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# Unseen costs: the inequities of the geography of innovation

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## Abstract

Notwithstanding the wide consensus around the undeniable positive effects of innovation, there is increasing awareness that innovations may also have their dark sides. These dark sides of innovations have received little attention in regional studies. This editorial to a special issue on The Dark Side of Innovation and its Geography argues there are clear geographical footprints to this, which are related to both the inputs and the outcomes of innovation processes. In particular, we discuss how innovation activities have geographically uneven outcomes, driving spatial inequality, and how they require material inputs located in certain places, meaning that their costs are also unevenly distributed across space.

**Keywords:** dark side of innovation, harmful innovations, critical and conflict materials, regional inequality, geography of innovation

**JEL codes:** O25, O30, O31, O33, Q34, Q55, R11

## **1. Introduction**

Economic geographers have long had a keen interest in studying innovation, viewing it as the main driver of regional economic growth and development (Audretsch and Feldman 1996; Asheim and Gertler 2005). However, economic geography and regional studies literatures have almost exclusively focused on the positive effects of new technologies, and on their contributions to solving grand societal challenges across geographical scales. Technological innovation boosts firms' productivity, industries' international competitiveness, digital and green transitions, and the overall economic performance of national and local economic systems. The opening up of regions to external networks and the strengthening of their technological and innovative capabilities have largely been the mantras of most such literature and related policy recommendations. This research has also constituted the foundation for R&D and innovation policies, whose underlying rationale has so far predominantly been to foster the creation and diffusion of innovation. Over the past few decades, a gigantic wave of scholarly investigation has vivisected the topic of economic growth and regional development, focusing on what is most needed: first and above all, more innovation, but also more entrepreneurs, spin offs, venture capitalists, global knowledge networks and value chains, skills and capabilities, markets, talents and training, multinational enterprises, related and unrelated variety, complexity, etc.

Notwithstanding the wide consensus around the undeniable positive effects of innovation, this research agenda has suffered from two fundamental limitations. First, it has generally left undisputed the idea that innovation and economic growth underlie greater wellbeing and prosperity, stronger institutions and more peaceful societies. Second, it does not consider the distribution of costs and benefits across different stakeholders of the pursuit of innovation by businesses and other organizations. Indeed, costs and benefits of technological paradigm shifts,

currently represented by the digital and green transitions, are highly unevenly distributed. Together with the connected modularity and separability of production stages in global production networks and value chains led by huge and powerful multinational enterprises (MNEs), technological change is seemingly strengthening inequality between the Global North and the Global South, across countries and regions in both parts of the world, and even within subnational regions, cities and rural areas. Additionally, most research considers innovation in terms of proximity to the technological frontier and as being related to the capacity of firms to patent new discoveries, assuming that such discoveries are by default a good thing to have. Extant research rarely considers the negative impacts that the generation, use and spread of innovations can have on people, society and the environment.

Innovation has always had a 'dark side'. This is a core topic in long-standing fields of research around science, technology and innovation, ethics, and responsible research, and is increasingly emphasised in some recent contributions to innovation studies (e.g. Biggi and Giuliani 2022; Coad et al. 2022; Gonzalez-Roma and Hernandez 2018). However, these dark sides have largely been ignored in economic geography and regional studies. Meanwhile, research in other fields has rarely considered the geographical, and in particular the regional, dimensions of the drawbacks of innovation (Fitjar et al. 2019). Yet, there are clear geographical footprints to the dark side of innovation, which are related to both the inputs and the outcomes of innovation processes.

It is not difficult to think of innovations that have mixed, contested or even outright negative impacts. Consider contested technologies of such diverse types as DDT, asbestos, glyphosate, petrol cars, junk food and social media. While each has brought sufficient value to be widely adopted in its time, research has also shown their detrimental impacts on human health, on social behaviour, human rights and equity, and on the natural environment (Coad et al. 2021) – costs

which in many cases far outweigh the benefits of these innovations. These negative effects have a global scale, but often affect specific regions more than others, depending on their geographies of production and consumption.

The spread of harmful innovations is not an historical accident occurring sporadically and only in the context of insufficient knowledge and regulatory imperfections. It is instead increasingly regarded as a normal feature of the functioning of contemporary capitalism (Giuliani 2018), characterized by pervasive market failures. Nelson and Winter (1982) described innovation as a “process of change [...] continually tossing up new [negative] “externalities” that must be dealt with in some manner or other” (p. 389). For this reason, it is often the case that innovations have positive effects for some, and negative effects for others. In a geographical perspective, neither all technologies that generate economic value for firms, nor all innovations that allow societal progress, are necessarily good and useful for people and places everywhere in the world, at the macro-regional, national and subnational levels. The one-sided perspective on innovation as an input to regional growth has tended to forget that innovative efforts respond to firms’ profit-maximising objectives which do not automatically align with the social good and sustainable development goals of territories.

This paper, and those to follow in the Special Issue, discusses the geography of the negative externalities of innovation. We broadly consider the discrepancies between private and social benefits and costs involved in knowledge creation and diffusion across space. We discuss how innovation activities have geographically uneven outcomes, driving spatial inequality, and how they require material inputs located in certain places, meaning that their costs are also unevenly distributed across space. We organise the discussion to follow along these two main topics, starting with the relationship between innovation and territorial inequality, before delving into the geography of critical raw materials essential for today’s most pressing innovation activities.

We aim at opening up questions about the legitimacy of the way in which economic geographers look at innovation processes and outcomes. Such drawbacks are not minor issues but call for a novel research agenda that forcefully takes them into account along with economic goals. This Special Issue on “The Dark Side of Innovation and its Geography” gathers contributions presenting a variety of perspectives and cases on the topic. Together – and inviting further research with geographical lenses – we hope to stimulate a debate and set the basis for an ongoing conversation on the future relationship between innovation and regional economic development.

## **2. Innovation and territorial inequality**

The discussion about the dark side of innovation is not new. Schumpeter (1942) already argued that innovation has positive but also negative sides, and that the two are inextricably intertwined, a process which he dubbed creative destruction. A classic, well-documented example is the Luddite movement of cotton workers in Nottinghamshire that protested against the mechanization of textiles in the early 19th century (Sale 1996). A current example is the impact of automation and AI, with its labour-displacing effects resulting in the disappearance of certain types of occupations (Autor 2015; Acemoglu and Restrepo 2019; Bessen et al. 2019). Some regions have high shares of jobs ‘under threat’ or jobs whose tasks will change (Muro et al. 2019; Felten et al. 2021). Consequently, the overall net effect of AI on jobs might be negative for some regions and positive for others (Zhang et al. 2024).

The potentially destructive forces of innovation on our entire economic system can be well illustrated by the example of financial innovations that contributed, among other factors, to the financial crisis of 2007-2008 (Vives 2010; Ülgen 2014). New financial products in derivatives and securitization had been introduced into the market, facilitated by a lax monetary policy and

financial market deregulation preceding the crisis. These innovations led to bubbles in the housing and credit-supply markets that eventually burst. The crisis had major economic and social implications for many regions, leading to unprecedented levels of unemployment (Martin 2011). Dörry (2022) in this Special Issue discusses the dark sides of financial innovations in major financial centres and the economic and social inequalities they generate.

The dark side of innovation is clearly visible when looking at intra-regional inequality. The most innovative cities in the US are also often the most unequal ones (Florida 2006). The recent experience of Silicon Valley as the most innovative hub in the world is telling. Its unprecedented innovative success – mostly accruing to a few giant firms, the Big Tech – has been accompanied by a sharp increase in intra-regional inequality, with a crowding out of low-income people due to a lack of affordable housing (Gyourko et al. 2013), as well as interregional inequality, with the network-based and platform monopoly of the Big Tech draining resources from other US regions (Feldman et al. 2021; Ioramashvili et al. 2024). For European regions, studies have also found a positive relationship between innovation and wage inequality (Lee 2011; Lee and Rodríguez-Pose 2013). This is part of a tendency of increasing labor market polarization in large cities where high-wage workers benefit from technological progress and increase the demand for local services, resulting in employment growth in low-wage jobs (Moretti 2010; Lee and Clarke 2019), while new technologies hollow-out the middle segments of the labor market (Goos et al. 2014). The result is that large cities hosting highly complex activities, such as New York and San Francisco, show high and growing wage inequalities (Marco et al. 2022). The positive relationship between complexity and intra-urban inequality may be attributed to the co-existence of low and high complex activities in large cities, with relatively few job opportunities for middle-income people (Hartman and Pinheiro 2022).

Innovation also reveals its dark side when we examine its effects on inter-regional inequality. Many innovations, as measured by patents, are developed in core urban regions where high-quality research infrastructure, highly skilled people and knowledge diversity are heavily concentrated. This results in the local accumulation of capabilities in a process which is cumulative, self-reinforcing and does not diffuse easily across space (Antonelli 2000; Boschma 2004), especially when it concerns complex technologies (Balland and Rigby 2017). There is a super-linear relationship between patent and urban size (O’Huallichain 1999; O’Huallichain and Leslie 2005; Bettencourt et al. 2007a; Bettencourt et al. 2007b), especially in a-typical (Mewes 2019) and complex technologies (Balland et al. 2020). This implies that innovation may reinforce, rather than weaken, centre-periphery structures. The paper of Wirkierman et al. (2024) in this Special Issue confirms this uneven geographical pattern when examining the role of trade and technological relations between regions in Europe. The study observes a fractal structure of regional employment inequalities that is characterized by a centre-periphery structure between four trade blocks as well as inside each trade block in Europe.

This regional imbalance is not restricted to high-tech industries only but includes all kinds of activities. This is confirmed by another measure of innovation than patents: the ability of regions to diversify into new activities, such as industries or occupations. This topic has been taken up in this Special Issue by Pinheiro et al. (2022). From studies on regional diversification, it is well-known that regions tend to diversify into new activities that are related to existing ones in the region, following the principle of relatedness (Boschma 2017; Hidalgo et al. 2018). The contribution of Pinheiro et al. (2022) shows that this process of related diversification occurs in both high-income and low-income regions. However, high-income regions tend to diversify into more complex activities, while low-income regions tend to move into less complex activities. High-income regions also have the highest potential to continue to enter into more complex technologies and industries in the years to come, given their strong local capabilities. This is likely

to contribute to the widening of income disparities between regions, because complex activities on average pay higher wages and bring higher economic benefits to regions in terms of GDP growth (Rigby et al. 2022). This is a wicked problem for policy in the EU: the strategies to improve the innovativeness of Europe as a whole to compete globally might disproportionately benefit the more developed regions and foster inter-regional disparities.

Kemeny et al. (2022) in this Special Issue looks at the distributional implications of the emergence of disruptive technological breakthroughs. Such breakthroughs are considered one of the key drivers of long-term economic growth (Esposito 2023; Steijn et al. 2023) and may have the potential to destabilize centre-periphery structures and transform the geographical landscape of innovation (Hall and Preston 1988; Perez and Soete 1988; Boschma 2021). Analysing patents over two Industrial Revolutions in the US, they observe that disruptive technologies concentrate heavily in space. Their emergence is accompanied by increasing spatial income inequality, and technological leadership has shifted across Industrial Revolutions.

This concentration of innovation in large cities and core areas is often seen as a more or less natural trend, following automatically from the consolidation of the knowledge economy. Yet, as an emerging literature is pointing out, these trends are not equally present in all countries or for all technologies (Fritsch and Wyrwich 2021; Broekel et al. 2023). Some peripheral regions are able to compensate for the lack of local buzz with more external networking (Fitjar and Rodríguez-Pose 2011; Grillitsch and Nilsson 2015), tranquillity (Gong and Xin 2019), more multiplex interactions (Meili and Shearmur 2019) and complementary inter-regional linkages (Balland and Boschma 2021). From some perspectives, the periphery may even offer opportunities that core regions do not have (Glückler et al. 2023). Less developed regions in the EU have more opportunities to contribute to green technologies and innovation than more

developed regions in the EU (Bachtrögler-Unger et al. 2023). The idea that innovation mainly happens in cities may then to some extent be a function of the concentration of identification, marketing and promotion of innovation in urban areas (Shearmur 2012), and of core regions' specialisation in certain highly attractive and profitable technologies.

The role of policy in bringing about or preventing the dark side of innovation should therefore not be ignored. As Lee (2023) in this Special Issue highlights, policy-makers sometimes conceptualise innovation as being mainly about STEM, R&D and high-tech. This leads them to search for competitiveness by establishing the Silicon Somewheres (Hospers 2006) in which these sectors thrive. In this approach, innovation policy should mainly foster industries which can attain globally leading positions within current technological paradigms: the result is that innovation policy tends to channel resources particularly towards core regions. This pattern is not exclusive to competitiveness-oriented innovation policy. It also affects mission-oriented innovation policies, which may also concentrate resources in communities that have the greatest potential to contribute towards the missions (Cappellano et al. 2023). Hence, rather than evening out the differences created by the market, government interventions may come to reinforce them.

One reason for these centralising tendencies is the Matthew effect (Merton 1968) inherent to innovation policy, whereby the initial leaders extend their advantage through self-reinforcing mechanisms. This is a well-known phenomenon in science and innovation, affecting citations, project funding, among other things (e.g., Bol et al. 2018). Matthew effects are reinforced by the increasing emphasis on excellence in the research policies of many countries (Langfeldt et al. 2015). Besides being relevant at the individual and organisational level, this also has implications for the geography of the distribution of research and innovation funding. Cities and regions that are endowed with leading research universities receiving more government base funding will be

able to invest in facilities and in top researchers. Subsequently, this puts them in a better position to win grants through competitive funding schemes.

To escape this dark side of innovation, there is a need to broaden the perspective on what innovation policy is for (Lee 2024). We need to go from a narrow focus on the development of innovation to a broader perspective on how to ensure its diffusion, contrasting its adverse externalities, and paying attention also to the demand side of innovation (Coenen et al. 2015). Lee (2023) in this Special Issue examines inclusive innovation as a new policy approach which aims to widen participation and share the benefits of innovation. Yet, when implemented in practice, such policies are often ineffective, suffering from the same fixation on technology as traditional innovation policy. Conversely, there is also a need to examine more closely how some of today's innovations, e.g. in the finance industry, channel innovation towards a small number of places. Dörry (2022) in this Special Issue shows how innovation in the asset management industry manipulates the global geography of profits from production.

This also involves a broader understanding of which industries can deliver innovation and of the different forms which innovation itself can take. Paying attention to innovation in low-tech industries and in resource-based ones and understanding how to use the assets that more peripheral regions can offer is essential for developing an innovation policy that can support the development of opportunities in all regions.

### **3. An example of policies for the green transition: the race for critical raw materials and its regional footprints**

The debate on critical raw materials (CRMs) – i.e. rare metals such as Cobalt, Lithium and Tantalum, or rare earth elements – is nowadays becoming increasingly hot, given their irreplaceable role in providing a material infrastructure to emerging technologies and industries

(e.g. in this Special Issue Diemer et al. 2022; Li et al. 2024). Green and digital technological transitions have put CRMs at the centre of the global resource competition: their availability, use and supply chain dynamics are shaping public and scholarly discussions on the economic futures of countries and regions.

The material infrastructure of technological change is by no means a new phenomenon. Innovations are first and foremost based on new combinations of “materials and forces” (Schumpeter 1934). Especially after the emergence of Material Science in the 20<sup>th</sup> century, technological development in a variety of fields has shown growing dependence on natural input materials, with paradigm shifts always closely related to change of materials, appearance of new ones, as well as new uses for those existing and the disappearance of those outdated and/or proven harmful (e.g. Dosi 1982; 1988; Dosi and Nelson 2010). Seminal work in economic growth theory has considered the interplay between technological change, availability of natural resources and economic growth (e.g. Solow 1974; Stiglitz 1974; Barbier 1999; Bretschger 2005; Acemoglu et al. 2012). In general, existing economics and innovation research provides important insights into the co-evolution of natural resource supply and technological change. However, most such studies rest on two strong assumptions: the first is that of substitutability between capital and resources or between different inputs, implying that the shortage of natural inputs stimulates the generation of new technologies that make more intensive use of abundant resources as substitutes for scarce ones. Thus, technological innovation can solve, or at least improve, issues related to resource scarcity, enabling society to overcome resource supply constraints and achieve sustainable development. The second assumption is that the specific features of natural resource inputs such as materials are homogenous, and that such materials are generally available across space in an open world economy. Thus, growth models typically treat them as standard and a-specific production inputs freely accessible across countries and regions.

Clearly, this overall ‘technology optimistic’ perspective on natural resources is unable to consider the idea of criticality, which makes some materials indispensable for achieving certain technological functions, especially in frontier applications such as those in the current green transition (Grandell et al. 2016; Li and Iammarino 2024). Hence, contemporary technologies and industries face often very limited options to circumvent CRM criticality, as for most of these materials “no suitable substitutes can be found no matter what price is offered without performance and function being seriously compromised” (Graedel et al. 2015, p. 6299). On the one hand, technology optimistic views overlook the endogeneity of technological change to the natural environment: innovation itself may be adversely influenced by material and resource supply conditions, slowing down the green and renewable energy transition and causing environmental bottlenecks of a global nature. On the other hand, the optimistic perspective is non-specific and a-geographical, assuming that the distribution of CRMs – highly heterogenous in their technological criticality – is evenly distributed or equally accessible across locations. In reality, private and social benefits and costs of the green transition have a highly situated nature (e.g. in this Special Issue, Barbieri et al. 2023; De Marchi 2024).

Studies on CRMs across disciplines have developed rapidly in recent years. The current literature, however, is mainly conducted at the global, national, or sectoral level, focusing on metal mining, demand prediction, trade networks and material flow analysis, as well as supply risk assessment. Research on regional growth and development has instead almost entirely focused on the role of intangibles; physical materials, although constituting the basic building blocks of transition technologies as well as the primary constituents of renewable energy products, have been overlooked.

Why does all this matter for subnational regions in Europe and elsewhere? The European Union is speeding up towards the target of climate neutrality by 2050, and CRMs provide a vital material

basis for this shift. Recently, the issue of CRM supply risks – due to mineral scarcity, geographical concentration of deposits, political instability of producing regions, geopolitical risks and conflicts affecting global trade and investments, low material substitutability and recycling rates, and also potential pandemic and natural disasters – has made clear that the geography of such value chains matters (in this Special Issue, Diemer et al. 2022), prompting policy actions for ensuring a more stable supply through domestic production. The EU Critical Raw Materials Act (EC 2023), in line with the European Green Deal and part of the wider EU Open Strategic Autonomy, is intended to make the EU more competitive and autonomous by promoting innovation along the entire value chain, upstream from CRM extraction and processing to renewable energy products, to new technologies on alternative materials and recycling, enhancing European supply according to environmentally-friendly mining and production methods.<sup>1</sup> However, the EU remains highly vulnerable: the effort is to reach a target of at least 10% autonomy from imports, particularly from China, Russia and a number of developing economies where many of such natural resources are abundant.

Private costs are the costs related to firms' decisions based on market prices: business companies are central actors upstream, in the mining, processing and organisation of CRM supply chains, and downstream, in the industrial and technological use of CRMs; profits are the benefits for such companies, mostly large MNEs at both ends of the chain. The socio-economic costs of the regions and their people are also at both ends of the value chain, which shows a multilayered geography. On the supply side, CRM producing regions and their communities – many in the Global South, but some also in Europe, mostly in its periphery – have to face serious environmental and social consequences of mineral exploitation and extraction. Whilst the EU regions involved may be able

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<sup>1</sup> <https://www.europarl.europa.eu/news/en/press-room/20231208IPR15763/critical-raw-materials-plans-to-secure-the-eu-s-supply>

– with the help of place-specific innovation policies – to partly balance such costs by developing capabilities in high value functions, regions in poor countries such as, for example, the DRC Copperbelt in the Lualaba and Katanga provinces see their precious geological resources failing to catalyse local economic development, MNE profits going abroad, benefits accruing to restricted national elites, and additional negative impacts in the form of conflicts and serious violations of human rights (e.g. Diemer et al. 2022; Hilson et al. 2023). In the advanced nations, costs might be also compensated by the demand side: emerging industries requiring CRMs – for instance, core renewable energy sectors such as wind and solar energy products – are highly concentrated in a few EU regional innovation systems, where new technological trajectories are developing to ensure the green transition and achieve higher degrees of substitution and recycling of CRMs. This, however, tends to intensify the territorial concentration of wealth in the EU, as discussed in Section 2 above or in Barbieri et al. (2023) in this Special Issue.

Yet, the wedge between benefits and costs, private and social, is complex to calculate precisely for its multilayer geography across the macro-areas of Global North and South. Environmental issues are global in nature but have highly local – regional – manifestations in relation to all dimensions that the green transition entails (Barbieri et al. 2023). Benefits in terms of firms' growth and profits are not necessarily offsetting negative impacts such as, for example, environmental damages of extracting materials from the deep sea either in the Mediterranean or along the Atlantic southern coast of Namibia (e.g. Wiedicke et al. 2015; Randazzo et al. 2023). In Europe, the growing push from research and policy circles towards de-risking CRM supply chains through diversification of sources and increase of CRM domestic production cannot avoid looking more in depth to the subnational level: the Open Strategic Autonomy can be seen as a macro industrial policy with no regional focus but highly localized impacts at both ends – upstream and downstream – of the value chain.

Analysing such CRM-based value chains in their entirety across and beyond the EU territory is paramount to find new modes to build interregional cooperation and linkages among EU, often peripheral, mining regions, between them and EU regional centres of excellence for technological progress and advanced manufacturing, and crucially, between all EU regions involved and other regions in developing parts of the world where untapped reserves of many of these crucial natural resources are located. This is essential for leveraging opportunities for local and regional economic development during a costly transition, on the one hand providing a sounder knowledge base to inform strategies for mitigating supply risks, on the other ensuring truly fair and equitable exchange and partnership with less developed CRM-rich regions, starting with sub-Saharan Africa, that have been systematically ignored in the distribution of the benefits of technological shifts (Hilson 2016).

#### **4. Conclusions**

In this article, we have revamped an old discussion on the possible dark sides of technological innovation. While pioneering contributions in innovation studies pointed to negative effects of innovation on inequality and labour (Schumpeter 1942; Freeman et al. 1982) and also hinted at the pollution-related externalities tossed up continuously by innovative processes (Nelson and Winter 1982), this critical area of research has for some time remained in the shadow in favour of a more optimistic account of innovation impacts on societal well-being.

However, the emergence of new policy-relevant sustainability goals – including the need to reduce within-country inequalities, address political discontent, combat climate change and pollution – has crafted a new space for debating and exploring the role that innovation plays in meeting these goals. While, again, a significant body of research is now looking at innovation as a technological fix for the many sustainability challenges – consistent with the rising body of

evidence on green, inclusive or otherwise defined social innovations, we suggest here that scholars should be equally interested in critically assessing the consequences of regular innovations for society and the natural environment, and how they affect regions differently. Investigating the dark sides of innovation means to study its unintended and negative consequences, alongside its positive effects. In regional studies, the spatial dimensions of these consequences are of particular interest.

This Special Issue includes contributions that add a geographical perspective to the discussion on the dark side of innovation by exploring the regional distribution of the benefits of innovation and of its costs. On the one hand, we highlight the effects of the polarization of regional innovation in core regions on increasing spatial inequalities. On the other, we explore the concentration of the costs of innovation in some peripheral regions of the world, North and South. Here, as an example, we stress the need to reframe sustainability transitions policies in light of the manifest dependency of green technologies on CRM-providing regions, where extraction of critical natural resources is known to occur below acceptable Western human rights and environmental standards. While these two areas of inquiry are significant and complex enough to call for more research in the future, we would also recommend other potential areas of interest that this Special Issue has not been able to cover but that certainly deserve closer scrutiny.

One possible area of interest is the geography of substitution between clean and dark (or dirty) innovations. As evidence suggests that dirty innovations are path dependent (Aghion et al. 2016; Acemoglu et al. 2012), questions arise about how long it will take for cleaner innovations to supplant dirty ones and whether there is a geography of innovation that differently characterizes dirty and green innovations. These questions are even more relevant considering the EU Green Deal oath to “do no harm” and its zero-pollution ambitions, as one important side of reducing pollution is through the phasing out of dirty innovations used in the market. To date, there is very

limited knowledge about the geography of dirty inventions and whether and how the regions that are leaders in these technologies are also becoming leaders in their cleaner substitutes. Nor do we know, in the current multi-polar world, whether regions specializing in dirty technologies – both in invention and production – are different from those specializing in cleaner alternatives – as sometimes the knowledge base is radically different.

A related area of inquiry is around the link between pollution and innovation. Research in environmental studies has already started to assess whether air pollution decreases regional innovation through the crowding-out of skilled human resources moving to safer regions (Wang et al. 2024). Other studies look at the extent to which greener innovations emerge out of the most polluting organizational or spatial contexts (Li et al. 2022; Wang et al. 2022). As pollution is certainly one of the key sustainability challenges of our times and given the geographical concentration of pollution in toxic hotspots – locations where toxic emissions from production plants or other primary activities may expose local populations to elevated health risks – research providing evidence of its link to innovation is worth pursuing. Toxic hotspots are, in fact, a manifestation of the dark side of past industrial innovations (Shapiro and Zingales 2017) and their legacy and impacts on local communities is relevant to regional policy.

Overall, we call for new theoretical and empirical research in innovation studies, taking into account both positive and negative socio-economic effects of innovation across space, its bright and dark sides in different places, and developing new conceptual and methodological tools to study, compare and assess multidimensional and contrasting effects of innovations in a broader interdisciplinary framework. This new departure will entail an in-depth discussion of how to capture the balance of the effects of innovation at the regional level, how to measure them, and how to assess their benefits and costs according to different social welfare functions and institutional settings.

These issues do have important implications in terms of R&D and innovation, and more generally economic development policy. Since innovations and technologies have complex and multi-dimensional effects – positive and negative, economic and non-economic, at different levels of geography – how can policy-makers assess and define whether a given innovation process should be given public support, or instead regulated and limited? The multi-dimensional and complex nature of innovation processes and their spatially uneven footprints present policy-makers with a variety of trade-offs and complex choice sets, which call for a continuous development of new conceptual and methodological tools.

To be sure, we do not mean to build a “silo-type” conversation where social, environmental and human rights issues are seen as hyper-specialized side topics of no interest to innovation studies, economics, international business or economic geography and regional studies. Rather, we want to promote a discussion where considerations about regional economic development (and growth) are balanced with innovation-related side effects, bright and dark, across the regions in the Global North and South of the world.

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