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Science Fiction and Economic Cycles. A Dialogue on Technological Expectations

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Abstract

Was the 2007-8 financial and economic crisis brought about by the exhaustion of the current techno-economic paradigm, and will a new paradigm will lead to eventual recovery? Lundvall and Steinmueller respond to Archibugi's *Blade Runner economics*. Lundvall argues that whilst it is useful to think in terms of techno-economic paradigms to understand the uneven process of technological and social advancement, the main reason for the crisis and the main requirement for a new upswing are both socio-political rather than technological in nature. There is a link between the neoliberal deregulation regime that led to the crisis and ICTs. This regime might actually slow down the formation of a new techno-economic paradigm based around genetic engineering, artificial intelligence and nanotechnology. Steinmueller discusses what role science fiction might play in developing insights about possible futures. Might the present day equivalent for techno-economic paradigm change be more about the innovations necessary to rebuild or retrofit our existing technologies than about producing new growth sectors? Taking on board these insights, Archibugi contends that we need to understand why the economic crisis has been so long, so deep and so wide. An innovation-based recovery will need to take advantage of technological opportunities. Pro-active public intervention in science and technology will additionally be required, combined with new social imagination.

Keywords: Technological opportunities, Techno-economic paradigms, Social acceptability, Regulatory regimes, Schumpeterian Economics, Creative destruction, Information technology, Bio-technology, Base and super-structure, Social innovation

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Is there a technological fix for the current global stagnation?

A response to Daniele Archibugi, 'Blade Runner economics: will innovation lead the economic recovery?'

Bengt-Åke Lundvall

a) Introduction

The issues raised by Daniele Archibugi (DA) are certainly important: are the current stagnation and the 2008 crisis a reflection of the fact that the technological foundation of a long economic upswing has now been exhausted? Are there newly emerging technologies that will form the basis for a radically different techno-economic paradigm and will those lead the next recovery? If so, will they be dominated by biotechnology or are there other candidates as pervasive general purpose technologies that will drive growth?

I share Archibugi's view that it is useful to think of economic history in terms of techno-economic paradigms. But I disagree regarding the main cause of the 2008 crisis and its possible remedy. The crisis did not reflect that the exhaustion of technological opportunities, and new technologies will not *lead* the next recovery. Rather the 2008 crisis reflected a combination of dubious politics and fundamental inherent contradictions in the current globalizing form of capitalism. If those contradictions are not resolved, there are no general purpose technologies, however radical, that can break the current stagnation. I will also argue that information and communication technologies played a role in the crisis but only in an indirect manner.

In his paper, DA refers to Perez (2013) and Mokyr (2013) as arguing that there is still potential for job creation based upon new technologies "provided that the social and economic systems allow for their introduction and diffusion". My main point is that this precondition is more difficult to overcome than indicated in the discussion paper. The current socio-political paradigm is incompatible with a new techno-economic paradigm that may eventually coalesce from today's emerging technologies. The most critical issues have to do with the contradiction between neoliberal national political governance, on the one hand, and financialization and economic globalization, on the other hand.

Moreover, even if a social transformation took place that allowed for the introduction and diffusion of emerging new technologies, economic growth and job creation would depend more on the generalized use of existing technologies in 'the rest of the world' (Latin America, Africa, China, India and Indonesia) than on the application and wider use of the brand-new technologies in the OECD-area. It is surprising that DA who is a world-leading expert on globalization including working on global citizenship, does not have more to say on the importance of location. It stands in contrast to the insights offered in contributions to the excellent handbook he recently co-edited (Archibugi and Filippetti 2015).

DA reflects on how his children and grandchildren will experience the advent of new technologies. I agree with him that there is no reason to doubt that future generations will be confronted with fancy and unforeseeable new phenomena reflecting technological change. But there are reasons related to societal risk and acceptability for believing the Blade Runner technologies that DA presents as

primary candidates for forming the technological basis of the future long upswing might not become as all-pervasive as he assumes.

My conclusion is that politics and new forms of governance will matter more than the economy and technology for the eventual upswing and sustained economic growth – a conclusion that might seem inappropriate and even surprising from someone with a life-long career as an expert on the economics of innovation.

b) On the usefulness of the concept of a techno-economic paradigm

The concept of a techno-economic paradigm is helpful when it comes to understanding economic and social change. It reminds us that technological change takes place at an uneven pace in which clusters of independent technical innovations form that then prove superior in terms of how they contribute to economic performance compared with existing technologies. It also reminds us that the new technological systems will confront technological, social and cultural barriers that reflect how institutions and organisations have adapted to earlier generations of technology.

One recent example is the set of social, organizational and infrastructural transformations that have taken place in connection with the wider use of information and communication technologies. The Solow paradox (later on taking the opposite form of the 'new economy' hype) referred to the fact that the widespread use of this revolutionary technology was not (initially, at least) reflected in higher rates of productivity growth. In Lundvall (1991) and Lundvall (2009), I referred to research showing how Danish firms at the end of the 1980s introducing this 'superior technology' *without combining the introduction with organizational change and training of employees* experienced a fall in productivity. In an important paper, Paul David (1991) went back one hundred years and showed that a similar slow impact came from introducing electricity as a substitute for steam power.

One of the interesting ideas of Perez and Freeman is that they link new techno-economic paradigms to shifts in global leadership. The classical example is how Germany and the US overcame the UK and took the world lead (gaining an absolute advantage) in an era when electricity and chemistry became more important than mechanical engineering, steel and coal. Fifty years later, countries such as Japan, Singapore and Korea were able to join the rich countries on the basis of information and communication technologies. One reason for this change in leadership is that the very success of adapting institutions so that they match the existing core technologies subsequently becomes a handicap for the prevailing lead country (or countries) when new technologies become dominant. DA gives some attention to the location of the new techno-economic paradigm but only in connection with an analysis of European countries. However, his analysis is more on the persistence of investments in R&D than on how the qualitative characteristics of the national systems of innovation may or may not match a future techno-economic paradigm.

Yet while it is useful to discuss how changing technological systems are reflected in shifts in absolute advantage and how existing institutional forms are challenged by such shifts, it is more problematic to propose that such shifts will 'lead a recovery' or to argue that the exhaustion of the existing paradigm lies behind the crisis and the ensuing period of stagnation. I find much more convincing the argument that the 'recovery' after the great depression was 'led by' the Second World War and that post-war economic growth reflected the aftermath of the war rather than being led by new technologies. Der Wirtschaftswunder in Germany and the rapid growth in Japan reflected a unique historical experience in which physical infrastructure had been largely destroyed while the advanced knowledge base remained more or less intact. To this was added the politically motivated and comparatively

successful Marshall plan that made it possible for Western European countries to engage in catching up with the US, the world's lead economy.

c) Where did the 2008 crisis come from?

There is already a voluminous literature on why the recent financial crisis came about and I will not attempt to give a full answer but merely point to what I see as the most crucial factors.

The deregulation of financial markets and weak governance more generally represent the single most important factor in explaining why there was deep financial crisis in 2007-8. Financial deregulation was a politically orchestrated process that started in the second half of the 1970s in the US and accelerated and became world-wide in the 1980s.[1] An important mechanism behind the acceleration and wider spread of financial deregulation was interstate and international competition. Financial institutions in the US became located in peripheral states offering minimum regulation as early as 1977 (Sherman 2009. In order to become the preferred host of financial institutions, nation states competed in offering ever more lax regulations.

The globalization of finance contributed to the globalization of trade and foreign direct investment, and it went hand-in-hand with neoliberal strategies that led to increasing inequality and to financialization, whereby enterprises became increasingly focused on trading in financial assets as compared to investments in production capacity. Expansionary monetary policy in the US and elsewhere promoted asset price inflation while the increase in income inequality slowed growth in aggregate effective demand. The room for national fiscal expansion became narrow as speculative attacks on national currencies grew in scale.

The 2008 crisis was triggered by insolvency in US subprime mortgage markets but there could have been many other triggers to bring about the global financial collapse. The asset inflation and a myriad of transnational Ponzi schemes with fictive liabilities and assets would surely have collapsed sooner or later. The combination of globalizing financial markets and neoliberal economic strategies with weak transnational governance ultimately proved unsustainable. The crisis illustrates why the idea of a technological fix for stagnation problems is inadequate and why the institutional and political framing of technological development needs to be brought into the analysis. Nevertheless, as we shall see in the next section, information and communication technologies may indirectly have contributed to the crisis.

d) On the contradictory impact of information and communication technologies

While the widespread diffusion of ICTs eventually had a positive impact upon productivity growth world-wide, it also indirectly prepared the ground for the financial crisis. It made it possible for Asian countries, such as Korea, Singapore, Taiwan and more recently China, to catch up with the US and Europe. Those countries could enter fast-moving information and communication technologies as windows of opportunity opened up and thus they could leap-frog from low to high technology industrial growth (Lee 2013; Perez and Soete 1988). The wider use of ICTs also provided a boost to productivity growth within Western countries even if this boost was delayed and much less strong and

[1] At the start of the 1980s I was member of an OECD ad hoc expert group with a mandate to analyse the role of science and technology with regard to competitiveness. Half way through the process, the DSTI Director (who was from the US) came to one of our meetings and told us that we should reorient our work and focus on how deregulation could contribute to competitiveness. The group did not comply and we ended up with recommendations to build 'structural competitiveness' through investments in knowledge infrastructure. Those conclusions were not widely disseminated at the time – the final report was held up because of a supposed lack of printing capacity at OECD!

durable than it appeared in the hype around the new economy. Altogether, this had a positive impact upon the rate of global economic growth.

At the same time, however, the widespread use of information technology prepared the ground for the financial crisis. World-wide communication networks contributed to the formation of global financial markets and this was used as an argument for global deregulation and for neoliberal economic policies. Thus, ICTs deepened the contradiction between a globalizing economy and national political governance. A typical neoliberal argument linked the arguments for deregulation of financial markets to the spread of ICTs:

Trade liberalization and the information revolution have paved the way for the globalization of financial markets. The pace of financial globalization, however, will depend critically on whether governments get out of the way of the market or whether they try to block the natural course of market forces by erecting new barriers to the globalization of trade and finance (Dorn 1993).

In 1994 I witnessed the visit of an OECD delegation led by the organization's Secretary General to the Governor of Federal Reserve, Alan Greenspan. On its return, the idea that OECD-countries had now entered a 'new economy', where the limits for expansion through lax monetary policy had been considerably expanded because of the positive impact of ICTs upon productivity, was widely diffused within the organization. For the very first time, OECD macroeconomists were asked to take into account the role of a specific technology when designing economic policy. The optimism lasted for about a decade and ended with the collapse of the Dot-com bubble in 2000-02, a collapse which proved to be a precursor to the 2008 financial crisis.

In 2000 I was involved in discussing the Lisbon strategy aiming at making Europe the most competitive region in the world with enhanced social cohesion and better jobs. The focus was still on the use of ICTs and the US was seen as model for how to create ideal conditions for these technologies. The intention was to combine US flexibility and deregulation with elements of European social security and international economic convergence within Europe. Within five years that strategy had been narrowed down to an essentially neo-liberal strategy, but then came the financial crisis, which completely subverted the strategy (Lundvall and Lorenz 2014).

The link that was established between ICTs, on the one hand, and neoliberalism and deregulation of financial markets, on the other, reflected primarily the ideological climate of Reaganomics and Thatcherism. But there were also other more substantial connections that these ideological ideas were perceived to be based upon. In order to realise the potential for world-wide communication, deregulating the national telecom monopolies was seen as a necessary first step. In addition, the implementation of information technology contributed to increased inequality since it went hand-in-hand with a reduction in demand for low skilled labor. Without appropriate policy actions to upgrade the skills of the low skilled, this almost inevitably leads to greater income inequality (Lundvall 2013)

I would therefore argue that the 2008 crisis can be associated with ICTs. However, the relationships are more complex than suggested by DA. It is not because the technological potential was exhausted that the crisis occurred. Rather, the exaggerated expected impact of ICTs on the economy was used as an argument for establishing the ultimately unsustainable governance regimes that precipitated the crisis.

e) Robert Gordon on faltering innovation and headwinds

DA refers to the much debated contribution of Robert Gordon (2012) and it is natural to compare DA's ideas with Gordon's. There are two important differences between the two sets of ideas that need to be taken into account. First, Gordon abstracts from the financial crisis and takes a long historical view, referring to three industrial revolutions – the most recent reflecting the use of ICTs. Second, while it is not very clear from DA's discussion where we should look for new lead countries, Robert Gordon explicitly limits his discussion to the growth prospects for the US. This implies that even if Gordon is right in his prognosis of US stagnation, there might still be world-wide economic growth with new lead countries.

Gordon argues that the first and second industrial revolutions involved much more important forms of progress than the third Industrial Revolution represented by the wider use of ICTs. These technologies changed completely both living and working conditions and they involved the building of new infrastructures. He contends that important growth-promoting processes such as the movement of citizens from the countryside to cities and the increased participation of women in the workforce could only happen once. And he sees no similar grand changes on the horizon.

He also argues that ICTs accelerated growth in the US only for a rather short period (1996-2004) and that we should not expect much more growth on that basis over coming years. In contrast to DA, he has little to say about which technologies will shape the future. He mentions only in passing the driver-less Google car and research on the genome that may result in more effective treatment of cancer and other diseases before presenting 'six headwinds' that would neutralize the positive impact of such new technologies. The six headwinds relate respectively to stagnating population, weak educational performance, the negative impact of globalization on national income through factor price equalization, rising inequality, the cost of environmental protection, and the overhang of consumer and government debt.

One interesting direct lesson from Gordon's work is that potentially revolutionary technologies may have limited impact upon macroeconomic performance if they do not give rise to a new wave in terms of capital accumulation and public investment in infrastructure. Another lesson is that the geographical setting matters for the impact. As indicated by Freeman and Perez, while technological revolutions may have a global impact, their epicenters are nonetheless localized. At the end of my discussion I will return to that issue.

f) Are there emerging technologies that can provide the basis of future economic growth?

DA presents 12 technologies that McKinsey (2013) claims will have an economic impact between now and 2025. Most of the technologies with the strongest impact are ICT-related. Next-generation genomics comes in with a more modest impact and the same is true for advanced materials, energy storage and renewable energy. The McKinsey list can be combined with a list of the most promising technologies identified by OECD for the Danish government (Ministry of Higher Education and Science 2016). This list does not rank technologies on the basis of likely economic impact but instead takes a longer perspective, the aim being to give a sense of direction to research. Some of the technologies from the McKinsey list reappear but the OECD study gives more equal weight to specific technologies within the four fields of digital technology, advanced materials, biotechnologies and energy/environmental technologies. The report also points out that several of the new technologies may lead to increased inequality.

Within the digital field the report points to the internet of things, artificial intelligence and big data analytics as three key technologies with broad impact. Within biotechnology special emphasis is given to neurotechnologies and synthetic biology. Advanced materials include nanomaterials and additive manufacturing, while the energy and environment field includes micro- and nano-satellites, biofuels and advanced energy storage.

Both these lists appear somewhat confusing in referring simultaneously to specific knowledge fields close to basic science such as nanomaterials and synthetic biology, on the one hand, and to specific fields of application such as artificial intelligence and energy storage, on the other. It would perhaps have been more informative to present technologies in a matrix form, illustrating how basic science fields are linked to specific fields of application. Such a presentational form would also provide a more realistic understanding of the potential and limitations of families of technologies. In what follows, I will offer some reflections on three fields of application: health, environment and knowledge production.

g) Emerging technologies applied to the health system

As pointed out by DA, the expectations of major socioeconomic impact from the application of biotechnology have not been met so far. This may have to do with the fact that there has been a major gap between advances in basic knowledge and the expansion of the potential fields of application. Going back to Freeman's list of factors characterizing a technology that could give rise to a technological revolution, we find that the technology should combine major economic impact with social and environmental *acceptability* (Freeman 1984).

Several of the technologies listed above – in particular, genomics, neurotechnologies and synthetic biology – have great potential to revolutionize the health system. When combined with the internet of things and nanotechnologies, very sophisticated new health-related processes could be developed. One way to attain a better understanding of the potential role of Blade Runner technologies could be to study the emerging technological systems related to human health and well-being.

With reference to Pisano (2006), DA discusses some of the factors that may be constraining the impact of biotechnology such as the strong intellectual property rights and the weakening of public support in combination with long lead times from basic research to economic returns and the difficulties of integrating different technologies. I do agree on those points, and the successful Cuban experience where biotechnology was driven by needs rather than by short-term profits illustrates his points. However, there are certainly other factors that may hamper or stimulate the application of biotechnology in the health sector. These have to do with risk, inequality and acceptability.

On the one hand, the appetite for health, prolongation of youth and avoidance of disease are without limits. On the other hand, the application of new technologies is intrusive and early use often involves great risks. In a society with a high degree of inequality, the implications may be unacceptable and almost unbearable. Testing new high-risk technological processes on the very poor in order to prolong the healthy life of the rich would represent a new dimension of inequality. In order to achieve acceptability for such practices, there would be a need to dehumanize the poor or to conduct clinical testing out of sight in the poor periphery (as happened in the United States with the Tuskegee syphilis experiment between 1932 and 1972).

But we should also expect to see accidents such as unforeseen mutations or the unintended spread of dangerous nanoparticles in the core countries. Such accidents may force governments to declare a moratorium on research and thus slow the rate of progress. This reinforces DA's arguments for a stronger role of the public sector in organizing both the research efforts and the applications of the new technologies.

While the development of ICT technologies has gone hand-in-hand with deregulation and neoliberal economics, the Blade Runner technologies will require a strong state role and tough regulation in order to achieve acceptability. There is a contradictory relationships between governance based upon neoliberal ideas and the deregulation trends that were developed in connection with ICTs and the implementation of biotechnology in health systems. In short, one of the major headwinds for introducing the Blade Runner technologies is current neoliberal ideology and the institutional settings it fostered in the era of ICTs.

h) Emerging technologies as applied to energy and environment

Different combinations of emerging technologies have great potential to contribute to the reduction of global warming and also to a reduction in pollution of air and water. A specific step referred to on the lists of major potential breakthroughs is new methods for energy storage. Advances here would make solar power a much more effective and attractive form of energy. Another specific innovation close to widespread use is the driverless electrical car, with Google planning to distribute such cars for general use by 2020.

This technology is interesting because it illustrates a case where co-existing 'competing technologies' – cars with drivers and those without – create new types of risks and potential conflicts. While it would be relatively easy to establish an infrastructure and a legal framework for a traffic system with only driver-less cars, it is much more complex to do so when driver-less cars have to co-exist with traditional ones.

With a growing use of artificial intelligence, we will encounter more and more such examples. One consequence is that we should not expect the introduction and wider use of these technologies to be smooth and swift. Indeed, the disturbance created by the new technology for those using the old may be such that it is greater than the benefits for the users of the new technology. If this is the case, it would certainly affect the social acceptability of the new technology and slow down more widespread use.

Such problems are akin to those that have been constraining the implementation of new sources of energy. Those new sources do not easily fit into the common grid adapted to traditional energy sources. One way to avoid such problems of *conflictual co-existence* could be to build new cities that from the very beginning make use of the full potential of new energy sources. This is what happens in Transcendence, the other dystopian film that DA refers to.

In countries such as China and India faced with growing environmental problems in giant cities, it might be tempting to build new high-tech cities both in order to respond to the requirements of the elite and in order to promote technologies to cope with energy and environment through full-scale experimenting. We might therefore increasingly see the development of 'New Cities as Laboratories'.

Again, these are areas where there is a need for an active role of governments. Without governments giving direction to the development and use of technologies, and without regulations, the rate of

technological advance toward sustainable development will be slow. The required scale of investments in infrastructure also points to an active role for the state.

i) Emerging technologies and the production and use of knowledge

Some of the emerging digitalized technologies will have a major impact upon scientific work, education and the use of human skills. While suppliers of those technologies have a tendency to exaggerate the speed of diffusion and their impact, we can already now see how digitalization has started to transform these activities. (Indeed I see this as raising important issues that could merit a new round of debate in *Research Policy*.)

The new communication technologies make global collaboration in science a realistic option. Access to data-mining technologies promotes an innovative kind of research where new patterns can be detected without much reference to theory. Electronic publishing and conflicts around intellectual property protection are becoming more and more important.

In the future, attempts to develop artificial intelligence and the increasing use of supercomputers to handle big data, together with new forms of communication, will lead to dramatic changes in knowledge production and knowledge use with a major impact on society and economy. How they will affect global social and economic development is a major issue, since those trends will determine both the implementation of the Blade Runner technologies and what will be the next generation of technologies.

My own intuition is that progress in the direction of a data-driven world may promote globalization but that it might not represent progress in terms of promoting the learning society. In an address to Globelics, Chris Freeman cited the famous sentences on information, knowledge and wisdom by T.S. Eliot:

> "Where is the wisdom we have lost in knowledge?
> Where is the knowledge we have lost in information?"

In several papers, my colleagues and I have raised doubts about whether the 'codification' of knowledge is always a positive development, and have demonstrated that countries and organisations promoting 'experience based' knowledge and combining it with science-based knowledge are more innovative than those that only give attention to codified knowledge (Johnson et al. 2002; Jensen et al. 2007). This work is based on the belief that learning from experience *may* feed wisdom and that learning societies where men and women are expected to contribute to the production and use of knowledge are to be preferred to societies where only small intellectual elites produce knowledge.

If left to itself, the current mode of knowledge production and learning contributes to increasing inequality at all levels (global, regional and national), and the application of new technologies will, if left to operate without corrective action, further strengthen this impact. I have argued that a new 'new deal' with a redistribution of access to knowledge and learning is necessary to counter these tendencies (Lundvall, 2013). Without such efforts we run the risk of encountering all the downsides of the Blade Runner society.

j) On global headwinds

I see several global headwinds that will slow down the application of new technologies. The combination of the global rule of financial capital, economic globalization and neoliberal austerity has led to increasing inequality, and we can now see the social and political impact in terms of growing emigration from poor countries and growing nationalism in several high-income countries. These general trends will undoubtedly have an impact upon innovation, knowledge and learning.

1. Financialization in the business sector shifts attention from the real economy and from innovation to speculative activities. Bright people who could fulfil a valuable role with regard to other functions are instead attracted to the powerful financial-industrial complex.
2. The global rule of finance and neoliberal economics lead national governments to pursue austerity policies that limit investments in science, technology and education.
3. Increasing income inequality has a negative impact upon the participation of workers in the processes of organizational learning.
4. Negative views on the role of government undermine its capacity to develop the necessary regulative framework for creating social acceptability of Blade Runner technologies.
5. The growing gap between an elite that can benefit from the current form of globalization and those segments of the population who bear the costs of globalization may spill over into the debate on the 'social acceptability' of technologies.
6. With the current regime of globalization we risk getting stuck in stagnation, and we even risk that the current asset inflation where property prices rise in a deflationary economy will explode. Indeed, the IMF has recently issued a warning that we may be close to a new major financial crisis (The Guardian April 13 2016).

The global rule of financial capital is no natural law. It was created through politics and it can be changed by politics. However, it requires a new socio-political paradigm – without such a change we are most unlikely to see a new techno-economic paradigm lifting us out of stagnation.

k) Local surprises and open questions

In the beginning of my response to Daniele Archibugi, I criticized him for not being more specific with regard to the geographical dimension. Here I will illustrate this point.

Consider a thought experiment in which China's economy had behaved as India's did during the period 1990-2015, in which case the global growth rate would have been much lower. The double digit growth in China had a major impact upon growth in the rest of the world – obviously for countries in Africa and Latin America but also for growth in Europe and the US. Without China's growth, there would probably have been no reduction in world-wide poverty.

Nonetheless, few experts gave much attention to China's role until quite recently. In connection with developing a strategy for Europe (the Lisbon Strategy), as late as 2000 the main concern was with how Europe could emulate the relative success of the US. China and Korea are countries that have taken the idea of 'the knowledge based economy' seriously and there has been a shift towards Asia in

the global knowledge landscape. One important issue for future economic growth is how these countries will engage in the Blade Runner technologies.

Another important issue is what will be the next surprise in the world economy. Will large countries such as India and Indonesia be able to pursue new growth paths on the basis of the old and the new technologies? If they did, that would make a major difference. Will Europe get its act together and advance toward a federation ready to take on the rule of financial capital and go back to its original commitment to social cohesion? Will the new BRICs investment bank represent a step toward a more balanced and progressive global financial governance structure?

Will the Paris meeting on sustainable development be followed up by action and by the emergence of some form of transnational governance of energy and environment? Will people around the world be able to form movements that oppose the current tendency toward inequality and will they be able to unify across national borders on such a scale that it truly makes a difference?

There are many such questions and most of them have the same answer: We simply do not know.

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Science Fiction and Innovation: A Response[2]

W Edward Steinmueller

Introduction

Daniele Archibugi's article takes the film 'Blade Runner' as a foil for discussing how Schumpeterian economics may be related to epochal changes in the direction of long-term economic growth. He explores whether an exhaustion of technological opportunities is part of the explanation of the financial crisis of 2008 and the continuing shortcomings in the recovery from it, and, ultimately, what opportunities exist for future economic growth and technological innovation. This is a heavy burden for a film, the central theme of which is the equally weighty question of what it means to be human. In the film, this theme is developed using artificial human beings or 'replicants,' who are violently 'retired' (somewhat gratuitously since they are past their sell-by date and programmed to self-destruct anyway) by the film's noir anti-hero who develops divided loyalties. The film offers rich visual detail of an imagined future but a rather sparse account of how that future came to be. As Archibugi observes, while the film is set in a distant future, it recapitulates features of our contemporary world such as the physical stratification of wealth and social class, the continuation of war (although conflicts seem to have been relocated to certain 'off world colonies'), the migration of people, and, perhaps, the consequences of climate change. Thus, the film offers elements of both discontinuity and continuity which Archibugi argues are characteristic of Schumpeterian growth processes.

Epochal changes in the direction of long-term economic growth – Part I

In considering epochal technological change, Archibugi focusses our attention on two groups of technologies that feature in the film -- information and communication technology (ICT) and biotechnology. He observes that since the film was produced, our accomplishments have outstripped the film's vision with regard to the first, but barely progressed against the second. As technological prediction, therefore, the film is not very helpful (the predictive value of science fiction will be considered further in the conclusion). Archibugi seeks to explain this disjunction in the rate of progress in these two groups of technologies since the film's original release in 1982 by recourse to technological uncertainty and technological opportunity, and the complementary role of investment and entrepreneurship. Biotechnology's technological potential, and the opportunities to transform it into a general purpose technology that might be used to grow plant or animal 'replicant' tissues for our food, fibres for our clothing, or even, as in the film, companions and soldiers, have not (as yet) materialised. Instead, as Archibugi observes, most of the realisation of biotechnology's potential is in a relatively small segment of the pharmaceutical industry. In this industry, instead of creating giant new firms such as the film's Tyrell Corporation, biotechnology has most often augmented the size of incumbents and clearly has not achieved 'creative destruction' that portends epochal technological change. A large part of the potential of ICT has materialised in contrast, with corresponding inflows of investment and outflows in the form of diffusion and adaptation which imbue everyday objects with increasing information processing and display capabilities – be they phones, cars, home appliances, and so forth. In terms of entrepreneurship, if we take the film to represent a vision of a few decades into our future, the man in the high castle of the film may be more akin to an aging Elon Musk, rather than Eldon Tyrell, the film's mastermind of replicant production.

[2] Helpful comments from Ben Martin and Robin Mansell on earlier versions are gratefully acknowledged.

The 2008 crisis and the recovery

The deeper issue that Archibugi addresses is the contributory role of technological opportunities to the slow recovery from the 2008 crisis experienced to date. Crises of the magnitude of 2008 have many sources. The leading technology of our era, ICTs, certainly contributed to the instabilities and volatility that provided the tinder for this conflagration. ICTs, in combination with other technologies such as containerised shipping, accelerated global merchandise and service trade, enlarged the accompanying financial flows at risk of financial instability. ICTs, in combination with a neoliberal faith in the economic rationality of markets, helped to create and to gain acceptance for financial instruments that subsequently became toxic banking assets. Institutions meant to regulate risk-taking, again under the influence of neoliberal ideology, demonstrated their incapacity to adjust to this changing landscape. More positively, the same landscape conditions also supported a huge expansion in market access for rapidly growing developing countries and with it the resulting transformation of millions of peoples' lives, generally for the better but, in some cases, for the worse.

The widespread belief that innovation will restore economic growth to the robust levels of an earlier era is, indeed, worthy of critical examination. Archibugi portrays the engine of this restoration as being fuelled by expectations and this leads him to the question of where opportunities are opening up to fuel those expectations. In other words, with positive expectations, investment that would restore jobs and boost final demand should follow. Contrasting with this entrepreneurial explanation, (Mazzucato and Perez, 2015) argue that surges of technological innovation are fuelled by government investments that demonstrate the feasibility of new market opportunities – with private sector entrepreneurship following the lead of the entrepreneurial state (Mazzucato, 2015). For Perez and Mazzucato, the absence of bold 'productive' government investments is the source of both the weak aggregate demand and the weak levels of entrepreneurial initiative underlying the current malaise. A third, fiscal policy oriented approach is that it is the insufficiency of aggregate demand (for both investment and consumption) that requires state action at a level resembling America's New Deal or the Marshall Plan for the reconstruction of Europe. The persistence of low long-term interest rates offers the opportunity for the state to borrow in order to make productive investments – not only in innovation, but also in aging infrastructures. Unfortunately, public debt has become a toxic political issue under several narratives including that based on the notion of inter-generational equity. Yet, as Summers has observed in the United States context, future generations might actually prefer owing the debt to inheriting an infrastructure with an enormous deferred maintenance bill (Summers, 2016). Similar opportunities may exist in other rich nations, while the infrastructure investments required to 'modernise' in middle and low income countries offer enormous opportunities for both investment and innovation. These positions recapitulate the persistent debate regarding the origins of technological opportunity – whether it can be manufactured by stimulating demand, whether it arises naturally from research investment or whether it requires the particular visionary skills embodied in entrepreneurs who also have a fanatical commitment to opening up and exploiting these opportunities. In order to determine what policy or mix of policies might be of value, evidence about the current levels of expectations and technological opportunity is required.

Epochal changes in the direction of long-term economic growth – Part II

In commenting on current global economic conditions, Archibugi offers a pessimistic short-term outlook comparable to, and citing, Robert Gordon's recent case for pessimism (Gordon, 2016). In short, Gordon's argument in the United States context is that productivity-improving innovations beginning in the late 19th century and extending to the first decades of the 20th century have become a spent force. In Gordon's view, the late 20th century innovations related to the ICT revolution may similarly have exerted most of their impact already, with no new technologies of comparable effect on the horizon. Archibugi is rather more optimistic than Gordon, predicting growth through a

consolidation and a deepening of the current paradigm. This, however, seems to be matter of faith rather than of evidence, since the primary support for his optimism is a Delphi-like study from McKinsey which assesses the main medium-term opportunities that will stem from ICT applications including robotics. His own work (Archibugi, Filippetti and Frenz, 2013; Archibugi, Filippetti and Frenz, 2013) on expectations suggests a more pessimistic prospect. This stems from the continued business hesitancy in Europe to invest in R&D in order to bring about the consolidation and deepening of the existing (ICT) paradigm (or anything else for that matter). Europe, however, has been afflicted by its own overdue structural crisis arising from the institution of a common currency without correspondingly forceful regulatory institutions to govern the effects of economic disparities within the European Union.[3] This crisis is ongoing with European banks continuing to have a propensity to hold assets rather than to make loans.[4] Outside Europe, the processes of modernisation and adaptation to globalisation are, in fact, sustaining growth rates in some countries (e.g. China) that would, twenty years ago, have seemed astonishing and very acceptable in others (e.g. India). It is also remarkable that the nearly universal slower pace of inflation means that the real gains from growth are larger. The story on expectations, therefore, is mixed – perhaps weak at the traditional frontier where new and large opportunities would be helpful, but stronger behind the frontier where catching up processes are still vigorous.

The elephant in the room, however, is the seemingly inexorable march towards a set of crises – catastrophic climate change, spiralling inequality, and an ever-expanding movement of people fleeing war or poverty. These emerging issues challenge the prospects for innovation investments continuing as usual and may be exerting strong effects on expectations shaping long-term business investment. The threat of climate change means that most of the world's agricultural and industrial systems, including transport and housing, need a massive retrofit to avoid catastrophic changes in the earth's environment. This requires an accelerated depreciation of many fixed assets. Barring science fiction type solutions such as Blade Runner's emigration to 'off world colonies', this will require major investments, a means to make returns on those investments (which will probably involve significant tampering with market prices) and innovations that will improve the return on, and reduce the scale of, those investments to manageable proportions. Despite the recent Paris accord, the direction of the market interventions needed to achieve what is now a matter of common agreement remains uncertain; hence, expectations about returns on investments in a more sustainable future are low.

ICTs are implicated in inequality to the extent that they have reduced the substantial number of middle-income human information processors, also called middle managers, and made it possible to outsource or automate many low-skill jobs and change the skills needed for some medium-skill jobs, preventing competition for labour from raising wages and salaries. Few governments have addressed the challenge of building new skills or even of determining what skills will be relevant in the new economy implied not only by ICT, but also by sustainability. The emphasis on STEM (science, technology, engineering and mathematics) subjects clearly neglects the scale and scope of the creative industries, which constitute one of the more rapidly growing sectors needed to sustain higher long-term growth rates. Beyond this, new types of jobs involving community-based production and services that allow the accumulation of skills will be needed to re-integrate Europe's youth into the labour force and to provide opportunities for employment in localised production in other countries. Experimentation with the most effective forms of organisation for such jobs is a new form of research and development which needs protected (and subsidised) spaces in order to take root.

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[3] Moreover, the EU faces important constraints stemming from its limited fiscal position relative to its Member States (see (Dabrowski, 2010) for a useful overview).

[4] Although bank lending generally is not a principal source of R&D investment, its absence means that fixed investments and working capital levels compete with R&D for company cash flows.

ICTs are even implicated in the migration of human populations, since they provide a window on life elsewhere and an immediate capacity to communicate with those who have already emigrated and who, in turn, are able to send remittances to those left behind. Emigration is not a first choice for most people, even in difficult circumstances. However, it can become the only choice if community-based development or urban employment are absent. Although it has always been in the interest of the richer countries to provide development assistance, the case for doing so now seems even stronger than in the past.

The direction of markets, including markets for innovation, is shaped not only by supply-side innovation but also by the aggregation of individual consumer demand which, despite a small contingent of 'green consumers' (and voters), seems intent on continuing business as usual. This creates inertia in the systems in place. A different pattern of collective action than the aggregation of individual preferences (i.e. the market) or the often democratically deadlocked state seems necessary to steer economies in both rich and poor countries along a different path. This is where the potential for transformative innovation exists. What is needed is the entrepreneurial imagination to conceive of a way to tap this potential.

A return to science fiction?

Other features of the Blade Runner film that Archibugi does not discuss point to a world in which dramatic change has come to Los Angeles – the ever present rain, the billboards for emigration to the 'off world colonies', and the apparent success of this campaign in depopulating the city (and perhaps the world?). It is possible that space may become a frontier -- the solar system offers bounteous energy and material resources, all consumable without atmospheric consequences so long as we are able to get there without destroying what is left of our fragile environment. As science fiction readers and most others are very aware, however, it is a frontier beyond our reach with current technology. This redoubles the need for assuring that the 'home planet' remains habitable rather than being treated, as our present economic incentives and regulatory practices tend to do, as an unlimited consumable resource.

If science fiction is taken as prediction, it is more often dystopian than utopian. With disturbing frequency, the future earths of science fiction authors are depopulated through some *deus ex machina* of megadeath – whether through nuclear incineration, disease or, with increasing regularity, the replacement of human beings with machines, the latter being tested in prototype in the film Archibugi cites as the next step in imagination, Transcendence. Transcendence explores the idea of 'uploading' human consciousness and, to its credit, again raises the question of whether the entity thus created remains human. This vision may be preferable to that presented in another recent film, The Road, where civilisation has been reduced quite literally to ashes and the quality of human life to the struggle for survival. Transcendence is within the realm imagined by Richard Brautigan: 'I like to think (it has to be!) of a cybernetic ecology, where we are free of our labors, and joined back to nature, returned to our mammal, brothers and sisters, and all watched over by machines of loving grace.' (Brautigan, 1968:117) Of course, the machines might not exercise even this modicum of care, as Transcendence suggests and as envisaged more viscerally in the various incarnations of the Terminator films and TV series. The dystopian qualities of science fiction have always served to identify dangers inherent in the path that we are currently following.

Rather than prediction, science fiction is thus a genre which offers imaginaries of a more hopeful future (as in Star Trek, for example) as well as confrontations with the more disturbing elements of the world in which we live. It is less a guide to the future than a recognition that the road on which we travel into the future has many branches. It is less a storehouse of innovations waiting to be brought forth than it is an imagination of what consequences current innovations might potentially have for human experience. Perhaps it is then significant that some of the younger authors (e.g. Paolo

Bacigalupi) as well as older ones (e.g. Margaret Atwood or Kim Stanley Robinson) are increasingly imagining an environmentally degraded world with drowned cities, blighted crops, and hopeless people. These visions are more common in print than in film, where audiences are likely to prefer a more palatable vision of the future. The recent film Interstellar is an exception that combines both optimistic and pessimistic elements. These contemporary science fiction visions of ecological disaster join the historical evocations of nuclear and biological war, overpopulation, meteor strikes, superhumans and machines vying to replace humans, and other horrors that remind us that we face a bleak future if we do not succeed in making the innovations necessary to sustain life on earth. In making these innovations, we may indeed address both the question of human survival and the need to discover a new paradigm that can serve as the basis for future economic growth.

Archibugi suggests that the current ICT techno-economic paradigm may have run its course, with another paradigm (such as bio-technology) emerging in the wings to carry on the process of economic growth as we have experienced it in the last seventy years (the Post World War II era) or the various periods that can be associated with the industrial revolution (ranging from two centuries in the case of England to decades for rapidly emerging economies such as South Korea). Against these time scales, it is premature to conclude that the ICT paradigm has run its course and particularly hazardous to do so in the aftermath of the most profound economic crisis in the industrialised countries since the Great Depression of the 1930s. The next steps in the ICT paradigm involve the extension of robotics, ICT assisted restructuring of the cycles of production, use and re-use rather than the discarding of artefacts, the advent of the new approaches to artificial intelligence, and the continued development of the computational and communication infrastructure. These are all opportunities for a resurgence of growth in output and productivity in the current paradigm. This ‘business as usual’ perspective, however, misses the point that we have reached a time when a more fundamental rethinking of the nature of mass production and consumption is required. This is essential in order to avoid the catastrophic outcomes that, without mitigation, the current system will bring in the course of its further extension to a larger share of the world’s population (Schot, 2016). This ‘rethinking’ called by various names – transition, transformation or renovation – involves innovations in new areas of technology (materials, energy generation, and biotechnology) as well as ‘retrofitting’ of current technological systems in a similar way, but at larger scale, than was accomplished as the result of the petroleum crises of the 1970s. Drawing back from the brink of environmental catastrophe will require major investment and through that investment, the creation of jobs and growth on a similar scale to the onset of a new techno-economic paradigm. In effect, what is needed is the sort of mobilisation previously undertaken in preparation for war. To engage in this scale of mobilisation without substituting command and control processes for markets and entrepreneurial initiative is the challenge facing the next generation of citizens and policymakers.

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The social imagination needed for an innovation-led recovery

Daniele Archibugi

i) On the origin and persistence of the crisis

I am grateful to Lundvall (2016) and Steinmueller (2016) for commenting on *Blade Runner Economics*. Their remarks contain many fruitful insights and, even though we belong to the same neo-Schumpeterian school of thought, there are important disagreements. The first relates to the origin of the 2008 crisis and the reasons for its persistence.

Lundvall and Steinmueller rightly recall that the origin of the 2008 crisis was primarily due to unscrupulous behaviour in the financial sector rather than problems associated with the real economy. When interviewed by the House Committee on Oversight and Government Reform, former Federal Reserve Chairman, Alan Greenspan, was forced to admit he had been far too optimistic about the self-regulatory capabilities of financial markets.[5] Greenspan's admission validates those heterodox thinkers, including Lundvall, who already in the 1990s were warning of the impending instability of the economic expansion but who unfortunately were not taken seriously by policy-makers.

When in November 2008 Queen Elisabeth II visited one of the great temples of economic wisdom, the London School of Economics, she asked with regard to the crisis: "Why did nobody notice it?", expressing the puzzlement felt by many.[6] In a *Harvard Business Review* article I first read in 1999, the author claimed: "Many policy makers at the Fed contend that the new economy is a fragile bubble - and that with the 'irrational exuberance' of the capital markets, the sky is going to fall on the U.S. economy. That couldn't be further from the truth. As long as the government doesn't interfere the economy is sturdy, resilient, and raring to grow" (Sahlman, 1999). Such prophets of turbo-charged capitalism clearly over-estimated the stability of the system and overlooked the dangers ahead. Others were more cautious and far-sighted. As our mentor, Christopher Freeman, stated in 2001: "No one can predict the future course of events with certainty. Neither the evidence about long-term productivity changes…., nor the scale of corporate and household debt, nor calculations of the possible future rate of returns on ICT investments, can conclusively show that there will be a hard landing for the US economy. Nevertheless, taken together, they should give cause for serious reflection". Freeman (2001) concluded its article with a warning: "Fasten your seatbelts". The collapse of the dot.com bubble did not, unfortunately, lead to greater caution in subsequent years.

We have learnt from the history of economic crises that finance often offers both the match that lights the fire and the wind that spreads the flames (Kindleberger, 1978). But when the world economy goes into such a serious recession as we have experienced since 2008, it is difficult to believe that a combination of financial mismanagement and poor policies can explain everything: there must surely be a large amount of inflammable material ready to catch fire and a lack of water to extinguish it. In spite of energetic public intervention to boost confidence and prevent the collapse of banks and companies, the economic recovery continues to be weak in much of the Western world. The United States is doing better than Europe and Japan, and some emerging countries have been doing well, but the ghost of the 2008 economic crisis is still affecting the real economy. In particular, the rate of

[5] Edmund L. Andrews, 'Greenspan concedes error on regulation', *New York Times*, 23 October 2008.
[6] Andrew Pierce, 'The Queen asks why no one saw the credit crunch coming', *Daily Telegraph*, 5 Nov 2008.

investment continues to be disappointing in spite of the fact that interest rates are very low (for a European analysis, see Revoltella et al., 2016).

I am arguing that, even if finance is the single most important culprit with regard to its origin, this does not explain why the crisis has been so wide, so deep and so long. The basic reason why there has not yet been a satisfactory recovery is lack of confidence, which in turn leads to very low investment. Interest rates are at their lowest level historically, showing that the traditional tools of macro-economic policy have already been deployed but with limited effect. The lack of recovery, even more than the origin of the crisis, is associated with the fact that new economic, social and technological opportunities are not perceived by entrepreneurs and investors. The gales of destruction may have being blowing for several years but the creativity they should have liberated has not materialised.

If new technological opportunities had been properly exploited and brought to market, they could have contributed to boosting investment, creating new companies and new jobs, and mitigating the adverse consequences of the financial crisis. And, as has often happened previously, they could have also made up for misguided speculation, poor regulation and flawed government interventions.

ii) Where are the new opportunities?

After a major storm, it is unlikely that investors will risk their money unless they see genuine opportunities. Some believe that the lack of investment is associated with an exhaustion of scientific and technological opportunities (Gordon, 2016), certainly not the first time this has been predicted. I disagree. I see this as a re-occurrence of the technological anxiety that has been disproved by history on numerous occasions (Mokyr et al., 2015). As the long-wave literature has indicated, a new economic phase should be based on a combination of new opportunities as well as the exploitation of existing knowledge. Biotech is the obvious candidate to become the leading sector of the next economic phase, and *Blade Runner* provides a powerful visual forecast. But there is still a missing link between new technologies and innovations which needs to be further investigated by science policy scholars.

iii) Who is leading the dance?

I agree with Lundvall and Steinmueller that new technologies by themselves will not affect a change to society unless there is the infrastructure that allows for it. Any major general purpose infrastructure built during the history of capitalism needed the combined contribution of the public and business sectors, as the examples of electrification, air travel and internet navigation have shown. 150 years ago, Marx identified the relationship between the economic base and the cultural and political superstructure as a key component of capitalist development (Marx, 1859/1977). Similarly, Perez (2003) stressed that economic crises are likely to be associated with a mismatch between the technological infrastructure and the socio-economic fabric, while periods of expansion are generally related to better coordination between the two. The long-wave tradition has further explored these insights, trying to create a periodization and associating with each phase specific dominant technologies, production modes, and social and political institutions (Tylecote, 1992; Freeman and Louca, 2001).

Lundvall argues that the failure to achieve full recovery is mostly due to a lack of appropriate political conditions and that “politics and new forms of governance will matter more than the economy and technology for the eventual upswing and sustained economic growth”. He suggests that political reform will lead the dance and that, in its absence, a new techno-economic regime is unlikely to emerge. I am not convinced. There is often a process of co-evolution between technological potential and politics that is difficult to predict. Marx was astute in terming the relationship between the base

and super-structure 'dialectical', and perhaps we should continue to follow his lead: in most cases, we only manage to establish who has actually led the dance once the music is over.

Certainly technological opportunities need to be shaped to the social context and this is often associated with deliberate policy choices. In several cases such as with automobiles, the decision to develop adequate public infrastructure to allow cars to travel followed what the business sector had created: powerful lobbies of industrialists and motorists managed to obtain from governments what they needed. Indeed, the automobile technological paradigm proved so strong that neither the Soviet Union nor China managed to stop it.

However, I accept Lundvall's and Steinmueller's reproach for having somewhat overlooked the role of government in shaping opportunities. If we succeeded in landing on the moon but not in sorting out the problem of urban ghettos (to echo Richard Nelson's (1977; 2011) metaphor), it is because political attention, knowledge and funding were directed towards one objective rather than another. My colleagues are therefore right to stress that public policies should explore which scientific and technological areas could be developed and how they may change our lives, as should scholars and policy-advisors in the area of research and innovation policy. Public institutions should be able to outline the desired outcome and to combine technological opportunities with social needs.

We need to revert to major involvement of the public sector in steering, selecting and assessing scientific and technological opportunities. Mazzucato (2013) has clearly shown the relevance of the public sector in shaping technological opportunities. In many cases, the public sector has opened up new areas that the business sector has been happy to exploit. The danger of a retreat of the public sector from knowledge creation is that scientific and technological opportunities will not be available as and when we need them (Archibugi and Filippetti, 2016).

iv) The changing geography of innovation

Often, a change in techno-economic paradigm is also associated with a change in economic and political leadership. Lundvall rightly points out that new emerging regions are gaining ground, eroding the privileged position of the triad of North America, Europe and Japan. As the founder and motivating force of Globelics, a highly successful network of academics and policy advisers, Lundvall is certainly ideally placed to observe how fast the world is changing and how certain regions are catching up (see Lundvall et al., 2009; see also Archibugi and Filippetti, 2015). Those predicting secular stagnation tend to focus on an American or Western perspective, not on emerging nations (Gordon, 2016). Yet given that China and India achieved average annual growth rates of 8.6% and 7.0% respectively in the post-crisis period 2008-2015, they can hardly be considered as stagnant.[7]

Nevertheless, one doubts whether a major new techno-economic paradigm will emerge from outside the triad. Emerging countries like China and India are certainly increasing their R&D spending, and already by 2014 Chinese R&D intensity had overtaken Europe and within a decade it may be higher than in the US (Battelle, 2016, p. 13). However, from data on the impact of scientific articles and on patents, it would seem that emerging countries are still catching-up with the triad (see Iammarino and McCann, 2013; Zhou and Li, 2015). Outside the scientific and technological domain, one has yet to see the emergence of significant social and political innovations that might offer an alternative path to the triad.

The next techno-economic paradigm will also need a new socio-political infrastructure. We are far from being satisfied with what, thus far, has been delivered under capitalist democracy. Indeed, in the

[7] Data drawn from the World Bank's World Development Indicators database (3 August 2016).

search for a new model it will be vital to integrate other regions of the world, allowing them to become not just rule-takers but also rule-makers.[8] Many of us are eager to learn from new experiences in the political and organizational domains, but up to now, most emerging countries have apparently been merely adapting to what is offered in the triad. In the political domain, an alternative to Western democracy is yet to emerge, with the BRIC countries struggling to introduce (as in the case of China) or consolidate (as in Brazil, India and Russia) such a model. A new techno-economic paradigm as well as a new form of social organization is more likely to emerge in the West than in the rest of the world.

v) Social imagination and technological innovation.

For several decades, the Schumpeterian school focused on *technological* innovations, particularly those in *manufacturing*. Only rather slowly has our attention (and our data) been directed towards the service economy (Gallouj and Savona, 2009) and non-technological innovations (Smith, 2005; Filippetti, 2010). Technological innovations in manufacturing have often been the driver for larger social transformations, but the time is ripe to consider the wider context of innovation. Significantly, the Community Innovation Survey, the largest quantitative exercise to assess innovation, has dropped the qualification of "technological" and is now devoted to exploring "innovation" in all its forms, and has included the service sector on a par with manufacturing. It is equally becoming crucial to understand how innovations in technology are associated to organizational changes (Evangelista and Vezzani, 2010).

But it is time to go further. If we really wish to understand how changes affect society, and what are the main obstacles to their introduction, we also need to identify how the government and the non-profit sectors contribute to innovation and how social transformation is linked to technological and economic factors. A new stream of research is today devoted to "social" innovations, showing that many have been facilitated by the availability of new technologies (Moulaert et al., 2013). Take the case of what has been labelled the "sharing economy": exchanging homes, automobiles and personal services is largely possible because the Internet allows it to be done cheaply and quickly. This has generated new clusters of opportunities that both profit and non-profit organizations are exploiting. All this has often occurred in the absence of political interest and economic regulation.

The search for a new techno-economic paradigm is not a task for scientists, engineers and businessmen alone. New ideas often originate in other social contexts. Steinmueller, a true connoisseur of science fiction, rightly reminds us that most contemporary science fiction is dystopian rather than utopian: artistic imagination is more likely to be captured by the dangers associated with human progress rather than the opportunities it opens up. Italian teachers know very well that their students are fascinated by Dante's *Inferno* rather than by *Paradiso*, suggesting humans have an intrinsic predisposition towards pessimism. Despite the steady increase in life expectancy, the more extensive concerns about climate change suggest that film-makers and writers may be more in tune with the human psyche than politicians and businessmen. Perhaps it is time to challenge such pessimism and deliberately to go back to the original meaning of utopia of Thomas Moore, Tommaso Campanella and Frances Bacon; an exercise in which artists and engineers, film-makers and political theorists, architects and businessmen attempt to imagine how existing scientific and technological opportunities can be exploited and incorporated in the social fabric – in short, how another world is possible.

[8] As indicated by Lundvall, I am among those who strongly support such a goal from a normative viewpoint (see Archibugi, 2008).

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