



technology, children, schools and families

How will technological change affect opportunities for creating new economic activities, new sectors and new industries to the year 2025?

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Introduction: why 'Computopia' didn't happen.

'Apparently there are potholes in the road to the future.'
(Geels and Smit, 2000).

When attempting to predict the development trajectory of any work technology, and its likely interaction with the path of economic activity, we have little choice but to start by observing and analysing current and emergent trends in technological, social and economic development and projecting these into the future.

Yet the record of such attempts is rather chequered. 'Future images of the development and impact of technology can often be seen to have gone unrealised when judged retrospectively' (Geels and Smit, 2000). Change has gone in different directions from those predicted, or has been faster or slower than was thought. For example, if we look back at some of the popular predictions about the coming 'Information Society' that were being made in the early 1980s, we can find on the one hand gloomy predictions of the 'collapse of work' (Jenkins and Sherman) and, conversely, talk of a coming bright 'Computopia' (Masuda) while, according to Toffler, between 1/3 to 1/2 of the working population would be teleworking by the 1990s (for a critical review of these accounts see Baldry, 1988). Two decades later we know the outcome was neither all black nor all blue sky but rather the usual mixture of both. It might be argued that these were, in the main, populist accounts rather than measured academic assessments but these are the

stories that grip the public imagination, and are more likely to be read by, and have influence on, business practitioners than a long, detailed (and less dramatic) research report.

Looking back at these broad utopian and dystopian predictions concerning the outcome of the information revolution we can see that many of them were based on two analytical fallacies:

- An implicit level of technological determinism
- A too-narrow definition of technology

Prior to any attempts to predict current relations between technological change and sectoral employment, we therefore need to accept two preconditions:

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2. Preconditions

2.1 The avoidance of technological determinism

Technological determinism essentially is reflected in the idea that, if we have the capacity to develop technology in a certain way, then we will or should do it and that this development will have an 'impact' on the rest of our social and economic life.

Technological development thus becomes both an imperative and a determinant. Here our actions are reduced to those behaviours that will ensure the speedy uptake of the new technological possibilities (Brown et al, 2000) and any objections can be tagged as 'standing in the way of progress', usually with some reference to the Luddites.

In reality, of course, human agency *does* steer the course of take-up and diffusion. We are able to make decisions about which applications seem relevant or useful: a good example is the poor take-up of 3rd generation mobiles compared to the unexpectedly rapid diffusion of the relatively low-tech text messaging (Cliff et al, 2008). Having said this, we also need to recognise that the majority of such decisions will be made by those in society with the economic and social power to define what is 'useful' and what is a problem worthy of a technological solution. Not all problems get technology thrown at them: in our society we can conveniently get money from a hole in the wall, but two thirds of the world has trouble in getting a clean water supply.

Past mistakes in forecasting often stem from a failure to acknowledge this inter-relation between the technical and the social. However, to say that technologies, once the decision has been made to develop them in a particular way, have no effects beyond those which have been planned is equally delusory. We have to avoid both technological determinism on one hand but also the view which sees technology solely as a social product on the other. While technologies are undoubtedly shaped by the processes of social and economic decision making they, in turn, affect the policies, the users and the infrastructure associated with them – thus technologies reflect society but also shape and modify it (McKenzie and Wajman, 1987; de Laat, 2000).

For example, the path or trajectory may be influenced in this way by non-technological factors but, once a step is taken for whatever reason at the time, further developments will often follow on from it in a pattern of irreversibility and path dependency. A good example is the QWERTY keyboard which was originally developed to slow the pace of typists down because of the technical limitations of the early mechanical typewriter, yet which remains the dominant model for all digital keyboarding. We therefore need to appreciate the consequences of existing or emerging technological trajectories as, once established, their inertia may limit the possibilities of choice.

We can say therefore that technological trajectories are constructed by societies in an interactive process between scientific innovation, citizens' demands, the intervention of relevant actors such companies or government, and the responses of economic and legal institutions (Peláez and Kyriakou, 2008).

2.2 Taking a broad definition of technology

What we mean by 'technology' is in reality a socio-technical system. A purely 'hard' scientific/technical view of technology as essentially 'tools' is too narrow, for hardware only becomes a particular technology (for example, the assembly line, the call centre) when it is made part of social and economic life and organisation. The 'soft' aspects of technologies are the other side of the technological coin to the hardware; soft aspects are the capabilities such as knowledge, skills, processes and values which are needed to apply the hardware within specific socio-economic contexts. To develop soft technology can require training, organisational change, or the provision of new services.

This is because technology is how we apply scientific and empirical know-how to meeting and fulfilling economic goals and social *needs* in real life. Thus, to plot the trajectory of change we need to identify likely technical advances, *and* map them against the developing socio-economic needs.

3.0 What is the connection between technological development and economic activity?

Lee and colleagues for the Work Foundation point out that the neoclassical economic model saw technological change as an exogenous variable, external to the working of the economy. Newer economic approaches (endogenous growth theory) see a growth in knowledge affecting both technological change and economic growth (Lee et al, 2007). This conception of growth thus places a high value on the role of innovation.

When looking at technological trends in the context of the economy, the popular focus is often to concentrate first on:

- a) new *products* (such as PCs or DVD players) and the sectors which produce them. Actually it could be argued that equally important changes to our way of life have been through
- b) modifications to existing products (phones) and
- c) to the application of technology to change the ways we do things (shopping, banking). Indeed 'innovations are framed in terms of letting us do things faster, over a greater distance and more conveniently than they are done today' (Brown et al, 2000).

Using the past experience of ICT we can, in Table 1 below, identify three related areas where technological development will affect economic activity (modified from Brinkley, 2008).

Table 1: Technological development and economic activity

1	As a knowledge-based sector	As the sector which produces the technology. Characterised by a high level of investment in R&D, and subject to rapid change
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2	As an enabler of new industries/sectors	New technologies allow new forms of industrial/service activity previously not considered feasible or technically possible
3	As capital	The technology is itself a capital good; investment in the technology will increase productivity

In 2 and 3, the ‘technological frontier’, the boundary of what can be produced with current resources (including knowledge), is pushed outwards as new methods of production and new products are created (Lee, Schneider and Brinkley, 2007).

In addition, the degree to which any of these will flow from any particular technological development will depend on several contextual factors including:

- The business environment (including labour, product and financial markets)
- The education system.

4.0 Looking ahead to 2025

The task of predicting where technological change is going to transform our patterns of work and employment is complicated by several factors.

- Technological convergence and blurring of the boundaries between technologies
- The technology/social need interface
- The increasing difficulty of defining discrete sectors of economic activity
- Public attitudes towards particular technologies
- Exogenous factors which may have an equally strong effect on patterns of employment (Cliff et al, 2008).

5.0 The path of technological development and convergence

5.1 Increasing levels of automation

Ever since the industrial revolution and the demise of the handloom weavers technologically-enabled labour displacement has always generated both negative and positive scenarios. In the short term large-scale job shedding in declining or outmoded sectors has created undoubted emiseration for whole occupations, and the prospect of technological change is inevitably seen with some foreboding by many sectors of the workforce. It can be argued that to focus solely on this immediate effect is to assume that there is a fixed amount of output to be produced and that the replacement of labour by technology will yield a zero-sum end result: the machines will get a bigger slice of the economic activity cake but the cake will remain the same size. Against this, the positive scenario argues that realistically we should adopt a positive-sum model as, in the long term, the increases in productivity stimulate the economy and create jobs often in totally unforeseen industries: the ‘cake’ gets bigger. However, even if true, we should note that this is not quite comparing like with like: when occupations die, the negative effects (loss of income, career, status and hope) are often concentrated in specific geographical localities, whereas the consequences of growth are usually more widely dispersed.

Existing predictions concerning labour substitution through automation see a trend of intensification in existing semi-automated sectors and the diffusion of automation to previously untouched sectors as the cost of intelligent automation continues to fall.

Extracting from the graphical projections produced by Peláez and Kyriakou (2008) Table 2 indicates the following approximations for different sectors for the year 2020:

Table 2: Predictions of sectoral levels of automation in EU countries by year 2020

Employment sector (EU)	% of tasks automated by year 2020
Automotive	60
Chemicals	40
Metallic	40
Shoe and textile	38
Food and drink	40
Health	35
Hospitality and tourism	20
Agriculture	20
Construction	15
Security and defence	15
Education	15

[Source: Figures adapted from Peláez and Kyriakou, 2008]

It is clear from the above that even sectors previously immune to labour displacement are likely to experience this within two decades.

5.2 Technological convergence

The above, however, is a prediction for a single category of technology. We know from our two decades' experience of digital technologies that key technologies have a tendency to converge and that, when technologies do converge, the pace of technological change speeds up and the uses of the technologies become more diffused throughout different areas of social and economic life. For example, the convergence of IT and telecoms has meant that the same technologies are now used for work, consumption and entertainment and the same services (voice, internet, video) can now be provided through several different technologies – mobile, optical fibre, co-axial cable TV, fixed radio and satellite.

Current predictions indicate that technological convergences in the next two decades may prove even more dramatic as scientists from different disciplines perceive complementary lines of development. For example, the prospects for robotics and advanced automation will include improving robotics with the addition of more 'human' capabilities: eyesight, intelligent interaction, integration in a language system and mobility in open spaces. In industrial biotechnology, it is predicted that we could be using biological processes in the transformation of materials that at present require high energy and pollutant-emitting processes (Sager, 2001). When these two trends converge we will see the development of biological-computer interfaces (Cliff et al, 2008) and eventually of NBIC (Nano-Bio-Info-Cogno) convergence, with the time horizon for such convergence of biotechnology, robotics and nanotechnology estimated to be 2025 (Sager, 2001; Peláez and Kyriakou, 2008).

It must be stressed that these are *technical* predictions: whether these possibilities are taken up and disseminated will depend on the social and contextual factors indicated above.

5.3 The technology/need interface

This raises the question of whether the task of prediction should start from the science/technology end or from the social need/market end? Is it a question of problems searching for solutions or solutions looking for problems to be solved? Realistically, it is safe to assert that it has always to be a combination of both. An interesting approach to mapping this comes from the French Foresight exercise which used socio-technical grids to identify what were going to be key technologies.

Here (Table 3) the grid example is showing the relationship between fuel cells and economic developments on one side and technical/scientific developments on the other. The grid represents the recognition that, as discussed above, the path of technological development is the result of an interaction between social-economic need, the state of technological knowledge and the critical developmental issues that must be overcome. The underlined category is described as the 'flag': in identifying a flag for a key technology we can either flag the social need (column 3) or the technology need (column 4). In other words we cannot start with applications (Column 2) or even sectors for application (column 1) as these are unlikely to be causal in their operation. Similarly, while critical technology points (Column 5) are also seen as key to development, the areas of scientific domain (Column 6) are too far removed to be causal in their operation.

Where we can identify a need but, as yet, there might be a range of technological solutions, the flag stays in column 3. Once a clear lead is taken by one of the technologies (as in this example) the flag shifts to column 4. The process produced a list of 'key technologies' which were key either for their attractiveness (a potentially favourable application of some kind) or their effect on competitiveness, or were seen as key with primary reference to the dynamics of technology.

Table 3: Identification of key technologies: the example of fuel cells

1	2	3	4	5	6
Industries	Example of use	Function fulfilled	Technology	Critical technology points	Scientific domains
Transportation, offshore platforms, building and housing, space.	Electric cars, boats, trains, power generators, propulsion and ancillary power units, domestic heating and cooling, cogeneration	Power generation with low CO2 emission	Fuel cells	Yield, life duration, storage, miniaturisation, safety control, hydrogen generation, system integration costs	Electro-chemistry, physico-chemistry of fuels, solid physics, optimisation

[Source: from Durand, 2003]

Biotechnology, new materials and ICTs were seen as the three 'enabling' technologies whose presence is evidenced across a wide number of traditionally separate product sectors, although ICTs were pervasive in the technology mapping in that they seemed to colonise the entire field. Biotechnologies were the second major area but with a longer 'wavelength' and less immediate effect and penetration power into other fields. (This may be a little faster in the UK as we have been ahead of other EU member states in

developing specialist biotechnology companies, particularly in biopharmaceuticals, diagnostics and agri-environmental areas (DTI, 1999)).

5.4 The difficulties of defining sector boundaries

Our task in this paper is to predict where such key technologies will be deployed (in other words, Column 1 in the grid) and here it becomes even more difficult. Our experience of IT diffusion has demonstrated how a common technological base allows the blurring of once-discrete employment areas – supermarkets now act as banks, for example, and TV companies supply phone and internet services. This often makes it difficult to identify those new employment sectors which will require different skills from those which are current in the sector from which they emerge. Few people in the 1980s foresaw the expansion of call centres, and call centre work as a distinctive area of employment did not immediately show up in the employment figures, as banking call centres were counted as banking employees and utilities call centres as utility employees.

This suggests that, in thinking about potential future economic activity, traditional economic and employment segmentations are often misleading. For many years we have popularly used classifications which derive from the traditional threefold division of the workforce into:

Primary (such as agriculture, lumbering, mining and other extractive processes)
Secondary (industrial manufacturing, engaged on transforming raw materials into products), and
Tertiary (engaged in providing not products but services, such as transport, finance, and retailing).

This classification is first credited to the New Zealand economist A.G.B. Fisher, writing in 1935, but was later refined by Colin Clark in 1940. The coming of the information revolution prompted some 1980s authors to suggest the addition of a fourth category of

Quaternary or information workers, involved in the transmission, processing and receiving of information.

This concept has more recently been replaced by that of knowledge workers, who are said to take their identity from the existence of a Knowledge Economy. Most current predictions are predicated upon the existence of the knowledge economy, a frequently vague concept which has, however, been usefully operationalised by the Work Foundation:

'The knowledge economy is a story of how general purpose technologies have combined with intellectual and knowledge assets – the 'intangibles' of research, design, development, creativity, education, science, brand equity and human capital – to transform our economy' (Brinkley, 2008, p9).

The Knowledge Economy (KE) is seen as comprising technology and knowledge-based industries reflecting R&D intensity, high ICT usage, and the development of large numbers of graduate and professional workers. The Work Foundation correctly observe that these characteristics cut across most sectors and industries, at the same time blurring the traditional boundaries between sectors such as manufacturing and services and enabling the emergence of previously marginal sectors such as the creative industries. In this, technological development is seen as a supply-side enabler of the KE (Brinkley, 2008).

Eurostat continues to use sectoral boundaries for measurement purposes and sees the KE as comprising high to medium tech manufacturing and communications and a knowledge service sector broken down into four groups: high tech services (R&D and computing), financial services, market-based knowledge services (communications, travel and business) and other knowledge services (education, health, recreational and cultural services). Table 4 shows that using this break-down, the composition of the knowledge industries in Europe (EU15) in 2005 was as follows:

Table 4: Europe’s knowledge industries (2005)

EU15	% of total employment
Tech-based manufacturing	6.9%
- High-tech manufacturing	1.1%
- Medium-tech manufacturing	5.8%
Market services	15.3%
- High-tech services	3.5%
- Financial services	3.2%
- Business/communications	8.6%
Health, education, cultural	19.4
All tech and knowledge based	41.5%

[source: Eurostat, quoted in Brinkley and Lee, 2006]

The role of knowledge, however defined, reminds us of the importance of soft technology. Soft technology, when interpreted into the jobs people do, translates as service employment and most predictions agree that services will constitute the heart of the economies of the 21st century.

In their analysis of the service sector, Miozzo and Soete (2001) have shown how ICT has allowed services to be produced in one place and consumed simultaneously in another. This has increased service transportability, changing modes of delivery and contributing to a new technical division of labour. ICT applications are particularly apparent in key sub-sectors in services, namely:

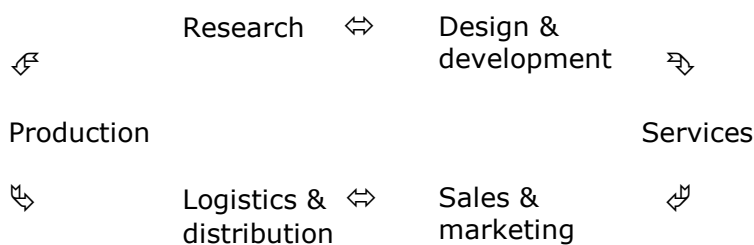
- a) *information network services* (finance, insurance, telecoms) which involve large-scale information processing, and
- b) *physical network services* (transport, travel, and wholesale and retail distribution) which involve support for logistics and route planning (Miozzo and Ramirez, 2003).

What is significant here is that this has restructured not only the service sector but has affected all other economic activities. The service content of many manufactured goods has increased through an expansion in ‘front-end’ employment such sales, technical help, product development and marketing. Many producer services, which were historically internal to large organisation (accounting, advertising, distribution), are increasingly externalised so that those knowledge-intensive activities previously classified as manufacturing are now service activities. As the authors comment:

‘Contrary to the alleged ‘de-industrialisation’ of industrialised countries, technological change is leading to a ‘splintering’ and ‘disembodiment’ process whereby goods spring from services, and services, in turn, from goods’
(Miozzo and Soete, 2001).

This analysis of the blurring of traditional economic boundaries very much coincides with the current policy model of High Value Manufacturing (HVM). The IfM/DTI report on HVM points out that, whereas the traditional definition of manufacturing was the transformation of raw materials into finished products (the basis for the old Standard Industrial Classification of jobs), today there is blurring of boundaries between production and services. The broad definition behind HVM sees manufacturing as a broad cycle of activities from R&D, production, logistics and services to end of life management, all within a socio-economic context (Figure 1).

Figure 1: A Broad definition of manufacturing



[Source: DTI/IfM, 2006]

What this means is that *production* and *manufacturing* are not the same: production becomes only one activity of a manufacturing company (and indeed production itself may be outsourced); a high technology company like Rolls Royce actually obtained half its revenue from services in 2004 (DTI/IFM, 2006).

5.3 Diffusion and public attitudes

The diffusion of the kinds of converged technologies indicated above may take longer than the very rapid diffusion of ICT over the past two decades. For one thing the developmental time-frame for biotechnology is much longer and slower paced, but for another thing it may involve a greater degree of organisational learning on the part of management and employees: whereas many of the younger generation of IT workers saw working with IT as a logical extension of their home and school IT experience, the diffusion of biotechnology into working life may require the diffusion of values promoting acceptance.

This was recognised a decade ago in the DTI's report on biotechnology (DTI, 1999), where one of the major variables affecting whether diffusion was 'steady , fast, slow or failed' was seen to be consumer and manufacturer attitudes and acceptance/rejection of biotechnology (the example of GM crops was clearly to the fore at this time).

6.0 Exogenous factors

6.1 The economic, financial and physical environment

Contemporary work arrangements have been made very insecure and volatile by the accelerated pace of technical change and by the volatile nature of world economic systems (see Taylor et al, 2005). While foresight exercises attempt to systematically relate key technologies to the major challenges faced by society such as environment, education, health, security, working conditions, there will clearly be some that we cannot accurately predict and which will inevitably skew the direction of technological and economic development. The full consequences of climate change, for example, we can

only guess at, although there have been calculations of the effect on the world's growing zones and consequent arguments in favour of GM as a means to combat future agricultural crisis. Similarly the moment when 'peak oil' is reached is bound to affect where the links in global supply chains become located as higher transport costs may cancel out lower production costs.

6.2 Transnational flows

However, much of the discussion of new employment sectors is still bounded by notions of a *national* economy: this no longer corresponds to economic reality. New products *will* be manufactured and new services provided but where will this take place in terms of employment? As the current international financial crisis demonstrates, we are locked into transnational flows of finance, capital, goods, services and labour.

While we have become familiar with this as it applies to production supply chains, less commented on has been the degree to which mergers and acquisitions have created international service conglomerates providing a diversified range of services (such as management and computer services) which are traded across national borders and subject to FDI. These organisations have become increasingly diversified as the incremental cost of adding additional information-based services is very low but at present such advanced and specialised business services remain highly concentrated in developed countries. Future trade is as much likely to involve the 'movement of people as carriers of expertise as much as the movement of material objects' (Miozzo and Soete, 2003).

We may have to reverse our thinking about the role of 'labour intensive' and 'capital intensive' processes. According to a recent Japanese view, labour intensive processes will be knowledge-intensive, requiring a high education base and will be retained in the advanced economies, while capital intensive processes will be those subject to automation and will be located in Asia and Eastern Europe (Fukutani, 2008).

7.0 Implications for education and skill development

Another caveat in prediction making is to avoid the common assumption that technological change will entail a qualitative paradigm shift from the work we know today. In other words, to avoid the tendency to focus on the new and ignore those continuities with the present and the past (Baldry et al, 2007). Thus, in talking of future or emergent high tech or knowledge intensive sectors of the economy we should remember that this by no means implies that all *jobs* in those sectors will be empowered and knowledge-based. Recent work on local labour markets has shown that by the early 21st century many ICT-based jobs were low skilled and relatively low paid (Warhurst et al, 2006; Baldry et al, 2007).

Having said this, the pointers toward a greater economic reliance on a range of knowledge-based service sectors have several implications for the future of the educational system. We can envisage alternative educational scenarios.

One issue that has already been noted is the relationship between the highly remunerated knowledge/technology sector of the labour market and the relatively lower paid non-knowledge sector, forming the so-called 'hour-glass' workforce. Several current predictions on work futures see this as inevitable or remaining for the foreseeable future:

'Affluent workers at the top of the glass will continue to buy restaurant, care and other services from people on low pay at the bottom'.

(Moynagh and Worsley, 2005,

p2).

If this pessimistic view holds true this, in turn, has implications for the education system. A polarised education system which, to a greater extent than even is the case at present, places its priorities and resources towards 'meeting the needs of the economy' by supporting the brighter pupils while consigning those who cannot play the educational game to the uncertainties of the low-pay sector, would simply continue and promote acute social divisions within society.

Conversely, an educational system that was *genuinely* aimed at developing the potential and worth of *all* young people may be out of kilter with the labour market unless we revise our approach to job design. Otherwise we may witness the sort of mismatch between skills and jobs that we have seen in some areas of call centre employment: call centre managers in some customer-facing services like to hire graduates because they have better language and social skills, yet the stressful and repetitive nature of call centre jobs are not what graduates expect to do with their intellect, and the flat organisational structure offers no career prospects, contributing to very high turnover rates.

It is also clear from the discussion in this paper that the idea of our education terminating at the current conclusion of secondary or tertiary education (in other words, essentially nothing after age 22, and for most young people a lot earlier) is unlikely adequately to equip future citizens for the volatile and rapidly changing world they will inhabit. New challenges – whether from technologies, climate change, or the exhaustion of finite resources – will require frequent new learning.

These points raise more philosophical questions which lie outside the remit of this paper:

- Is the primary job of an education system to meet the 'needs' of the economy?
- If so, do those needs include both design engineers and care-home staff, both biotechnologists and baristas?
- If not, how do we educate our citizens so as to empower them with control over their learning throughout life?
- What kinds of jobs would such learning-empowered citizens expect to take up and find personally fulfilling?

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