century. Compare Paul A. Samuelson, Economics: An Introductory Analysis (New York: McGraw-Hill, 1964), 231ff, with N. Gregory Mankiw, Principles of Macroeconomics (Mason: Cengage Learning, 2009), 484ff. The only significant change appears to be the addition of a potential constraint, crowding out, on the multiplier. Indeed, the basic analysis was worked out as early as 1935 in John Maynard Keynes, The General Theory of Employment, Interest, and Money (Createspace edition, first published on December 13, 1935), pp. 50-57.

[5] We are thus answering Schumpeter's plea for historical reasoning in entrepreneurship research but coming to conclusions that neither the master nor his recent scholarly servants might approve. See, for instance, R. Daniel Wadhwani and Geoffrey Jones, "Schumpeter's Plea: Historical Reasoning in Entrepreneurship Theory and Research," in Marcelo Bucheli and R. Daniel Wadhwani, eds., Organizations in Time: History, Theory, Methods (Oxford: Oxford University Press, 2014), 192-216.

[6] For some other mentions of an entrepreneurial multiplier, see the following sources:
Sankaran Venkataraman and Saras Sarasvathy, The Fabric of Regional Entrepreneurship: Creating the Multiplier Effect (World Entrepreneurship Forum, 2008). Enrico Moretti and Daniel J. Wilson, "State Incentives for Innovation, Star Scientists and Jobs: Evidence from Biotech," Federal Reserve Bank of San Francisco, Working Paper 2013-17. Mümtaz Keklik, Schumpeter, Innovation and Growth: Long-cycle Dynamics in the Post-WWII American Manufacturing Industries (Farnham, Surrey: Ashgate Publishing, Ltd., 2003), 26, 35note 7, 48.

[7] See, for examples, Richard N. Langlois and W. Edward Steinmueller, "The Evolution of Competitive Advantage in the Worldwide Semiconductor Industry, 1947-1996," Roberto Mazzoleni, "Innovation in the Machine Tool Industry: A Historical Perspective on the Dynamics of Comparative Advantage," and Rebecca Henderson, Luigi Orsenigo, and Gary Pisano, "The Pharmaceutical Industry and the Revolution in Molecular Biology: Interactions Among Scientific, Institutional, and Organizational Change," all in David C. Mowery and Richard R. Nelson, eds., Sources of Industrial Leadership: Studies of Seven Industries (Cambridge: Cambridge University Press, 1999), 24, 181, 206, 275.

[8] The textile industry is frequently cited since factory spinning of yarn preceded factory weaving of cloth. David S. Landes, The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present (Cambridge: Cambridge University Press, 2nd edition, 2003), 83-88. As Landes points out (p. 87), the "pattern of challenge and response" also can also be seen in "the preliminary processes of cleaning, carding, and preparation of roving." Finishing was transformed, as was printing of the cloth.

[9] See, for instance, Albert O. Hirschman, The Strategy of Economic Development (New York: Norton & Company, 1958); and Timo Tohmo, Hannu Littunen and Hannu Tanninen, "Backward and forward linkages, specialization and concentration in Finnish manufacturing in the period 1995-1999, European Journal of Spatial Development, 19, April 2006, at http://www.nordregio.se/EJSD/-ISSN.

[10] Joseph A. Schumpeter, The Theory of Economic Development: An Inquiry into Profits, Capital, Credit, Interest, and the Business Cycle (New York: Oxford University Press edition 1961), especially 131-56; the entrepreneur "has also triumphed for others, blazed the trail and created a model for them which they can copy. They can and will follow him, first individuals and then whole crowds." (133); Schumpeter later extended the model but kept the same focus on the economic roles of the entrepreneurs and their followers in Capitalism, Socialism, and Democracy (New York: Harper & Brothers Publishers, 1947 third edition); the gale of competition that follows innovation is the key to "The Process of Creative Destruction," 81-86.

[11] Mark Casson, the preeminent theorist of entrepreneurship, uses an even broader definition than we do: Casson includes arbitrage as an entrepreneurial function; we leave that out in an effort to keep a relatively tight focus on innovation. See Mark Casson, et al., Entrepreneurship: Theory, Networks, History (Cheltenham: Edward Elgar, 2010), 3-41; and Martin Ricketts, "Theories of entrepreneurship: Historical development and critical assessment," in Casson, et al. The Oxford Handbook, 33-58.

[12] See Nathan Rosenberg, Inside the Black Box: Technology and Economics (New York: Cambridge University Press, 1982). We consider start-ups in agriculture, as in transport and other industries, as entrepreneurial enterprises. New farms combine land, labor, and capital in novel ways; no new farm is exactly the same as another. The individual farm has little impact on the local, regional or national economy, but the cumulative impact on a society like the United States can be great – as it was during the first two centuries of American history. Like immigration, agricultural innovation contributes to an entrepreneurial culture.

[13] (New York: Harper Business Book, 2000, first published in 1997). (New York: Doubleday, 1999, first published in 1996).

[14] David S. Landes, The Unbound Prometheus, especially pp. 41-123.

[15] See E.H. Cameron's early, uncritical biography of Samuel Slater: Father of America Manufactures (Portland, Maine: Bond Wheelwright, 1960), and Barbara M. Tucker's admirable study of Samuel Slater and the Origins of the American Textile Industry, 1790-1860 (Ithaca: Cornell University Press, 1984). Tucker carefully explains the links (including the tensions) between Slater and the commercial partnership of Almy and Brown, pp. 50-107, as well as the subsequent ventures of Slater, who was early on a bundle of entrepreneurial energy. Later, he was slow to adopt power weaving and steam engines.

[16] Like J. S. Metcalfe (endnote 2, above), we believe that entrepreneurship gives to capitalism its fundamental character as a "restless system." We applaud Metcalfe's evolutionary analysis of the entrepreneurial process even

though our primary audience is in history, not economic theory. We are also indebted to Luigi Orsenigo for his approach to entrepreneurship in a dynamic system; see, for instance, "Technological regimes, patterns of innovative activities and industrial dynamics" Cahiers d'economie et sociologie rurales (CESR), INRA, 37 (1995), 25-67.

[17] Barbara M. Tucker, Samuel Slater and the Origins of the America Textile Industry, 1790-1860, touches briefly on the commercial sequences related to early mill development in her chapter on "Industrial Community Life," pp. 125-38. As she notes on pp. 158-59: "In 1832, twelve shops operated in Webster: five grocery and dry good stores, three general stores, a hardware store, a bakery, a boot and shoe shop, and an establishment that sold drugs and liquor." On pp. 151-52, the author mentions the local taverns. For Slater's influence on Oneida Country, New York, see Mary Ryan, Cradle of the Middle Class: The Family in Oneida County, New York, 1790-1865 (New York: Cambridge University Press, 1983 edition), p. 44. On sequences related to industrialization in Oneida County, see pp. 48-49, 53, 56-57, 64, 94-95, 110-11, 114-15, 128-31, 134-35, 138, 140, on developments prior to 1845.

[18] Howard W. Gitelman, Workingmen of Waltham: Mobility in American Urban Industrial Development, 1850-1890 (Baltimore: Johns Hopkins University Press, 1974), 6 We are indebted to Gitelman for his meticulous research that goes far beyond the subject in his title. In the 1840s, when the population increased by an astonishing 76%, the town acquired more new retail stores and taverns on its Main Street (ibid., pp. 13-14, 21.

[19] The information on this firm is available at www.waltham-comunity.com/history.html.

[20] MHC, Reconnaissance Survey Town Report: Waltham (1980), 5.

[21] See http://files.usgwarchives.net/ma/norfolk/bios/metcalf74gbs.txt. See also "The handbook of Medway history: a condensed history of the town of Medway, Massachusetts, available at archive.org/stream/handbookofmedway02maso/handbookofmedway02maso_djvu.txt. On the spread of textile machinists see David R. Meyer, Networked Machinists: High-Technology Industries in Antebellum America (Baltimore: Johns Hopkins University Press, 2006), 50-72. The author's initial focus is on the machinists closely linked to Slater; they were in demand throughout New England and New York.

[22] George Sweet Gibb, The Saco-Lowell Shops: Textile Machinery Building in New England, 1813-1949 (Cambridge, MA: Harvard University Press, 1950), 24.

[23] This is the central theme of David R. Meyer's book, as indicated by the title: Networked Machinists. On Moody see especially pp. 65-66. Moody was a small-town mechanic. While he had only a rudimentary education, he had experience in weaving, nail production, and the development of textile machinery.

[24] The textile mills spread technically trained men around the Northeast, and the railroad shops would later do this over much of the nation. See Albert Fishlow, American Railroads and the Transformation of the Antebellum Economy (Cambridge: Harvard University Press, 1965). As David Meyer notes in Networked Machinists, p. 70: "Boston's satellites and inner hinterland, extending out as much as one hundred miles, constituted the single greatest arena of textile machinery patenting in the East, especially in power looms…." See also Barbara M. Tucker and Kenneth H. Tucker, Jr., Industrializing Antebellum America: The Rise of Manufacturing Entrepreneurs in the Early Republic (New York: Palgrave Macmillan, 2008), pp. 74-5, on the links between textile machinery and gun production.

[25] George Sweet Gibb, The Saco-Lowell Shops, especially pp. 39-55, for the years 1814-24. Thomas R. Navin, The Whitin Machine Works Since 1831: A Textile Machinery Company in an Industrial Village (Cambridge, MA: Harvard University Press, 1950). Both of these books were in N.S.B. Gras, ed., Harvard Studies in Business History, and a number of the other volumes in that series deserve re-analysis and additional research to establish the full economic impact of their subject firms.

[26] Gibb, The Saco-Lowell Shops, 33-39.

[27] In 1824, the machine shop became a part of the Merrimack Manufacturing Company (MMC) and then part of the Locks and Canals on Merrimack River, a firm owned by MMC. In 1845, the machine shop became a separate enterprise. Gibb, 55-58, 63-64. The location was actually in East Chelmsford, but it became Lowell as the leaders of the enterprise developed their grand plan.

[28] Gibb, The Saco-Lowell Shops, 22-23.

[29] Gibb, ibid., finds 13 "hostelries" in 1835. There was also a new foundry in Chelmsford that supplied castings to the machine shop.

[30] The work of Alvin Hansen supplanted the earlier studies by Wesley Claire Mitchell and used machine tools to analyze the built-in turning point that would inevitably end a phase of industrial expansion.

[31] After 1831, the Whitin brothers were also bringing new and more efficient machinery into the textile mills and were as well improving the productivity of their own operations in machine-tools. Thomas R. Navin, The Whitin Machine Works since 1831, 28-37. In the 1850s, the Whitin as well as the Lowell shops faced increased competition from British and American machine-tool specialists.

[32] The Lowell Directory (1832), available on http://www.accessgenealogy.com.

[33] Whitinsville, the site of the Whitin Machine Works, evolved along a somewhat different path than Lowell. The firm owned most of the farms and houses in Whitinsville and had a company store. There were tradesmen in the village, but Whitinsville did not develop the kind of lively commercial sector that Lowell had. Thomas R. Navin, The Whitin Machine Works Since 1831, 62-88, 171-72.

[34] Naomi R. Lamoreaux and John Joseph Wallis brilliantly analyze the political institutions in "States, Not Nation: The Sources of Political and Economic Development in the Early United States," available in the American Capitalism working paper series on the website of the Institute for Applied Economics, Global Health, and the Study of Business Enterprise.

[35] Max Weber, The Protestant Ethic and the Spirit of Capitalism (First published in 1905; Allen and Unwin edition in 1930). As Barbara M. Tucker and Kenneth H. Tucker, Jr., point out in their important study of Industrializing Antebellum America, different first- and second-generation entrepreneurs had particular cultural-orientations, ideologies, and personalities; so too does Naomi Lamoreaux, who methodically demolishes the central thesis of the "moral-economy historians." Lamoreaux demonstrates to good effect that the behavior of manufacturers and merchants – no less than farmers – can best be explained by reference to the complex interactions between their cultural environments and their drive to turn profits and build capital. Competition was frequently leavened by cooperation, and family ties were the norm in the early nineteenth-century American economy. Our interest is in one aspect of that cultural environment: the general emphasis upon change, innovation, and its related risk-taking. Naomi R. Lamoreaux, "Rethinking the Transition to Capitalism in the Early American Northeast," Journal of American History, 90, 2 (September 2003), 437-61. See also B. Zorina Khan, The Democratization of Invention: Patents and Copyrights in American Economic Development, 1790-1920 (New York: Cambridge University Press, 2005). As the author notes (p.3), "The American system of intellectual property was based on the conviction that individual effort was stimulated by higher expected returns."

[36] For the most recent, broad-scaled treatment of inequality under capitalism see Thomas Piketty, Capital in the Twenty-First Century (Cambridge: Harvard University Press, 2014). Piketty writes in a tradition firmly established by Marx and the neo-Marxists of the twentieth century.

[37] There were downturns in 1817-22, and 1829-30, and the first of the major industrial depressions the United States experienced after 1837. It lasted until 1843.

[38] For earlier problems between a mill owner and labor, see Barbara M. Tucker, Samuel Slater and the Origins of the American Textile Industry, 1790-1860, especially pp. 78 ff.

[39] The social tension over capitalism and the entrepreneurial culture has, of course, deep roots that can be traced back to religious opposition to materialism, to usury, and, to some extent, to commerce itself. The utopian socialists sought to escape from capitalism and the scientific (that is, Marxist) socialists sought to eliminate capitalism's contradications by way of a new proletarian society, communism. In pre-industrial America, there was tension grounded in religion; see, for instance, Bernard Bailyn's description of the agony of seventeenth-century merchant Robert Keayne, who was "struck down by both church and state" for charging high prices for goods in demand. The New England Merchants in the Seventeenth Century (Cambridge: Harvard University Press, 1955), 41-44.

[40] See the important study by Peter A. Hall and David Soskice, eds., Varieties of Capitalism: The Institutional Foundations of Comparative Advantage (New York: Oxford University Press, 2001). We have also benefitted by reading Naomi R. Lamoreaux and John Joseph Wallis, "States, Not Nation: The Sources of Political and Economic Development in the Early United States" (Manuscript, available in the American Capitalism working-paper series at krieger.jhu.edu/iae/americancapitalism/index.html).

[41] Howard W. Gitleman, Workingmen of Waltham, 9-10.

[42] The literature on Lombardy's economy is extensive. Some of the most significant works: S. ZANINELLI (ed.) 1988. *Storia dell'industria lombarda*, vol. 1, *Un sistema manifatturiero aperto al mercato. Dal Settecento all'unità politica*, Milan, Il Polifilo; K.R. GREENFIELD 1985. *Economia e liberalismo nel Risorgimento*. *Il movimento nazionale in Lombardia dal 1814 al 1848*, Rome-Bari, Laterza; B. CAIZZI 1972, *L'economia lombarda durante la Restaurazione*, Milan, Banca Commerciale Italiana; R. CIASCA 1923. *L'evoluzione economica della Lombardia dagli inizi del secolo XIX al 1860*, in *La Cassa di Risparmio delle province lombarde nella evoluzione economica della regione (1823-1923)*, Milan, Alfieri e Lacroix, pp. 341-405. For a broader interpretation of industrialization in northern Italy, see L. CAFAGNA 1989, *Dualismo e sviluppo nella storia d'Italia*, Venice, Marsilio (parts 7,10,11,12). An in-depth profile of the historiography on Lombardy industry and firms can be found in F. AMATORI 2004, *Industria e impresa in Lombardia. Alla guida dell'industrializzazione italiana*, in A. Di Vittorio, C. Barcile Lopez, G.L. Fontana (eds.), *Storiografia d'industria e d'impresa in Italia e Spagna in età moderna e contemporanea*, Padua, Cleup, pp. 45-61.

[43] Although the political situation might have provided opportunities to develop the type of unproductive or destructive entrepreneurship that William J. Baumol discusses (endnote 2, above) that appears not to have been the case in Lombardy.

[44] On the cotton sector, see: S. ZANINELLI 1967, *L'industria del cotone in Lombardia dalla fine del Settecento all'unificazione del paese*, Turin, Ilte; R. ROMANO 1990. *La modernizzazione periferica. L'Alto Milanese e la formazione di una società industriale 1750-1914*, Milan, FrancoAngeli; S. A. CONCA MESSINA 2004, *Cotone e imprese. Commerci, credito e tecnologie nell'età dei mercanti-industriali. Valle Olona 1815-1860*, Venice, Marsilio; S. ANGELI 1982, *Proprietari, commercianti e filandieri a Milan nel primo Ottocento*, Milan, FrancoAngeli. On the silk industry, see: A. MOIOLI 1993. *Il commercio serico lombardo nella prima metà dell'Ottocento*, in Simonetta Cavaciocchi (ed.), Istituto Internazionale di Storia economica "Datini" di Prato, *La seta in Europa*. *Secc. XIII-XX*, Florence, pp. 723-739; R. TOLAINI 1996. *Gli imprenditori serici nella prima metà dell'Ottocento. Comportamenti innovativi e circuiti di formazione*, in Duccio Bigazzi (ed.), *Storie di imprenditori*, Bologna, il Mulino, pp. 15-51. M. ROMANO 2012. *Alle origini dell'industria lombarda. Manifatture, tecnologie e cultura economica nell'età della Restaurazione*, Milan, FrancoAngeli. R. TOLAINI 1993, *Note sulla diffusione di una innovazione tecnologica: le filande a vapore nell'Italia settentrionale nella prima metà dell'800*, in Simonetta Cavaciocchi (ed.), Istituto Internazionale di Storia economica "F. Datini" di Prato, *La seta in Europa*. *Secc. XIII-XX*, Florence, pp. 351-362; R. TOLAINI 1994, *Cambiamenti tecnologici nell'industria serica: la trattura nella prima metà dell'Ottocento. Casi e problemi*, in «Società e storia», 17 (1994), n. 66, pp. 467-542; A. COLLI 1999, *Legami di ferro: storia del distretto metallurgico e meccanico lecchese tra Otto e Novecento*, Catanzaro, Meridiana Libri.

[45] R. TOLAINI 1993, *Note sulla diffusione di una innovazione tecnologica: le filande a vapore nell'Italia settentrionale nella prima metà dell'800*, in Simonetta Cavaciocchi (ed.), Istituto Internazionale di Storia economica "F. Datini" di Prato, *La seta in Europa*. *Secc. XIII-XX*, Florence, pp. 351-362; R. TOLAINI 1994, *Cambiamenti*

tecnologici nell'industria serica: la trattura nella prima metà dell'Ottocento. Casi e problemi, in «Società e storia», 17 (1994), n. 66, pp. 467-542; A. COLLI 1999, *Legami di ferro: storia del distretto metallurgico e meccanico lecchese tra Otto e Novecento*, Catanzaro, Meridiana Libri.

[46] S. A. CONCA MESSINA 2006. *Cotone e macchine. L'innovazione e la trasmissione tecnologica nell'industria cotoniera lombarda dell'Ottocento (1820-1860)*, in Michèle Merger (dir.), *Transferts de technologies en Méditerranée*, Paris, Presses de l'Université Paris-Sorbonne, pp. 415-430.

[47] S. A. CONCA MESSINA 2004 and ID. 2009, *Reti e strategie nel setificio: la famiglia-impresa Gnecchi Ruscone (1773-1900)*, in F. Amatori and A. Colli (eds.), *Imprenditorialità e sviluppo economico. Il caso italiano (secc. XIII-XX)*, Milan, Egea, pp. 1209-1249 (abstract pp. 338-340).

[48] On the role of the institutional setting, see Baumol (endnote 2, above).

[49] G. FIOCCA 1984, *Credito e conoscenze: le condizioni dell'ascesa imprenditoriale*, in Giorgio Fiocca, (ed.) *Borghesi e imprenditori a Milan. Dall'Unità alla prima guerra mondiale*, Rome-Bari, Laterza, pp. 13-85.

[50] G. FIOCCA 1984.

[51]G. FIOCCA 1984.

[52] S. A. CONCA MESSINA 2004.

[53] P. MACCHIONE 1987; R. ROMANO 1990.

[54] P. MACCHIONE 1987; R. ROMANO 1990.

[55] R. ROMANO 1975, *Il cotonificio Cantoni dalle origini al 1900*, in «Studi storici», a. XVI, n. 2, April-June 1975, pp. 461-494; P. MACCHIONE 1987, *L'oro e il ferro. Storia della Franco Tosi*, Milan, FrancoAngeli; R. ROMANO 1990. *La modernizzazione periferica. L'Alto Milanese e la formazione di una società industriale 1750-1914*, Milan, FrancoAngeli.

[56] Alfred D. Chandler, Jr., with Takashi Hikino, Scale and Scope: The Dynamics of Industrial Capitalism (Cambridge: Harvard University Press, 1990), is a standard source on business developments in the United States, Germany, and Great Britain. See also Chandler's important study of the United States, The Visible Hand: The Managerial Revolution in American Business (Cambridge: Harvard University Press, 1977).

[57] See Stanley L. Engerman and Robert E. Gallman, The Cambridge Economic History of the United States, II, The Long Nineteenth Century, and, III, The Twentieth Century (New York: Cambridge University Press, 2000).

[58] We are of course carefully selecting our cases to illustrate how the multiplier works. We are thus intentionally "cherry-picking" examples because we are interested in illustrating a process, not in proving or disproving an hypothesis.

[59] The process was discovered simultaneously in America by Hall and in France by Paul L. T. Héroult.

[60] The founders were joined by Arthur Vining Davis, who provided energy but not capital to the enterprise.

[61] George David Smith, From Monopoly to Competition: The Transformations of Alcoa, 1888-1986 (New York: Cambridge University Press, 1988), pp. 21-33.

[62] Ibid., pp. 1-42, 77-131 carries the company history through the end of World War I.

[63] David Cooper, ed., New Kensington Jubilee Souvenir Book (New Kensington, PA: City of New Kensington, 1966); we say "quickly" because the town was built in a year! Sue Wrbican, "Portrait of Braeburn," Pittsburgh History (Spring 1992). See also the excellent study by the U.S. Department of the Interior, National Park Service, "Historic Aluminum Industry Resources of Southwestern Pennsylvania, 1888-1947;" "Alcoa and the Aluminum Industry in Southwestern Pennsylvania, 1888-1971," prepared by Bonnie J. Wilkinson.

[64] James A. Rock, "A Growth Industry: The Wisconsin Aluminum Cookware Industry, 1893-1920," Wisconsin Magazine of History, 55 (1971-72), 86-99. Frank Haettel, "Design for a sign-letter," JUSD28955, 1898, http://www.google.com/patents/USD28955. Ann Durkin Keating, Chicago Neighborhoods and Suburbs: A Historical Guide (Chicago: University of Chicago Press, 2008), 191-92.

[65] On the economic and ethnic development of Massena, see Claire Frances Parham, "A Tale of Two Cities: A Comparative History of Cornwall, Ontario and Massena, New York, 1784 to 2001" (Dissertation, SUNY Binghamton, 2001), especially pp. 73, 91-92, 132-33. The silk mill and "intimate apparel factory" that followed the aluminum company into the town employed the wives of the former agricultural and canal workers who now labored for the aluminum firm. Alcoa employed 94% of the workers in Massena as late as 1950. The immigrants were "predominantly Italians, Eastern Europeans, and Jews" (who apparently had no nationality in Massena).

[66] Gordon Scott Bachus, "Background and Early History of a Company Town: Bauxite, Arkansas," Arkansas Historical Quarterly, 27 (Winder 1968), 330-57.

[67] We have been unable to acquire information so far on the development of real-estate firms in the wake of the first two industrial revolutions. When scholars begin to focus on this aspect of business history, they will be able to bring business, economic, and urban history closer together and provide a more complete history of the innovation-related increases in capital that were so vital in a growing, capital-poor country. The Cambridge Economic History of the United States left this subject out of volume II, The Long Nineteenth Century, but in volume III, The Twentieth Century, Carol E. Heim addressed the subject in an excellent essay on "Structural Changes: Regional and Urban," pp. 93-190. Heim adds "hypermarket forces: speculation and the search for large capital gains from property development and increasing land values" to the customary dichotomy between market and nonmarket (government, for instance) factors (pp. 96-98). She concludes that: "Property developers were the agents at the nexus of all three sets of forces, and their role in U.S. regional and urban history deserves much more detailed examination." We agree.

[68] We are grateful to Margaret B.W. Graham for providing us with a draft copy of her chapter on "Capitalist Routine, Organizational Routines, and the Routinization of R&D at Alcoa."

[69] Louis Galambos, The Public Image of Big Business in America, 1880-1940: A Quantitative Study in Social Change (Baltimore: Johns Hopkins University Press, 1975).

[70] The company agreed not to participate in cartels, not to create contracts that restricted competition, and not to attempt to influence the supply or price of aluminum products made by other companies. The consent decree was completed (1912) in the shadow of the government's successful prosecution of Standard Oil and American Tobacco for unreasonable restraints of trade under the Sherman Antitrust Act. George David Smith, From Monopoly to Competition, pp. 111-12.

[71] Samuel P. Hays, Beauty, Health, and Permanence: Environmental Politics in the United States, 1955-1985 (New York: Cambridge University Press, 1987). Christopher C. Sellers, Hazards of the Job: From Industrial Disease to Environmental Health Science (Chapel Hill: University of North Carolina Press, 1997). See also the special issue of the Business History Review, 73 (Winter 1999), edited by Christopher C. Sellers and Christine Rosen, on "Business and the Environment."

[72] For an outstanding history of these developments see Margaret B.W. Graham and Bettye H. Pruitt, R&D for Industry: A Century of Technical Innovation at Alcoa (New York: Cambridge University Press, 1990), especially pp. 17-180.

[73] Ibid., and Graham, "Capitalist Routine, Organizational Routines, and the Routinization of R&D at Alcoa."

[74] Ibid., 217-23; Smith, From Monopoly to Competition, 191-214.

[75] David Jean Beaud Michel, Danjou Pierre and (1975) : 21.

[76] Bars of aluminium, made at the Javel Chemical Works in Paris (with the financial support of Napoleon III, had been exhibited in 1855 at the Paris Exposition Universelle. The metal was, however, an expensive curiosity used primarily to make jewelry. Kent R. Van Horn (2015).

[77] F. Bouchayer, Les Pionniers de la houille blanche et de l'électricité, Dalloz, 1954, quoted in Beaud Michel, Danjou Pierre and David Jean (1975) : 22.

[78] Froges closed down in 1895.

[79] In 1913 France was the first producer of bauxite in the world and the 90 % of the workers in the mines were Italians, see Gallois, Lucien (1917): 387-388

[80] Chabert, Louis (1973) : 32-33.

[81] Blanchard, Raoul (1950) : 183-184.

[82] Graham, "Capitalist Routine, Organizational Routines, and the Routinization of R&D at Alcoa."

[83] Beaud Michel, Danjou Pierre and David Jean (1975): 220-221.

[84] Edwards, Clive (2001): 207. French production increased from 900 tons to 10,550 tons.

[85] French production increased from 900 tons to 10,550 tons; world output went from 5,650 to 79,950 tons. The trend of the demand was constantly positive and increased enormously after WWI. The production augmented, at a *world level*: 1938: 601,950 tons; 1950: 1,507,000 tons; 1960: 4,633,300 tons; 1965: 6,608,200 tons.; in *France*: 1938: 45,300 tons; 1950: 60,700 tons; 1955: 129,200 tons; 1960: 235,200 tons; 1965: 340,500 tons; 1966: 363,000 tons, see Savey, Suzanne (1968): 570-571.

[86] In 1968 the cisterns worked under 100,000 Amperes consuming around 15,000 Kw per ton, Savey, Suzanne (1968): 574, 577.

[87] Savey, Suzanne (1968): 574.

[88] Steven Kendall Holloway, *The Aluminium Multinationals and the Bauxite Cartel*, Macmillan, 1988, quoted in Edwards, Clive (2001): 208.

[89] Cameron Rondo and Bovykin V.I., eds. (1991) : 240.

[90] Beaud Michel, Danjou Pierre and David Jean (1975) : 23.

[91] Hyungsub Choi, Manufacturing Knowledge in Transit: Technical Practice, Organizational Change, and the Rise of the Semiconductor Industry in the United States and Japan, 1948-1960 (Baltimore: Dissertation, Johns Hopkins University, 2007).

[92] Several of the essays in David C. Mowery and Richard R. Nelson, eds., Sources of Industrial Leadership: Studies of Seven Industries (New York: Cambridge University Press, 1999) are excellent guides, including: Richard N.

Langlois and W. Edward Steinmueller, "The Evolution of Competitive Advantage in the Worldwide Semiconductor Industry,1947-1996," pp. 19-78; Timothy F. Bresnahan and Franco Malerba, "Industrial Dynamics and the Evolution of Firms' and Nations' Competitive Capabilities in the World Computer Industry," pp. 79-132; and David C. Mowery, "The Computer Software Industry," pp. 133-68. See also the essays in Sally H. Clarke, Naomi R. Lamoreaux, and Steven W. Usselman, eds., The Challenge of Remaining Innovative: Insights from Twentieth-Century American Business (Stanford: Stanford University Press, 2009); especially pertinent are Kenneth Lipartito, "Rethinking the Invention Factory: Bell Laboratories in Perspective," pp. 132-59; Stephen B. Adams, "Stanford University and Frederick Terman's Blueprint for Innovation in the Knowledge Economy," pp. 169-90; Steven W. Usselman, "Unbundling IBM: Antitrust and the Incentives to Innovation in American Computing," pp. 249-79. See as well, Giovanni Dosi and Louis Galambos, eds., The Third Industrial Revolution in Global Business (New York: Cambridge University Press, 2013).

[93] See, for instance, the three magnificent volumes by Manuel Castells on The Information Age: Economy, Society and Culture (Malden, MA, Blackwell Publishing, 1996-2004). See also Andrew L. Russell's excellent study of Open Standards and the Digital Age: History, Ideology, and Networks (New York: Cambridge University Press, 2014).

[94] This was one of the central themes of Schumpeter's most famous book, Capitalism, Socialism, and Democracy. See also James Burnham, The Managerial Revolution: What is Happening in the World (New York: John Day Co., 1941), and Friedrich Hayek, The Road to Serfdom (London: George Routledge & Sons, 1944).

[95] Angus Burgin, The Great Persuasion: Reinventing Free Markets since the Depression (Cambridge: Harvard University Press, 2012). For a review of the massive outpouring of literature on the emergence of a conservative trend in American politics after WWII see Kim Phillips-Fein, "Conservatism: A State of the Field," Journal of American History, 98, 3 (2011), 723-43.

[96] Michael Lewis, The New New Thing: A Silicon Valley Story (New York: W. W. Norton & Co., 1999).

[97] (New York: Crown Publishing Group, 2012).

[98] From this point on, all of the references to 3D printing are available (unless otherwise noted) on the www, as is "3D Systems (DDD) Company Profile." The other major firm is Stratasys – see "World Leader in 3D Printing: Stratasys."

[99] Zack Whittaker, "General Electric on 3D Printing," April 3, 2014.

[100] "HP Unveils Industrial 3D Printer…," November 17, 2014.

[101] The historical literature on industrial entrepreneurship has for the most part ignored financial innovations; in American business history, this can be traced largely to the influence of Alfred D. Chandler, whose paradigm focused on industrial production, not finance. I am grateful to Christopher L. Culp for a discussion of this anomaly in the literature. See, for instance, one of Culp's many articles, "The Revolution in Corporate Risk Management: A Decade of Innovations in Process and Products," Journal of Applied Corporate Finance, 14, 4 (2002), 8-26. See also one of his post-2008 articles: "Syndicated Leveraged Loans During and After the Crisis and the Role of the Shadow Banking System," Journal of Applied Corporate Finance, 25, 2 (2013), 63-85.

[102] 3D hubs, 3D Printing Trends October 2014. A recent article in the Wall Street Journal reminded crowdfunding participants that entrepreneurial startups are risky. See "There's No Refunding in Crowdfunding" (November 26, 2014). See also Evelyn M. Ruisli, "'Crowd' Sites Let Startups Tap Small Investors' Cash," Wall Street Journal, February 9, 2015, A1.

[103] See p. 4 and note 7 above. For a spirited challenge to Christensen see Jill Lepore, "The Disruption Machine: What the gospel of innovation gets wrong," The New Yorker (June 23, 2014).

[104] Lyndsey Gilpin, "10 industries 3D printing will disrupt or decimate," TechRepublic, November 17, 2014. See also 3ders.org, 3D Printing in 2013: Year in Review.

[105] "3D printing scales up," The Economist (September 7, 2013). pp. [ ].

[106] This appears in the Goldman Sachs annual report for 2013. Several of the key 3D printer patents are expiring, making entry into the industry less expensive. 3ders.org. "Let the revolution begin: key 3D printing patent expires today," November 17, 2014. There is already an Open Source movement in 3D printing in an effort to eliminate other patent constraints.

[107] Yahoo Finance, as reported in "Maker Movement and 3D Printing: Industry Stats," February 13, 2014.

[108] Jerome Groopman, "Print Thyself: How 3-D printing is revolutionizing medicine," The New Yorker (November 24, 2014), 78-85, provides an excellent review of recent developments with a minimum amount of hype.

[109] Bin Duan, Laura A. Hockady, Kevin H. Kang, and Jonathan T. Butcher, "3D Bioprinting of Heterogeneous Aortic Valve Conduits with Alginate/Gelatin Hydrogels," Journal of Biomedical Materials Research (May 2013), 1255-64. Also published online by NIH Public Access. See also ASME, "Creating Valve Tissue Using 3-D Bioprinting," May 2013. The bladder is a relatively simple organ; the target is the liver, which is a very complex organ that performs many functions.

[110] Brandon Griggs, CNN Tech, "The Next Frontier in 3-D Printing: Human Organs," April 3, 2014.

[111] Steven Leckart, "How 3-D Printing Body Parts Will Revolutionize Medicine," Popular Science, posted August 6, 2013. Autodesk, which has a Bio/Nano/Programmable Matter Group, is working with Organovo in developing new CAD programs for bioprinting. See also Kakshmi Bharadwaj, "Applications of 3D Printing in Stem Cell Biology and Bioengineering, Knoepfler Lab Stem Cell Blog, September 4, 2013; and "Making a bit of me," The Economist, February 18, 2010.

[112] On the history of risk and uncertainty, see Frank Knight, Risk, Uncertainty and Profit (Chicago: University of Chicago Press, 1921); and more recently, Jonathan Levy, Freaks of Fortune: The Emerging World of Capitalism and Risk in America (Cambridge: Harvard University Press, 2012).

[113] See Kenneth Lipartito and David B. Sicilia, Constructing Corporate America: History, Politics, Culture (Oxford: Oxford University Press, 2004).

[114] New York City just recently passed Milan, Italy, as the leading global "hot spot" for 3D printing, but for a different conclusion than ours, see Gary P. Pisano and Willy C. Shih, "Restoring American Caompetitiveness," Harvard Business Review (July/August, 2009), 2-13.

[115] This is confirmed in José Ernesto Amorós and Neils Bosma, The Global Entrepreneurship Monitor 9 (GEM), 2013 Global Report; this report is also discussed in Matt Moffett, "New Entrepreneurs find Pain in Spain," Wall Street Journal, November 28, 2014. The GEM studies are realistic about the high failure rates in entrepreneurial ventures. For evidence of an overall decline in recent new business creation in the United States see Robert W. Fairlie, Kauffman Index of Entrepreneurial Activity, 1996-2013 (Ewing Marion Kauffman Foundation, 2014). This recent trend could be a major concern if it continues through the nation's economic recovery.

[116] Antonello Salerno, "Luca Beltrametti: Stampa 3D, per le PMI grandi vantaggi," (September 11, 2015), www. corrierecomunicazioni.it. Frederico Guerrini, "How do you get the biggest benefits from 3D printing?" (May 5, 2015), www.zdnet.com. Riccaqrdo Luna, "E' italiana la super stampante 3D," La Repubblica, September 15, 2015. "Italian 3D-Printing Company Creates Unique Furniture Combining Traditional Craftsmanship & 3D Technology," 3DPrint.com. "Laser Specialists Form 3D Printing Joint Venture," Metal Powder Report 69, 4 (July 2014).

[117] "DMG Mori Presents an Additive Manufacturing Breakthrough," http://metalworkingnews. "3D Printing and 5-Axis Machining Combined in One Machine," www.engineering .com.

[118] UK Intellectual Property Office Patent Informatics Team, "3D Printing Report," November 2013, www.ipo.gov.uk/informatics. "UK National Strategy for Additive Manufacturing and 3D Printing," May 1, 2015. www.3dp-research.com. Derek Korn, "Renishaw Opens New Innovation Center in the UK," Modern Machine Shop, 88, 4 (September 2015), 48. Will Stirling, "Renishaw Posts 'Incredible' Results as Turnover Nears £500m," Engineer (Online Edition), July 29, 2015).

[119] In this regard and several others, we have added new concerns as well as new assumptions and conclusions to the Chandlerian synthesis of modern business history. On the Chandler paradigm see the sources cited in endnote 27 above, and William Lazonick and David J. Teece, eds., Management Innovation: Essays in the Spirit of Alfred D. Chandler, Jr. (New York: Oxford University Press, 2012).

[120] This, we believe, is compatible with the new structure of business history developed in Naomi Lamoreaux, Daniel M. G. Raff, and Peter Temin, "Beyond Markets and Hierarchies: Toward a New Synthesis of American Business History," American Historical Review, 108 (April 2003), 404-33; and with the in-depth, historical studies Lamoreaux, et al., have done in recent years on entrepreneurship: Naomi Lamoreaux, and Margaret Levenstein, "Patenting in an Entrepreneurial Region during the Great Depression: The Case of Cleveland, Ohio," (January 1, 2014); Naomi R. Lamoreaux, Kenneth L. Sokoloff, and Dhanoos Sutthiphisal, "The Reorganization of Inventive Activity in the United States during the Early Twentieth Century," NBER Working Paper 15440 (October 2009); and Naomi R. Lamoreaux and Kenneth L. Sokoloff, eds., Financing Innovation in the United States, 1870 to the Present (Cambridge: MIT Press, 2007). For the contrast between financing of innovation in the first and second industrial revolutions see Naomi R. Lamoreaux, Insider Lending: Banks, Personal Connections, and Economic Development in Industrial New England (New York: Cambridge University Press, 1994).

[121] Peter A. Hall and David Soskice, eds., Varieties of Capitalism. While the editors give appropriate attention in their introduction to innovation as a source of comparative advantage, the subsequent chapters in their book focus almost entirely on the evolution of the various political and labor organizations that produce the variations of central importance to this analysis of capitalism.

[122] For a recent and very broad treatment of these issues see Daron Acemoglu and James A. Robinson, Why Nations Fail: The Origins of Power, Prosperity, and Poverty (New York: Crown Business, 2012). The authors make extensive use of the Schumpeterian concept of "creative destruction." Also see Angus Deaton, The Great Escape: health, wealth, and the origins of inequality (Princeton: Princeton University Press, 2013).