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Innovation and social welfare: A new research agenda

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Abstract

Innovation research is motivated by the understanding that innovation contributes to address societal challenges and foster welfare. Extant research in this field has however adopted a rather narrow definition of social welfare, which focuses on economic performance and material well-being, and that mostly disregards distributional impacts of innovation. This paper outlines a new research agenda that will investigate the impacts of innovation on individuals' well-being and aggregate social welfare. The new research program has two major pillars. First, it adopts a broader notion of agents' well-being that comprises also non-economic factors and capabilities alongside income and material wealth. Second, it argues that welfare analyses of innovation must explicitly take into account equity and social justice in addition to efficiency and economic performance. This new research agenda opens up several novel questions for future innovation research and policy-making, pointing to the existence of trade-offs and dilemmas between efficiency and equity, and between short- and long-run impacts of innovation on social welfare.

Keywords: Innovation; well-being; social welfare; welfare economics; social justice; innovation policy

1. Introduction

Innovation fosters social welfare. Technological and organizational changes create new terrific opportunities to address societal changes and so improve human life. This is the fundamental motivation that has traditionally spurred the development of innovation research and policy-making during the last 50 years or so (Martin, 2016). The proposition that innovation fosters social welfare, though, is implicitly based on two important assumptions that have so far dominated both scholarly research and policy-making in the field of innovation.

The first assumption is that new technologies affect individuals' well-being by increasing their income and consumption possibilities. Hence, the field has so far implicitly adopted a notion of individual well-being that focuses narrowly on economic determinants and material wealth, and that typically disregards non-economic dimensions. However, this assumption is problematic: it is reasonable to think that innovations have a broad variety of impacts on individuals' quality of life, that comprise multiple economic, social and psychological factors and capabilities (Castellacci and Tveito, 2018). An important challenge for future research is thus to adopt a broader notion of well-being that will enable to investigate together economic and non-economic impacts of innovation within the same framework.

The second assumption refers to the notion of aggregate social welfare. Schumpeterian research has so far typically focused on the positive impacts of new technologies on economic performance (GDP per capita, productivity, competitiveness, employment). The focus on efficiency effects is implicitly rooted in a simple utilitarian notion of social welfare, which focuses on the overall net benefits that innovations may lead to for the whole population, but it disregards the study of distributional impacts and the equity dimension. This approach is questionable, because we know that the process of creative destruction does affect the relative position of winners and losers, and that these differences tend often to increase and persist over time, sometimes leading to growing inequalities, polarization and social exclusion (Witt, 1996). Thus, it is paramount that future innovation research will question the use of a standard simple utilitarian notion of social welfare, and develop a broader framework that will enable to combine efficiency and equity dimensions.

Taken together, these twin research challenges call for the development of a new research agenda to study innovation and social welfare. The present paper intends to outline the main objectives and pillars of this research program, the new research directions that it calls for, the conceptual issues that it will face, and its implications for the foundations and objectives of innovation policy. The new agenda will consist of two major pillars. First, it will adopt a

broader and more inclusive notion of individual well-being, and so develop a conceptual framework that will seek to study together economic and non-economic effects of innovation (Alkire, 2016). Second, it will adopt a broader notion of social welfare that will give explicit consideration to the important distributional impacts of innovation, and hence study the relationships and possible trade-offs between its impacts on efficiency and equity (Weymark, 2016).

This new research program calls for a cross-fertilization of innovation research with two important neighboring fields that have so far been largely neglected in Schumpeterian research: well-being studies, on the one hand, and welfare economics, on the other (Adler and Fleurbaey, 2016). Drawing insights from these well-established fields, innovation research will develop a more thorough understanding of what types of innovation contribute to individual well-being and social welfare, those that do not contribute, the time horizon and trade-offs related to these impacts, and thus build up a more solid foundation for R&D and innovation policy.

It is worthwhile to note some recent contributions that are largely in line with the motivation that spurs the present work. Specifically, some conceptual discussions on evolutionary welfare economics and inclusive science and innovation formulate concerns about extant research that are to some extent similar to the two challenges noted above, pointing out the importance of discussing social justice and inclusive outcomes of innovation processes (Cozzens, 2007; Bozeman et al., 2011; Schubert, 2013; Les and Papaioannou, 2018; Papaioannou, 2021). However, these papers suggest new research directions that are sharply different from those that will be presented in this paper, since they openly reject theories and analytical tools developed in the field of mainstream welfare economics, and call instead for a new communitarian approach, which is in our view appealing but hard to conceptualize in future research, and also difficult to implement by policy given the current market and institutional context. By contrast, the new framework that we will develop in this paper calls for a bridge between well-being studies and welfare economics, on the one hand, and Schumpeterian innovation research, on the other.

The paper is organized as follows. Section 2 will spell out the two research challenges noted above and explain their relevance. Section 3 will briefly review the main strands of research on innovation and social welfare, and illustrate why and how they meet these two challenges. Section 4 will present the new research agenda, and the main questions and issues that this future research will have to address. Section 5 will discuss the implications that this new research program will have for innovation policy, calling for the development of a brand-new innovation policy paradigm. Section 6 will summarize the main points and contributions.

2. Innovation and social welfare: the twin research challenges

2.1 Challenge 1: Bias on economic effects of innovation

The field of Schumpeterian economics is implicitly based on one major assumption: innovation fosters social welfare by increasing economic opportunities and sustaining individuals' material wealth. The introduction of new products, processes, services, raw materials and organizational innovations increases firms' profitability and productivity, and it fosters employment creation and economic growth. Economic agents thus benefit from innovation first and foremost because increased dynamism of the supply-side leads to higher wealth and consumption patterns, which in turn make it possible to satisfy individual preferences and so achieve higher utility levels.

This assumption originates from a mainstream economics framework in which agents' well-being is obtained by means of preference satisfaction, and in which material wealth and consumption are the key arguments of individuals' utility function. In Schumpeterian economics, this approach is reflected in theoretical models in which innovation and spillover effects drive social welfare through economic growth (Arrow, 1962; Jones & William, 1998), and empirical studies that estimate the welfare effects of innovation by focusing on profitability effects on the supply-side (Trajtenberg, 1990), and benefits for the consumers of innovations on the demand side (Trajtenberg, 1989; Petrin, 2002).

This standard assumption does however present two important issues. The first relates to the relationships between economic wealth and individual well-being. The large and influential literature on subjective well-being and happiness has in recent years convincingly shown that higher income and consumption possibilities do not necessarily translate into greater well-being. Relative income levels and social comparisons may be more important for well-being than the absolute level of wage and income (Clark and Senik, 2010). This literature has also shown that a more dynamic economic performance does not necessarily increase well-being at the same pace, since individuals' preference satisfaction may also be hampered by rising expectations and adaptation effects (Schwandt, 2016; Castellacci & Schwabe, 2020). Hence, although innovation has important economic impacts, the extent to which these will affect human well-being is largely unknown.

The second issue is that, besides economic effects through income and consumption patterns, agents' well-being is also shaped by a variety of other dimensions, which are by definition

non-economic, and which cannot be measured by means of monetary metrics only (Bozeman & Sarewitz, 2011; Bozeman, 2020). Specifically, the domain of life framework points out that individuals' well-being is multifaceted and that it is closely related to a variety of dimensions in different domains of life, such as working life conditions (beyond wage), leisure activities and social life, personal and family conditions, health and education, and quality of the physical and institutional environment (MacKerron, 2012). It is reasonable to think that technological innovations may have a multiplicity of effects on these dimensions, and thus a complex variety of impacts on agents' well-being. For instance, it is well-known that the introduction and diffusion of information and communication technologies do not simply lead to profitability and productivity benefits for companies, but do also affect workers' routines, work practices, and individuals' social and personal life (Castellacci and Tveito, 2018).

Non-economic impacts of innovation are widely documented and investigated in a variety of different fields within the social sciences. It is however a major problem that the field of innovation studies *per se* has so far predominantly focused on economic impacts of innovation and almost entirely neglected non-economic effects, arguably due to the fact that these are hard to conceptualize and measure within a mainstream economics framework. Extant research in this field does not provide theoretical and empirical knowledge that enables to study and assess economic and non-economic effects of innovation within the same framework. Such an integrated framework, combining economic and non-monetary dimensions, is paramount, because it would help to identify those technological trajectories that contribute to well-being and social welfare in broader terms, and that should be promoted and supported by public policies.

2.2 Challenge 2: Bias on efficiency effects of innovation

The second major assumption that implicitly provides the foundation for the field of Schumpeterian economics and innovation studies is that innovation is typically thought to have positive overall effects on social welfare. Although the seminal Schumpeterian metaphor of "creative destruction" pointed out both creation and destruction effects, most research in the Schumpeterian tradition has traditionally focused on the positive effects that technological innovation has in the long-run (on e.g. productivity, economic growth, international competitiveness, employment), and often neglected the study of the corresponding negative

(destruction) effects, assuming that these will be offset and progressively reabsorbed by the economic system over time (Witt, 1996; Schubert, 2009; 2013).¹

The negative impacts of innovation – what very recent research calls the “dark sides of innovation” (Biggi & Giuliani, 2020) – can entail for instance obsolescence of industries, firms’ bankruptcy, technological unemployment, skill polarization, income inequalities and environmental degradation. As we will show in the next section, most theoretical and empirical research in this field has largely neglected the possible negative impacts of innovation. Some strands of modelling research, though, have studied both positive and negative effects within the same framework (e.g. models of skilled polarization, automation and artificial intelligence). However, these approaches typically assess the overall net effects of innovation on welfare using a simple utilitarian approach, which focuses on the overall efficiency effects on social welfare but it disregards distributive considerations.

The problem with this is that bright and dark sides of innovation often come together. The same innovation will typically have positive impacts for some individuals and social groups, and negative impacts for others. The destruction effects may sometimes be hard and persistent, leading to a cumulative process that generates increasing disparities between winners and losers over time, even if total GDP of the economy (the size of the cake) is increasing.

In welfare economics, the trade-off between efficiency and equity objectives of economic policy is a central topic that has a long tradition (Adler and Fleurbaey, 2016). Interestingly, the field of innovation studies has so far predominantly focused on the efficiency dimension (emphasizing positive net impacts of a given innovation on welfare), whereas it has mostly been silent about the equity dimension (i.e. neglecting the negative impacts that the same innovation has on other socio-economic groups). It is indeed surprising that inequality, an inherent flip-side of the innovation process, has so far largely been neglected in this field, as the next section will show.

Such positive bias and the focus on efficiency effects of innovation do not only characterize innovation research, but they are also clearly visible in R&D policy programs’ evaluations. Most policy programs that provide public support to R&D and innovation are typically evaluated by empirically investigating whether the policy scheme has had so-called “additionality effects” – a standard approach that implicitly assumes that additional R&D spending and innovation output will be beneficial for the society, regardless of their distributional consequences.

¹ For a discussion of Schumpeter’s notion of welfare and the normative aspects of his theory, see Schubert (2013).

When we seek to investigate the impacts of a given innovation on social welfare, the challenge is to build up a conceptual framework that comprises both positive and negative effects for different social groups, and that enables a comparison and assessment of different *states of the world* (or *social alternatives*). This framework should make explicit the ethical, philosophical and political value judgements that underlie innovation policy choices, pointing out clearly the reasons why public authorities would choose to support some technological trajectories that strengthen opportunities for some socio-economic groups *vis-à-vis* others.

Why are these *twin challenges*? Before proceeding, it is important to clarify the reason why the two challenges that we have noted in this section are closely related to each other, so that we could not address one without considering the other. Social welfare is an aggregate concept, referring to the welfare of an entire population; whereas well-being is a micro-level concept, referring to the individuals that are part of that population. Based on methodological individualism thinking that is common in economics and innovation studies, in order to understand aggregate social welfare we must start from the micro level of analysis, and investigate first and foremost individuals' well-being. Hence, the micro-level concept of individual well-being is the key starting point that provides the micro foundation to understand the aggregate notion of social welfare.

When we adopt this general and common way of thinking, it becomes clear why the two challenges noted in this section are closely related twin challenges. Our paper is motivated by the understanding that social welfare is a broad, multifaceted and complex notion. To study how innovation affects aggregate welfare, we need first of all to develop a broad micro-level understanding of how it impacts individuals' well-being (challenge 1). Relatedly, social justice, distributional issues and inequalities are also complex and multifaceted notions: innovations do not only affect income distribution, but they may arguably also shape the distribution of other capabilities and opportunities that individuals and social groups are subject to. Hence, it is necessary to consider a broader spectrum of dimensions in order to understand how innovation affects both efficiency and equity (challenge 2). This paper does therefore argue that a new research agenda to study innovation and social welfare must address both of these twin challenges together.

3. The literature on innovation and social welfare

This section will briefly review the main strands of theoretical and empirical research that are relevant to study the effects of innovation on social welfare. For each strand of research, we do not intend to provide a comprehensive survey, but rather a brief and selected review that focuses on the two main challenges noted in section 2. Table 1 summarizes this discussion and provides an overview and comparison of the various strands of relevant literature.

3.1 Theoretical models

Innovation and economic growth. Schumpeterian models of innovation and economic growth have been developed by two distinct approaches and strands of research: new growth theory and evolutionary economics (Castellacci, 2007). We focus on the former approach here, and we will consider the latter in section 3.2. In the seminal models in new growth theory (e.g. Romer, 1986; Lucas, 1988; Romer, 1990), representative agents' utility depends on consumption. Agents maximize an intertemporal utility function whose main argument is consumption. In these models, welfare analysis is typically carried out using the same approach as in other strands of growth modelling research. A social planner seeks to maximize the representative consumer's utility function, subject to constraints (production possibilities and available fiscal resources). The social planner's optimal level of R&D is usually higher than in the decentralized ("*laissez faire*") economy, because of the existence of spillover effects and externalities. The divergence between private and public optimal R&D investment levels denotes a failure in the knowledge market and it thus provides the foundation for public policy support (e.g. through R&D subsidies or fiscal incentives).

Social justice and distributive questions are not taken into account in this tradition. The social planner maximizes total utility (consumption), regardless of how income and consumption are distributed. The social planner implicitly adopts a *simple utilitarian social welfare function* in order to maximize social welfare. A simple utilitarian social welfare function defines social welfare of a given state of the world as the simple (unweighted) sum of agents' utility. Distributive questions cannot be considered in this framework for two reasons: (1) representative agents are by definition homogenous, hence it is not possible to point out distributional impacts for winners and losers of the innovation process; (2) negative (destruction) effects of technological change are neglected, as the models focus on positive efficiency effects related to the economic growth process.

Aghion and Howitt (1988; 1992)'s Schumpeterian models provide a step forward, since they also consider the possibility that an innovation may have a “*business stealing effect*”, because it will make previous innovations obsolete, thus destroying monopoly rents of incumbents. This is an interesting attempt to consider some of the possible negative effects of innovation on the supply-side, in line with Schumpeter's original idea of creative destruction. However, these models are still subject to the same issue noted above, since the social planner maximizes the intertemporal utility (consumption) of representative (homogenous) agents. This means that these works still implicitly rely on a simple utilitarian social welfare function that seeks to maximize total utility regardless of distributive considerations.

In recent years, agents' heterogeneity has become a new cornerstone in several strands of economic modelling research. In new growth theory, models with heterogeneous households have recently been introduced to extend seminal models of innovation and growth. Specifically, Jones and Kim (2017) and Chu & Cozzi (2018) introduce agents' heterogeneity in the Schumpeterian model of creative destruction. Jones & Kim (2017) model heterogeneous entrepreneurs who accumulate wealth and foster top-income inequalities. Innovation and creative destruction erode this wealth accumulation process by introducing new ideas and activities, thus counteracting the rise of income inequalities over time. Chu & Cozzi (2018) model an economy in which households have different levels of wealth. A strengthening of patent protection or a raise in R&D subsidies leads to a higher rate of economic growth. The real interest rate increases, leading to an increase in asset income, which in turn increases income inequality. However, R&D subsidies also affect income distribution in an opposite way, since they foster creative destruction and destroy monopoly rents of incumbents (hence, R&D subsidies have an overall ambiguous effect on the income distribution). Aghion et al. (2019) differs from the other models noted here because it assumes that innovation increases mark ups in a given sector, thus increasing income inequalities.

These recent theoretical works are relevant for our discussion because they model wealth and consumption inequality in the context of heterogeneous agents, thus potentially enabling an analysis of the effects of innovation on the income distribution. Nevertheless, these works do not explicitly carry out social welfare analysis (e.g. through the social planner' standpoint), so they do not provide an analysis of the aggregate implications of innovation in terms of efficiency, equity and social welfare.

Technology, skills and employment. A variety of models studies the relationships between technological change, workers' skills and employment. These works are relevant for our discussion for two reasons. First, working conditions (employment, wage, unemployment)

represent an important determinant of agents' well-being. Hence, if innovation changes working conditions this will have relevant welfare implications. Second, most of these models point out that the effects of technological change are often heterogeneous, affecting workers differently depending on their skills and occupation type. Specifically, when technological innovations will lead to a process of increasing polarization in the labor market, this will implicitly have consequences in terms of the wage and income distribution (and thereby social justice).

For instance, Aghion, Deaton et al. (2016) present an original model studying how innovation and creative destruction affect individuals' well-being, defined in terms of current employment and future employment prospects. The model points out that innovations will improve job prospects for the unemployed, but also increase the probability that an employed worker will lose her job in the future. Hence, the model is in line with Aghion & Howitt's Schumpeterian growth models noted above, because it considers both positive and negative effects of innovation and creative destruction.

In recent models of automation, artificial intelligence and employment, workers are assumed to have different skills, and/or to perform different tasks. Automation affects labor demand and wages differently for different groups of workers, strengthening the relative position of some groups and negatively affecting others (Schwabe and Castellacci, 2020). For our discussion, this approach is relevant because it explicitly considers agents' heterogeneity, thus taking into account both positive and negative effects of innovation.

The modelling research noted here, though, is still implicitly rooted in a simple utilitarian way of thinking, and it typically considers that social welfare is higher when the net effect of new automation technologies is positive, regardless of distributive implications and losses for the low skilled. For instance, Acemoglu and Restrepo (2018) present a model in which in the absence of labor market frictions, automation has overall net positive economic effects on GDP. In the presence of labor market frictions, though, the equilibrium level of automation reduces GDP and social welfare. The authors conclude that in a labor market with frictions, "*a utilitarian planner would choose a lower level of automation than the equilibrium*" (Acemoglu and Restrepo, 2018: 31). The quote illustrates the fact that this class of models, along others in this field, implicitly adopts a simple utilitarian notion of welfare that corresponds to the sum of agents' utilities (which are here related to their working and employment conditions).

3.2 Empirical analyses

In the economics of innovation, the standard economic approach to empirically assess the effects of innovation on welfare is to estimate the social returns to R&D, which include both direct impacts as well as indirect effects through knowledge spillovers (Arrow, 1962; Jones & William, 1998). Focusing on micro-level econometric studies, two main empirical approaches have been used to empirically analyze the welfare effects of innovation.

Demand-side effects. More than three decades ago, Trajtenberg (1989) originated a new empirical approach that focused on the estimation of welfare effects of innovation for the consumers of new technologies. Trajtenberg (1989)'s work is an extension of the so-called "characteristics approach to demand" (Lancaster, 1966 and 1977), which makes use of discrete choice econometric models to estimate the relationships between product characteristics, on the one hand, and consumers' purchases (representing their preference satisfaction and utility), on the other. Trajtenberg (1989) studies welfare effects of product innovation within medical technologies by focusing on consumers' willingness to pay for new product varieties. The study uses product-level data (sales, characteristics, and prices of new product varieties) linked to buyers' (hospitals') characteristics. Using a multinomial logit model, it estimates the parameters of utility functions, and then computes social welfare by comparing changes in utility over time. Petrin (2002) adopts a similar approach, and it estimates welfare effects in the automotive sector (minivans) by means of demand and utility functions for new products commercialized in this market.

This approach did not become highly influential in the economics of innovation, arguably due to the strong supply-side bias that characterizes Schumpeterian research, and/or to the fact that the characteristics approach to demand requires detailed micro-level data on new product varieties that are often not available. For our discussion, it is important to point out that this approach adopts a notion of welfare that basically corresponds to preference satisfaction through consumption (see challenge 1 above); and that it neglects other types of social (non-economic) effects of innovation that are not captured by consumption data (e.g. effects of new drugs on health, functioning and well-being). The approach is also not able to consider explicitly distributional effects and equity aspects, since it is often hard to obtain data on consumption that also provide detailed information on agents' income, socio-economic status and other personal characteristics.

Supply-side effects. The other empirical approach is to focus on welfare effects of innovation on the supply-side, e.g. by estimating profitability and growth effects for firms that invest in R&D. The micro-econometric literature studying productivity and profitability effects of firms

investing in R&D rapidly expanded in the last couple of decades, fostered by greater availability of firm-level data (such as the innovation surveys), and rapid diffusion of applied microeconomic methods to study the economic impacts of innovation, such as for instance the CDM model (Crepon et al., 1998). For the present paper, it is worthwhile to point out that empirical works in this huge strand of research have a great deal of common characteristics. First, they focus on the supply- and invention side (innovations and spillover effects), and they neglect other impacts that new technologies may have on the demand side (related to consumption, or other users' activities). Second, this research is mostly focused on a purely economic notion of social welfare, as measured by firms' economic performance (see challenge 1 in section 2.1). Third, this econometric approach does typically not consider distributional implications that arise when innovation and creative destruction negatively affect some firms or sectors, but rather seeks to estimate the overall net effects of innovation investments. Hence, this empirical research does implicitly adopt a notion of welfare that focuses on efficiency and neglects equity considerations (see challenge 2 in section 2.2). There is in fact paucity of research that explicitly studies the relationship between innovation and income inequalities, with very few exceptions (e.g. Aghion et al., 2019; Consoli et al., 2021). This is surprising indeed. Most scholars of innovation would agree that technological trajectories have contrasting effects on winners and losers, and that cumulativeness and path-dependency may make these differences persistent and stronger over time. However, this conceptual understanding has not fostered the development of empirical research studying how innovation affects income distribution and social justice, and the related trade-offs between efficiency and equity.

3.3 Heterodox approaches

It is also worthwhile to note a couple of other strands of research that are well-known and influential in the innovation academic community, and that are relevant for our discussion. Both of these approaches are heterodox in the sense that they criticize the conceptual foundations of mainstream Schumpeterian economics (new growth theory, and related empirical research noted above), and provide a different understanding of how innovation affects economic change.

Evolutionary economics. Evolutionary theory starts from the assumption that economic agents (firms and consumers) have bounded rationality, and that they are heterogeneous (Nelson and Winter, 1982). Variety is a fundamental feature and key driver of change and transformation of the economic system. In a radically uncertain world, individuals follow

routines and habits of thought in their economic activities. Evolutionary models of innovation and growth are based on the idea that the routinized character of the productive process carried out by a population of heterogeneous firms generates a relatively stable pattern of economic activities and relationships over time. Such inertial forces and inherent persistency are counteracted by dynamic forces that continuously push the economic system towards evolution, change and transformation. These dynamic forces are technological competition and selection, on the one hand, and innovation, on the other. (Castellacci, 2007).

Evolutionary economics does therefore develop a theoretical framework in which an optimal level of R&D and innovation cannot be defined, because both economic agents and policy-makers have bounded rationality and limited information that does not enable maximizing behavior (Castellacci, 2008). This goes against the mainstream economics idea of a social planner that is able to impartially observe the system and define the level of R&D investments that would maximize social welfare. By contrast, the role of public policy in evolutionary economics goes well beyond the correction of market failures, and it entails the facilitation and guidance of markets, so that variety and competition are encouraged, as well as the creation of new markets (Moreau, 2004). These conceptual insights were recently developed further in the so-called mission-oriented approach to innovation policy, which emphasizes the entrepreneurial role of the State and how important this is in order to address major societal challenges (Mazzucato, 2015).²

For the present paper, it is worthwhile to point out that – although evolutionary economics represents a clear and novel departure from mainstream growth research – its conception of social welfare is essentially the same as in mainstream Schumpeterian economics. First, evolutionary economics research has typically adopted a concept of individual well-being that is merely economic (measured by income and GDP per capita; consumption; employment), and not taken into consideration the fact that innovation may also have non-economic impacts on other dimensions of agents' well-being. Second, evolutionary economics models and empirical research have largely focused on the efficiency dimension of social welfare (focusing on economic growth, and net overall effects of innovation), and neglected distributional impacts and the equity dimension of welfare. This is surprising, though, because evolutionary theory is in principle well-equipped to study inequalities, given its framework based on agents'

² In a recent critical appraisal of the mission-oriented approach, Papaioannou (2020) points out that this view lacks a proper foundation and theory of the State. The approach does not clarify the theoretical foundation that provides justification for having an entrepreneurial State, and whether and how different forms of State (e.g. welfare State, liberal) would be able to implement and sustain the mission-oriented role.

heterogeneity, and given the emphasis given to disequilibrium features of technological change (e.g. cumulativeness, path dependency, tacit knowledge, geographical clustering).

There are some conceptual contributions that argue for the development of a new evolutionary welfare economics (Schubert, 2009; 2013; Binder, 2013; 2014; Schmidt, 2018). These position papers mostly emphasize issues related to endogenous preference formation, and point out the need to abandon the tools of mainstream welfare economics. However, these recent works have not yet proposed a clear alternative framework and set of analytical tools to develop an evolutionary theory of welfare. On the whole, in spite of its major differences from mainstream innovation economics research, evolutionary economics does not present a substantial departure when it comes to its notion of social welfare, and of how innovation affects this.

Inclusive science and innovation. A recent strand of research within science policy and innovation studies emphasizes the nexus between science, innovation and inequalities, and it calls for a major shift in conceptual paradigm underlying innovation and its policy foundations. The main idea of this approach is to consider ethical implications of scientific and technological change, and work for the development of an innovation process that will have more equal and more inclusive benefits. Cozzens (2007) discusses the philosophical foundations that underlie current S&T policies, pointing out four alternative theories of distributive justice that are seldom considered in innovation research: (1) the libertarian approach of Nozick, which focuses on equality of IPRs; (2) the utilitarian approach that is dominant in economics, and that emphasizes efficiency effects; (3) the contractarian approach of Rawls, which may accept inequalities as long as the situation of the worst off individuals will improve; (4) and the communitarian approach, a theory of justice that focuses on the importance of social relations. Cozzens (2007), like other contributions in the inclusive innovation literature, argues in favor of the communitarian approach to social justice, thus proposing a clear departure from the notion of social welfare that is studied in welfare economics. In line with this, Bozeman and collaborators develop the “public values science” theory, which argues that the distributional impacts of S&T policies are often unequal, and that research should first and foremost seek to contribute to the society by creating social value that goes beyond private economic benefits (Bozeman, 2002; Bozeman et al., 2011; Zehavi & Breznits, 2017).

The literature on inclusive innovation and public values theory is potentially relevant for the topic of this paper, since it has an explicit focus on distributional effects of innovation and hence the equity dimension of social welfare. However, this literature rejects altogether welfare economics theories and analytical tools. By contrast, the new framework that we will outline

in this paper calls for a bridge and cross-fertilization between mainstream welfare economics, on the one hand, and Schumpeterian innovation research, on the other.

Table 1: Overview of research strands on innovation and social welfare.

Approach	Challenge 1: Determinants of individual well-being	Challenge 2: Determinants of social welfare: Efficiency <i>versus</i> equity
<i>Theoretical models</i>		
New growth theory models	Income	Efficiency (simple utilitarian social welfare function)
Technology, skills and employment	Employment; wage; income	Efficiency (simple utilitarian social welfare function)
<i>Empirical analyses</i>		
Supply-side	Firms' profitability and productivity, which lead to GDP growth	Efficiency (overall net effect); distributional effects are not considered
Demand-side	Consumption (which reflects agents' preference satisfaction and utility maximization)	Efficiency (overall net effect); distributional effects are not considered
<i>Heterodox approaches</i>		
Evolutionary economics	Income; consumption; employment	Efficiency (no social choice analysis; equity dimension is not explicitly considered)
Inclusive innovation	The notion of individual well-being is not explicitly defined and discussed	Focus on equity and social justice

4. A new research agenda

The twin research challenges noted in section 2 call for the development of a new research agenda to study innovation and social welfare. This new agenda will develop a conceptual framework that will study together economic and non-economic effects of innovation (challenge 1), as well as its distributional impacts, and the related trade-offs between efficiency and equity (challenge 2). This section will point out and discuss the major pillars of this new research program, and the future research directions that it calls for.

Let us first define the underlying question and objectives of this new framework. It seeks to compare two states of the world (or social alternatives), one without innovation (*status quo*) and the other with innovation. If the latter state of the world will lead to higher social welfare, then society should invest in innovation in order to achieve that social alternative in the future. To fix ideas, let us assume that the probability of developing an innovation in an economy at time t depends on the total amount of R&D that is invested by that country at time 0 (plus other characteristics).³

$$\Pr \{IN_t\} = f(RD_0) + \varepsilon \quad (1)$$

A state of the world is defined as a vector $\mathbf{X}$ that denotes the bundle of resources and capabilities allocated to each individual in that given situation. Our framework seeks to compare social welfare that is associated with state of the world $\mathbf{X}_{NI}$ (social alternative with no innovation) and $\mathbf{X}_{IN}$ (social alternative in which R&D investments lead to an innovation).

To analyze this question, this section will outline two major general pillars of the new research agenda. The first pillar seeks to define individual well-being that is associated with a given state of the world, and to study how innovation affects economic and non-economic determinants of well-being (section 4.1). The second pillar discusses how we should define and analyze social welfare when innovations lead to both efficiency effects and distributional impacts (section 4.2). Overall, the logic of exposition of the new research agenda follows a micro-to-macro approach: the first pillar focuses on the micro-level concept of individual well-being (pillar 1), which provides the necessary micro foundation to investigate further the aggregate notion of social welfare, and related issues of efficiency and equity (pillar 2).

³ We use a very simple formulation here in order to introduce our framework and formulate its questions and objectives. In more specific modelling exercises that will develop further this framework in the future, equation 1 could of course be extended by modelling innovation as a continuous function of R&D, and by specifying further other confounding and control factors that may affect this relationship.

4.1 Pillar 1: A broader notion of well-being

The first conceptual pillar of this new research program is to adopt a broader notion of individuals' well-being, which should go beyond the traditional economics concept of utility maximization through preference satisfaction (Adler & Fleurbaey, 2016). This represents a central topic in the fields of well-being studies and welfare economics, but it has so far been overlooked in innovation studies. There are two related notions of well-being that are relevant in order to study the effects of innovation on social welfare.

On the one hand, the notion of *subjective well-being* points out well-being as perceived by each individual (Kahneman & Deaton, 2010). This notion has its philosophical foundations in the classic utilitarianism of Jeremy Bentham, and it is empirically operationalized in current research by using measures of happiness and life satisfaction reported by individuals in large-scale surveys (MacKerron, 2012).

On the other hand, the concept of *objective well-being* focuses on the attainment of objective goods which enable individuals to achieve key functionings, and so to undertake a valuable life (Ryan & Deci, 2001; Graham & Nikolova, 2015; Alkire, 2016). This approach has its classical foundations in Aristotle's philosophical principles, and it is also related to research in the capability approach (Sen, 1985). Empirically, objective well-being is analyzed in current research by means of a multidimensional framework (so-called «inclusive measure of well-being approach»), in which each individual is assigned a vector, based on her scores on various objectives goods and capabilities (Chakravarty & Lugo, 2016).

We argue here that innovation research should study social welfare effects by adopting a broad notion of individuals' well-being that combines subjective and objective dimensions.⁴ In very general terms, an inclusive notion of well-being may be defined as follows. Each individual's utility (or well-being) function has an argument composed of d dimensions, representing the different goods and capabilities that shape agents' well-being according to extant research (e.g. income, consumption, leisure and social life, family, education, health). In state of the world X , individual i is allocated the bundle X_i , which provides the following utility:

$$U_i(\mathbf{X}_i) = U_i(X_{i1}; X_{i2}; \dots; X_{id}) \quad (2)$$

⁴ Piacquadio (2017) has recently put forward a new criterion, "opportunity-equivalent utilitarianism", in which individuals' well-being is based on their endowments on a bundle of commodities, comprising both objective achievements and other aspects. This work provides a relevant example of how subjective and objective notions of well-being could be combined into a single theoretical framework of welfare analysis.

In dynamic terms, the intertemporal utility function may be written as:

$$U_i(\mathbf{X}_{it}) = \int U_i(\mathbf{X}_{it}) e^{-\rho t} dt \quad (3)$$

where ρ is the rate of time preference, accounting for the fact that well-being today is preferred to well-being tomorrow.⁵ This dynamic formulation is important for our framework because innovation is an inherently dynamic activity: some of its effects will manifest in a short-period of time, whereas others will only become visible in a longer term perspective. It is thus important to make an explicit distinction between short-run and long-run effects, because these may have different relevance in terms of social effects and related options for innovation policy makers.

To distinguish between short- and long-run effects, suppose that each individual lives for L years (what we call the *long-run*), and that S is the number of years that represents the more limited time horizon that is relevant for policy-makers (which we define for simplicity as the *short-run*). 0 is the current period, the time at which we seek to assess the future expected effects of an innovation, and hence decide whether or not to support R&D investments that will develop a given technological trajectory. We may then specify individual well-being that is associated with different time horizons: $U_i(\mathbf{X}_{iS})$ is short-run well-being (if the integral in (3) is defined between 0 and S); and $U_i(\mathbf{X}_{iL})$ is long-run well-being (if the integral in (3) is defined between 0 and L).⁶

Equation 3 provides a rather general formulation, whose main objective is to fix ideas and define the questions that this new research agenda will investigate. There are several conceptual and methodological aspects that future research would have to address in order to translate this general formulation into a more specific theoretical and/or empirical model. Specifically, three of these are important: (1) to define the set of resources and capabilities that are included in the vector d (well-being determinants), and a related set of indicators that can measure these

⁵ The formulation in equation 3 adopts a standard exponential discounting of future utility. This is also called a «discounted time-additive lifetime well-being structure», in which future well-being is considered in discounted form (Ponthiere, 2016).

⁶ This is also individual's lifetime utility. Note also that some innovations have very long-run effects that will affect the well-being of future generations (e.g. green innovations). This general formulation may in principle be extended by adopting a well-being structure that accounts for the well-being of future generations in discounted form. This may be defined as $U_i(\mathbf{X}_{i\infty})$ (if the integral in equation 3 is defined between L and infinity). The literature discusses pros and cons of discounting future well-being (Broome, 2016; Asheim & Mitra 1999).

dimensions in empirical analyses; (2) to specify a functional form of U that aggregates these different dimensions for each individual, in order to obtain a single index of well-being for any individual (and the related assumptions that this aggregation rule requires in terms of intra-personal comparability); (3) to define a set of weights for each of these dimensions, if there are reasons to believe (conceptually or empirically) that some determinants of well-being are more important than others. The welfare economics literature provides extensive discussions of these issues (e.g. Alkire, 2016; Chakravarty and Lugo, 2016; Duclos and Tiberti, 2016; Fujiwara and Dolan, 2016; Weymark, 2016).⁷ However, we do not seek to discuss these issues further here. As noted above, the present paper intends to present a new research agenda for future research, focusing on its general questions, objectives and challenges for future research (and thereby neglecting several specific conceptual and methodological issues that this future research will have to address).

The key point of our interest here is to use the general formulation noted in equations 2 and 3 above to point out the channels through which innovation affects the various determinants d of individual well-being, and thus overall well-being for a given individual. Based on the large literature on subjective and objective well-being, a promising way forward is to use the so-called *domains of life framework*. A large literature on well-being has in the last decades extensively investigated the main dimensions that contribute to shape individuals' well-being in different domains of life (Dolan et al., 2008). What are the possible effects of innovations in individuals' life domains? We may think of a large set of relevant channels and mechanisms that future research should consider. Table 2 provides an overview and some examples.

A first major domain of life is individuals' work and employment. Innovation and creative destruction lead to changes and transformations on the supply-side of the economy: some firms and industries emerge as winners, whereas others progressively lose market shares and are eventually driven out of the market. This process may impact individuals' well-being in a variety of ways, such as changes in their absolute wage level, relative wage *vis-à-vis* other peers and colleagues, quality of workplace, future job prospects, and thereby job satisfaction (Castellacci & Bardolet, 2018).

⁷ Another conceptual issue is that the standard welfare economics framework assumes a fixed and stable correspondence between a given state of the world and the vectors of individuals' utility. However, individuals change over time. A given innovation may lead to different well-being over time (e.g. due to adaptation effects; Shafir, 2016). This is an aspect that is particularly important in evolutionary economics, in which it is emphasized that agents' preferences change over time (Schubert, 2013). However, according to an objective definition of well-being, this issue is arguably less crucial, and it is reasonable to assume that individual utility functions may be rather stable over time.

A second main life domain relates to consumption activities. This is obviously important, as assumed in a mainstream economics framework, since consumption of new products and services may lead to preference satisfaction and hence higher utility levels. However, based on the well-being literature, it is reasonable to argue that it is not only the quantity and pace of new consumption that matters for well-being, but also the *type* of new goods and services that are purchased. Consumption of new goods and services that are related to key activities, capabilities and functionings (e.g. health, education) must be considered particularly important for well-being, whereas purchases of new varieties that are non-strictly necessary do not have any relevant impact on individuals' well-being, and only provide temporary pleasure that swiftly vanishes over time due to adaptation effects. Further, some recent digital innovations (e.g. e-commerce and online banking) also affect consumption by increasing information and shortening time related to search and purchasing activities (which in turn may affect the pace and/or the type of new goods and services that are purchased).

Third, the well-being literature emphasizes the importance of individuals' leisure activities, social and personal life. Empirical research convincingly shows that this is a crucial life domain for agents' well-being. Innovation may have a variety of relevant impacts on this dimension. For instance, new digital services and communication tools lead to profound changes in the way individuals communicate and interact with each other, whose impacts on well-being are complex and multifaceted (Castellacci & Tveito, 2017). The personal life domain is also shaped by the physical environment and the socio-institutional environment that characterizes the place where individuals live, and that innovations may affect in a variety of different ways.

Finally, in addition to these three major life domains, it is worthwhile to emphasize the relevance of some cross-cutting dimensions, which have pervasive effects on well-being in all domains of life. These are agents' capabilities and functionings, which provide individuals with the freedom and opportunity to carry out activities to conduct a meaningful life (Sen, 1985). Technological innovations that sustain and foster capabilities and functionings will arguably have positive and pervasive effects on all other dimensions of life. For instance, health innovations often provide individuals with greater opportunities to carry out working, leisure and social activities that are conducive to well-being. Further, technological and organizational innovations related to education and training may in principle extend the availability and/or improve the efficiency and quality of educational services, which will in turn strengthen individuals' position in the labor market, as well as their overall culture and life perspective, which are important determinants of well-being.

In short, the main point of these examples is to illustrate that the effects of innovation on well-being are complex and multifaceted. They go well-beyond impacts that are defined in economic terms (such as changes in wages, income and consumption patterns), and comprise also psychological and social dimensions that cannot easily be defined in strictly monetary metrics, and that are known to be important for individuals' well-being.

This perspective has important implications for future innovation research. The major general implication is that each innovation will have different effects on distinct domains of life, and it is therefore paramount that innovation research will in the future develop a detailed typology to classify different types of innovations depending on the extent to which and the channels through which they affect individuals' well-being. There are three specific relevant aspects.

One aspect refers to the *scope* of effects that different innovations have on agents' well-being. Some innovations have broad and pervasive impacts that cut across and impact several domains of life (e.g. digital technologies; health innovations), whereas other innovations have instead a more narrow and limited effect on one specific domain of life. A second aspect relates to the *extent* of these effects, which may be stronger or weaker (both in a positive and in a negative direction). A third aspect refers to the *time-horizon* over which these effects will manifest. In general terms, innovations that have effects on consumption and income-related patterns may have short-run impacts for individuals, but no permanent effects on their perceived well-being. On the other hand, innovations that have effects on key capabilities, functionings and/or leisure and personal life may have longer-term effects on individuals' well-being. Yet other innovations may instead reduce well-being in the short-run, while leading to higher well-being of future generations (e.g. green innovations that tackle climate change).

On the whole, it is paramount that innovation research will in the future achieve a better conceptualization and empirical analysis of the three dimensions noted here, in order to be able to distinguish further innovations that have strong and pervasive effects on individuals' well-being, from those that have more limited (or sometimes even negative) impacts. This future research will also have relevant implications for innovation policy, as we will discuss in section 5 below.

Table 2: Effects of innovation in different life domains: Some examples

Domain of life / Dimension	Channels through which innovation affects individuals' well-being	Examples
Working life (supply-side)	Wage level (absolute income)	Innovative firms achieve higher profitability and wage increases
	Relative income and social comparisons	Online tax records
	Quality of workplace	Telework; automation
Consumption (demand-side)	Preference satisfaction	Purchase of a new mobile phone
	Time saving and information enhancing (impacts on consumption activities)	E-commerce; online banking
Leisure and personal life	Social life and communication: greater possibilities and new challenges	Social media
	Physical environment: cleaner production	Renewable energy
	Socio-institutional environment: Foster government and security services	Big data for crime prevention
Capabilities and functionings (cross-cutting dimensions)	Health	New drugs; covid-vaccine
	Education	MOOCs; digital teaching

4.2 Pillar 2: Social welfare analysis and the distributional effects of innovation

The second pillar that provides the foundation for this new research agenda is a conceptual framework that assesses aggregate impacts of innovation for different individuals and social groups, considering together positive impacts for some and negative effects for others, and that takes into explicit consideration distributional impacts and the equity dimension of innovation. The underlying question that motivates this endeavor is the following: since an innovation will lead to a shift from state of the world NI to IN, is welfare associated to IN greater than welfare associated to NI – and if so why? The comparison of welfare associated with different states of the world is a theme that has a long history in the field of welfare economics, but it has so far been largely neglected in innovation studies. We argue here that innovation research should make more systematic use of the theories and tools developed by welfare economics. This is a well-established field of economics research that has a long tradition to investigate different ethical and philosophical principles that provide the foundations for policy choices, and particularly to discuss how these different principles address relationships and trade-offs between efficiency and equity (Adler and Fleurbaey, 2016). By drawing insights from welfare economics, innovation studies will strengthen the scholarly knowledge base that it is necessary in order to provide clearer analytical foundations and a stronger rationale for innovation policy. Specifically, we propose that a promising way forward for innovation research is the use of *social welfare functions* (SWF), an analytical tool that has long been used in welfare economics to theorize the foundations of public choices (Weymark, 2016). A SWF is a function that assigns a numeric value of welfare to any given state of the world, based on the set of individuals' utilities (well-being) that are associated to each social alternative. The SWF is a simple conceptual tool that makes it possible to rank different possible outcomes of policy actions, and so decide which of them public policy should pursue.

A standard way to define a SWF follows the Bergson-Samuelson approach (Weymark, 2016). The theoretical framework assigns individual utilities associated to each state of the world, and it then aggregates these individual utilities by means of a social welfare ordering (Balasubramanian, 2015). The social welfare ordering is an analytical function that implicitly represents a «value judgement», i.e. the normative and ethical assessment that a researcher or policy-maker formulates about the importance of inequalities, the underlying theory of social justice, and hence the relationships between efficiency and equity.

As noted in section 3, the most standard and widely used type of SWF is the so-called «simple utilitarian», which defines social welfare as the simple sum of individuals' well-being (utility). This is a formulation that disregards equity considerations, and it is the SWF that is commonly

adopted (implicitly or explicitly) in Schumpeterian modelling and empirical research (see sections 3.1 and 3.2). There are however several other types of SWF discussed in welfare economics that do consider equity aspects as important.⁸

We argue here that if we want to consider equity effects of innovation too, alongside the efficiency dimension, then we must adopt a SWF and an underlying theory of social justice that makes this possible and explicit. The present paper does not intend to suggest the use of a specific SWF and a specific theory of social justice. This is a broad task for future research. Our objective here is to provide a general framework that intends to open up and guide this future line of research in innovation studies. This general framework can be presented by using the following formulation:

$$W(\mathbf{X}_t) = \sum gU_i(\mathbf{X}_t) \quad (4)$$

where W denotes social welfare that is associated with state of the world X at time t . In this social alternative, each individual i has a resource and capability allocation denoted by the vector $\mathbf{X}_i$, which delivers utility U_i . Equation 4 aggregates utility for all individuals by first multiplying each individual utility using a function g , and then summing them up together. This is a so-called *generalized utilitarian* SWF. The weighting function g may be thought to be a continuous, increasing and strictly concave function, so that its concavity reflects inequality aversion (see e.g. Piacquadio, 2017: 1270).⁹

Given this definition, the objective of the new framework is to compare social welfare in two social alternatives: without innovation (NI, *status quo*) and with innovation (IN). If welfare associated to IN is higher than that associated to alternative NI, then innovation should be pursued by society because it leads to a preferred social alternative:

$$W(\mathbf{X}_t)^{IN} > W(\mathbf{X}_t)^{NI} \quad (5)$$

⁸ For instance, a “weighted utilitarian” SWF is a generalization of the simple utilitarian that multiplies individuals’ utility by a positive scalar or weight; the set of weights assigned to different individuals or social groups represents the policy-maker’s views on the relative importance of different individuals in the society. The «single-parameter Gini» SWF defines welfare as the weighted sum of rank-ordered utilities, so that individuals in lower ranks of the distribution receive higher weights. Finally, another classical example is the “leximin» SWF, representing Rawl’s theory social justice, in which welfare is higher for those states of the world in which the worst-off individuals improve their situation.

⁹ Note that a key aspect of this general formulation is agents’ heterogeneity. In equation 4, agents are heterogenous as they are allowed to have different: (1) endowments in their vector of well-being determinants; and (2) utility functions U_i . It is paramount to have a theoretical framework with heterogenous agents in order to consider distributional aspects of innovation.

In mainstream modelling terms, this type of question could be formulated as a social planner problem, following the tradition of innovation and growth research. A social planner must define the optimal level of R&D investments at time 0 that will develop the desired innovation at time t , which will maximize social welfare – given the distributional requirements that are specified in the function g of the generalized SWF (4). The social planner would thus face a typical problem of intertemporal dynamic optimization subject to constraints, defined by the available fiscal resources and production possibilities related to R&D activities.

This type of dynamic approach based on the social planner metaphor is standard in mainstream growth theory, but it is criticized in heterodox approaches such as evolutionary economics, which argue that agents' bounded rationality and limited information make it hard to think that a social planner would ever be able to maximize social welfare (see section 3.3). Anyway, although this type of criticism is relevant in general terms, it does not affect the main argument that we are developing here. The question of our interest could in principle be formulated in different terms without any reference to maximizing behavior and steady state analysis. We seek to assess whether investments in R&D today will lead to an increase in social welfare in the future; and to ensure that the expected future benefits of these investments (i.e. the increase in social welfare) will be higher than the costs (i.e. private and public resources invested in R&D, and the related opportunity costs). This is a general formulation that most scholars and policy-makers would agree with, regardless of theoretical schools and modelling approaches. The social welfare framework represented by equation 4 opens up several relevant new directions for future research in innovation studies. We point out two of them here, which we believe to represent the two most important issues for both innovation research and policy-making: one is the trade-off between innovation incentives and inequality; and the other is the relationship and possible trade-offs between short- and long-run effects of innovation on welfare.

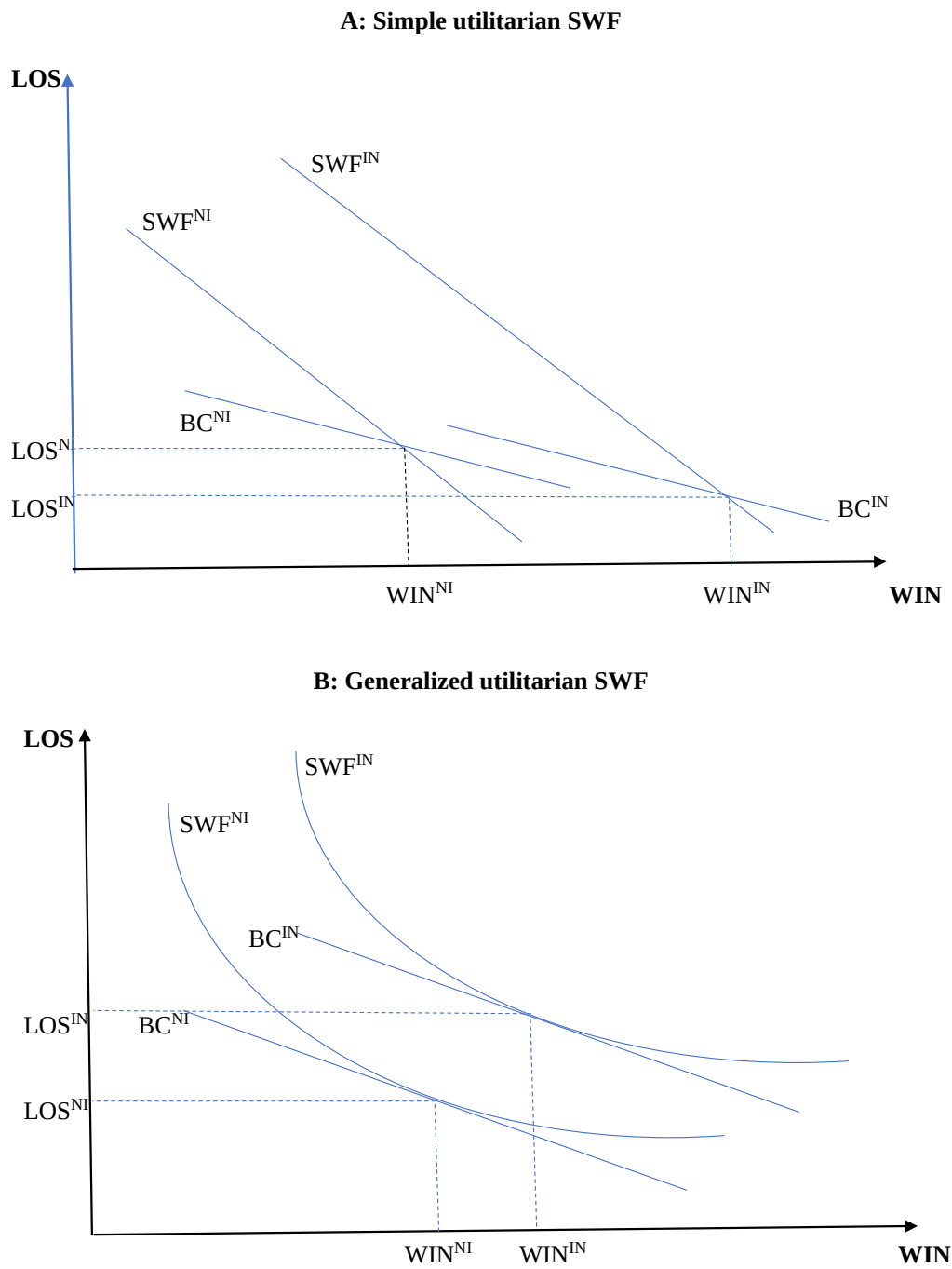
Trade-off between innovation and equality. If we disregard the distributional impacts of innovation, as it is typically the case in innovation research, then all that matters are the efficiency effects of innovation. A policy-maker (or social planner) must ensure that R&D investments will be large enough to generate innovations that will foster overall economic growth, consumption and employment dynamics (regardless of how these factors are distributed among individuals and social groups). However, a society that seeks to give an explicit role to distributional aspects, because these are considered important according to the

policy-maker's view of social justice, will face an important trade-off. On the one hand, if policy-makers take into account and seek to avoid negative distributional impacts of innovation, then the latter will have more inclusive outcomes that will not substantially worsen the distribution of income or other relevant capabilities. On the other hand, though, taking into account distributive aspects will also reduce the incentives for innovators to invest in R&D, since these will be subject to redistributive taxes to compensate losses for some other social groups; and/or they will receive more limited public policy support to R&D activities. Hence, the overall level of R&D and innovation in the economy will arguably be lower in an inequality-adverse system compared to a *laissez-faire* system that only focuses on efficiency objectives (Witt, 1996).

This trade-off is represented graphically in figure 1 by comparing a simple utilitarian SWF that disregards equity consideration (figure 1a) with a generalized utilitarian SWF (e.g. like the one noted in equation 4) that seeks to avoid inequalities (figure 1b). Figure 1 provides a simplified illustration of the static effects of an innovation on two social groups: winners (which benefit from innovation) and losers (which supposedly worsen their relative position when the innovation will arise). The example shows that in the simple utilitarian approach (figure 1a) an innovation increases substantially the welfare of the winners, while decreasing that of the losers – the innovation does therefore increase total welfare but it also exacerbates inequalities between the two social groups. By contrast, in the generalized utilitarian approach (figure 1b), the innovation will result in a more limited welfare increase for the winners, while at the same time also enabling a small welfare increase for the other social group – the innovation does in this case have lower total effects on social welfare (compared to situation 1a), but it will also foster equity.

The example presented in figure 1 is provocatively simple, and its main intention is to illustrate the possible trade-off that society faces when it seeks to avoid inequality effects of innovation while at the same time fostering efficiency and overall social welfare. This topic has so far largely been neglected in innovation research, and it represents an important direction for future research.

Figure 1: Effects of innovation on social welfare: comparing a simple and a generalized utilitarian social welfare function (SWF)



Legend: WIN: winners; LOS: losers; BC: budget constraint

Short-term versus long-term effects. The second relevant direction for future research relates to the relationships and possible trade-offs between short- and long-run effects of innovation on welfare. Since innovation is a dynamic phenomenon that unfolds over time, some of its effects may be visible in the short-run (S), whereas others do sometimes take many years to manifest, and they will only be visible in the long-run (L). Further, it is reasonable to posit that the effects of innovation on social welfare change over time: some innovations may have *decreasing impacts over time* (strong in the short-term, vanishing in the long-run), whereas other technological changes may have *increasing effects over time* (small in the short-term, and strong and pervasive in the long-run). This means that an important task for research and policy is also to compare social welfare between different time horizons, since there might be contrasting patterns and complex trade-offs between short- and long-run effects of innovation. To illustrate this further, let us define $W(\mathbf{X}_S)$ as social welfare in the short-term (year S), and $W(\mathbf{X}_L)$ as welfare in the long-term (year L). If we focus on the short-term effects (as policy-makers are sometimes prone to), then we seek to ensure that within this time horizon innovation will increase overall welfare compared to the social alternative without innovation, see condition 6. On the other hand, condition 7 is relevant if we seek to focus on the effects of innovation over a long-term horizon:

$$W(\mathbf{X}_S)^{IN} > W(\mathbf{X}_t)^{NI} \quad (6)$$

$$W(\mathbf{X}_L)^{IN} > W(\mathbf{X}_t)^{NI} \quad (7)$$

Using these definitions, figure 2 and table 3 illustrate four possible cases of interest. Figure 2 represents social welfare as a function of time. This function may be increasing or decreasing (depending on the type of innovation that we consider), and it may have different dynamics over time for the two social groups that are affected by innovation (for simplicity, we call them again the *winners* and the *losers*). Table 3 summarizes four possible combinations of interest. The top-left quadrant (case A) points out a situation in which the positive impacts of innovation become stronger in the long-term for the winners, while the costs for the losers become progressively less important. Think for instance of a new green innovation: this will arguably have increasingly positive effects for the eco-innovating firms (winners), but also decreasing costs for non-green incumbents (losers).

The bottom-right quadrant (case D) reflects a symmetrical situation: positive welfare effects will be decreasing in magnitude for the winners, and negative impacts will increase over time

for the losers, so that social welfare will be highest in the short-term. For example, think of automation technologies that will strengthen the relative position of skilled workers employed in automating firms in the short-term, but also weaken job prospects for the unemployed in the longer-term. Although different from each other, these two situations do not present any trade-off between the short- and the long-term, and it is straightforward to point out in these examples that welfare effects of innovation will be strongest in the long-term (in the former case) or in the short-term (in the latter), respectively.

On the other hand, the other two quadrants of table 3 illustrate social alternatives in which the time trend of welfare for different social groups (winners and losers) go in opposite directions over time, so that innovation will lead to a trade-off between its short- and long-term impacts, which policy makers must assess and deal with. Specifically, the bottom-left quadrant of table 3 (case C) denotes a situation in which the winners experience increasing benefits over time, whereas the losers have stronger negative impacts in the long-run. This situation is interesting because it presents a trade-off between short-run effects (small efficiency benefits, combined with limited inequality impacts) and long-run impacts (large efficiency gains, coupled with high inequality costs). For instance, artificial intelligence innovations may be expected to raise employment and productivity for innovative companies, generating a cascade of positive effects for these firms in the years to come, but they may also exacerbate income and skill disparities *vis-à-vis* workers in non-innovative firms, which will in the long-run negatively affect social cohesion in a cumulative manner.

Finally, the top-right quadrant (case B) is a social alternative in which innovation has impacts that manifest rapidly in the short-run (positive for the winners, and negative for the losers), but which will progressively weaken and eventually vanish over time. This situation is relevant because it points out again a trade-off between short-run effects (strong efficiency benefits, coupled with substantial inequality impacts) and long-run impacts (limited efficiency gains, combined with low inequality costs). A possible example of this situation relates to social media use, and its impacts on the welfare of different demographic groups: younger users may experience decreasing benefits over time, whereas the elderly may initially be excluded and then learn to use the new digital tools after some years of their introduction.

These examples are rather stylized, and they could be refined and elaborated in a number of ways. Taken together, however, they illustrate one important fact that has so far been overlooked in innovation research. Welfare effects of innovation may vary over time, and dynamic patterns for different social groups, winners and losers, may in some cases be aligned with each other and in other cases contrast with each other, depending on the type of

technological trajectory that we are considering, and on the type of social groups that will experience its effects. These issues open up new relevant questions that future innovation research should investigate, and that will have important implications for the foundations and objectives of innovation policy.

Figure 2: Short-run (S) and long-run (L) effects of innovation on social welfare (Legend: WIN: winners; LOS: losers)

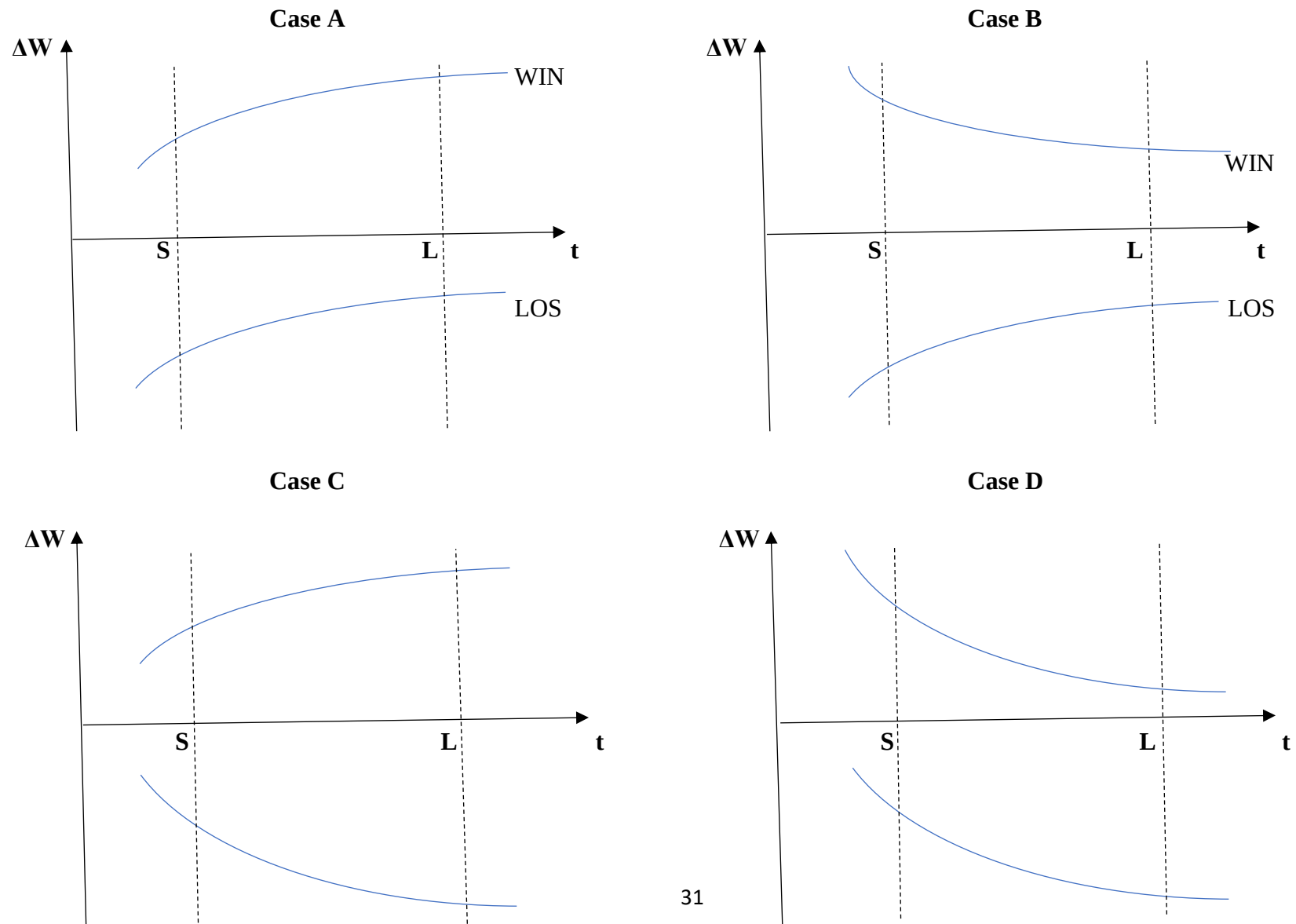


Table 3: Short-run (S) and long-run (L) effects of innovation on social welfare

		WINNERS	
		Increasing welfare over time	Decreasing welfare over time
LOSERS	Increasing welfare (lower losses) over time	Case A Stronger welfare effects in L. E.g.: green innovations (incumbents vs new eco-firms)	Case B Trade-off between S and L. Lower inequality in L. E.g.: social media (young vs elderly users)
	Decreasing welfare (higher losses) over time	Case C Trade-off between S and L. Lower inequality in S. E.g.: AI (skilled vs unskilled workers)	Case D Stronger welfare effects in S. E.g.: automation (skilled vs unemployed workers)

4.3 The role of uncertainty

An important conceptual issue that this new research agenda will have consider is that innovation is an inherently uncertain activity. At the time when a new innovation unfolds, it is often hard to say exactly what new state of the world the innovation will lead to, and when this will arise. According to some, uncertainty challenges the development of an innovation theory of welfare (e.g. Binder, 2013; Schubert, 2013). Although this issue is relevant, we do not regard it as a fundamental challenge that hampers the development of the new research agenda outlined in sections 4.1 and 4.2. We briefly discuss this aspect here.

First of all, it is important to clarify that there are two types of uncertainty that it is relevant to consider. One is uncertainty about innovation outcomes: R&D investments will not necessarily lead to an innovation; and if they do so, it is uncertain when the new technology will be developed and commercialized. Hence, the new state of the world due to innovation is by its own nature unknown.

Second, uncertainty may also refer to the effects of innovation on agents' well-being. If the innovation represents a radically new trajectory (e.g. artificial intelligence), it is in general hard to say exactly how it will develop in the future, and what effects it will have on individual well-being. On the other hand, for an incremental innovation that is part of an already existing trajectory (e.g. a new product variety), it will in most cases be possible to anticipate what its

effects on individual well-being will be (based on the effects that other varieties of the same product line previously had).

Now, if we adopt a notion of computable risk rather than full and radical uncertainty (as it is common in modelling research), then we may postulate a probability distribution that specifies a set of k possible outcomes of R&D activities. In this situation, the new framework could be extended by assigning a probability distribution to innovation outcomes, and hence to different possible states of the world (Harsanyi, 1953; Mongin & Pivato, 2016). For instance, the formulation noted in section 4.1 could be generalized to a stochastic setting by assuming that the probability to obtain an innovation depends on the amount of R&D plus a stochastic component (e.g. following Aghion & Howitt's models of creative destruction):

$$\Pr(\text{INN} = 1) = f(\text{R\&D}) + \varepsilon \quad (8)$$

Let us say that there may be k different possible innovation outcomes that we can expect as a result of R&D investments, and $\mathbf{p}$ (from p_1 to p_k) denotes the vector of probabilities associated with these different outcomes. Hence, for each dimension i in the vector of well-being determinants, individual well-being may be defined as the expected outcome of these uncertain events:

$$U_{ip}(\mathbf{X}_i) = U_i(p_1X_1 + \dots + p_kX_k) \quad (9)$$

Social welfare may thus be defined as before as a generalized utilitarian function of individuals' expected well-being, given the set of probabilities $\mathbf{p}$.

$$W(\mathbf{X}_t) = \sum gU_{ip}(\mathbf{X}_t) \quad (10)$$

However, heterodox approaches such as evolutionary economics often argue that the economic system cannot be represented in a framework of computable risk, since it is characterized by radical uncertainty, which makes it hard to formulate a probability distribution associated to the k uncertain future events (Nelson and Winter, 1982). According to this argument, our new research agenda would be faced with an important conceptual challenge, since it would not be possible to compute *ex-ante* individuals' well-being and social welfare that is associated with the state of the world that will be generated in the future by R&D investments that are undertaken today.

Nevertheless, this problem is less challenging for our framework than it may seem at first. First, the degree of uncertainty is arguably higher for radically new technological trajectories. Though, for most incremental innovations that are part of an already established technological trajectory, it may be reasonable to formulate well-informed expectations about the expected innovation outcomes and their effects on well-being (based on the experience of previous incremental innovations belonging to the same technological family, and empirical data on their diffusion and effects). So, even if it is hard to postulate a precise probability distribution, researchers and policy-makers can certainly carry out a scenario analysis considering different possible future outcomes, and specify a range of probabilities that are associated with each scenario.

Second, the extent of uncertainty largely depends on the time at which the technology assessment is carried out. If we are at time t , some years after R&D investments were undertaken, and when the new innovation is already being commercialized, then uncertainty is arguably not a major issue. This means that we are carrying out an *ex-post* assessment of welfare effects of already commercialized innovations, e.g. using existing data. On the other hand, if the technology assessment exercise is undertaken at time 0 , when R&D investments are still being undertaken, then uncertainty is arguably stronger and more radical. This means that we are carrying out an *ex-ante* assessment of future and uncertain welfare effects of an innovation that might be commercialized some years later. This situation is not easy to address, but it may be dealt with by using technological forecasting and public ethical committees. Public authorities can play an important function here and provide expertise that enables to understand and assess possible future effects of an innovation. As Witt (1996) notes:

“Scientific boards, councils, and advisors who collect and utilize information which emerges from innovative ventures can not only be important sources of expertise for potential victims but also for the innovators themselves. Because of the very nature of novelty, even the best expertise cannot eliminate unforeseeable risks. Yet, it may help, in some cases, to discover earlier where danger is brewing and to find ways of avoiding it - calling a halt to an ongoing innovation being only one of them”. Witt (1996: 128).

Concluding this point, it is certainly true that uncertainty represents a conceptual challenge to understand and predict how innovation will develop over time, when it will manifest, and what societal effects it will have. However, this general issue cuts across all innovation research, and it is not a specific problem for the new agenda that is proposed in this paper. In other words, the very same issue does also challenge extant innovation research, which adopts a narrow

economic definition of well-being, and only focuses on the efficiency dimension of social welfare.

5. A new departure in innovation policy

The new research agenda outlined in this paper will have important implications for R&D and innovation policy. This new research program does indeed call for a radical shift and rethinking of the rationale and foundations of innovation policy. Table 4 presents a brief comparison of the new innovation policy framework that will be developed based on the research agenda outlined in this work *vis-à-vis* the three main approaches that are dominant in extant innovation policy research: R&D policy, systemic policy, and the more recent mission-oriented approach (see a more extensive overview of these three approaches in Edler and Fagerberg, 2017; and Fagerberg, 2017). All three established frameworks, in spite of important differences, share the two major limitations that were noted above: they typically focus, in one way or another, on economic impacts of innovation; and they do not explicitly consider its impacts on equity and distributional aspects.

By contrast, the new research agenda outlined in this paper provides a brand-new rationale and foundation for innovation policy that sharply differs from previous approaches. First, the new agenda is based on the idea that aggregate social welfare of a given population (nation) must be defined by means of the well-being of its individuals. Hence, the main objective and rationale of innovation policy is to foster individual well-being, and support individuals in their quest for well-being (Layard, 2005; Frey and Stutzer, 2010). Therefore, differently from other approaches to innovation policy whose rationale is by and large based on an aggregate notion of social welfare – such as “market failures”, “systemic failures” and “missions” – the rationale of public policy in the new approach is to support innovation only to the extent to which the latter will support individuals’ well-being.¹⁰

Going beyond a narrow definition of economic well-being and material wealth, the new innovation policy paradigm will seek to distinguish explicitly different types of innovation, depending on the effects that these have, or are expected to have, on agents’ well-being. As noted in section 4.1, some innovations have strong positive impacts on individuals’ well-being,

¹⁰ The new innovation policy approach will therefore provide an analysis of the micro foundations of the aggregate notions of social welfare that are adopted in extant policy approaches (“market failures”, “systemic failures” and “missions”), based on the micro notion of individual well-being. Future research on this topic may thus investigate various market failures and societal challenges that are typically emphasized by current policy approaches, and discuss whether and how these are related to the well-being of individuals and different social groups.

which are pervasive and cut across several domains of life, whereas others have more limited (or sometimes even negative) impacts. Further, some new technologies may have short-run effects that will gradually vanish over time, whereas others will enable enduring impacts in agents' quality of life in the long-run. Hence, the new agenda calls for a technology-specific rationale of public policy, which will seek to promote those innovations that are expected to have strong and pervasive impacts on individuals' well-being, and monitor, regulate and hamper the development and diffusion of technological trajectories that will not foster human well-being.

Second, shifting the focus to the aggregate level of analysis (national social welfare), the new research program points out the need to consider the important distributional impacts of innovation, and therefore combine efficiency and equity dimensions in the definition of the rationale and objectives of innovation policy (section 4.2). This calls first of all for a more explicit discussion of the ethical and political views, and the related theory of social justice, that underlie innovation policy choices. Ethical and political views may of course differ, and so will innovation policy strategies. Our point here is to emphasize that these values must be discussed and made explicit in innovation research and in the innovation policy debate.

Now, thinking of more specific policy implications of an innovation theory of welfare that combines efficiency and equity dimensions, if a society wants to give importance to distributive effects of innovation, this could be done in two ways: (1) by means of redistributive taxes from the winners to the losers, if we regard that the innovators as "responsible" of the negative externalities they produce to others, and that they must therefore compensate the losers by means of taxes (this logic is based on the well-known *Pigou-Dalton transfer principle* in welfare economics); (2) and/or, the State may regulate and hamper the diffusion of those innovations that have negative impacts on equality and social cohesion. In both cases, however, innovative firms will face a lower incentive to invest in R&D activities, and/or lower public support, so that the overall rate of innovation in the economy will be lower compared to a *laissez-faire* economy that disregards distributional impacts of new technologies. Hence, innovation policy faces here an important dilemma on whether it is worth for the society to accept a lower rate of innovation in order to achieve better equity and social cohesion.

A second policy implication relates to the time horizon at which the effects of innovation on social welfare will manifest, and the relative dynamics for different social groups (e.g. winners and losers within a given market, sector, etc.). As noted in section 4.2, dynamic welfare patterns for different social groups may in some cases contrast with each other. In these situations, innovation policy-makers could be faced with trade-offs and difficult questions, e.g. on whether

it is better for the society to have high efficiency gains with negative distributional impacts, or rather lower efficiency and a more equal economy. This type of questions is of course hard to answer, and it calls for a broader and more explicit scholarly and policy debate on the social welfare impacts of innovation, which is precisely the main message of this paper.

Table 4: The new innovation policy framework compared to three other established approaches.

	R&D policy	Systemic policy	Mission-oriented policy	Innovation policy for well-being and inclusive social welfare
Theoretical foundation	New growth theory	Innovation system approach	Evolutionary economics / Entrepreneurial State	Well-being studies; Welfare economics
Policy rationale and role of State	Correct market failures	Correct system failures	Foster variety creation; Manage selection mechanisms	Foster individuals' well-being and enhance social welfare
Objectives	Increase size of R&D sector	Strengthen interactions among economic agents	Market-creating and market-shaping to solve grand challenges	Support development of innovations that enhance well-being and social welfare; hamper and regulate those that do not
Typical instruments	R&D fiscal incentives; IPRs regulations	University-industry links; Cluster policies	Public procurement	Instruments must target technologies differently, depending on their welfare effects
Potential drawbacks	Simple utilitarian framework that neglects non-economic and distributional impacts	Lack of social welfare analysis. It neglects interaction costs	Non-market failures. Paternalism. It neglects opportunity costs	Multi-dimensionality and multiple trade-offs. Hard to derive simple analytical models and specific policy rules

6. Conclusions

Innovation research and innovation policy are motivated by the assumption that technological and organizational changes are fundamental to address major societal challenges and thus improve human welfare. However, extant research in the Schumpeterian tradition has until now not provided an extensive and thorough analysis of the multiple channels through which innovations affects social welfare. Specifically, this paper has shown that innovation research presents two major challenges. One is that it has until now adopted a rather narrow notion of individual well-being, which emphasizes economic aspects and material wealth but disregards other important non-economic dimensions, which well-being research has convincingly shown to be crucial to foster the capabilities and quality of life of human beings. The second major challenge is that extant research typically focuses on the net overall effects of innovation on economic performance (e.g. GDP, productivity, competitiveness, employment), and it does not take into adequate consideration the important distributional consequences that it may have, affecting individuals, firms and social groups differently.

Motivated by this twin gap, the paper has outlined a new research agenda to study the impacts of innovation on social welfare. The new research program intends to broaden up this theme by developing two major pillars. The first pillar argues that innovation studies should adopt a broader notion of well-being, which considers both economic and non-economic dimensions that are relevant in individuals' different life domains. This new research calls for a cross-fertilization between innovation studies and well-being research, since the latter has for several decades already provided relevant knowledge on objective and subjective dimensions of well-being, and the large set of factors that shape these. Adopting a broader notion of agents' well-being opens up several new questions and opportunities for future research, which we have pointed out in section 4.1, as well as relevant implications for innovation policy, which we have noted in section 5. Overall, the major point of this first pillar is to emphasize that different technological trajectories and different innovations have substantially distinct effects on individuals' well-being, and the study of these technology-specific impacts should be a cornerstone of future research and innovation policy.

The second pillar of this new research agenda posits that it is paramount to take into explicit consideration the distributional impacts of innovation, and therefore to adopt a theory of social welfare that combines efficiency and equity considerations within the same framework. This is a traditional theme of research in welfare economics, and the paper has argued that innovation research should make more systematic use of theories and analytical tools

previously developed in this field of research. Specifically, section 4.2 has argued that the use of social welfare functions that reflect inequality aversion may represent a fruitful way forward in order to develop this future research.

By outlining this new research agenda and its major pillars, the main contribution of this paper is to raise a variety of new research questions that should be investigated in future research. One could envisage a broad set of research lines and different approaches that may develop this agenda in the coming years. Specifically, theoretical research may develop conceptual frameworks and typologies investigating how different types of innovation affect individual well-being, and how this affects the welfare and relative position of different social groups. Modelling research could develop these questions by studying analytically the links between micro-level well-being and aggregate social welfare, using social welfare functions to point out the implications of different theories of welfare and different views of social justice. Further, empirical analysis could exploit the availability of large datasets that provide rich information on individuals' well-being and their determinants for a large number of countries in the world and for a long period of time, which are publicly available both as pooled cross-sections for comparative cross-country analysis and as panels for individual countries (for an overview of available survey data sources on well-being, see Kahneman and Krueger, 2006; MacKerron, 2012). Linking these available data sources with data on innovation (e.g. supply side innovation and capabilities; and/or demand-side use of new technologies) will provide relevant opportunities to empirically investigate the relationships between different types of innovation, on the one hand, and well-being and social welfare, on the other (Castellacci and Tveito, 2018). The paper has also pointed out that this new research agenda will open up interesting and relevant questions for policy. Considering equity alongside efficiency means that there will be complex trade-offs between these two dimensions, both in a static set up and in dynamic terms. These trade-offs do not only necessitate analytical tools and research, but they also call for a broader policy and societal debate on the ethical and political views that underlie policy choices, and hence the theory of social justice that a given innovation theory and policy strategy is based upon.

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