Introduction

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The information age is all around us. Our children and grandchildren text messages to each other at a frantic pace. They listen to music and play obscure games on their computers and cell phones; most of them seem far more comfortable with the new age than their parents will ever be. At work, we nevertheless plug away at our word processors and regularly tap the deep oceans of information instantly available on the world wide web. For many, the Blackberry has become a way of life, an electronic companion that ensures us that we never will be very far away from our work. It's apparent every day that our lives have been transformed by the electronic marvels of the third industrial revolution.

This may prompt us to jump to the conclusion that business, like our personal lives, has been reshaped by the invention of the transistor, the integrated circuit, the computer, microwave transmission and the Internet. I had already set forth my own position in 2005: "The third industrial revolution," I wrote, "is barreling with hurricane force across national boundaries. The new technology, which has been applied most widely in the United States, has spread throughout the world and continues to reverberate in the developed and developing nations. This revolution is grounded in new information technologies (IT) that have transformed most of our institutions and the way they function. The resulting changes – like those of the first and second industrial revolutions – are

occurring across a very broad front and appear to be deep, ongoing, and irreversible" (Galambos, 2005).

There already existed a broad range of publications, academic and journalistic, that guided one toward that conclusion. The attention focused on this subject has been truly awesome. A Goggle check on "the third industrial revolution" produces more than five million entries. The "information age" does even better with more than 150 million items, ranging from the inevitable Wikipedia articles to analyses of the privacy issue and explanations of how to wire your home for new-age electronics.

Closer to home for our concerns here are the serious academic books and articles on the history of the third industrial revolution. One of the most important is by the distinguished historical sociologist Manuel Castells, who developed a grand synthesis that emphasizes the sharp break in history created by *The Information Age*. According to Castells, *The Rise of the Network Society* (the title of volume one in his trilogy) decisively altered global economies, societies, and cultures (his subtitle). "The new economy emerged in the last quarter of the twentieth century," Castells said, "because the information technology revolution provided the indispensable, material basis for its creation." The new economy was global and "*networked* because, under the new historical conditions, productivity is generated through and competition is played out in a global network of interaction between business networks." The ability 'to generate, process, and apply efficiently knowledge-based information" was the vital determinant of the competitiveness of firms (Castells, 2000, 2004).

Numerous other scholars began to add work on a broad historical context for this late twentieth-century technological breakthrough in information processing and transmission. Their efforts were handicapped by the fact that aggregate IT statistics are not available, as such; so the IT sector could not be studied in the same manner as other industries. Undeterred, Moses Abramovitz and Paul David charted "American Macroeconomic Growth in the Era of Knowledge-Based Progress: The Long-Run Perspective." Their analysis placed IT in a framework that stressed a first transition in knowledge-based productivity gains near the beginning of the twentieth century and a second after World War II, as the information age began to have an impact on the United States (Abramovitz and David, 2000). David Mowery and Nathan Rosenberg filled out more of the context of that second transition in their study of "Twentieth-Century Technological Change." As they noted: "The development of

the U.S. electronics industry complex illustrates a fundamental change in the nature of the U.S. 'resource endowment' and its relationship to technological innovation." Now the key variable was "the abundance of scientific and engineering human capital . . . , as well as an unusual mix of public and private demand for electronics technology" (Mowery and Rosenberg, 2000).

Naomi R. Lamoreaux, Daniel M. G. Raff, and Peter Temin developed a complementary but different context for the impact of IT on the American business system. Taking a long view, they concludedthat the new information age had called forth different strategies and structures in the corporate world. No longer, they said, was the vertically integrated business of the second industrial revolution the dominant business form. Now firms were frequently purchasing components instead of making them in-house. They were looking more to networks of suppliers, service firms, and business partners in foreign and domestic markets than to their own internal capabilities in dealing with those markets (Lamoreaux, Raff, and Temin, 2003).

All of these attempts to set the IT transition in its proper historical context emphasized the broad, deep impact and largely positive results of the electronic innovations, but there were challenges to this literature and its evaluations. Frank Webster chipped away at one aspect of Castells' paradigm, challenging the fundamental concept of a new age, an information society (Webster, 2002). Others – including the eminent business and economic historian Geoffrey G. Jones – were skeptical about the claims for a decisive historical watershed as a result of the electronic breakthroughs. There was, after all, considerable, carefully documented information on IT firms but less evidence for the businesses in significant commodity industries like those in aluminum and oil. Economist Robert J. Gordon asked, "Does the "New Economy' Measure up to the Great Inventions of the Past?" He concluded that the answer was "No:" "The New Economy, defined as the post-1995 acceleration in the rate of technical change in information technology together with the development of the Internet, has been both a great success and a profound disappointment . . . [T]he New Economy has meant little to the 88 percent of the economy outside of durable manufacturing; in that part of the economy, trend growth in multifactor productivity has actually *decelerated*, despite a massive investment boom in computers and related equipment." The information age, Gordon said, did not measure up to the revolutionary innovations of the second industrial revolution (Gordon, 2000).

The *Journal of Economic Perspectives* symposium in which Gordon's article appeared left the central issue in controversy (see also Oliner and Sichel; and Brynjolfsson and Hitt, in the same issue), and these questions prompted the Bocconi University in Milan, Italy, to collaborate with Johns Hopkins University in Baltimore, USA, in hosting an international colloquium (November 2006) to explore the impact of IT on business. The colloquium asked "Has There Been a Third Industrial Revolution in Global Business?" Professor Franco Amatori and his colleagues at Bocconi brought together a number of distinguished scholars who had written or were researching subjects that promised to improve our understanding of the direct and indirect effects of IT on global business. The essays that follow were chosen from among the papers presented at that conference.

Giovanni Dosi, Alfonso Gambardella, Marco Grazzi and Luigi Orsenigo combine forces to answer the colloquium's central question with a decisive "No." In Chapter one, they focus on "Technological revolutions and the evolution of industrial structures: Assessing the impact of new technologies upon the size, pattern of growth and boundaries of firms." They began by conceding that IT has given "rise to new industries but, even more importantly, deeply transformed incumbent industries (and for that matter also service activities), their organizational patterns, and their drivers of competitive success." But then they use firm-level data to examine the size of firms, their patterns of growth and industrial concentration. They find that "the evidence . . . does not support any notion of revolution. . . . " There is, they find, "hardly any sign of a 'third industrial revolution,' at least if by the latter one means a revolution in the role of the 'visible hand' of organizations (as distinct from market exchanges) and in the relative competitive advantage of size such as compared to previous phases of capitalist development." Their global "map," with its emphasis on structural continuity, supports the general perspective developed by the late Alfred D. Chandler and challenges the other authors contributing to this volume to explore the balance between continuity and change from different perspectives.

Howard Gospel and Martin Fiedler take on this task in Chapter two. They describe and analyze "The Long-run Dynamics of Big Firms: The One Hundred Largest Employers from the United States, the United Kingdom, Germany, France and Japan: 1907–2002." They too bring into focus the Chandlerian paradigm with its emphasis on structural continuity and the powerful competitive advantages of first-movers. Unlike Dosi, et al., however, Gospel and Fiedler bridge the first, second and

third industrial revolutions, include state-owned enterprises (SOEs) in their data-base, and use employment as their measure of firm size. After tightening the focus in this manner, they find evidence that the rate of growth is increasing, with the fastest growth rate in the era of the third industrial revolution. The rate of new entrants has also gone up. Along other dimensions, they find additional signs that the IT transformation has shifted the focus in their population of giant enterprises: retailing, services and communications have pushed to the top, while SOEs have decline in importance. Contra Chandler, they conclude that "death was more common than survival." Around the end of the twentieth century, they find a phase of high turbulence, "with a large number of exits and new entrants, major compositional change, and major changes in country contributions."

Pamela Adams, Stefano Brusoni, and Franco Malerba introduce even more complications in their chapter on "Knowledge and the Changing Boundaries of Firms and Industries." They step back from the firm and the industry and adopt a perspective that emphasizes the knowledge base of an economic activity, the resulting division of labor, and the sector in which the base is applied to innovation and production. In this paradigm, IT is a "pervasive technology" that cuts across boundaries and makes it difficult to use traditional measures of economic activity (such as those using SIC categories). Employed over a span of two centuries and three industrial revolutions, this framework relates structural change to the several transformations that have taken place in technology and science in the modern era.

The authors find "new forces" related to "increased specialization in knowledge production" emerging in the last two decades. The structural responses include the growing importance of outsourcing, vertical disintegration, differentiated knowledge sources and modular design. By cutting the costs of handling information, IT fosters network evolution. Some of the networks are tightly coupled, some loosely coupled and others modular and hence decoupled. In a non-revolutionary way, "knowledge integration" has gradually become "the core competence of . . . large, post industrialist firms. . . . " Part of the knowledge increasingly comes from users and consumers, and here too, IT accelerated a secular process of change. Control has, meanwhile, remained in the hands of the large firms, the system integrators and network firms.

The knowledge base of sectoral development also attracts the attention of Richard N. Langlois in chapter four, "Organizing the Electronic Century." His richly detailed and documented essay spans the sweeping

timeframe from the beginning of electronic innovation to the major developments of this century. He challenges Alfred Chandler's excessive emphasis upon very large firms that build their activities upon an "integrated knowledge base." Langlois concludes that "the most recent manifestations of the electronic revolution . . . are notable precisely for the ways in which they have diminished the role of the large multidivisional firm as a generator of innovation and a repository of economic capabilities." Large firms like Intel, he finds, have a "supporting nexus" that plays a crucial role in developing the sector's knowledge base. Langlois keeps the multinational firms in his history but emphasizes their "deverticalization" and links to external institutions. Here in the heart of the new era, he finds more structural change than Dosi, et al., could document in their much broader data base.

A different angle on change is provided by aircraft production, which helps us understand the impact of IT on the complex products as well as the processes in a large, batch-production setting. As Andrea Prencipe establishes in chapter five, "Aircraft and the Third Industrial Revolution," this industry can be seen as a "meso-system" that brings together an innovation superstructure, manufacturers who are the integrators, an innovation infrastructure and government interveners. There is a significant flow of innovations between electronics and aircraft production/operation, one of the several networks shaping change in this industry. The integrators, manufacturing firms, have considerable power to shape outcomes by governing learning and the diffusion of knowledge. Meanwhile, "the use of information and communication technology-based tools has enormously improved the management . . . " of the production interfaces. Both cost and risk dictate a network, rather than an integrated firm approach, to the supply of components. So much so that Prencipe envisions the process as "cascade of hierarchical contracting relationships. . . . " The most important contracts are of course those with customers, especially the airlines, and they have a decisive impact on technical development in this industry. The author concludes that in aircraft production and in air carriers, the impact of the third revolution can be seen – but only weakly.

The information age is even less likely to show up as a decisive break in a commodity industry like aluminum. Margaret Graham places the changes that took place since the 1970s in a broad sketch of the industry's history since its inception in the late nineteenth century. The era of regional oligopolies gave way, Graham says, to global concentration and then to an industry sharply divided between the developed and the

developing nations. Applying ideas from the work of Manuel Castells, Graham surveys the aluminum networks and their efforts to recast an industry increasingly dominated by Russian output and Chinese demand. Drawn always to cheap power, new firms continued to emerge in the developing countries. Many of them are encouraged and supported by their governments. The Russian firm Rusal, she says, is becoming the Alcoa of the twenty-first century. "Mastery of information technology, and access to technological expertise through networks of associations certainly are helping it to achieve unprecedented scale in plant-size. . . . " Graham sees "information-sharing and networks" as a response to technological change: "Information technology has clearly been a combinatorial factor in this mix. It was also been a powerful enabler." The "turbulent times," she suggests, and the major dislocations they induce, are likely to continue: "In this sense, the aluminum industry may well be the canary in the mine."

The role of government is discussed in several of the chapters and Andrea Colli and Nicoletta Corrocher deal systematically with this subject in chapter seven, "The Role of the State in the Third Industrial Revolution: Continuity and Change." Using state activity in the second industrial revolution as their benchmark, the authors explore the complex networks of public, private and nonprofit actors that have fostered innovation in the electronic age. They highlight the characteristics of state involvement: With information and general purpose technologies at its core, the new paradigm employs highly flexible, shifting networks that make for convergence, technologically and organizationally, in the "knowledge bases and research activities in different domains." In the information/communications and biotechnology sectors, they find substantial evidence of the new patterns of state activity. Public technology procurement and standard setting, as well as a massive international deregulation drive, have transformed telecommunications. The state has been less active in biotechnology except in the shaping of intellectual property rights and, in Europe, in controlling prices. But overall, the authors conclude, state involvement has "profoundly changed" in form as a result of the third industrial revolution and changed in intensity in some sectors. As a result, the economically active state has remained a vigorous and significant participant – directly and indirectly – in the political economy of the electronic era.

Mary O'Sullivan's history of the U.S. stock market's "appetite for young firms" is perforce optimistic about change. She finds a decisive transformation taking place in the post-World War II years: "Particularly notable

was the development of a cluster of industries which constituted the electronics sector." When that happened – and continued to happen into the latter years of the twentieth century – the market was already differentiated and the institutions of investment banking and venture capital were well established. NASDAQ, which completed a transition that was well underway by 1971, provided "a vibrant outlet for the stocks of promising new entrants. . . . " As the development of NASDAQ illustrates, the market for new stock markets was open to entry, and from World War II to the present, the newer markets were the most responsive to the demand for capital coming from startups and young firms in electronics. That was also the case with the growing Over-The-Counter (OTC) market and for investment banking. The electronic age was thus contributing significantly to the reshaping of the financial markets and the institutional setting for entrepreneurial ventures in America.

The final chapter is on labor and labor institutions, subjects that all too often are ignored by business historians. Indeed, for the late Al Chandler, the world's leading historian of business, labor was acted upon by business but was never a primary causal factor in the evolution of modern capitalism. Stefano Musso sets out to correct this imbalance in chapter nine on "Labor in the Third Industrial Revolution: A Tentative Synthesis." The information age, Musso concludes, accelerated the transition from manufacturing to services and began to undercut the economy of mass-produced, standardized goods made on rigid, dedicated machines and assembly lines. The so-called high performance work systems reduced the organizational layers in business and pressed employees "for active cooperation in reducing costs and enhancing quality." Musso's careful comparison of the employment conditions in the developed economies indicates that there is substantial variability in the different labor systems despite the globalization of the past half-century. Throughout most of the world, however, global competition has increased the sense of job insecurity, put downward pressure on wages, and weakened labor union. The trade-off was increasing employment – although not always the best kind of employment – in the developing world.

Musso's chapter is followed by a brief conclusion in which I attempt to pull these various strands of evidence and analysis into an answer to the question posed by the original colloquium: "Has There Been a Third Industrial Revolution in Global Business?" If my answer seems mixed, hesitant, too tentative, I hope our readers will bear in mind that we are still living through the dramatic economic, technological, political, social and cultural changes of the information age. Moreover, a tentative

conclusion is an invitation for the reader to add his or her voice to an ongoing debate. We hope that will be the case.

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1

Technological Revolutions and the Evolution of Industrial Structures

Assessing the Impact of New Technologies on the Size, Pattern of Growth, and Boundaries of Firms[1]

GIOVANNI DOSI, ALFONSO GAMBARDELLA, MARCO GRAZZI, AND LUIGI ORSENIGO

INTRODUCTION

There is little doubt that over the last three decades the world economy has witnessed the emergence of a cluster of new technologies – that is, a new broad techno-economic paradigm in the sense of Freeman and Perez (1988) – centered on electronic-based information and communication technologies. Such information and communication technologies (ICTs) gave rise not only to new industries but, even more important, to deeply transformed incumbent industries (and for that matter also service activities), their organizational patterns, and their drivers of competitive success.

Granted such "revolutionary" features of the emerging ICT-based (and possibly life-science-based) technologies in manufacturing and services, what has been their impact on the vertical and horizontal boundaries of

[1] The statistical exercises that follow would not have been possible without the valuable help of the Italian Statistical Office (ISTAT) and in particular of Roberto Monducci and Andrea Mancini and of the French Statistical Office (INSEE). The data have been elaborated by one of the authors (G.D.) in collaboration with M.G. on Italian data and Nadia Jacoby on French data (fulfilling all the obligation on nondiffusion of the data involved in the agreement of access). We are grateful to several participants to the Sixth International Colloquium in Business History, Bocconi University, and to the conference Innovation and Competition in the New Economy, University of Milan Bicocca for useful comments.