

3. The Social Shaping of Technological Revolutions

If technological revolutions remained as forces of change in the economic sphere and society adapted gradually and easily to the new products and means of transport and communication the whole process could be described simply as the form taken by ‘progress’ and technology could be treated as an exogenous variable. Such changes, however, are far from smooth. Societies are profoundly shaken and shaped by each technological revolution and, in turn, the technological potential is shaped and steered as a result of intense social, political and ideological confrontations and compromises. It is precisely this systemic character that makes the whole question of technical change so crucial in understanding capitalist development.

A. From Technological Innovations to Institutional Revolutions

The notion of ‘creative destruction’, very much influenced by Nietzsche, was a significant element in the European *Zeitgeist* of the early twentieth century, as the nature of progress by innovation. Much in the same spirit as that of the Renaissance, it was seen as Mankind’s noble and pleasurable duty to invent,²³ to break the forces of inertia that threatened to chain and enslave society in a cult of status quo. It was the German economist Werner Sombart, in his *Krieg und Kapitalismus*, who first used the term ‘the creative spirit of destruction’ in economics.²⁴

Today we usually credit Schumpeter with the notion of ‘creative destruction’ as the way to describe the contradictory nature of technological revolutions.²⁵ In fact, he understood innovation, be it new products, new processes or simply new ways of doing things, as the very essence of the capitalist engine of growth. He saw capitalism as a ‘process of industrial mutation ... that incen-

23. For a discussion of this tradition, see Reinert and Daastøl (1997).

24. Sombart (1913) p. 207.

25. Schumpeter (1942:1975) Ch. VII, p. 83.

santly revolutionizes the economic structure *from within*, incessantly destroying the old one, incessantly creating a new one.²⁶

Due to the double nature of the process of creative destruction, Schumpeter saw innovation not only as the force propelling progress but also as the cause of recurring recessions and in general of the cyclical behavior of growth rates and other economic magnitudes. Yet, in spite of his awareness of social and institutional factors, Schumpeter remained very much attached to market equilibrium forces as the determining factor and to the economy alone as the place where the transformation was absorbed. Be it the 3–5 year Kitchin cycles or the 7–11 year Juglars or the 45–60 year Kondratiev long waves,²⁷ they would all be related to deviations from equilibrium due to bursts of innovation. When defining the longest – 45–60-year – cycles, or long waves, he referred to each as ‘the irruption of a technological revolution and the absorption of its effects’.²⁸

Explaining the shorter ‘inventory’ and ‘investment’ cycles mainly in terms of economic forces may possibly be justified. However, this is certainly not warranted in the case of the longer-term phenomena usually called ‘long waves’, which should be understood as much more complex, society-wide processes.²⁹ In fact, in this book a different label has been chosen in order to definitely distance the concept and the object itself from any narrowly defined purely economic cycle. The term ‘great surges of development’ was introduced in the previous chapter to represent the turbulent process of diffusion of each technological revolution, lasting half a century or more. The intention is to take the accent away from the symptoms and endeavor to understand the underlying causes.³⁰

These difficult long-term processes of transformation are in the nature of the capitalist system and involve intense interactions between the economy and social institutions as well as profound changes in both. Each technological revolution is received as a shock, and its diffusion encounters powerful resistance both in the established institutions and in people themselves. Hence, the full unfolding of its wealth-creating potential at first has rather chaotic and

26. Schumpeter (1942:1975) Ch. VII, p. 84 (original emphasis).

27. Kondratiev (1926).

28. Schumpeter (1942:1975), p. 67.

29. Perez (1983), p. 359.

30. Since 1983, and up to now, the author herself had used the term ‘long waves’, though attempting to mark the distance. The change of label now emphasizes the difference in concept. Kondratiev, Schumpeter and most followers measured each wave from trough to trough, which in practice meant encompassing the second half of one revolution and the first half of the next. Here they are identified – though not measured – from peak to peak, covering the complete life cycle of a single revolution. This is the reason why the present model follows the deployment of each surge and the structural transformations it induces across the economy and society, rather than examine growth statistics.

contradictory social effects, it later will demand a significant institutional recomposition. This will include changes in the regulatory framework affecting all markets and economic activities as well as the redesign of a whole range of institutions, from government, through financial regulation, to education, as well as modifications in social behaviors and ideas. It is thanks to that restructuring of the context to fit the potential of the revolution that ‘golden ages’ can occur.

The Victorian boom, from the mid-nineteenth century, materialized two decades after the ‘Rocket’ steam engine showed its power to pull the Liverpool to Manchester railway and not before a network of railroads had been installed, before and during a mania that led to a financial panic. That prosperity was brought about on the basis of a whole set of new institutions that ordered national markets and regulated the national banking and financial worlds. These facilitated the continued expansion of the railway system and the network of steam-powered factories in the growing industrial cities.

Two decades after the big-bang of the Age of Steel, profound changes had to be made again. The ‘*belle époque*’ based on the unleashing of the full potential of the third paradigm, with its truly international markets, required worldwide regulation (from the general acceptance of the London-based Gold Standard to universal agreements on measurement, patents, insurance, transport, communications and shipping practices), while the structural changes in production, including the growth of important science-related industries had to be facilitated by deep educational reforms and social legislation.

The unleashing of the ‘golden age’ based on the mass-production technologies of the fourth paradigm that had been diffusing since the 1910s and 1920s demanded institutions facilitating massive consumption, by the people or by the governments. Only in such a context could full flourishing be achieved. At the time, Fascism, Socialism and Keynesian democracies were set up as very different socio-political models giving impulse to growth processes based on mass production and consumption.³¹ They all tended first to homogenize consumption patterns within national markets and then to use these as a platform for international expansion.

Creating the appropriate context for cohesive growth, based on the potential of the information revolution, would seem to require a global network of institutions, involving the supranational, national and local regulatory levels.

Thus, each technological revolution brings with it, not only a full revamping of the productive structure but eventually also a transformation of the institutions of governance, of society and even of ideologies and culture, so deep that one can speak about the construction of successive and different *modes of*

31. These examples point to the variety of possibilities with each paradigm and to the importance of the socio-political processes for defining the specific mode of growth.

growth in the history of capitalism.³² The process of creative destruction occurs then, every 50 or 60 years, both in the economy and in the socio-political framework.³³

Such changes tend to be forced by a mixture of pressures coming at first from the requirements of the rapidly changing economy and later from the consequences of the turbulent manner in which the new technology diffuses, leading to intense and sometimes violent social tensions. Ultimately, the most effective pressure for institutional change, and especially for some form of state intervention in the economy, comes from the recession following the collapse of the financial economy, which tends to occur a couple of decades after the initial big-bang.

It is in such a period that Keynes made his case for the state to implement countercyclical policies.³⁴ And even Schumpeter was willing to suspend his faith in the healing powers of the pure market and to recognize that ‘the case for government action was incomparably stronger’,³⁵ when it was a question of pulling the economy out of a depression.

In fact, though technological revolutions are indeed profound transformations of the economy, the working of markets cannot by itself explain the recurrence of major crashes and depressions or the appearance of long-lasting centrifugal trends, turbulence and chaos, much less to account for the return to prosperity. To explain the emergence of such wider phenomena affecting the very fabric of society the analysis must bring into the picture the tensions, resistance, obstacles and misalignments that arise from within the wider social and institutional scene.

B. The Absorption of Technological Revolutions as Decoupling and Recoupling of the System

It is precisely the need for reforms and the inevitable social resistance to them that lies behind the deeper crises and longer-term cyclical behavior of the system. Each technological revolution, originally received as a bright new set of

32. The concept is somewhat akin to that of *mode of production* proposed by Marx (Marx and Engels, 1847) for long-term historical changes. Mode of growth has a much narrower sense and refers to systemic institutional changes within capitalism.

33. From Daniel Bell (1973), through Toffler (1980) to Castells (1996, 1997 and 1998), many voices have been hailing the present changes as leading to a different society, a ‘post-industrial’ one. This seems to happen with each technological revolution (the term ‘revolution’ is not used lightly!). For those who witness the upheaval it certainly appears each time like a fundamental discontinuity. Nevertheless, it is fair to concede that, this time, the growing share of intangibles in production and trade strengthens the case for interpreting it as a deeper break.

34. Keynes, (1936).

35. Schumpeter (1939) Vol. I, p. 155.

opportunities, is soon recognized as a threat to the established way of doing things in firms, institutions and society at large.

The new techno-economic paradigm gradually takes shape as a different 'common sense' for effective action in any area of endeavor. But while competitive forces, profit seeking and survival pressures help diffuse the changes in the economy, the wider social and institutional spheres where change is also needed are held back by strong inertia stemming from routine, ideology and vested interests. It is this difference in rhythm of change, between the techno-economic and the socio-institutional spheres, that would explain the turbulent period following each big-bang and therefore the lag in taking full social advantage of the new potential.

It is thus that the first 20 or 30 years of diffusion of each technological revolution lead to an increasing mismatch between the economy and the social and regulatory systems. The latter were developed to fit the requirements of the previous paradigm and cannot cope with the new conditions. In addition, the changes occurring in the techno-economic sphere imply a huge social cost in loss of jobs and skills as well as in geographic displacement of activities. The previous framework is unlikely to be prepared to absorb or counterbalance those costs. Thus, as the mismatch increases, centrifugal tensions and decoupling processes rip apart the fabric of the economy, leading to problems of governance and to questioning the legitimacy of the established institutional framework. There can be persistent social demands or violent outbreaks, which can take many different forms as was seen in the 1848 revolutions in Europe or much later in the various revolts, the *coups d'état* and the acute social tensions of the 1920s and 1930s. The demonstrations against the global free market policies of the World Trade Organization (WTO) in their Seattle meeting, in November 1999, may well have marked the beginning of growing open international political pressure to change the so-called 'Washington consensus'.

Whatever the manifestation, the political pressures calling for action finally propel the required changes. The financial collapse that usually marks the end of this period is the final and often the strongest instrument of persuasion to bring about the necessary changes. Once the new 'match' has been achieved through the articulation of an appropriate mode of growth, a process of recoupling and convergence ensues. The following 20 or 30 years witness the full deployment of the new paradigm in intensity and extension, from sector to sector and across regions and countries.

By statistical measures these 'eras of good feeling' are not necessarily the times when rhythm of growth is highest, yet they are the periods generally felt and accepted as 'golden ages', for they represent a more harmonious growth process, involving most sectors of the economy. They can also be a time of improvement in the lot of larger and larger groups of the population, espe-

cially in those countries centrally involved in the diffusion of the paradigm and where the most appropriate institutional frameworks have been set up.³⁶

The sequence of 'good and bad times' would thus have its origin in the interaction between the dynamics of the economy, as such, and that of society as a whole. Further still, this very phenomenon is one of the main factors explaining why what appears as continuous technical evolution occurs inside the successive envelopes of different revolutions.

C. Why Technical Change Occurs by Revolutions

Kuznets cast doubt on Schumpeter's causal link between the clustering of innovations that form technological revolutions and the bunching of entrepreneurial abilities.³⁷ Indeed, this is a key question for all proponents of innovation-based economic fluctuations. It will be suggested here that these bursts of entrepreneurship actually do occur, but that they do so in response to opportunity explosions. Such bunching of opportunities occurs with the appearance of a new techno-economic paradigm, which defines a new and wide design, product and profit space that can inflame the imagination of potential innovators. In other words, the great clusters of talent come forth *after* the revolution is visible and *because* it is visible.

That raises two crucial questions. One is, if talents are always there to come forth, then why is change not continuous, why does it occur by revolutions? The other, derived from that, is the issue of the prime mover, or how do the few breakthroughs that initiate the revolution come together?

The favorable conditions for the next revolution are created when the potential of the previous one approaches exhaustion. The process involves a complex set of inclusion–exclusion mechanisms resulting from the nature of social adaptation to each paradigm. The full assimilation of a technological revolution and its techno-economic paradigm occurs when society has accepted its common sense, put in place the appropriate regulatory framework and other institutions and learned to gear the new potential to its ends. This leads to two conditions that favor compatible innovations and filter out incompatible ones.

On the one hand, the social and institutional environment has become highly conducive to the unfolding of any opportunity and possibility compatible with the paradigm. Externalities of all sorts are so overwhelmingly favorable to it that engineers, designers, managers, entrepreneurs and investors 'naturally' follow certain common principles as obvious good business. A thousand plas-

36. These qualitative aspects of growth are rarely included in the usual interpretations of 'long waves'.

37. Kuznets (1940) pp. 261–2.

tics followed the first breakthroughs in synthetic materials, wired houses could take on dozens of successive new electrical appliances, the agricultural revolution could combine the use of oil-driven machinery of increasing variety and specialization with any number of petrochemical pesticides and fertilizers. The same has occurred this time with computer games, with software packages, with the various generations of personal computers and then with 'dot com' services in the Internet. Once the path has been successfully signaled, growing bunches can join the bandwagon. And so it goes with each of the interrelated systems that conform a particular technological revolution and its associated 'common-sense' paradigm.

That is in fact the technological and business equivalent of what Kuhn defined as 'normal science'.³⁸ Once the valid trajectories for new products and processes as well as for their improvement are known, successive and successful innovations will follow. They will be compatible among themselves, they will interact smoothly, they will find the required supplies, qualified personnel and market channels and will encounter increasing social acceptance based on learning with the previous products.

On the other hand, these favorable conditions become a powerful *exclusion* mechanism for all possible innovations that are *incompatible* or not well geared to the existing framework. Attempts to introduce such innovations could be rejected by investors or customers or, as often turns out to be the case, could be successfully adapted in a minor way to the prevailing paradigm. Such adaptations can nevertheless lead to the growth of important industries that will become central in a future paradigm. For the moment, they grow restricted to whatever uses fit well in the existing fabric of the economy before their most important uses are even surmised. Railways were first developed to help get coal out of the mines; their real significance as the main means of transport of people and goods was difficult to even imagine in a world of canals, turnpikes and horses. Oil refining and the internal combustion engine developed within the steam-engine world of the third revolution, being used mainly for luxury automobiles. Semiconductors, in the form of transistors, served to stretch the market for radios and other basic appliances of the mass-production paradigm by making them portable, before anyone could possibly conceive of a micro-computer.

The most conspicuous exception to the exclusion mechanism is war-related expenditure. The application of political and military criteria, rather than economic logic, opens avenues of research, technology and production that could lead far from the reigning techno-economic paradigm, usually involving extravagant costs that could not be normally recovered in the market. When the war takes place in the maturity phase of the paradigm, these voluntaristic ex-

38. Kuhn (1962:1970) pp. 10 and 24.

cursions into new technological territory could become a seedbed for the next technological revolution. The 1960s Space and Arms Race is, of course, the most notorious example of such expenditures.

Whatever their origin, the real possibilities of a radical innovation can be so difficult to envisage, before the appropriate paradigm is there, that even those who carry them out may grossly underestimate their potential. Edison thought the phonograph he invented in the 1870s would be useful for recording dying people's wills; in the 1950s the boss of IBM still thought a few computers would cover the world's total demand, and so on.³⁹ Those innovators who do see far into the future can have great difficulty in being understood by others, as happened to Alexander Graham Bell, with his still primitive telephone in a world of efficient telegraph.⁴⁰

By contrast, when an innovation is within the natural trajectory⁴¹ of the prevailing paradigm, then everybody – from engineers through investors to consumers – understands what the product is good for and can probably suggest what to improve. Even such minor and doubtfully useful products as the electric can-opener or the electric carving knife are thought worth designing, producing, buying and using in a world that is already accustomed to dozens of electrical appliances in the kitchen. The same happens with the successive applications of the general principles of the prevailing paradigm. In the case of continuous mass production, for example, after manufacturing had fully developed all its principles and refined its organizational practices, the task of applying the model to any other activity became straightforward. Mass tourism, of the 'assembly-line' type, moving people from airplane to bus, from bus to hotel and from hotel to bus, was obvious to conceive, easy to put into practice and readily accepted by consumers at the time.

Yet, trajectories are not eternal. The potential of a paradigm, no matter how powerful, will eventually be exhausted. Technological revolutions and paradigms have a life cycle of about half a century, which more or less follows the type of logistic curve characteristic of any innovation.

As shown in Figure 3.1, in phase one, after the big-bang, there comes a period of explosive growth and rapid innovation in the new industries. New products follow one another revealing the principles that define their further trajectory. Thus the paradigm is configured and its 'common sense' can guide the propagation of the revolution.

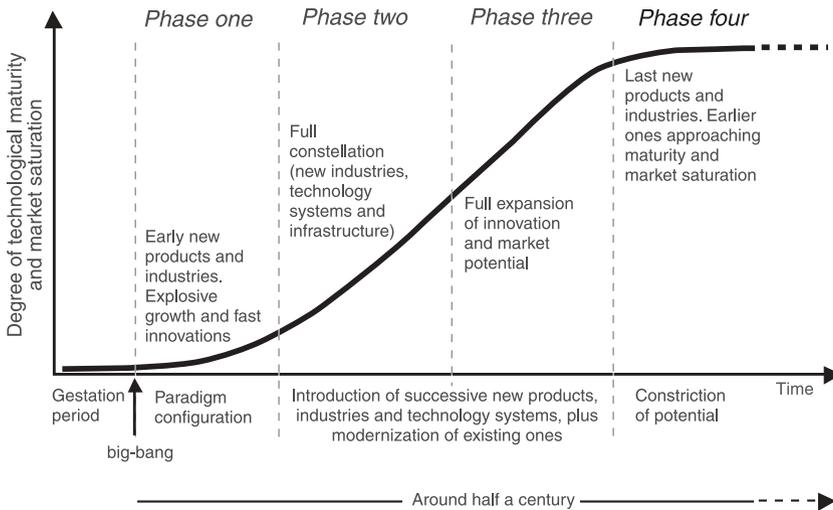
Phase two is one of fast diffusion, seeing the flourishing of the new industries, technology systems and infrastructures with intensive investment and

39. There are of course cases of foresight such as Diebold (1952), who from very early on wrote about the future potential of computers.

40. Mackay (1997).

41. Nelson and Winter (1977, pp. 36–76) used the expression 'natural trajectory' to refer to the path which appears to be naturally followed by successive innovations to a technology.

Figure 3.1 The life cycle of a technological revolution



market growth. Fast growth continues in phase three with the full deployment of the paradigm across the productive structure.

Phase four is the encroachment of maturity. At a certain point, the potential of the revolution begins to confront limits. There are still new products being introduced, new industries being born and even whole technology systems, though they are fewer and less important. But the core industries that had served as the engines of growth begin to encounter market saturation and decreasing returns to technological innovation. This announces the approaching maturity of those industries and the gradual exhaustion of the dynamism of that whole revolution.⁴²

When the potential of a paradigm begins to reach limits, when the space opened by a paradigm becomes constricted, productivity, growth and profits are seriously threatened. Thus the need and the effective demand appear for new solutions, for radical innovations, for stepping out of the well-trodden paths.⁴³ Yet, by this time, after decades of successful development under the established paradigm, the environment has over-adapted. Not only firms but

42. The phenomenon is similar to Wolf's (1912) Law of diminishing returns to investment in incremental innovations to individual products and processes. It is also akin to the product life-cycle theory developed by Hirsch (1965 and 1967), Vernon (1966) and others.

43. Kuznets (1953, p. 113) had already suggested something of this sort, when trying to understand Schumpeter's point about clustering: 'we may say that electricity did not become available sooner because it had to wait until the potentialities of steam power were exhausted by the economic system'.

also people and society as a whole have accepted and adopted the logic of the established paradigm as *the* 'common-sense' criterion. Yet the way forward along that route is now barred by impending exhaustion.

The core industries of the technological revolution, now maturing, are reaping the last benefits of economies of scale and are probably tied up with huge fixed investment.⁴⁴ They are also likely to be in a very strong position (oligopoly or near-monopoly), which gives them the means to seek effective solutions to break out of the trap. These probably include mergers, migration and some unorthodox practices that will be discussed in Chapter 8 in relation to financial capital. For the present purpose, however, the significant processes are those that lead to the next technological revolution. Of these, one of the most important is the willingness to try out truly radical innovations as improvements that will stretch the life cycle of established technologies or reduce the cost of peripheral activities.

Crude versions of the high pressure engine were tried in the early 1800s to increase the productivity of textile machinery; 'scientific management' of work organization, which is the core of mass production, was first developed by Taylor at the turn of the century to increase the productivity of moving steel products in the steel yards; automation was given trial runs by the automobile industry in the early 1960s, control instruments in their pre-digital forms went far in development in the process industries from early on, numerical control machine tools were introduced in shoe manufacturing and aerospace in the 1960s and 1970s. So, the introduction of some truly new technologies can be tied to revitalizing mature industries in trouble.

There can also be a readiness to introduce radical innovations that widen the range of technologies already in the market, as was the case with transistors in audio products that, by allowing portability, opened huge new markets from the late 1950s.

The more sectors and firms confront maturity and saturation, the more intense the various trial and error activities become. As in Kuhn's model of 'revolutionary science', breaking the trend and searching in new directions is fostered and facilitated by the confrontation of limits and crises in the established paradigm.⁴⁵ The specific obstacles encountered by each techno-economic paradigm as it is developed to its ultimate consequences, will serve as powerful guidelines in the search for the new set of technologies.⁴⁶ Yet, in order for a technological revolution to emerge, radical new paths have to be opened and crucial breakthroughs have to be made.

44. Soete (1985) made this point in support of the possibility of catching up for newcomers who are not bogged down by heavy investment in the old technologies. It was taken up again in Perez and Soete (1988).

45. Kuhn (1962) Ch. VII–VIII.

46. Freeman and Perez (1988), Table 3.1 Column 7, pp. 50–53.

Radical innovations can occur at any time, though their gestation period can be long. Due to the relative autonomy of the production of science and technology, there are always potential innovations in various fields waiting in the wings. At any point in time, therefore, the spaces of the scientifically conceivable and the technologically possible are much wider than those of the economically viable or the socially acceptable. Hence, many major technologies at various stages of development can already be in the economy, in minor or narrow uses. The real potential of some will become fully visible once they converge to form a revolution (others may have to wait many more decades or never be fully exploited). So, given the appropriate conditions of pressure and demand, a new constellation of radical technologies can gradually come together from already available developments.⁴⁷

Thus, technology evolves by revolutions because the prevalence of a specific paradigm, with its vast interrelated opportunities, induces deep social adaptation to its characteristics. This creates powerful inclusion–exclusion mechanisms, which avoid radical departures from the prevailing paradigm until the huge potential of that revolution has been spent and approaches exhaustion.⁴⁸ It is then that entrepreneurial abilities of the sort that nurture radical innovations are more likely to be in demand. However, just as there is a high likelihood that the successful candidates to become the new paradigm in a particular science might be found by practitioners from another science, so the radical new departures in technology are likely to come from ‘outsiders’, from technologists or entrepreneurs who were not imbued with the previous paradigm, who may well be young and outside the powerful established firms like Carnegie or Alexander Graham Bell, Edison or Ford, Noyce, Steve Jobs or Bill Gates.

In order to understand how the gates break open so the excluded can enter in a throng, the role of financial capital needs to be examined.

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47. Gerhard Mensch (1979) advanced a very similar hypothesis, suggesting that a ‘stalemate in technology’ was at the origin of recessions (such as the stagflation which began around the early 1970s). Unfortunately his method of proving this was counting and comparing the radical innovations made at various periods to identify clusters coinciding with recessions. So he took the actual date of first introduction as the full birth of an innovation. This made him open to criticism from Freeman et al. (1982) who showed that radical innovations can be scattered widely in time and that what really matters for significant growth impact is diffusion of combinations of innovations.
48. The identification of such an exclusion mechanism was one of the conditions demanded of long-wave proponents by Rosenberg and Frischtak (1984).

D. The Role of Financial Capital in the Emergence of New Paradigms

In contrast with the scientific world, commercial innovation is made with profit in mind. Whether the innovator works in the laboratory of a big firm or in his/her garage, someone will have to see it as a possible source of huge profit and be willing to put up the required investment money to test the process, launch the product or expand production. It is here that, as Schumpeter says, the institution of credit, in one form or another, plays a crucial role.⁴⁹

Someone's money has to be available to break the routine trajectories and make radical changes. The big established firms, as they face paradigm constriction, will probably put forward money to try stretching solutions to their own products and processes, which could involve, as they often do, minor uses of radical new technologies. They might also try to widen the range of known technologies and do research in new directions. All these activities can lead to completely new products and technologies (as was the case of Bell labs with the transistor, for example). Yet, they are not likely to fund true 'outsiders'.

It is here that the separation between financial and production capital has its most fruitful consequences. It is because there is available money looking for profit in the hands of non-producers that the new entrepreneurs can bring their ideas into commercial reality. It is here that the possibility of operating with borrowed money becomes a truly dynamic force. Financial capital will back the new entrepreneurs and it will be more likely to do so, in spite of the high risks, the more exhausted the possibilities are for investing in the accustomed directions.⁵⁰

As the low-risk investment opportunities in the established paradigm begin to diminish, either in innovation or in market expansion, there is a growing mass of idle capital looking for profitable uses and willing to venture in new directions. Thus, the exhaustion of a paradigm brings with it *both* the need for radical entrepreneurship *and* the idle capital to take the high risks of trial and error.

Under these conditions several strands of innovation come together, some from the big firms overcoming obstacles, others from novel entrepreneurs with new ideas and others associated with the many underutilized or marginalized innovations that had been introduced before. These are likely to incorporate part of the vast pool of applicable knowledge waiting in the wings or to bring

49. Schumpeter (1939:1982) Vol. 2, Ch. III, pp. 109–18.

50. This was one of the main points made by Mensch (1979). His formulation came quite early in the debate, just as venture capital was being made available to Silicon Valley and other innovators.

forth new knowledge. Eventually, the necessary breakthroughs are made – or recognized – and brought together with other new or redefined technologies to conform the next technological revolution. From then on, financial capital is even more widely available for entrepreneurs to innovate exploiting the novel trajectories of the new paradigm. As will be discussed later (Chapters 9 and 13), new financial instruments are developed at this time to accommodate the peculiarities of the new products and their diffusion.

There is probably no easy way of testing whether during other times there are as many would-be entrepreneurs trying to get their innovations funded as there are at the end of the life cycle of a paradigm. What one can say with little risk of erring is that, once the design, product and profit space of a new paradigm is made visible, the imagination of a vast number of potential engineers, designers and entrepreneurs is fired to innovate within the new general trajectories. As available finance makes their projects possible and as their astounding successes makes the paradigm even more visible and attractive to a greater number of people, the ranks of those that feel the calling will invariably swell.⁵¹

So, the signs of exhaustion of the prevailing paradigm create the demand for profitable new innovation trajectories, pent-up supply of technological options begins to flourish, idle financial capital provides the fertilizer, the ensuing articulation of new technologies eventually leads to crucial breakthroughs, the new paradigm multiplies the supply of innovative entrepreneurs, their successes bring forth more financial capital and more entrepreneurs and so on.

Thus, there is certainly variability in entrepreneurship as Schumpeter held, but the origin of this variability is in the changing conditions and opportunities surrounding it. This is not to be understood as claiming that only ‘outsiders’ are real innovators. On the contrary, if it were mainly a question of numbers, over time one would probably find that the great majority of innovations are made inside existing firms, not only the minor and major modifications of technologies in use but also the introduction of many new products and processes. Even some of the crucial breakthroughs (such as the precursor of the integrated circuit in Bell Labs, already mentioned) can occur inside established firms or are acquired and introduced by them.

Nevertheless, long-standing firms are the main carriers of the prevailing paradigm. As discussed before, the paradigm is such a powerful guiding model that it becomes an inclusion–exclusion mechanism, strongly reinforced by social adaptation and gradual overadaptation. Therefore, in technological terms, one could say that the most powerful firms at the time of the exhaustion of a particular paradigm are likely to become the most conservative forces. Although some intelligent firms may make major innovations, their heavy investment in some of the now mature technologies makes them prefer to avoid

51. Schumpeter’s (1942) bandwagon effect.

truly revolutionary change, which might make their equipment and practices obsolete. Yet, ironically, since their productivity, market and profit growth rates are probably stagnating, their main hope for revitalization lies in radical change.

Thus, existing large firms are likely to be both agents and victims of paradigm closure. Breaking out of it is bound to demand the participation of outsiders. When they appear, idle financial capital allows them to manifest themselves fully and fructify.⁵²

52. One could wonder if the reason why Soviet socialism was unable to make the innovations that would have helped it overcome paradigm constriction since the 1970s was not in part the lack of an institution capable of providing equivalent flexibility to facilitate change. See Gomulka (1990).