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EDITED BY
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Beijing Information Science and Technology University, China

REVIEWED BY
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The University of Texas at El Paso, United States
Kuan-Chi Wang,
Academia Sinica, Taiwan

*CORRESPONDENCE
Valeria Sodano
✉ valeria.sodano@unina.it

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Food system digitalization and power shifts

Valeria Sodano*

Department of Political Sciences, University Federico II of Naples, Naples, Italy

The article provides new insights into the assessment of food system digitalization by analyzing how the entire process is mainly power-driven rather than the outcome of fair competition among alternative technological patterns. It focuses on the power forces that have accelerated the digital revolution in the food system and how this revolution is enabling certain subjects to exercise old and new forms of power in the economic, political, and geopolitical spheres. The analysis begins with a brief review of food digital technologies and how the existing literature has discussed their possible benefits and risks. It then focuses on the role of agenda power in promoting digitalization and on hegemonic power as the most important form of power produced by digitalization. The aim of the study is to offer a new perspective, based on the analysis of shifts from one form of political power to another, to better analyze the political issues raised by food system digitalization. The results suggest that to resist the negative aspects of digitalization, it is necessary to transform covert conflicts into overt ones and to understand the mechanisms through which the exercise of power blocks the transition from awareness of conflicts to political action.

KEYWORDS

power, innovation, digitalization, food system, artificial intelligence

1 Introduction

While the digitalization of the food system is hailed as a solution to world food insecurity and the environmental and ethical issues associated with food production, scant attention has been paid to the many risks posed by digital innovations. Although current food policy interventions, such as the European Union (EU) Common Agricultural Policy (CAP), are primarily focused on digital innovation, a thorough assessment of the risks and benefits associated with such innovations has not yet been provided. An underlying tenet of this paper is that such an assessment should be a priority in policy decision-making processes, and its absence might jeopardize food system sustainability and lead to the inefficient and unfair allocation of public financial resources. To support this statement, a sound assessment of the effects of food system digitalization should be carried out. Unfortunately, such a task would require so much data and research effort that it is unattainable by the present study. Instead, the objective of this study, more limited in scope, is to investigate a specific effect of digitalization: power shifts within the global food supply chain.

Literature on the digitalization process of the food system can be roughly divided into two strands, reflecting two opposing attitudes toward the phenomenon. On the one hand, proponents of digitalization enthusiastically preach its positive economic and environmental effects. On the other hand, critics of digitalization, while recognizing its possible beneficial uses for environmental purposes, highlight its negative effects at a political and social level. The EU is an outstanding example of a proponent of food system digitalization. According to the EU, the digitalization of the European agricultural sector has the potential to revolutionize

the industry, promoting efficiency, sustainability, and competitiveness (The Digitalisation of the European Agricultural Sector | Shaping Europe's digital future (europa.eu)). EU politicians have long applauded the digitalization of the agri-food system. The praise and incentives for precision agriculture (or smart agriculture) in the framework of the past CAP and in the document "From Farm to Fork" have been followed by significant funds for research (around 200 million euros allocated) in the EU Research and Innovation Program 2021–2027 (Horizon Europe). For the Commission, technologies such as artificial intelligence (AI), robotics, the Internet of Things (IoT), and 5G can offer invaluable support for farmers and agribusinesses.

Critics of food system digitalization can be found mainly among civil society organizations and independent research institutions (ETC Group, 2018; GRAIN, 2021). The recurring theses enunciated by critics concern three crucial aspects that would accompany the spread of digitalization: unequal distribution of costs and benefits, excessive growth of concentration and economic power in the food system, and lack of democracy in regulatory decision-making processes. Much emphasis is placed on the political dimension of digitalization risks, which includes questions of power, participation, and property rights regarding these technologies and the distribution of the benefits they generate. This paper adds new insights into the assessment of food system digitalization by analyzing how the entire digitalization process is mainly power-driven and not merely the outcome of 'neutral' technological advances. By showing the power dynamics behind digitalization, the paper also endorses literature on technological changes that oppose the hypothesis of the neutrality of science and technological determinism. We refer to power in its traditional political meaning, that is, the ability of one or a few subjects (individuals or organizations) to impose their will on other subjects in a way that receives obedience to their own orders. When socioeconomic and technological changes are mostly driven by power instead of by decision-making processes shared by all the subjects affected by the changes, sociopolitical systems can deviate dangerously from their democratic structure. In other words, unveiling the role of power in the process of food system digitalization highlights a neglected and underestimated risk: the risk to democracy.

The terms 'food system' and 'power' can have many meanings, as they have been used by different disciplines and for different research purposes. The concept of food system in the field of agricultural economics and policy research was introduced in the 1980s (Marion, 1986) as an analytical instrument useful to adjust previous studies of the marketing of agricultural products (Brunk and Darrah, 1955; Kohls, 1955; Kohls and Uhl, 1980) to the ongoing technological and organizational innovation dynamics. In the 1970s and 1980s, other terms were also proposed to account for the growing dependence of the agricultural sector on other economic sectors (primarily the food manufacturing and distributive sectors) and on increasingly complex technological and institutional environments. Concepts such as 'subsector' (Shaffer, 1973), 'agribusiness' (Davis and Goldberg, 1957; Goldberg, 1974), 'filière agroalimentaire' (Combris and Nefussi, 1984), and 'agri-food supply chain' can all be considered precursors of the concept of food system. From the 1990s onwards, many conceptual frameworks have been elaborated, from more holistic perspectives, which have increasingly framed food systems as large, dynamic, coupled socio-ecological systems (Brock, 2023). In this article, I use the following general (and broadly used) definition of the food system given by FAO, which accounts for the economic, institutional, technological, and socio-cultural features of food production, distribution, and consumption:

> "*Food systems (FS) encompass the entire range of actors and their interlinked value-adding activities involved in the production, aggregation, processing, distribution, consumption, and disposal of food products that originate from agriculture, forestry, or fisheries, and parts of the broader economic, societal, and natural environments in which they are embedded. The range of actors importantly includes science, technology, data, and innovation actors. A sustainable food system is a food system that delivers food security and nutrition for all in such a way that the economic, social, and environmental bases to generate food security and nutrition for future generations are not compromised.*" (Food and Agriculture Organization (FAO), 2018).

Although this definition is primarily descriptive and does not capture some suggestions from other concepts of the food system, it fits the scope of the study, as it is a benchmark in most food policy documents and is consistent with the more individualistic methodological stances of Lukes' model.

Power is a contested concept, and in the realm of social sciences, there are various and controversial theories of power (Haugaard, 2002). However, there are consolidated definitions and theories of power useful for interpreting the dynamics of our socioeconomic systems, including those of FS (Sodano and Gorgitano, 2022). This article uses two concepts of power developed in the field of analytical political theory: agenda power and hegemonic power, following Lukes (2005) definitions and conceptualizations. Besides those from analytical political theory, there are theories of power elaborated in the fields (Haugaard, 2002) of modern social theory, nonanalytical political theory, and postmodern social theory, with the latter dominated by Foucault's widely studied theories of power. I chose power concepts from analytical political theory because they are useful for answering the main question of this article: "Is there a political will behind the ongoing digitalization of the food system?"

This study is an example and a starting point for reading the digitalization phenomenon through the lens of power. It focuses on the power forces that have accelerated the digital revolution in the food system and how this revolution enables some subjects to exercise old and new forms of power in the economic, political, and geopolitical spheres. There are "power shifts" associated with digitalization, concerning both the forms of power and the subjects holding power. This study focuses on the power shifts toward the two forms of political power defined as agenda power and hegemonic power. The paper is organized as follows. The first section reviews the main fields of application of digital innovation along the food supply chain with a brief assessment of the possible associated risks. The second section briefly illustrates the theories of power used in the analysis. The third section offers an interpretation of the current push for the digitalization of the agri-food system in terms of agenda power and shows how this results from the alignment of the interests of the main decision-makers, both public and private, in agri-food policy. The fourth section provides examples of how food system digitalization might allow for the exercise of three-dimensional power, which can jeopardize individuals' autonomous will and freedom of choice,

affecting both domestic and geopolitical equilibria. The concluding section summarizes the main findings and calls for interventions to mitigate some of the negative effects of digitalization.

2 Food system digitalization and associated risks

To understand the broad impact of digitalization, it is important to specify what is meant by digitalization and mention some fields of application in the agri-food sector. In this article, I define digitalization and digital technologies as follows: digitalization is the use of digital technologies to change a business model and provide new revenue and value-producing opportunities (Verhoef et al., 2021). Digitalization differs from "digitization," which refers to changing an analog process into a digital form without altering the process itself. Based on this definition, digitalization primarily concerns business and management models and is therefore based on soft sciences (economics, sociology, psychology, law, anthropology) in addition to hard sciences. Digital technologies are defined as electronic tools, systems, devices, and resources that generate, store, or process data, meaning that data production and distribution are at the core of digital innovations and digitalization. Data are thus the key resource for mobilizing the digitalization process and enabling new means of extra-profit appropriation (Zuboff, 2019). Examples of digital technologies include the IoT, cloud computing, advanced robotics, AI, social media, innovative digital platforms, blockchain technologies, geographic information systems, wireless sensor networks, computing technologies, radio frequency identification, big data analytics, and remote sensing technologies such as drones.

Proponents of digitalization emphasize how individual digital technologies could benefit society by offering "technical" solutions to socially sensitive issues, such as those related to health, environment, and climate. This view assumes the existence of an innovation and technological system driven by the will of 'good' managers and financiers devoted to the 'public good.' Here, the 'public good' is defined and understood through the alignment, via democratic processes, of the interests of free and autonomous individuals in equal decision-making positions (as in the model of liberal democracy proposed by Rawls' concept (Rawls, 1971) of the veil of ignorance). This view entails a belief in technological determinism, with blind faith in scientists and technology. Critics of digitalization have a more realistic and rational view of technological change, seeing it as the product of complex economic, social, and technoscientific systems where various forces, stimuli, and incentives acting together may lead to outcomes that are "not for people," in Noble's words (Noble, 1995).

Literature with a critical attitude toward digitalization identifies at least three kinds of risks and shortcomings of food system digitalization processes (Fraser, 2019; Sodano, 2019; Prause et al., 2020; Hackfort, 2021). Firstly, there appears to be an asymmetric distribution of benefits, with large farms and intensive conventional agriculture reaping much more from digitalization than small farms and alternative agricultural practices. Most digital innovations available so far, such as guidance systems, semi-autonomous tractors, and harvest robots, have been developed for large-scale industrial farming, creating a disparity between large and small farmers. Moreover, the currently proposed digital innovations might negatively affect alternative agricultural systems, such as agroecology and organic farming (Ajena et al., 2020). Digital innovations might marginalize the cultural and ecological knowledge of small-scale farmers, replacing their knowledge with data analytics and AI. The main risks from digitalization for alternative agriculture practices lie in the possibility of small farmers losing their knowledge and skills, as well as their right to repair their equipment or access sensitive data.

Secondly, there are security and political issues associated with data access and property rights. These issues stem from the lack of clear and effective regulations on data protection and exploitation rights amidst data harvesting and processing practices led by the world's largest internet and agribusiness multinational companies. For farmers, key issues include who controls access to the data generated on and about farms, and how the value created from that data is redistributed (Jouanjean et al., 2020). A significant concern is that farmers do not own their data, which limits their ability to transfer historical data between technology providers or choose who services their machinery.

Thirdly, digitalization may promote consolidation along the food supply chain, offering many opportunities for anti-competitive practices and market power exploitation. Digital technologies provide several sources of market power exploitation. Some sources, like patents, scale economies, network externalities, asymmetric information, industrial secrets, and lock-in effects, are well-known to economists and common to other technologies. Others, like scalability, reinforcing network effects, and value co-production, are newer and are generated by the development of digital platforms. Most digital technologies are privately owned, making patents a significant source of market power. Companies selling digital products benefit from economies of scale; once software, applications, and platforms are launched, each new customer reduces the average production cost of digital platforms. Control of digital platforms offers firms extreme competitive advantages and profitability due to high scalability and reinforcing network effects (Verhoef et al., 2021; Runck et al., 2022). The appropriation of quasi-rent associated with asymmetric information and contractual incompleteness is another important source of extra profits. Contractual incompleteness stems from business secrets, confidential information, and the lack of an effective legal framework to ensure contract enforceability, due to the delay of regulatory policies relative to the accelerated rate of digital innovation. Lock-in effects occur when actors in the digital network become 'locked-in' to market relationships where strategic resources are controlled by their counterparts. Actors become 'locked-in' either because they cannot find alternative partners due to the disruption of previous business models, or they incur sunk costs to adapt to the technological standards required by the counterparty. For example, once a farmer buys a new sensor-endowed tractor linked to other digital technologies (like engines for remote control, software for management advice, and special nozzles for new pesticide spraying technologies), they bear costs that are non-recoverable (sunk costs) outside that market relationship. Companies selling the new tractor will take advantage of such a lock-in effect by exercising market power and increasing their market share due to the disruption of the previous market.

Overall, consolidation and anti-competitive practices produce negative effects not only in terms of inefficiencies associated with market power exercise but also in terms of a higher level of economic power imbalance along the supply chain. Examples of economic power imbalance include small farmers being disadvantaged compared to large farms, the agricultural sector losing even more

contractual power toward both its suppliers and customers, and the largest players in ICT (Big Tech), such as Amazon, Apple, Meta, Alphabet's Google, XCorp, Microsoft, Alibaba, and Tencent, gaining predominant roles in food chain coordination and value-added appropriation (GRAIN, 2020, 2021).

3 Food system digitalization and the three-dimensions view of power

The literature analyzing the role of power in the current process of food system digitalization tends to focus either on the effects of new technologies in terms of economic power (and its distribution along the food supply chain) or on the power struggles for regulatory choices by policymakers. Here, I extend the analysis to two additional power-related topics: the role of agenda power in promoting digitalization and hegemonic power, as the most important form of power produced by digitalization. Both agenda and hegemonic power refer to a concept of power as domination and therefore are forms of 'power over' (Pansardi, 2012). They extend the previous definition of relational power given by Dahl in his seminal articles (Dahl, 1957, 1986) that inaugurated the power debate in community studies within analytical political theory (Haugaard, 2002). According to Dahl's definition, "A has power over B to the extent that he can get B to do something that B would not otherwise do" (Dahl, 1957, p. 202).

In my analysis, I will refer to the forms of power developed by Lukes in his multi-year work (Lukes, 1974, 2005, 2021). In his 1974 book "Power: A Radical View," Lukes laid down his new approach to the study of power, namely the three-dimensional view of power, joining the "so-called 'faces of power' debate grown out of the critique of the 'elite' theories of Mills and Hunter" (Lukes, 2021, p. 211). The novelty of Lukes' approach was the introduction of the third dimension of power, which is useful, in the words of Lukes, "to think about power broadly rather than narrowly—in three dimensions rather than one or two—and to attend to those aspects of power that are least accessible to observation: that, indeed, power is at its most effective when least observable." (Lukes, 2021, p. 5).

What follows summarizes the main traits of Lukes' view of power. Dahl's definition reflects, in the words of Lukes (2005, p. 29), the 'one-dimensional' view of power. It is relevant for analyzing decision-making processes in the presence of overt conflicts over a particular topic among different subjects in a community. It assumes a pluralist view, with confidence in the capability of the democratic political system to lead to a decision that will mirror the political preferences of citizens, with politicians with more vote preference making the decision that will solve the conflict.

In other words, in Dahl's view of power, subjective interests are seen as policy preferences revealed by political participation. Bachrach and Baratz (1962) challenged this optimistic view of democracies by introducing the concept of the "two faces of power," with the second face called 'agenda power.' This refers to the power that decision-makers have not only to choose among "choices on the table" (first face of power) but also to leave some possible "choices off the table," excluding them from the political agenda. Lukes expanded on the analysis by Bachrach and Baratz by better explaining the concept of agenda power, which he called the two-dimensional view of power, and by introducing a further form of power, which he called the three-dimensional view of power, also known as hegemonic power.

In the case of agenda power, power is exercised by excluding issues or potential issues from the political debate and agenda. In this way, some overt conflicts tend to be forgotten (marginalized in the public debate) or become covert, meaning they are excluded from the public debate. Consequently, conflicts are "neutralized," and parties interested in raising a particular issue cannot bring it into the political arena, despite experiencing grievances. A grievance is defined as an articulated demand based on political knowledge, as well as an undirected complaint arising from everyday experience or a vague feeling of unease or deprivation (Lipsitz, 1970; Lukes, 2005). The exclusion of an issue from the political agenda can result from specific actions and political pressure by individual actors or derive from the behavior of entire institutions, influenced by factors ranging from material interests to cultural and ideological perspectives.

The third form of power, the three-dimensional power (sometimes called hegemonic power), occurs when conflicts become latent. A latent conflict consists of a contradiction between the interests of those exercising power and the real interests of the dominated actors in the power relation. Dominated actors may not express or even be conscious of their interests, but the identification of those interests ultimately always rests on empirically supportable and refutable hypotheses. Lukes provides a meaningful definition of real interests by relying on Nussbaum's capability approach (Lukes, 2005, p. 28).

The three-dimensional view of power (hegemonic power) insists that non-decision-making power exists even when there are no grievances denied entry into the political process as issues. Real interests are denied not only entry into the political debate but also explicit recognition by the people with those interests. Lukes' words clearly express what hegemonic power is about: "Is it not the supreme and most insidious exercise of power to prevent people, to whatever degree, from having grievances by shaping their perceptions, cognitions, and preferences in such a way that they accept their role in the existing order of things, either because they can see or imagine no alternative to it, or because they see it as natural and unchangeable, or because they value it as divinely ordained and beneficial?" To assume that the absence of grievance equals genuine consensus is simply to rule out the possibility of false or manipulated consensus by definitional fiat" (Lukes, 2005, p. 28).

An important feature of Lukes' analysis of agenda and hegemonic power is that it refers to kinds of power where, while the "oppressed part" is clearly recognizable (in the form of individuals or groups of individuals), the part exercising power may consist of diverse individuals and organizations whose "intentionality" in exercising power is not clearly detectable, which is one reason why conflicts tend to become latent.

Although developed fifty years ago, Lukes' approach is still relevant for understanding many power dynamics within sociopolitical systems, as argued by Lukes himself in his more recent books (Lukes, 2005, 2021). In these books, Lukes adds new chapters, not to further develop the theory presented in 1974, but to claim its relevance and robustness in the face of criticism received over time (Marzano, 2022). Of particular relevance is Lukes' discussion relating to Foucault's concepts of biopower and governmentality (Lukes, 2005, p. 88–98), especially in light of their use in food policy literature (Leach et al., 2020; Juskaite and Haug, 2023; Smallwood et al., 2023). The Foucauldian notion of governmentality refers to the ways in which modern societies' various authorities administer populations, leading individuals to shape their own selves through disciplinary techniques

that allow for the exercise of biopower, a power inscribed in people's bodies, changing their attitudes and behaviors from the inside. Lukes' critics present such concepts as possible substitutes or necessary complements (in the form of a fourth dimension of power) to the third dimension of power. In his response, Lukes clearly illustrates the distance between his theory and that of Foucault and denies the significance of a supposed fourth dimension of power, as he recently reiterated: "In the third edition of my own book, I ask whether the proposed fourth dimension reveals modes in which power can be seen at work that are not visible from within the third. I wrote that I would leave the question undecided, continuing to view power in three dimensions, since I was not convinced that doing so conceals what advocates of a fourth dimension promise to reveal" (Lukes, 2022).

Particularly useful to the object of study of this article are the two chapters Lukes dedicates, in the 2021 edition of his book, to the use of the three-dimensional view of power in empirical research. One example is the study of digital media, with a discussion on how three-dimensional power could complement the concept of instrumentarian power introduced by Zuboff to explain power dynamics within surveillance capitalism. Another example refers to the extension of the three-dimensional view of power through the power cube, an analytical tool invented by Gaventa (2006), that "portrays the idea that all three dimensions (relabeled as visible, hidden, and invisible forms) can operate in different social or political spaces and at different scales or levels of action" (Lukes, 2021, p. 188). As acknowledged by Lukes, the power cube research has had the merit of bringing the power debate into the field of development studies and transformative change.

4 Agenda power as a driver for food system digitalization

The exercise of agenda power to promote food system digitalization in the EU and international forums is evident when considering that, for at least the past 10 years, documents from public and private institutions, including scientists from both hard and soft disciplines, have cited digitalization as the best and unique solution to address all the health, economic, social, and environmental issues associated with food production and distribution. Digitalization is viewed as the only way to ensure food security for a growing world population and to tackle the climate change crisis. Other approaches to these issues have been quickly dismissed and have disappeared from public debates and policymakers' agendas. These alternative approaches include environmentally friendly agricultural practices like agroecology, a slowdown in economic growth defined solely by GDP increases requiring unsustainable natural resource and energy use, a more equitable redistribution of wealth, and the end of wars and gender discrimination, which are primary causes of food insecurity.

In recent years, digitalization has become a cornerstone of development programs proposed by major international institutions working in the field of development and agri-food policy (European Union, 2019; Food and Agriculture Organization (FAO), 2019; Organization for Economic Co-operation and Development (OECD), 2019). Within the EU, the new CAP proposal outlines nine key objectives (European Community, 2018), built around three keywords: modernization through digitalization, simplification through digitalization, and compatibility with the ten priorities of the Commission, including "a connected digital single market" and "a Europe fit for the digital age." These keywords highlight the importance given to digital innovations for achieving CAP goals, further emphasized by the Member States' signing of the Declaration "A smart and sustainable digital future for European agriculture and rural areas" in Brussels on April 9, 2019 [Declaration. A smart and sustainable digital future for European agriculture and rural areas. Available online: DD3Declarationonagricultureandruralareas-signedpdf-(1).pdf (smartagrihubs.eu)]. According to the Declaration, "digital technologies such as AI, robotics, blockchain, high-performance computing, IoT, and 5G have the potential to increase farm efficiency and improve production, contributing to making farming systems more sustainable from an economic, social, and environmental point of view, as it is in other sectors. FAO's programs are also centered on digitalization. The FAO forecasts that 90% of the demand for global food production by 2050 will be met by increasing the yield of arable land based on advances in digital agriculture research (Food and Agriculture Organization (FAO), 2019).

The same narrative that hails digitalization as the sole path to sustainable food production growth is echoed by major agribusiness companies such as Syngenta, Bayer, BASF, YARA, John Deere, Corteva, Cargill, ADM, and CNH Industrial. For example, on BASF's website, genome editing, AI, and digital management tools are presented as the latest advances in science and technology that help balance the growing demand for food and the impact on the planet Trends in Agriculture (basf.com). Corteva's website also presents AI as the solution for food system sustainability, featuring AI-based innovations ranging from agriculture (bots that select the best individual plants for breeding, digital cameras that recognize and remotely monitor individual livestock, biomass assessment predicting crop yields for entire regions, rural 5G networks) to food retailing ("from farm to smartphone to table") (What Does the Future Hold for AI in Agriculture | Corteva).

Both public and private actors use a narrative that links digital technology to two of the most pressing global issues: food insecurity and climate change. Documents presenting both private sector investment strategies and public sector policies for the food system commonly state, "digital technologies will allow us to sustainably feed 10 billion people by 2050," thus closely associating sustainability and food security with digitalization. This narrative weakly emphasizes the uncertainties and risks of digitalization, focusing mainly on manageable concerns such as data privacy and security. However, the purported benefits in terms of sustainability and food safety are seldom questioned (Marvin et al., 2022; Rejeb et al., 2022), despite the lack of accurate and comprehensive estimates evaluating the environmental and social effects of large-scale digitalization of the agri-food system. On the contrary, there is empirical evidence of the substantial energy (Sedlmeir et al., 2020), water (Mytton, 2021), and natural resource (Eerola et al., 2021) usage required by digital technologies.

A study by the European Commission (Carrara et al., 2023) identifies a research gap in determining whether the total environmental benefits of ICT use outweigh the environmental impacts of the ICT sector. The study describes how digitalization is a major consumer of critical raw materials, competing for the same minerals as sectors like renewable energy and e-mobility. For some raw materials, such as indium, gallium, and germanium, the digital economy represents 80–90% of total consumption. Moreover, ICT infrastructure requires these same critical raw materials, most of

which are produced in China or Africa and transported over long distances.

Regarding the view of digitalization as a panacea for world food insecurity, it is worth noting that since Sen's entitlement approach, it is widely accepted that food security is not solely caused by reduced food availability but by entitlement failure and low purchasing power. In other words, poverty, more than food shortage, is the main cause of hunger.

The support given to digitalization, despite its risks and poorly assessed benefits, as the sole transformative pattern for the food system, and the dismissal of alternatives that are not considered valuable research topics or policy goals, can be viewed as a form of agenda power. In this case, power is exercised by supporters of digitalization over subjects such as small farmers, supporters of agroecology, organic farmers, and environmental organizations, who would have preferred alternative choices (overt conflict), or over subjects like marginal farmers, displaced workers, consumers, and citizens who might be denied access to natural food and others who bear the costs of digitalization (latent conflict). These individuals feel grievance because they are negatively affected by digitalization but are denied a public political fight due to the exclusion of alternative choices from the political agenda.

In supporting digitalization, agenda power proves to be particularly strong because power is exercised simultaneously by three groups of actors: national states, multilateral international organizations, and businesses. There has not been an explicit agreement among these parties, and their somewhat coordinated actions are not the result of a conspiracy but of an alignment of respective interests produced by the crisis of neoliberalism.

Over the last two decades, neoliberal states have faced growing popular discontent resulting from deindustrialization, new forms of poverty, and the reduction of public services. This discontent has weakened existing political parties. The demand for more progressive policies has not been met, mainly due to the absence of a valid, genuinely progressive political project. In other words, there has not been a new left capable of overcoming the old left, which remains theoretically and ideally anchored to Marxism while orphaned by real socialism. In this context, new populisms have emerged, both in the form of new progressive parties and old nationalist and conservative parties. Both left-wing and right-wing populisms have strong incentives to support the digital revolution. Left-wing populisms support digitalization by confusing technologization with democracy, with blind faith in the neutrality of science and technology. Right-wing populisms support digital technologies because they use its perceived political neutrality to hide from voters the most reactionary and anti-democratic aspects of their political project, including citizen control for the affirmation of new authoritarian governments central to their political program. Additionally, they look at its military uses in new war scenarios arising from nationalist and imperialistic resurgences.

The endorsement of digital technologies by businesses is explained by the fact that digitalization offers capitalism a new mechanism for extracting extra profits. Capitalism feeds on continuous economic growth and the discovery of new sources of extra profit extraction. Digitalization promises to overcome the limits to development resulting from climate change and the exhaustion of natural resources (such as fossil fuels and arable land) and offers a new source of expropriation to replace those (workers, natural resources, and the environment) of previous cycles of accumulation. This new resource to exploit is represented by data freely made available by people (Zuboff, 2019).

During neoliberalism, the perception of a well-established international geopolitical and military order (Fukuyama, 1992) and the belief in trade liberalization and economic globalization made many states willing to transfer organizational and regulatory powers to intergovernmental organizations. The economic and military crises that erupted at the dawn of the new millennium, such as the 2007/2008 financial crisis, the Twin Towers attack, the threat of Islamic fundamentalism, the Middle East crisis, and the resurgence of old empires (Russia, Iran, Turkey, China), changed the scenarios. National governments progressively tried to regain control of international policies, weakening the authority and policy scope of intergovernmental organizations. These organizations, which remained neutral territories for international cooperation devoted to solving global problems such as climate change, hunger, poverty, and terrorism, began to propose increasingly technology-based solutions. These solutions were perceived as neutral and therefore capable of attracting consensus from nations otherwise in clear conflict with each other. Digital technologies became the forefront of this technological-fix attitude, making international organizations new allies to digitalization proponents.

In conclusion, many organizations, for different motivations, have exercised a form of agenda power by focusing on digitalization as a driver of development and a tool for resolving social and environmental dilemmas while excluding alternative approaches and solutions from their decision-making agendas. Digitalization has offered everyone interesting opportunities: for businesses, the possibility to exploit new sources of profits without incurring regulatory burdens and social conflicts; for governments, the possibility of pursuing domestic authoritarian policies using tools difficult for citizens to understand and therefore resist; for states involved in geopolitical conflicts, the opportunity to develop new weapons and strategic levers of domination; for international bodies, a means to disguise their growing weakness. In other words, digitalization seems to be a game changer in market competition, the domestic political arena, and geopolitical scenarios, explaining the strong alignment of interests among states, businesses, and multilateral international organizations toward its support.

5 Shift to three-dimensional power

A form of three-dimensional power is exercised when the subordinated party in the domination relationship consents to being dominated, but such consent is not the product of a fully autonomous expression of its own needs and preferences. Instead, it is the product of some form of manipulation by the dominant party. Here, obedience is extorted through means not fully intelligible to subordinates, which blurs the perception of their lack of autonomy. At the core of the definition of hegemonic power are three important features. The first is the difference between obedience induced through encouragement and persuasion in the absence of conflicts of interest, which identifies a relationship of influence, and obedience induced through manipulation in the presence of conflict of interest, which identifies a relationship of domination (Lukes, 2005, p. 36). The second is the

difference between overt and covert conflicts of interest, as in the case of the one-dimensional and two-dimensional views of power, and latent conflicts of interest, which characterize the three-dimensional (hegemonic) view of power. The third, needed to complete the definition of latent conflict, is the concept of real interest, which refers to interests linked to conflicts that are not consciously perceived by a person but exist at an unconscious or instinctual level; where the adjective instinctual refers to everything that is part of the profound constitution of the human being and that characterizes the very essence of what is human.

The concept of real interest is the most controversial feature of the three-dimensional view of power. Lukes refers to many theories and approaches by notable social scientists to articulate it, such as Nussbaum's capability approach, Elster's concept of adaptive preferences, the Gramscian concept of hegemony and false consciousness, and Bourdieu's concept of habitus. Here, we fully accept Lukes' arguments. Therefore, we recognize the possibility that there are capabilities (borrowing Nussbaum's meaning of capability) of which no human being would like to be deprived. When someone deprives a human being of such capabilities, even if they are not aware of the deprivation, their interests have still been harmed, and therefore a relationship of domination can be prefigured. Based on these premises, we ask whether the digital revolution in the agri-food system can be associated with the exercise of three-dimensional power. We try to answer this question by presenting three examples. The first example refers to the use of three-dimensional power to ensure that the digital revolution also enters a part of the EU agricultural sector, namely organic farming, which has traditionally opposed most digital innovations. The other two examples refer to digital innovations in the food system that can lead to the exercise of three-dimensional power. Despite their limited scope, these examples are important because they highlight the need for food system scholars and policymakers to analyze this form of power and delve deeper into its various theoretical and empirical aspects, which are only rudimentarily addressed in the present study.

The first example illustrates how the current push for digitalization in organic farming relies on the exercise of three-dimensional power. In the EU, organic farming is institutionally defined by the principles set out in European legislation (Regulation (EU) 2018/848) and is supported by controls on farmers, processors, and traders, as well as by an EU-wide labeling system. Ordinary people understand that organic farmers do not use pesticides, fertilizers, and antimicrobials to reduce pollution caused by conventional agriculture. However, organic agriculture extends beyond these definitions. It was born as a social movement in the seventies, inspired by the democratic and anti-capitalist environmental movements of the sixties. These movements sought a new relationship between humans and nature, based on a holistic vision of living things, non-hierarchical thinking, a return to less industrialized foods, and the rejection of the deeply rooted modern capitalist notion of dominating nature. The intellectual roots of organic farming lie in the works of authors such as Masanobu Fukuoka, Rudolf Steiner, and Evelyn Fox Keller.

Many digital technologies in agriculture, as we have seen, profoundly contradict the original principles of the organic agriculture movement. However, the dominant narrative of digitalization as the obligatory path for more sustainable FS has sparked a debate (Hilbeck et al., 2020) among academics and organic farmers on the need for organic agriculture to embrace digital innovations, including gene editing, precision agriculture, and nanotechnologies. The acceptance by many organic farmers of these technologies can be seen as the effect of three-dimensional power. By accepting such technologies, they go against their real interests, which in this case must be understood as the safeguarding of the original principles of organic agriculture, the renunciation of which would signify its death. Farmers' difficulty in recognizing their interests stems from their inability to identify the intellectual and political origins of the organic movement, from which most organic farmers have internalized values and lifestyles. When the dominant narrative at the level of European institutions presents organic agriculture only as a tool to achieve narrow sustainability objectives (i.e., objectives expressed in terms of indicators such as carbon emissions, increased yields, and irrigation efficiency), every digital application that could impact one of these indicators is seen as compatible with organic farming, even by organic farmers themselves. In other words, organic farmers perceive, on an unconscious level, that digitalization distances the system from true sustainability and accelerates the process (Konstantinidis, 2018) of conventionalizing organic agriculture. However, they do not openly oppose digitalization and often accept it, succumbing to three-dimensional power exercised by European institutions. Instead of stimulating an open debate on digitalizing the organic sector, these institutions promote it indirectly, substituting digitalization for organic agriculture as the main 'greening' policy within the CAP. As a result, the conflict between organic farmers and institutions wanting to introduce currently banned digital innovations into organic farming becomes latent.

The second example of three-dimensional power refers to the automation processes promoted by digital technologies. Here, we assume that the "hidden real interest" underlying the latent conflict is the desire of people involved in some production process to understand the risks associated with their work and to participate, even partially, in risk management decisions. Such a desire is part of the principle of autonomous judgment, which characterizes the ethical integrity of a human being. Farmers must continuously make decisions in complex and uncertain contexts. They need good knowledge of the specific climatic and soil conditions of their territory and must have adequate economic and agronomic skills to respond effectively to crises induced by adverse climatic conditions or plant and animal diseases. Different farmers respond in different ways. Some rely on standard procedures, while others seek innovative responses. They can succeed or fail and may try to balance the economic and environmental impacts of their choices. The new AI-powered integrated farm management systems offer a bundle of coordinated digital technologies that link data continuously collected through sensors in the field to data centers owned by agribusiness suppliers (i.e., suppliers of irrigation systems, fertilizers, chemicals, and engineered seed).

These algorithms will use the data to provide ready-to-use customized solutions to farmers for tackling economic, weather, and disease issues. Consequently, the only knowledge required from farmers will be how to use system interfaces and operate the given instructions. AI-powered integrated farm management systems entail the adoption of system-level solutions that radically change farm organization, disrupting old organizational systems and management models along the supply chain. These changes will lead to a shift in power at the industrial level (data-rich industries becoming more powerful) and at the job level (with a few new valuable digital jobs

disrupting previous jobs). Farmers' skills and knowledge will be disrupted, and since they give away their data for free, their economic position (in terms of share of value added) within the food supply chain will be weakened.

Moreover, what farmers are giving up is not only their knowledge and skills but also their control over decisions and responsibility for the associated consequences. Therefore, another loss of power for farmers is in terms of hegemonic power, due to the shift of judgment power from farmers to machines. A trait of AI-powered management systems is that they decouple judgment (i.e., the capability of choosing among alternatives, relying on an individual's cognitive abilities and moral values) from decision-making. Machines cannot make decisions; the AI generates a prediction, and then the machine draws upon judgment codified in software by the creators of algorithms to execute an action. Users (in this case farmers) of the management system will make a decision by executing the action suggested by the machine without expressing their own judgment. Automation requires codifying judgment. This judgment is expressed not by the machine but by other persons, the algorithms' creators. Here we have the exercise of hegemonic power because farmers give up their judgment capability without being aware of the conflict of interest. Moreover, there is a shift in who makes the decision, with power moving from those who previously applied judgment (farmers) to those who provide it for codification (creators of algorithms) or own the system in which it is embedded (companies selling the management systems and the associated digital technologies). Codifying judgment also means that a person's decisions can have an extraordinary scale since all the machine users will act following the same judgment. The main problem with machine automation is that it obscures the ultimate person responsible for a decision, which is another reason why possible conflicts derived from such judgments become latent (Agraval et al., 2022).

The third example of three-dimensional power refers to the many digital innovations that are dramatically changing people's relationship with food, and their purchasing and consumption habits. These include smart packaging that signals the freshness of a food product, extends its shelf life, or enables AI-supported traceability systems; nanoencapsulation techniques used for enriched and nutraceutical food products; bioengineering technologies allowing the development of novel foods, such as plant-based meat; and AI-powered eating applications that serve as virtual nutritionist assistants (Devecchi et al., 2023). All these innovations produce three negative outcomes. First, they further promote the consumption of ultra-processed food, an unhealthy habit associated with the epidemics of many noncommunicable diseases (Mozaffarian, 2020; Katidi et al., 2023). Second, they make individuals lose control over their diet in terms of affordability and knowledge, not only of nutrients but also of production and preparation processes. In other words, digitalization shifts food knowledge from people to the algorithms created by multinationals controlling the digital market. Third, people lose a source of pleasure, with eating changing from a simple, relaxing, and joyful activity to a fitness/health race based on the best algorithm. In this case, three-dimensional power is exercised by imposing unhealthy and possibly more expensive dietary habits through adaptive preferences, with consumers' desires and beliefs shaped to adapt to the further food technologization demanded by food system digitalization. Once consumers are given no alternative choices and are persuaded of the benefits of new dietary models by AI-powered fine-tuned communication strategies, their real interests (i.e., healthier diets and autonomy over food choices and access) become hidden, and conflicts become latent.

6 Conclusion

Digitalization is a new business model based on data collection and processing using digital technologies, particularly AI. Food system digitalization may produce radical changes in how food is produced, distributed, and consumed, disrupting traditional agriculture and eating habits, displacing workers, and erasing rural communities and their knowledge of "natural" food growing and processing. The disruptive power of digitalization depends mainly on three important features. First, digitalization entails system-level rather than point-level innovations, which means innovations with high disruptive capacity. Second, digitalization enables many research fields, such as biotechnology, nanotechnology, and cellular agriculture, and therefore accelerates the transition to a diet increasingly based on ultra-processed food. Third, due to the scalability of digital innovations, it favors further consolidation of the food system at the global level, disrupting traditional local food chains.

Disruptive innovations produce power shifts, leading to negative social outcomes and the need for state intervention to mitigate possible social imbalances. This article brings new insights into the processes of power shifts produced by food system digitalization. It recalls the possible shifts of economic power along the food supply chain and introduces the analysis of political power shifts by illustrating how food system digitalization is associated with the shift toward two-dimensional and three-dimensional views of power (namely agenda and hegemonic power).

Results from the analysis of agenda power allow for the following understanding of technological change within the agri-food system. First, they reinforce the literature on technological change that rejects interpretations based on technological determinism. Consequently, they serve to relaunch studies of technological change from a critical perspective that simultaneously considers technological, economic, social, political, geopolitical, and ideological factors. Second, they help create a new narrative of the transformation of food systems that considers alternatives to digitalization. Third, they suggest that resisting the negative aspects of digitalization requires transforming covert conflicts into overt conflicts and understanding the mechanisms through which the exercise of power blocks the transition from awareness of conflicts to political action.

Results from the analysis of three-dimensional power help to shed light on two mechanisms of digitalization that hinder regulation for managing innovation risks. The first mechanism is the induction of adaptive preferences through behaviors influenced by predictions produced by algorithms based on deep learning techniques, which become increasingly effective as the volume of available data increases. The second mechanism is the separation in automated decision-making between the decision-taking step and the judgment step. When novel risks emerge or an AI decision-making tool proves ineffective or damaging to some actors in the system, for example, due to internal biases (Broussard, 2024), it is difficult to identify the

ultimate subjects responsible for mistakes and damages. Automation is enabled by algorithms (i.e., the rules, predictions, constraints, and logic that determine how a decision is made) with encoded judgments; therefore, the responsibility for these judgments lies with the creators and/or owners of the algorithms. When these subjects are difficult to identify or are a handful of very powerful people, regulatory interventions become extremely difficult.

The overall result of the study offers a further perspective, based on the analysis of shifts from one form of political power to another, useful for better understanding the political issues raised by food system digitalization. One important result has been to illustrate how the concentration of decisional and organizational power produced by new prediction techniques may endow the "few people in power" with a particularly subtle form of political power, i.e., the three-dimensional view of power (hegemonic power). Such power may lead to democratic backsliding due to its ability to neutralize conflicts through false consciousness.

The article offers only a first and limited attempt at analyzing the connection between digitalization and power and has some limitations. It addresses only the political dimension (in terms of domination, i.e., power over) of power, uses one analytical approach, and limits the analysis to the case of the EU. Moreover, the analysis of three-dimensional power is somewhat limited because, due to the restricted scope of the article, it does not address the many empirical and theoretical issues raised by such a concept of power.

Acknowledging these limitations helps to draw recommendations for further research, pointing to three strands of investigation.

First, further research should investigate other possible aspects of power (for example, stemming from psychological and sociological perspectives and considering also the 'power to' and the 'power with') and provide empirical evidence through case studies. In this regard, the power cube model allows us to analyze, in empirical research sets, processes of domination and resistance, and to address the dynamics of power relations among actors engaged in sustainable development projects (Discetti et al., 2020; Smith et al., 2022). Moreover, an expansion of the research field should also include the debate on the definition of the food system (Brock, 2023) and its consequences on the study of power dynamics.

Second, further research should assess the usefulness of other concepts and theoretical perspectives for unveiling the power-digitalization relationship. Different political and social theories may help to shed light on the 'power shifts' produced in the food system by digitalization, each of them fitting different issues, sectors, and research purposes (descriptive, analytical, normative). The use of alternative theories to analytical political theory would also help to better delimit the meaning and theoretical stances of the concept of hegemonic power. For example, comparing Lukes' view of hegemonic power with the Foucauldian power view would help to highlight the strengths and weaknesses of both perspectives. Both views acknowledge the embeddedness of power relations in social and cultural structures but with different analytical strategies to account for such embeddedness. Lukes maintains the hypothesis of the autonomy of agency in social relations (partially maintaining the hypothesis of methodological individualism), thereby limiting his analytical ability to capture the interplay between agency and structure. Foucault abandons the belief in human agency, allowing for a better description of real-world power relations and introducing what Digeser (1992) called the fourth face of power. However, by renouncing human agency without providing a consistent analytical framework for studying the interplay between agency and structure (and agency and culture), Foucault does not solve the deep epistemological dilemma of social sciences. As Archer, who devoted her academic work to addressing this dilemma, notes, it is essential to avoid both "Upwards Conflation (when the powers of the 'people' are held to *orchestrate* those of the part) and Downwards Conflation (when the 'parts' organize the 'people')" (Archer, 2000, p. 5).

Third, further research should extend the study of power and food system digitalization to other countries, especially the US and China, to investigate the link between food system digitalization and geopolitical power. The history of relationships between food and international conflicts is old and rich (Merleaux, 2015; Weinreb, 2017; Koch, 2021); it includes the intimate relationship between modern military technologies and food/agricultural technologies, the militarization of food, and food blockades. Food system digitalization could offer a new array of tools in food warfare scenarios; democratic states willing to protect world peace should be aware of such risks to prevent them, for example by regulating digitalization and protecting alternative food production systems.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

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