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Steering technological change?

Extended abstract

Political intervention into technological change, and particularly all attempts either to reinforce or mitigate its social consequences, require a proper understanding of its meaning. Technological change displays phases differentiated by the forces it is driven by, the scope of its impact, the disciplines and actors involved, the character of the associated activities of research and production, the groups being affected and their ways of adaption to and usage of technologies.

Technological change having broad impact on society results from the confluence of manifold processes in various fields: scientific research generating new knowledge, designs of artefacts and procedures ripening through technological experience, combinatorial ideas, social practices of adaption and usage, legal and institutional change in reaction to these. Before starting a more detailed inquiry into current information technology, a short look at a completed historical paradigm seems to be appropriate, because in such a case the relevant developments and their determining factors lay much more open to the eye. The paradigm taken here is the technology of book printing: its ground-breaking significance is hardly controversial and it is rather well researched, although not well documented.

Book printing is not understandable as a single, isolated invention, but rather as an excellent example for the proposition made above: as the confluence of manifold technological and social developments with a solid foundation in craftsmanship, indispensable in times before modern mathematical science found its way into technology, but today still with a part to play there. These include:

1) A diversity of advanced craftsmanship in:
   a) Mechanical arts: building complex machinery, mills, clocks etc., mainly from wood with a small number of metal parts at critical junctures, bearing heavy loads (e. g. the stone spindle in mills).
   b) Metal works: cutting steel, devising and casting lead alloys, wire drawing, sieve making.
   c) Chemical processing: printing ink with the required properties.

2) Availability of paradigms, materials and concepts:
   a) Xylography, copper engraving, wine press: after those older printing technologies had achieved wider circulation, the printing press did emerge not accidentally from a region where wine made a significant contribution to the economy.
   b) Efficient paper production through the employment of mills and sieves made from steel wire produced rationally by wire mills.
   c) The Latin alphabet: a small number of types cut into steel multiplies to huge numbers of letters via casting of a lead alloy.
3) Institutions and social groups conducive to the emerging technology:
   a) Ecclesiastical demand for the propagation of canonical texts and printed forms for the absolution letters which have been a major source of income for the Roman church.
   b) Increasing demand for literature, textbooks particularly, through educational expansion.
   c) Growing desire for religious and political expression by the emerging urban classes.
   d) Availability of capital through credit at low interest rates (ca. 4%): developing the new technology as well as setting up printing operations, as it happened in all major cities throughout Europe until 1500, was a capital-intensive business.

In printing technology, a number of combinatorial steps met with powerful economic and social forces to bring about a revolution in communication just within a few decades, triggering and accelerating a variety of social and political conflicts, most outstanding that between the roman church and the expressive demands of an urban citizenship growing in numbers as well as in economic influence. The church was, contrary to a widespread belief, not per se opposed to technological progress. It tried to reserve the new technology to its purposes of constraining the propagation of literature to those versions of the traditional texts it considered canonical and those new items conforming to its views. So, the printing press was followed by the imprimatur and the index very quickly. In the end, both have been in vain, but the struggle over who has — more or less privileged — access to the technologies of information propagation holds on into the age of the internet.

Anyway, to highlight here is the observation, that the configuration of social forces influencing — and being influenced by — the development and diffusion of technology is often far more complex than single-minded records suggest. The dominating western narrative that associates the printing press only with humanism and Protestantism misses an important point: before it helped to spread pamphlets against Rome and its trade in absolution letters, it was instrumental in scaling the latter business into new dimensions that in the first place might have triggered such strong reactions.

The patterns visible above apply likewise to modern information technology. Its roots are situated deeply in the 20th century, some fundamental achievements even in the first three or four decades of that century. These are in the fields of

1) Mathematics, linguistics and computer science:
   a) Metamathematics: logic, proof theory and computability.
   b) Syntax theory and programming languages.
   c) Logic, algebra, category theory and computational semantics.
   d) Functional analysis and numerical methods.
   e) Number theory and cryptography.
   f) Discrete structures and algorithms (graphs, trees, queues).
2) Physics:
   a) Quantum mechanics and atomic physics.
   b) Based on the latter, solid-state physics leads to semiconductors.
   c) Optics and electrodynamics lead to lasers and high frequency radio.
3) Technology:
   a) A tradition of building cybernetic, self-controlled devices (the mechanical clock and computing machinery, the Jacquard loom).
   b) Precision optics and chemical processing of high purity materials are essential for chip manufacture.
   c) Efficient manufacturing of discrete units with high variance.
4) Social forces:
   a) State agencies, the military in the first place, followed by others like the meteorological and geophysical services invest huge sums in the development of computing and related technologies, e. g. network protocols — the latter primarily for communication and resource sharing among scientists working for the military.
   b) The corporate sector, lead by the financial institutions in cooperation with computer manufacturers, develops systems for administrative and particularly for accounting purposes (ERP).

c) Industries engaged in the development and fabrication of manufacturing equipment and durable goods, together with partners from the electronics industry, develop systems for the control of such equipment and complementary design software (FEM, CAD, PLM etc.)
d) Falling prices and increasing packing density of integrated circuits enable the spread of networked computers to individual workplaces, particularly administrative ones, and into the home for leisure and private office work, leading to further price falls.

Particularly the latter development, which initiated an exponential diffusion of networked computers via the circular mechanism of widening markets enabling price falls through economies of scale, stimulating further market widening and price falls or, at least, providing more power at constant cost, started in the late 20th century and — although flattening out recently — is continuing up to the present, while its technological roots are seated deeply in the 20th century: it was solid state physics from the 1930s leading to semiconductors and large scale integration and complemented by precision optics, chemical and discrete processing technologies that brought about cheap computers for everybody. It was already in the 1960s that Gordon Moore predicted the exponential upscaling of integration levels known as Moore’s law.

In contrast to these more recently emerged dynamics involving small enterprises and consumer markets, the overall development of information technology in the 20th century was strongly influenced by state agencies, big corporate players and the respective massive investments. Beyond that, state oversight in the telecom sector played a significant role in the US, where rate of return regulation, publication and licensing obligations on AT&T, which was granted a monopoly in return, fostered strong investment in physical facilities, research and development, while making the results available to academia and the wider corporate sector. So, the AT&T Bell Labs played the role of the national, and beyond that, international, powerhouse of research and development in information technology and related fields (of physics for example) well into the late 1980s.

Since those times, the institutional setting wherein the development of information technology takes place, has changed significantly. This is — massive military sponsoring of certain areas left beside for the moment — due to a progressive restraint from state intervention in most of the industrialized economies on the one side, and to a broadening of the technology and its applications into fields hitherto unnoticed by state oversight. The driving forces are:

1) In hardware and network technology:
   a) Progressive miniaturization of devices.
   b) Availability of large storage and massive parallel computers.
   c) Pervasive networked processors, sensors and actors.
2) In software:
   a) Methods for the collection and handling of massive amounts of data.
   b) Advanced pattern recognition.
   c) Increased reliance on non-explicit specifications thereby (machine learning).
3) On the system level
   a) Proliferation of networked embedded systems (cyber-physical systems, IoT).
   b) Expansion of automatic system functions.
   c) Increased dependency on networked resources.
   d) Absence of complete and transparent specifications.
   e) Growing complexity and vulnerability.

Before this background, policies intended to steer technological and associated social developments should not stare single-mindedly on isolated technologies or artefacts, temporarily hyped at certain historical moments, but try to devise a broader view of the involved issues and options. Since World War II industrialized nations have consistently failed to address this requirement.

Overestimation of the potential of certain technologies has very often combined with underestimation of path dependencies. E. g. Western Germany has, after WWII, invested billions of federal funds into nuclear energy to almost no avail, while commercial reactor development did not take up the innovative schemes promoted thereby, but settled with the proven technology (the pressurized light-water reactor) pioneered by the US Department of Energy and Westinghouse for submarine propulsion and thereafter scaled up to industrial dimensions. While, as the case of nuclear energy shows, the state agenda in research and development can set-up, but also be rendered ineffectual by, path dependencies, neglect of certain areas by state policy can, on the other side, allow the development of powerful path dependencies through independent forces: this was the case with processor architecture and system software particularly, where technologically more advanced and promising schemes, like e. g. RISC architectures, the Transputer, microkernels like Mach or L3, programming languages with regular syntax and coherent as well as comprehensive type systems, went undernourished and fell back relative to less advanced technology that dominated the mass markets. As a result, the concern for secure and transparent systems did not receive the attention it deserves — a neglect with far-reaching consequences involving profound risks for the emerging societies depending largely and vitally on information technology.

The saturation with networked information technology at all levels of an expanding share of everyday life, in leisure as well as in work, creates a social and institutional configuration profoundly different from the one that dominated in the 20th century. Areas critical for any policy targeted at steering technological change and influencing its impact on society are the following:

1) The resilience of a socio-technological system depending on the continuous availability of the electricity grid and telecommunication networks along with the absence of interference into the working of critical components.
2) From the ever more comprehensive and pervasive connection of technical artefacts and humans beyond the boundaries of factories, organizations and homes through networked processors and sensors arises the need for standardized platforms of exchange, and from that the issue of who will define and control them.
3) The latter issue likewise applies to the infrastructure of connection and the design of the central hardware and software components (processors and operating systems) that constitute those networked systems.
4) The proliferation of electronic equipment implies an increasing demand for scarce minerals and energy, the latter both for its operation and even more for its manufacture (this is a 1:2 proportion), accompanied by ballooning masses of waste.
5) From the manifold options implied by comprehensively connected devices, only some are socially useful, ecologically responsive and economically efficient. These ones will have to be identified and implemented in a way that reinforces the fabric of the socio-technical system.
6) Particularly smaller enterprises and organizations that do not dispose about adequate resources of expertise need guidance and support in order to make use of advanced information technology.
7) Monopolies, inevitably emerging in the fields networked information systems (search machines, social networks), should be detained from amassing economic power and distorting information.

8) Scaling up near-distance social activities and relations (shopping, sharing, neighborly help, accommodation under friends, etc.) into global dimensions through information-technological intermediation (in the way of Amazon, Uber, AirB&B, etc. do it) creates a bunch of problems by avoiding traditional forms of regulation. Areas to be addressed by appropriate regulative approaches are:
   a) Urban space and habitation, as the increasing attractiveness of central locations — also due to information technology enabling as well as demanding an enforced concentration of management, marketing, research and development operations with global reach in metropolitan areas where a wealth of corresponding services, transportation and network facilities is at their disposal — results in an overload of urban transportation systems, ballooning real estate prices and a growing imbalance in the social composition of cities as a result of the new forms of tourism enabled by information technology.
   b) Increased traffic, energy consumption, waste and pollution, as consequences of electronic shopping creating masses of wrapping and delivery operations, and of car and ride sharing pushing up the number of kilometers travelled by car, both to the end of aggravating congestion in cities. The 'Uber jam' has already become a familiar notion in San Francisco.
   c) Labor relations, as deflationary tendencies, harmful working conditions and overwork show up more frequently as a consequence of job services avoiding existing regulations using networked information technology.

There are lessons to be learnt from the deceptions of the recent decades: A case to this point is urban and spatial planning, which have been, if not neglected totally, been founded on false promises for decades, in recent years additionally with a feeling of ease given by a false reading of signals from information technology: that it would render space and matter irrelevant and could deliver solutions to what social problems ever would remain. This means that appropriate policies have to address wider areas beyond technology and industrial politics in a narrower meaning, like labour regulation, spatial and infrastructure planning, social services and security, public health, education and transportation.

Labor regulation is of high importance here. Pie in the sky expectations of productivity boosts and corresponding expectations of an 'end of work'— as well as fears of massive job losses — lack solid foundations. Productivity growth has flattened since decades and almost stagnated recently in the industrialized nations.

There are strong indications that deflationary tendencies with falling GDP-shares of investment in industrial equipment and public infrastructure observable in all industrialized countries, together with the information technology enabled proliferation of ‘bullshit jobs’ depress productivity growth. The approved measure to reverse these tendencies is to increase labors share of the GDP (China has done so since the crisis of 2008/2009, but should do more so), which has declined in the industrialized countries since decades. If productivity growth should revive, the primary recipe to avoid massive job losses is, besides adaption through education, the golden rule: nominal wages should increase like productivity plus the intended rate of inflation. This ensures that a growing product can be bought by the producers.