Climate (of) change: the promise and perils of technology in achieving a just transition

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Abstract

Purpose – The paper aims to contribute to the broader literature on just transition by examining the intersection of technology and justice, and identifying opportunities for bridging the gap between theory and practice. The work seeks to emphasize the importance of transformative change, which ensures that no individual, community or sector is left behind in the transition towards a sustainable future, both on a global and local scale.

Design/methodology/approach – The paper explores the potential for linking justice to the ongoing technological transition, focusing on its impacts on climate and sustainability. Drawing on various sociological, environmental and technological studies, this work examines the intersections between justice and technological change. Through a qualitative analysis of case studies and a review of literature, the article offers insights and recommendations for policymakers, practitioners and scholars involved in the pursuit of a sustainable and equitable future.

Findings – The paper concludes that balancing environmental, social and economic goals is necessary on a large scale within the framework of a "just transition", in order to ensure that no individual, community or sector is left behind in the path to a sustainable future. This involves reflecting on sensitive issues such as competition, intellectual property, market openness, liability and fighting against inequalities. Additionally, it requires considering smart and welfare policies from a multilevel perspective.

Originality/value – The originality of this work lies in its contribution to advancing the understanding of the limitations of a technology-centric approach to climate action and the need for systemic changes. The paper emphasizes the importance of addressing social equity, policy reform and collective action in conjunction with technological transition to achieve a sustainable future. It highlights the risks of overlooking the systemic drivers of the climate crisis, such as unsustainable consumption patterns and reliance on fossil fuels, while pursuing technological solutions. Furthermore, the work emphasizes the relevance of the Sustainable Development Goals of Agenda 2030 in guiding a just transition towards sustainability.

Keywords Sustainable development, Communication technologies, Social inequality, Social change, Green economics, Climate change, Just transition, Social justice

Paper type Research paper

1. Introduction

Climate change is one of the most pressing global challenges of our time, threatening not only the natural environment, but also the lives of millions of people and the economies of many societies (Beck, 1998; Giddens, 2009; Latour, 2018; Urry, 2011). As the scientific consensus on climate change has solidified, there has been a growing recognition of the need for systemic change to address the root causes of the crisis. The plurality of concerns, the heterogeneity of

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critical aspects and the multiplicity of situations and dimensions closely related to climate change and its consequences clearly indicate that the topic requires analysis from a broader perspective. The current transition must aim for greener economies and societies without exacerbating inequalities among individuals, social groups or territories and without creating new forms of discrimination.

To ensure a sustainable future, ecological transition must aspire to be aimed at justice, being equitable for all, especially territories, economies and people who are most vulnerable to the impacts of climate change (Billi *et al.*, 2022; Galgóczi, 2020; Monaco, 2022; Yan, 2021). From a sociological perspective, justice is concerned with the fair distribution of resources, opportunities and benefits within a society. It involves a process of assessing how social, economic and political systems operate to create and distribute advantages and disadvantages among individuals and groups (Rawls, 1971; Sen, 1992; Young, 1990). In order to determine the extent to which justice is being achieved or threatened in a society, sociologists consider a variety of methods and dimensions, such as economic inequality, political power, social inclusion and cultural identity, among others (Fraser, 1995; Sen, 2009).

While the concept of the ecological transition has been a topic of discussion in the climate policy arena for some time, the specific role of technology in this process has gained increasing attention in recent years. With the need to transition away from fossil fuels and reduce greenhouse gas emissions, there is a pressing need to develop and implement new technologies that can facilitate this ecological transition in a way that is both environmentally, economically and socially sustainable.

Through a qualitative analysis of case studies and sociological, environmental and technological literature, the present paper focuses on the potential of new technologies to foster sustainability and the risks inherent in their use, and explores how the concepts of ecological modernization and environmental justice can be used to frame the relationship between technology and the ongoing transition. The paper analyzes the ways in which social, economic and political systems operate to create and distribute advantages and disadvantages among individuals and groups, and how technology can either exacerbate or mitigate these disparities. The paper concludes by emphasizing the need to balance environmental, social and economic goals on a large scale within the framework of the "just transition", advancing reflections on sensitive issues at the intersection of topics such as competition, intellectual property, market openness, liability, the fight against inequalities, and welfare policies and multilevel perspectives.

2. Understanding the climate crisis: a comprehensive overview

CO_2 emissions represent the main driver of climate change, leading to devastating impacts for the planet, such as floods, droughts, storms and heat waves. Other negative consequences include sea level rise, altered crop growth and disrupted water systems (Elahi *et al.*, 2022; Sauer *et al.*, 2016; Tehrani *et al.*, 2021).

Over the past 20 years, global carbon dioxide emissions have grown by more than 12%, while CO_2 levels have increased by more than 60% since 1992 (Peters *et al.*, 2020). The Intergovernmental Panel on Climate Change (IPCC) revised its target for limiting global warming from 2° to 1.5° in its 2018 report, aligning with the commitments made in the 2015 Paris Agreement (IPCC, 2018). Achieving this target requires keeping carbon levels below 430 parts per million. However, in 2016, emissions had already reached 400 ppm and have since increased to 414 ppm in 2021, leaving the 430 ppm threshold predicted to be reached around 2032 (Vitillo *et al.*, 2022).

To address the challenge of reducing emissions, countries have submitted nationally determined contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC) as part of their commitment under the Paris Agreement. NDCs are

emissions reduction targets and strategies determined at the national level and vary depending on a country's circumstances, capabilities and priorities. In addition to mitigation measures to reduce greenhouse gas emissions, the NDCs also include adaptation measures to cope with the impacts of climate change. Moreover, some NDCs include measures to remove excess carbon from the atmosphere, reflecting the growing recognition that reducing future emissions alone will not be sufficient to achieve net-zero goals.

Climate change is closely related to societies' economic systems and, more broadly, to human health and well-being. Desertification has had devastating effects on several regions, leading to the loss of livelihoods and exacerbating famine and hunger. For example, African communities are among the most vulnerable to the impacts of climate change (Freeman, 2017). Despite contributing very little to the increase in global carbon emissions, millions of people in Africa have been forced to abandon their homes and livelihoods due to the effects of desertification, leading to widespread poverty.

In recent years, increases in respiratory diseases, stress, mood swings and aggravations of nervous system disorders have been attributable, in large part, to climate anomalies too (IPCC, 2022). A number of recent studies have focused on the mental health impacts of climate change (Bourque and Cunsolo, 2014; Hayes *et al.*, 2018; Salamon, 2020), indicating that concerns about the ecological crisis are causing new forms of anxiety and distress in Western countries, which can be classified as "eco-anxiety" and "climate anxiety" (Kurth and Pihkala, 2022; Ray, 2020). However, these concerns should be considered in perspective, taking into account the more immediate existential threats faced by many people in the third world. While acknowledging that climate anxiety represents a form of first-world problem which may overshadow the immediate survival challenges of marginalized communities, from a sociological perspective, this phenomenon can be understood as a response to the social, political and cultural dimensions of the climate crisis. Sociologists view climate anxiety not only as a psychological response to environmental stressors, but also as a reflection of broader social and cultural anxieties about the future of society and the planet (Brulle, 2014).

In this context, several countries have committed to achieving a net zero carbon world (Deutch, 2020; Seto *et al.*, 2021) by reducing global CO_2 emissions to zero by 2050, as outlined by the COP26 climate agreements and reaffirmed during COP27 in Egypt in 2022. However, some researchers have raised concerns that many countries will not be able to fulfill their commitments (Diesendorf, 2022; Yuan *et al.*, 2022), and even if they do, it may only result in a reduction of global warming between 2 and 3°. Despite these challenges, most policy agendas have already considered various strategies for improving energy efficiency and promoting the transition to alternative sources of low-carbon energy (Hassan *et al.*, 2022; Gullberg *et al.*, 2014). At the same time, some countries are making efforts to improve collection, refrigeration, transportation and packaging techniques in supply chains and to encourage zero waste through social education policies (Leal Filho and Hemstock, 2019). In soil management and use new approaches are also being explored, such as restoring large green areas to increase soil carbon uptake and discouraging the use of fertilizers, replacing carbon-intensive products with those that have lower carbon footprints (Ángeles Muñoz and Zornoza, 2017; Montanarella and Panagos, 2021). Efforts to reduce emissions in soil management and use run into obstacles. The European Union's proposed net-zero emissions plan, for example, requires European forests to double their CO_2 absorption capacity by 2050. At the same time European forests are aging, and their effectiveness in absorbing carbon dioxide is decreasing (Vizzarri *et al.*, 2021).

Although the climate crisis has a prominent media profile in the contemporary era, Sociology has long offered important insights, for example the concept of "ecological modernization" was first explored in the 1980 and 1990s in response to growing concerns about environmental degradation and the limitations of traditional approaches to environmental management. This theory proposes that economic growth and environmental

protection are not necessarily conflicting goals, and that technological innovation can be used to achieve both (Beck, 1995; Dryzek, 1997; Mol, 1996). Ecological modernization stresses the need for policy and institutional changes to support the development and diffusion of environmentally friendly technologies and practices.

3. New technologies for climate action and environmental sustainability: prospects and pitfalls

Some scholars have identified a fourth industrial revolution characterized by the fusion of digital, biological and physical systems, highlighting the potential of new technologies in mitigating resource depletion and pollution (Elheddad *et al.*, 2021; Majid *et al.*, 2022; Monaco, 2021). Recent articles have explored the potential benefits of new technologies in combating climate change and enhancing the quality of the environment (Francisco Ribeiro and Camargo Rodriguez, 2020; George *et al.*, 2021; Panepinto *et al.*, 2021). Approaches range from monitoring satellite imagery to assess the impact of environmental disasters at the local level, to combating carbon dioxide emissions, to long-term weather forecasting to mitigate the impacts of the changing climate.

Carbon removal technologies offer another globally implementable measure to mitigate climate change. For example, negative emissions technologies (NETs), such as the extraction of bioenergy from biomass with carbon capture and storage (bio-energy with carbon capture and storage, or BECCS), and the direct capture and storage of carbon in the air via chemical processes that separate it from other particles (direct air carbon capture and storage, or DACCS) already exist (Suleman *et al.*, 2022). Some countries have developed solar geoengineering systems that shoot reflective particles into the stratosphere to increase the ability of clouds to repel solar radiation, thereby lowering the planet's temperature (McLaren and Corry, 2021; Parson and Reynolds, 2021). The long-term effects of these experimental solutions are still unknown. Some critical studies (O'Neill, 2022) have pointed out that the disproportionate cost of geoengineering technologies outweighs their manifest benefits.

The incorporation of big data analytics, artificial intelligence (AI), 5G networks and blockchain technology in environmental monitoring and management can lead to significant improvements in the collection, analysis and utilization of environmental data. With the help of these technologies, it is now possible to gather large amounts of environmental data from various sources and analyze it more efficiently and accurately. For instance, AI algorithms can also help identify patterns and trends in the data that might otherwise be missed by humans, leading to better predictions and decision-making. In the United Kingdom, for example, Vodafone, together with Defra and Forest Research, launched an experimental project to monitor the condition of English forests through sensors. The use of 5G networks and blockchain technology can facilitate the sharing and tracking of environmental data across different sectors and organizations, promoting transparency and collaboration in the efforts to combat climate change and enhance environmental sustainability.

However, while it is feasible to identify significant resources within new technologies, the ecological footprint of the digital sector persists to be substantial, which demands further critical examination. Information technologies currently generate about 4% of global CO_2 emissions. By 2025, the industry sector's IT transition alone will have a carbon footprint equivalent to that produced by about 436 million vehicles per year (Das and Mao, 2020). Currently, digital technologies use a significant number of energy sources (extraction, manufacturing, transportation and use processes), materials (metals, plastics, glass), chemicals for processing materials and water in the processing and assembly of components (Oeko-Institute, 2020).

Another problematic issue associated with digital technology is the impact on the environment caused by the extraction and disposal of materials. The explosives used in the

extraction of these materials releases hazardous substances into natural habitats, thereby altering them (Malhi *et al.*, 2020). Although it is possible to recycle 90% of metals—including aluminum, gold, silver and, to a lesser extent, copper—the constant growth in demand for digital industry products means that increasing amounts of new materials are still required above what is recycled.

5G systems—based on the fifth generation of wireless communication networks that provides faster Internet speeds and better connectivity—highlight the contradictions inherent in the technology. They can help reduce carbon emissions since the use of mobile technology for storage and inventory management can increase efficiency and decrease the energy consumed to light and cool storage areas. At the same time, according to some foresight studies (Pan *et al.*, 2022; Pervaiz *et al.*, 2018), the introduction of 5G systems could significantly affect energy utilization, as they consume up to 1.5 more energy than current mobile technologies.

Similar critical issues affect blockchain, a decentralized digital ledger that enables secure and transparent transactions of various kinds of data. The actual standard transaction verification process, based on the proof-of-work algorithm, is "extremely power-hungry" (De Vries, 2018) since it requires an overwhelming quantity of processing power—and consequently electricity—to perform the associated computer calculations. In addition, a rapid and premature obsolescence of devices enables blockchain operations. The average lifespan of the components is one and a half years, as they wear out quickly due to enduring constant stress (Bai *et al.*, 2020; Saberi *et al.*, 2019).

4. Green entrepreneurship and digital platforms: opportunities and challenges for the economy

Adopting an inverted perspective, which considers companies as possible providers of new solutions instead of sources of emissions, several authors recognize new forms of green entrepreneurship based on digital platforms, big data and blockchain as an important vehicle for the ecological transition, capable of positively impacting the economic sphere as well (Jones *et al.*, 2019; Rodríguez-García *et al.*, 2019; Sacchi, 2019).

Empirical evidence shows that many green start-ups have emerged in recent years, leveraging technological advancements to develop innovative products and services with a low environmental impact. For example, the Dutch company Fairphone is a leading example of the use of innovative technology to promote sustainable and ethical practices in the electronics industry (Akemu *et al.*, 2016). The company's approach is based on a modular design that allows for easier repair and recycling of electronic devices, which reduces waste and promotes the circular economy. In addition to products design, Fairphone also emphasizes responsible sourcing of materials, fair labor practices and transparency throughout their supply chain. This holistic approach to sustainability has earned them recognition and support from various organizations and consumers who value ethical and environmentally friendly products. Another example is the French start-up Ynsect, which uses a process known as insect farming, breeding mealworms and using them as a source of protein. This method has several advantages over traditional livestock farming, including a much smaller ecological footprint and fewer greenhouse gas emissions. In addition, Ynsect's protein powder is highly nutritious and has a wide range of potential applications, including use in animal feed, pet food and even human food products. This innovative approach demonstrates the potential of green entrepreneurship to address environmental challenges while also creating economic opportunities.

Furthermore, some platforms have transformed the traditional transportation and hospitality industries, leading to more efficient use of resources and a reduction in environmental impact (Acquier *et al.*, 2019). In terms of transportation, ride-sharing services

like Uber have been found to decrease the number of cars on the road, leading to reduced traffic congestion and greenhouse gas emissions. Similarly, Chinese company DiDi Chuxing has expanded its portfolio to include AI, big data and autonomous driving technology to optimize the efficiency of their transportation network (Ko, 2019). This has led to reduced wait times, improved reliability and lower costs for both passengers and drivers. DiDi Chuxing's investment in innovation and entrepreneurship has also resulted in job opportunities and economic growth, through the collaboration with start-ups, universities and research institutions. However, critics argue that these platforms have negative impacts on local communities, as they often bypass regulations and taxes, leading to an unfair playing field for traditional industries (Thelen, 2018).

In the hospitality sector, platforms like Airbnb have increased the efficiency of existing housing stock by allowing homeowners to rent out their extra space to travelers. This reduces the need for new construction and can help address housing affordability in popular tourist destinations. However, these platforms can also contribute to gentrification and displacement, as the influx of tourists and short-term renters can drive up housing prices and exacerbate inequalities (Gurran and Shrestha, 2021; Wachsmuth and Weisler, 2018). For instance, Airbnb has reduced the amount of rental accommodation in cities, thus leading to increased rental prices. To address this issue, some cities such as Paris and San Francisco have implemented regulations to limit the annual periods that people are allowed to rent out properties.

Additionally, the dominance of technology-intensive firms can weaken competition and limit opportunities for smaller players in the market (Guzman, 2018; Haskel and Westlake, 2017). The resulting spiraling effect represents a kind of paradox. In fact, barriers to competition not only increasingly steer the market toward large players—at the expense of many other firms around the world that cannot keep up—but also prevent the diffusion of new technologies, resulting in widening productivity and profitability gaps among companies (Aghion *et al.*, 2019; Cette *et al.*, 2016; Comin and Mestieri, 2018; Égert, 2018; OECD, 2021). In other words, during the digital technology boom, productivity growth in major economies slowed down rather than accelerated, holding back overall economic growth. According to several studies (BICF, 2019; Shambaugh *et al.*, 2017), the stalemate is partially due to the global absence of adequate public research programs and government funding in favor of the research and development sector.

5. How do technological changes influence social sustainability and shape the future?

Innovation and investment in technologies to help achieve net zero emissions must create green and inclusive growth and job opportunities from a broader perspective than simply their climate benefit. More in detail, digitization has prompted the creation of new jobs, making highly competent workers with IT, digital and Industry 4.0-related skills increasingly necessary. As the process of digitization advances from a sustainability perspective, their recruitment is increasingly central to meeting companies' innovation and conversion needs.

The digital transformation requires the identification of new vertically specialized experts in specific areas of the digital sphere, such as specialists in data analytics, cybersecurity, AI and market analysis. Similarly, the development of a green economy is closely linked to the implementation of business processes and models through which companies aim to reduce their environmental impact by taking on the role of social responsibility. In this sense, the ecological transition appears to be possible only with the support of professionals with extensive training in ecological issues.

While the digital transformation represents an opening for emerging occupations, labor markets have simultaneously witnessed increasing polarization, with the employment share

of medium-skill jobs declining and that of higher-skill and specialized jobs increasing. In other words, a critical consequence of the transformative processes currently underway involves an increase in differences among workers, both in terms of employability and wages (Adalet McGowan and Andrews, 2017; Autor, 2014; Baethge-Kinsky, 2020; Consoli *et al.*, 2016). Moreover, AI has the potential to automate many jobs in the professional sectors, which could lead in future to job losses for workers who currently perform those tasks. For example, AI can perform tasks such as data analysis, decision-making and customer service, which are currently done by human professionals.

Under these circumstances there is a risk that only a select group or select areas will benefit from the advantages of digitization (Bridge *et al.*, 2018; Bulkeley, 2010; York, 2012).

The transition to digital work increases the possibility of expanding the digital divide both among groups of people and among territories, in terms of differential access to infrastructure (communications infrastructure, availability of computers and other devices and access to the internet) and the skills, motivation and ability to use new technologies (Calderón-Gómez *et al.*, 2020; Monaco and Sacchi, 2023; Vasilescu *et al.*, 2020).

Although there are various factors contributing to income inequality in major advanced economies, such as political, educational, legal and fiscal imbalances, the deregulation of economies and the export of manufacturing jobs to the third world since the 1980s have been key reasons for the skills inequality (Piketty, 2014). This has resulted in a supply-demand imbalance for higher-level skills, which has led to wage premiums for those who possess them (Hanushek *et al.*, 2015; Lindsey and Teles, 2017). Since 2000, income inequality has increased significantly in Canada, Germany, Norway, the United States, Italy and Finland and decreased in the United Kingdom, Mexico, Greece and Australia (Chancel and Piketty, 2021). Wealth inequality is even greater, about twice as high as income inequality. The rise in inequality has been especially evident in the United States. Over a twenty-year period (1995–2015), disposable income inequality in the US increased by more than 10%. The income held by the richest 1% of the population has more than doubled since the early 1980s, to 22%. Likewise, the share of wealth in the hands of the top 1% of the US population has risen to about 40%. Middle incomes have lost ground at both the top and the bottom, while the typical worker has suffered prolonged periods of stagnant real wages (Chetty *et al.*, 2017). A similar situation also characterizes many of the major emerging economies—such as China and India—where inequality is rising sharply (Khan *et al.*, 2022; NILERD, 2018; Topcu and Tugcu, 2020; Zhang and Zhang, 2022).

Over the past 20 years, skills inequality in OECD countries has increased in all sectors, although it has been felt more strongly in those sectors that invest most heavily in digital technologies (IMF, 2021). According to the OECD (2020), about a quarter of workers on average report a mismatch between their skills and those required by their job. This phenomenon increases people's sense of inadequacy and thus insecurity and instability. Faced with this changing social scenario, people may begin to feel inadequate or experience ongoing change at the workplace as well as a fear of being left out. In support of this thesis, OECD's data indicate that over a single decade (1995–2015), the share of middle-skill jobs within total employment declined on average by about 9.5 percentage points in OECD economies, while the shares of high-skill and low-skill jobs increased by about 7.5 and 2 percentage points, respectively.

The consequences of the inequitable nature of the current transition are even more salient in non-OECD countries, where the impacts of global capitalism and environmental degradation intersect with existing social, economic and political inequalities. For example, in the coal-mining regions of India, the transition to renewable energy has resulted in job losses for coal miners (Majid, 2020). Additionally, workers in the informal sector appear to be particularly vulnerable to the negative consequences of the transition due to a lack of social protection and access to training programs. For instance, in South Africa, informal waste

pickers who collect recyclable materials risk being excluded from the formal waste management system, resulting in loss of income and job insecurity (Schenck *et al.*, 2019). In Brazil, the transition to a green economy has been criticized for prioritizing high-skilled jobs, while neglecting the need for investments in education and training for low-skilled workers (Bastos Lima and Da Costa, 2022).

In addition to the aforementioned consequences, another important aspect that should not be underestimated is the accentuation of the gender gap in the workplace due to the current scenario. Women's representation in the workforce is already low in Europe, with only 39% of the workforce being women (Eu-Ansa, 2022), and globally their representation in key transition sectors—such as energy, transport, water, waste, agriculture, forestry and fisheries—is even lower (Walk *et al.*, 2021). This gap can be further widened by the transition to a green economy, with potential negative consequences for women's economic empowerment and livelihoods. For instance, the potential for land-use change to displace agricultural workers and impact their livelihoods could be particularly detrimental to women farmers who already have limited access to education and resources, making it more challenging for them to adapt to the changing agricultural landscape (Cooper and Nagel, 2022; Leach, 2016). In Ethiopia, for example, the expansion of industrial agriculture for biofuel production has resulted in land grabs and displacement of smallholder farmers, with women often being disproportionately affected (Konte and Tirivayi, 2020).

6. Discussion

Contemporary society is characterized by increasing environmental risks and uncertainties, and responding to these challenges requires a shift towards a more reflexive and sustainable mode of modernization (Beck, 1992). New technologies can enable a sustainable digital transformation, furthering the process of digitizing the economy in a lasting, ecological and organic way, offering a promising avenue for achieving sustainable development goals and reducing greenhouse gas emissions and mitigating the impacts of climate change (Balogun *et al.*, 2020; Corbisiero *et al.*, 2022; Osburg and Lohrmann, 2017). However, technologies cannot be considered a panacea in themselves. As argued by Klein (2014), relying solely on technological and digital fixes to address the climate crisis is a form of "magical thinking" that can have significant downsides. The technological transition is a critical component of addressing the climate crisis, but it must be considered as part of a broader systemic change that addresses social equity, policy reform and collective action. The idea that technology alone can solve the climate crisis can lead to overlooking the necessary structural changes required to address the underlying causes of the crisis, including unsustainable consumption patterns and reliance on fossil fuels. As such, it is important to approach technological solutions to the climate crisis with a critical and informed perspective, considering both their potential benefits and drawbacks to ensure a just and sustainable future. These considerations make it clear that the technological transition must be viewed within the bigger picture of systemic change and collective action.

The analysis proposed here has shown that the development and deployment of new technologies can create winners and losers, with vulnerable people and groups often being left behind. This can be due to a variety of factors, including access to resources and infrastructure, education and technical skills and economic and political power. This highlights the importance of considering social equity and justice when pursuing technological solutions to climate change.

Given the constantly evolving technological landscape, incorporating "just transition" principles into policy and practice represents a promising approach to tackling contemporary environmental and social challenges, providing a valuable framework for bridging the gap between theory and practice. Specifically, the just transition approach recognizes the need for

transformative change ensuring that no individual, community or sector is left behind in the transition towards a sustainable future, both globally and locally (McCauley and Heffron, 2018; Stevis and Felli, 2020; Wang and Lo, 2021).

Understandably, a successful just transition requires more than technological innovation. It also requires systemic changes in policies, regulations and societal values. For example, shifting from a fossil fuel-based economy to a low-carbon economy necessitates policy changes, such as carbon pricing, renewable energy standards and regulations to phase out fossil fuel use.

Through a just transition lens, society can prioritize social equity, community engagement and environmental sustainability, ultimately moving towards a more sustainable and equitable future. Achieving effective implementation of these principles requires active engagement with various stakeholders, including communities, workers and policymakers, as well as the provision of sufficient resources and tools.

Today, at a global level, "ecological modernization" can be pursued integrating environmental concerns into all aspects of social and economic development, considering the transnational nature of environmental problems (Biermann and Pattberg, 2012; Ruiu *et al.*, 2023).

At the local level, an empirical example of how the principles of a just transition can be put into action is offered by the Transition Towns movement. It is a grassroots, community-led initiative that emerged in the mid-2000s as a response to the challenges of climate change, resource depletion and economic instability (Connors and McDonald, 2011; Hopkins, 2011; Wilson, 2012). The movement aims to support the transition to a more sustainable and resilient society, based on the principles of permaculture and the use of renewable energy sources. It emphasizes the importance of local action, and seeks to build local resilience in the face of global challenges. The Transition Towns movement encourages community education and awareness-raising around the challenges of sustainability and the need for systemic change. Eco-social work can be an important component of this type of community-based initiative, as it focuses on the intersection of ecological and social concerns, and seeks to promote sustainability and social justice through community empowerment and engagement (Beder, 2006; Gray *et al.*, 2013; Hölscher *et al.*, 2023). Through eco-social work, the Transition Towns movement can work to build stronger, more resilient communities that are better equipped to face the challenges of the future.

7. Conclusion and future perspectives

Technological evolution and ecological transition need to be complementary, and environmental, social and economic goals must be balanced on a large scale. While comprehensive governmental interventions are necessary, issues related to a just transition extending from the individual to the global require additional targeted efforts based on coordination among multiple actors and different levels of government. The outcomes of this transformative process depend on the institutional commitments made in individual countries and on the ability of leaders to develop shared policies and economies aimed at ensuring innovative work and ecologically sustainable well-being, while taking into account ecological and ethical constraints and limits that are qualitatively and quantitatively greater than in previous eras. Governments and international organizations need to commit to policies and regulations that promote a just transition. For example, implementing carbon pricing mechanisms, investing in green infrastructure and renewable energy (Bell *et al.*, 2023).

From a forward-looking perspective, cooperation between different levels of government—along with renewed trust between various institutional bodies, on the one hand, and between the public and private sectors, on the other hand—can facilitate the identification of proactive measures, which help to maximize long-term benefits, and reactive

measures, which aim to minimize the harms of transition. Without intense, coordinated and—most importantly—immediate global action, the world will no longer be capable of avoiding irreversible and possibly catastrophic changes (Pellizzoni *et al.*, 2022). Measures to support the digital transformation from a sustainable perspective need to be planned and implemented from a holistic point of view. Such an approach, adopted across economic sectors and across territories, can successfully support the dual transition to a just green and digital economy. As such, competition policies should be revamped to ensure that during the transition phase, markets continue to provide open and fair conditions for businesses within a regime that allows for true global competition. To do this, regulatory reforms and antitrust enforcement are both desirable (Rajan and Zingales, 2003; Rogerson and Shelanski, 2019). In addition, a just transition can be achieved through policies and regulations that promote environmental and social sustainability. For example, governments can implement regulations that require companies to disclose their environmental and social impact, or provide incentives for companies that prioritize sustainability in their operations. In an increasingly interconnected global economy with rapidly expanding digital trade, international cooperation on tax matters represents another area of action in which critical and shared thinking should be advanced.

Digital technologies are also transforming the world of work. This means that companies covet new professionals with specific green and digital skills at the expense of many other traditional workers. As a consequence, the challenges of the socio-economic transition also call for the consideration of eco-social or sustainable welfare policies that integrate various cross-cutting, socio-cultural objectives. The main policy challenge entails empowering people to acquire the new skills demanded by the labor market by improving access to affordable, quality education, with concessions and scholarships for economically disadvantaged populations (Turner, 2017). Likewise, to avert the shedding of workers who are unable to make the transition, during the adaptation process supportive policies that promote worker re-skilling and training programs, provide social protections for workers impacted by the transition and ensure that the benefits of the ecological transition are shared equitably among all members of society are necessary. For instance, governments can provide financial support and resources for re-training programs that help workers transition to jobs in the green economy, or implement policies that require companies to provide fair wages and benefits to their workers (Pollin, 2015). In addition, traditional formal education must be supplemented with new models of retraining and lifelong learning, capable of stimulating a dynamic adaptation of old jobs to new occupations (Acemoglu and Restrepo, 2018; Brynjolfsson and McAfee, 2017; Sundarajan, 2016).

Against this backdrop, the contemporary lightly regulated capitalist system and the absence of policies aimed at enhancing human capital have contributed to a fairly widespread increase in income inequality. Consistent with the Sustainable Development Goals of Agenda 2030, all countries are called upon to reduce inequality among citizens and improve living conditions for all. This can also be addressed by implementing targeted and more responsive welfare policies that encourage retraining, employment services and re-employment, including innovative unemployment insurance mechanisms (Fanizza, 2020; Sacchi *et al.*, 2022).

Finally, specific attention should be paid to gender issues from an intersectional perspective. This means recognizing that gender intersects with other forms of social identity and oppression—such as ethnicity, class and ability—and that these intersections shape people's experiences and opportunities. One key issue is the under-representation of women in key transition sectors such as renewable energy and sustainable agriculture. This gap can be addressed through the implementation of initiatives aimed not only at filling the skills gap in the labor market but also at addressing systemic barriers to women's participation in these sectors, such as gender stereotypes and discrimination. Not only is it important to encourage

businesses to hire more women and to provide support for women entrepreneurs and innovators (Allwood, 2020; Buckingham and Le Masson, 2017), but it is necessary to develop policies and practices that promote work-life balance and accommodate the caregiving responsibilities that are often disproportionately shouldered by women. In this sense, flexible work arrangements, parental leave policies and child care services can help to support women's participation in the labor force during the transition (Thomas, 2022).

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