The Direction of Technological Change and Disparities: an overview of analytical frameworks and a suggested policy packages approach

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Introduction

The past decades have witnessed an increase in income inequality worldwide and particularly within and across developed countries. Rapid technological change, innovation and globalisation are often depicted as the underlying and interconnected factors that have led to rising income disparities. Although the question of how technological change interacts with inequalities is not novel in itself, it is too often said that the current context exacerbates disruptive distributional effects due to the intensity and pace of change. Silicon Valley is often cited as the prime example of this situation: about 20 to 25 percent of the population works in the high-tech sector, growing their material wealth and driving up local living expenses, while the rest of the local population works in professions where wages have been stagnant or even declining. In looking for public policies to respond to this challenge, there has been a renewed interest in the question of how, if at all, it is possible to (re-)direct technological innovation towards more inclusive and equitable outcomes. In other words, rather than merely dealing with the effects of technological innovation as it diffuses throughout the economy, could we influence its nature and the dynamics of innovation in a way that could lead to more inclusive and equitable outcomes?

Before looking for policy responses to this challenge, we need to understand how the direction of technological change is related to disparities, both theoretically and empirically. The early answer to this question first emerged in 1957 when Robert Solow famously stated that wage inequality increases when the direction in a production technology favours the skilled labour over unskilled labour by increasing its relative productivity and thus relative demand (Solow, 1957). Since the Solow model skill-biased technological change, economists have substantially expanded their understanding of how technological change can bias and direct its benefits to certain groups and how it impacts income inequality. However, the question of directionality of technological change has also been considered through other perspectives, across economics, science technology and innovation (STI) studies, and sociology of science and innovation. It has also become a much broader analytical question of whether, and even how, societies develop and choose what kind of technologies they want. And it has also become a policy question of which technologies and technological trajectories we should support with public R&D investment and how to adequately regulate the development of new technologies.

It is this varied understanding of directionality of technological change and its relationship with inequalities that needs to be explored further, with an explicit policy objective to practically understand how influencing the direction of innovation can contribute to more equitable outcomes. Understanding the relationship between the *direction* of technological change, rather than its *pace*, and distributional effects is crucially important for shifting the policy discussion from dealing with the unintended effects and ex-post regulation of technological change to *affecting* the ways in which technological innovation is developed and then diffused throughout the economy. This more specific lens on technological change

builds on the work by Susan Cozzens (2015), which outlined some of the primary strands of thinking about the relationship between technology, innovation and disparities and suggested some policies at the global and international level to reduce innovation-related inequality.

In this short paper, we will focus on addressing the question of how the *direction* of technological change is related to income inequality, and what governmental policy can do to influence the directionality of technological change towards more inclusive and equitable outcomes. This is undoubtedly a complex question, and this paper primarily aims to provide an overview of different perspectives across disciplines that have considered this question, and then trigger questions that could inform the design of policy interventions, and innovation policy instruments in particular, which aim to influence the direction of technological innovation towards more inclusive outcomes. Bringing varied perspectives across disciplines together is often challenging and their linkages are not evident at first sight, but the decision is deliberate: it is to see how the question of directionality of technology and disparities has been considered through multiple lenses, and then see if they can collectively provide us with insights about whether it is feasible, and even legitimate, for public policy to redirect technological innovation towards a more inclusive future. These insights will hopefully stimulate the discussion at the workshop and form a background to the full chapter.

How does the direction of technological change relate to disparities? A review of analytical perspectives

In this section we review how different perspectives see the relationship between technological change and disparities. Drawing on perspectives across economics, STI studies, and sociology of science and innovation, our objective is to see how they see this relationship and assess whether their insights could be integrated in the way that would inform the policy design. Due to the diversity of perspectives, we clustered them in three broad categories, according to whether they see the direction of technological innovation as being mediated by (1) macro-level institutions, policies and dynamics; (2) meso-level socio-technological regimes and trajectories; or, (3) micro-level processes and dynamics of innovation development and diffusion. This section does not aim to provide a comprehensive overview of arguments and tends to lean towards more recent arguments.

Macro-level perspectives

This refers to perspectives that consider the direction of technological innovation as being mediated by macro-level economic institutions, policies or processes, and mainly include economic perspectives. In a traditional economic sense, technological change has been associated with 'bias' and direction when it produced specifically directed, 'biased' outcomes. The first model of non-neutral direction of technological change was proposed with 'skill-biased technological change' (Solow, 1957; Rosenberg, 1969) that describes the shifts in a production technology towards favouring the skilled workers over the unskilled ones, increasing their productivity and increasing the relative demand, which in turn leads to rising wage disparities.

The bias of technological change was further developed by Acemoglu (2002a; 2002b), who claimed, in the vein of the endogenous growth literature, that not only the speed—as traditionally argued—but also the direction of technical change is endogenous. Profit incentives of innovators determine the amount of R&D activity directed towards different factors of production (Acemoglu, 2002a). The main determinants of profit incentives are market size, relative prices and institutions. According to Acemoglu's model of 'directed technological change', economic policies and regulation can influence the relative profitability of developing different technologies by impacting their prices or market size. For example, in his analysis of green technologies based on the model of directed technological change, Acemoglu et al (2012) studied the response of different types of technologies to environmental technologies and found that optimal environmental regulation through both carbon taxes and R&D subsidies could help redirect technological change towards green technologies. This showed that, as policy intervenes by subsidising clean technology research, this starts making clean technologies better over time and thus competitive with conventional technologies. Private incentives directed everybody to invest in R&D for conventional technologies. In this way, temporary interventions can serve as sufficient to redirect technological change towards clean technologies.

As the economic literature introduced the bias in direction of technological change, it is generally accepted that in most situations the direction of technological change is not neutral: it benefits some factors of production more than others and some people more than others, and that distributional effects mean that some groups of people embrace some technologies and others oppose them. As showed by Acemoglu and many others, the government can play an important role in correcting for the 'bias' in the direction of technological change towards producing more inclusive outcomes.

The proposal for governments to deliberately redirect technological innovation towards certain outcomes so as to mitigate distributional effects was also recently put forward by the prominent inequality scholar Anthony Atkinson (2015). Given that the direction of technological change is not entirely exogenous, Atkinson argued that it is subject to policy control to at least some extent and that "the direction of technological change should be an explicit concern of policy-makers, encouraging innovation in a form that increases the employability of workers and emphasises the human dimension of service provision". Cozzens (2015) makes the point that part of any analysis of the impact of technology on inequality is to take into account sectoral differences. In the case of some information and communication technologies (ICT), for example, government intervention may only be necessary in relation to infrastructure. The impact of technology may be 'pro-poor' without specific and targeted policy initiatives.

The question of directionality has also been considered by Simon Kuznets (1955) who put forward a hypothesis of the 'Kuznets curve': as an economy develops, market forces first increase and then decrease economic inequality. The relationship between growth and inequality has received renewed attention in recent years. Some theorists (Aghion et al., 1999) argued that a similar type of non-linear dynamic also applies to rich countries as a consequence of the skill-biased technical change that has affected these economies over the last two decades. Countries that are initially less equipped with skilled labour can fail to break out from the poverty traps.

In a recent argument, Milanovic (2016) suggested that inequalities are also the outcomes of the 'Kuznets waves', or recurring economic patterns resulting in income inequalities. Since the 1980s new technologies have led to economic growth and a remarkable convergence between countries but increased inequalities within countries. While Milanovic notes rare experiments in "political voluntarism" whereby institutions and policies play in a role in preventing the emergence of disparities, his view is that this is unlikely to be a major and effective feature at scale. In his view, the major emphasis should be on designing a framework, fit for a now globalised world that can ameliorate the inherent tendencies of technology to generate inequality. On this view, the direction of technological change is almost inherently negative, producing inequalities due to recurring patterns in the economy.

In a similar line of argumentation, Perez (2009), merging an economic and sociological explanation, showed that historically, 'technological revolutions' pass through predictable phases and that understanding those phases is crucial to the understanding of both business cycles and uneven economic outcomes. New technological paradigms lead to quantum jumps in potential productivity and open the way for a great potential to increase economic wealth. The result is the presence of the long term fluctuations, or 'long waves', that result of successive couplings and decouplings of the techno-economic sphere of the system, as well as the socio-institutional sphere (ibid.). The good coupling of these two spheres tends to be followed a long period of two or three decades of stable growth, perceived as times of prosperity. In this way, Perez says that the instability of the present and the resulting inequalities have a techno-economic origin, but a socio-institutional solution. On the accounts by both Milanovic and Perez, technological change is viewed as having an almost intrinsic direction arising from the cycles underlying the trajectory of technological change. In their view, inequalities can therefore be viewed as inevitable outcomes of technological change, but the direction can however be mediated by policies and institutional frameworks that address the negative direction of innovation.

The highlighted macro-perspectives show that the direction of technological change has been thought of as having the bias towards producing negative outcomes and inequalities. However, there is a difference between whether this bias is seen as an intrinsic tendency of technological change or not. Despite the differences in their diagnosis and different starting points of analysis, macro-level perspectives tend to agree that to improve the trend towards greater equity, the direction of technological change should be a concern to policymakers and that any improvement in this direction is a result of conscious economic policies and institutional change. Whether or not patterns associated with inequities are ultimately the result of inevitable trajectories or the result of particular constellations of technological, economic and institutional structures that drive particular patterns, the end point of much of this analysis points in the direction of needing to think about how policy can influence the direction of technological change in practice and in relation to institutional and power arrangements that make the decision about whether the particular direction of technology is favourable or not.

Meso-level perspectives

A number of meso-level theories are related to work by Perez, an economist, but come from a different tradition of scholarship and draw more on sociological perspectives. These perspectives consider how socio-technical regimes and transitions lead to certain societal outcomes, exploring ways in which configurations of technologies, infrastructures, social practices, institutions and markets can change to fulfil their functions in a more sustainable way. These perspectives consider the question of directionality of technological change as a matter of the nature of *transition* from one socio-technical regime to another (Smith et al, 2005). While this literature has predominantly sustainability transitions, their analysis can be applied to transitions to inclusive growth where innovation contributes to more equitable outcomes rather than exacerbating inequalities.

Two important streams of literature relate to multi-level perspective (MLP) and strategic niche management (SNM) research. An MLP (Smith et al, 2005; Geels and Schot, 2007) has been developed to describe and analyse long-term transition processes and understand how policy initiatives can support transitions, one such transition being to a model of inclusive economic growth. In this perspective, transitions are "outcomes of alignments between innovations and innovation environments which can change rapidly, regimes which embody more stable networks of organisations and institutions, such as sets of regulations and funding bodies, and broader landscapes which change slowly (natural environment or overall industrial structures)" (Geels and Schot, 2007). Power relations are embedded in networks of institutions and organisations which limit consideration of the range of technological and institutional options available. Agency and the voice given to various actors in the process of transition are of central concern but these factors need to be seen in the context of a web of institutional networks that limit effectiveness of less powerful actors who are excluded or partially excluded from socio-technical regimes. The SNM perspective (Schot and Geels, 2008) suggests that sustainable innovation journeys can be facilitated by creating technological niches, i.e. protected spaces that allow the experimentation with the co-evolution of technology, user practices, and regulatory structures.

An important aspect of socio-technical regimes and their transitions is the 'guiding visions' that lay out expectations around technologies and innovations (Berkhout, 2004). This may be particularly important in relation to the relationship between technology and disparities. A somewhat simplified reading is that if technology and innovation are envisioned as agents that will provoke further disparity, pressures for those who are innovating to create innovations and dynamics that reduce inequality is lifted. This limits expectations of private and public actors in the system. Rather, what may be possible is a more nuanced and elaborate understanding and articulation of the different types of rules governing regimes that produce particular patterns of innovation and thereby an appreciation of what can be done to change institutional structures and incentives so that the patterns produce more equitable or socially desirable outcomes (Geels and Schot, 2007).

Meso-level perspectives broadly agree that policy has a key role to play in transforming socio-technical systems into more sustainable configurations. They help to formulate how alternative socio-technological configurations can fulfil social needs in ways that could bring about more equitable

outcomes. As Schot and Steinmuller (2015) claim, “experimenting with new socio-technical configurations is a key tool for promoting transformative change towards sustainability”. The meso-level perspectives are designed to help with policy analysis, and innovation policies in particular, and allow ex-ante assessment of their likely impact against the background of theorising about how large scale, socio-technical change happens. Analytically, they could also help to understand how policy influences specific processes at niche and regime level which are commonly claimed to be key for enabling transitions, such as transition towards more inclusive growth. They also put an emphasis on creating political spaces within which different policy options can be explored.

Micro-level perspectives

At the micro level, we can look at the micro-processes and dynamics of innovation and technological development and diffusion, i.e. micro-processes that influence the direction of innovation. They might affect the nature of innovation and technologies produced. Influencing the directionality of innovation as such rather than the changes it causes can be seen problematic, as innovation is generally seen as a non-linear and unpredictable process and it is therefore difficult to anticipate its unintended effects until the risks and consequences can be assessed. However, as Stirling (2008) claims, although innovation is not a process of following a single, pre-determined linear path, it nevertheless has an element of directionality: “Innovation is a vector, rather than just a scalar quantity” (ibid.). Stirling claims that, under different policies, innovation can take different directions, assume different forms, involve different processes, or bring in different actors and bodies of knowledge.

In recent years, there has been a growing body of literature studying the processes of innovation development and understanding how the nature of new innovations is influencing their effects. This includes various attempts to present alternative visions of how innovation processes can help achieve more inclusive and equitable outcomes. This includes the notion of ‘inclusive innovation’ which directly aims to cater for the needs of low-income populations are for various reasons becoming mainstream (Kaplinsky 2014). For Kaplinsky, inclusive innovation signifies a new kind of innovation development, and indeed a Schumpetarian dynamic, with low-income consumers taking centre stage as the driver of product and service innovation. Policy can be directed at supporting bottom up inclusive innovation initiatives but also working to institutionalise them into various ways with the hope that broader institutional and organisational networks referred to in the previous section (Chataway et al, 2014) begin to reorient themselves around this new innovation trajectory. Similarly, a changing innovation terrain with low-income consumers playing a more prominent role has been documented by Radju and Prabhu (2015) in work on ‘jugaad’ and ‘frugal innovation’. These alternative notions offer insights into more inclusive models of innovation and technological development, and how changing the nature of technological development can lead to more equitable outcomes has also attracted policy interest.

How to (re-)direct technological change towards more equitable outcomes?

There has been a renewed interest in the question of directionality in recent years. Yet, as we showed, there is a range of perspectives that have considered the question of directionality of technological

change and its relationship with inequality. These perspectives are often underpinned by different assumptions and produce different conclusions, but they broadly agree that the direction of technological change, not only its pace, can be influenced by policy intervention.

Micro perspectives offer us insights on how the nature and processes of innovation development and diffusion are influencing and shaping the direction in which innovation and technologies are evolving and what kind of outcomes they might produce. Meso-level perspectives shed some light on how different configurations of institutions and relations influence the creation of a socio-technological regime that determines the directionality of innovation. And, finally, macro-level perspectives, mainly drawn from economic literature, help to explain how technological change might not be factor-neutral and have the bias towards producing certain outcomes, for example in terms of income distribution, as a result of the economic, institutional and policy conditions in which those technologies evolve.

The question is whether, and if so how, the insights from different perspectives can be integrated to offer a more holistic understanding of how the direction of technological change is related to income inequalities. These perspectives help us think about the range of considerations that may need to be incorporated into change strategies – vital elements in creating policy packages that might bridge redistribution based interventions (taxation, education, or migration policy) and innovation policies focused on ushering in changes in directionality to foster science, technology and innovation activities that are more inclusive (targeted R&D funding for particular technologies, creation of new networks, direct involvement of low-income innovators in policy initiatives, regulation, procurement and incentives). The next step is naturally to understand how these insights can inform the design of governmental policy that could best support research and innovation activities in ways that maximise the economic benefits of technological change while mitigating the distributional effects of technology. In looking for appropriate policy responses, there is first a need to address several important questions that would help us gain a more rounded understanding between the direction of technological change and inequalities.

1. How is the direction of technological change related to inclusiveness and distributional outcomes? (e.g. What determinates the direction of technological change? Does technological change inevitably lead to income disparities? How does this understanding determine policy choices?)
2. How do we measure the direction of technological change? (e.g. When is the direction neutral, when is it positive and when is it negative?)
3. How can the direction of technological change be managed to promote more equitable outcomes? (e.g. What levers are available to affect the direction of technological change towards better distributional outcomes?)
4. To what extent is managing this process feasible and/or desirable? (e.g. To what extent is it feasible, and even legitimate, for public policy to ‘reverse’ the direction of a technology? What are alternative governance mechanisms required to manage this process?)

5. What is the appropriate 'policy mix' to manage this process? What supply- and demand-side measures could affect the direction of technology? What is the balance between horizontal policies, such as labour, migration or industrial policies, and sectoral policies and regulation?

These questions are undoubtedly complex, and our objective in this short paper was to shed some light on the first question. The questions aim to trigger and frame a different kind of conversation not only about how the outcomes of innovation and technologies can be managed, but also how the direction of innovation itself can be managed to help more inclusive outcomes. They form a basis for the discussion at the policy workshop and will be explored more fully in the full chapter.

This paper has brought together diverse perspectives on the first question in an attempt to trigger the discussion on the subject and show the diversity of views on how the direction of technological change is related to income disparities. We need more research to understand what is happening and why some technologies lead to inequalities more than others. But we also need a model of innovation policy that is designed to be inclusive. That is the challenge for our full chapter in which we will explore the scope for what the direction of innovation implies for innovation policy. We will look at what innovation policy instruments are feasible and legitimate to support technologies and innovations which do not foster inequality, in both conceptual and practical terms.

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