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Amidst a global race: how EU's food system can be competitive and sustainable

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Content

Foreword

The European Union is at a crossroads. Rapid geopolitical shifts — from rising global tensions and disrupted trade flows to the growing urgency of the climate and biodiversity crises — are transforming the very foundations of our union. These developments compel the EU to rethink its priorities and redesign its strategic autonomy.

The EU's food system is a case in point. Historically, Europe has excelled in this sector by combining productivity, innovation and safety. However, productivity growth is slowing, climate change is intensifying, and generational renewal is under pressure. Yet the sector's strategic potential is not sufficiently recognised in current European policy debates. While the recent Draghi Report on European Competitiveness offers valuable insights into Europe's economic future, it pays too little attention to the food sector, a critical pillar of the EU's strength, resilience, and innovation capacity. This blind spot must be addressed. The Agri and Food Vision rightly emphasises that if Europe makes its food system sustainable and circular, the sector can become a model of competitive advantage.

But how should Europe position its agri-food system globally? What are the geopolitical, economic, social, and environmental dilemmas? As global uncertainties multiply, Europe's ability to act coherently and decisively depends on the quality of its policies — which in turn depend on a strong knowledge base and trust among science, policy, and society.

At Wageningen University & Research (WUR), we believe science should guide policymakers. The complexity of today's challenges — from food security to sustainable production and from climate adaptation to geopolitical resilience — requires decisions informed by facts, not fears. The path forward demands collaboration across disciplines, borders, and institutions.
Evidence must remain the foundation on which we design our collective future. By aligning science with policy, and sustainability with competitiveness, Europe can secure its place as a global leader in agri-food innovation — not by looking back, but by courageously shaping what lies ahead.

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Summary

In the context of a turbulent world in which, today, cooperation seems less feasible and international dependencies can have negative connotations, this essay poses the question ‘Can the EU agri-food system produce and consume more sustainably and still be competitive?’ We explore how the EU food system can address the multiple challenges with respect to the need for healthy and safe food, good stewardship with respect to the environment, climate and biodiversity, and economic profitability and social viability. To address these challenges, and given the dominant societal values in the EU, we argue that a more inclusive competitiveness-concept is needed. Not one that solely focuses on short term (individual) business interests, but one that facilitates welfare outcomes of society as a whole, including future generations, and one in which economic profitability does not compromise stewardship of the environment, climate, and biodiversity.

The EU’s food system has an important position in the domestic economy as well as internationally. The EU’s largest manufacturing sector, the food and drink industry, directly employs 4.7 million people across 300,000 companies, mostly SMEs. This industrial ecosystem not only supports upstream agricultural activities (including input suppliers of seeds, fertilisers, feed and machinery) but also drives downstream market dynamics within EU’s single market and beyond. Taken together, the entire agrifood value chain generates more than €1 trillion in gross value added for the EU economy, surpassing for example the economic footprint of the EU automotive industry.

Where the Draghi report emphasises the need for innovation to increase productivity to ensure the EU remains internationally competitive (particularly vis-à-vis the US and China) and sustains economic growth, this essay focuses on options to sustainably strengthen the agri-food sector’s competitiveness, i.e. the ability to leverage competitive advantages and retain long-term viability. Competitive

advantage is not only dependent on current cost and price considerations, but more particularly on the ability to innovate and drive change to shift or even eliminate (future) constraints and dependencies. We argue that active governance with respect to breakthrough or transformative technologies (digital, biotech) can help to address ecological, agronomic, social and governance innovation gaps, and therewith generate an important contribution to the pillars of sustainable competitiveness.

Today, the EU is the world's largest exporter of agricultural and food products, with its trade contributing to the EU's GDP, employment and the provisioning of consumer demand for food, both inside and outside the EU. The growing trade surplus in the agri-food sector can be seen as an indicator for its competitive strength and it facilitates prosperity-enhancing specialisation. However, dependencies are increasing, especially as value chains have become more complex and lengthening. Luckily, research shows that for many products such dependencies, are not critical. The EU is, however, directly dependent on imports of tropical products, vegetable proteins and oils, and indirectly on global land-use, as well as on (imported) chemical fertilisers. Geopolitical tensions reinforce concerns about these dependencies. So far, the EU's strategy to cope with dependencies looks solid as the food system passed various stress tests (e.g. COVID crisis, Russian war at Ukraine, import tariffs against the EU by the US) successfully. However, in today's turbulent times, we need to update and improve this strategy continuously.

In summary, the main message of this essay is that the economy in general and the food system in particular must serve — not control — human needs, including those related to (caring for) the environment, climate, biodiversity, and (animal) welfare. The concept of competitiveness must be adapted to a broader welfare measure of well-being. Innovations, which will be shaped in part by the transformative digital and biotechnological innovations currently gaining momentum, are crucial to supporting the sustainable competitiveness of the EU food system. Innovations must be deployed across four dimensions: environmental, agronomic, social, and governance. To be competitive in the global race, the EU will need to focus its R&D efforts, investments, and policy interventions (regulations, incentives) on supporting the long-term sustainability and productivity of its food system.

1 Introduction

1.1 Turbulent times

We live in turbulent times

The world and the EU are facing turbulent times. From 2008 to 2015, the global financial crisis, with origins in the United States (US) housing market, affected the EU, leading to significant economic decline and rapidly rising unemployment, from which it has only slowly recovered. In 2020, this was followed by the Covid crisis, generating an unprecedented health crisis and a shock to population and the food system. Then, in 2022, Russia initiated a full-scale invasion of the Ukraine, following its 2014 invasion of Crimea. This marked the beginning of the first interstate war on the European Continent since World War II. Although coined as a 'regional conflict' by some, Russia had secured the 'friendship' of China, while the US and the EU responded with a set of sanctions against Russia. Controlling the Black Sea area, one of the world's breadbaskets, Russia used food as an additional weapon to strengthen its international 'diplomacy'. Even though other countries (e.g. India, South-Africa, Brazil) remained fairly 'neutral', the impact on global markets, particularly energy price, has been significant, and its impact on the geopolitical constellation is undeniable.

National political landscapes have also shifted, as evidenced by the rise of the political influence of populism combined with a resurgence of nationalism in many countries, not least the US following the re-election of President Trump and the reinstatement of significant trade tariffs. The debate on access to raw materials has intensified due to geo-political dynamics and is intertwined with the aforementioned developments. The relationship between the EU and the US has also been affected, requiring the EU to make significant investments in its defence and security systems (EY, 2024).

These developments come on top of existing major challenges related to climate change, migration flows, and unprecedented biodiversity loss. Climate change, for example, is intensifying across Europe, with the continent warming at more than double the global average rate (ECMWF, 2025). This acceleration is leading to more frequent and severe climate extremes, disproportionately affecting coastal regions, mountain regions, and agriculture in particular. In view of maintaining and growing a sustainable and resilient EU agri-food sector, ambitious climate targets are needed, with an important role for nature and biobased solutions from the EU agri-food sector.

The EU needs to respond based on its own vision and values

The dramatically changing external and internal 'environment' poses great challenges to society, business, and policy makers. In this new geo-political era, the EU urgently needs to reposition and rethink itself in the context of these recent developments and challenges. Compared to the US or China, the EU has always pursued a distinctly European approach. Where the US relies on unfettered (market-oriented) capitalism and China follows a pathway of state-oriented capitalism, the EU propagates a European Model (Draghi, 2024). The key difference is the way in which the EU seeks to combine economic growth with social values, valuing variation and its ambition with respect to sustainability. The choice to balance economic with social and ecological objectives can be traced back to the broad set of values underlying the EU experiment as well as the traditions of its Member States (e.g. for example Albert, 1991; Balkenende and Buijs, 2023). These values include human dignity, individual freedoms, representative democracy, equality, the rule of law, and human rights.[1] Relative to other countries, the EU is characterised by its increasing focus on a 'well-being economy' based on a 'broad welfare'-concept, emphasising the importance of societal flourishing rather than productivity and income alone.

The EU approach has proven successful. For example, it has built a single market that accounts for approximately 17% of global GDP, while income inequality is significantly lower than that in the US and China (see table 1.1 below; right column; estimated Gini-score). At the same time, the EU's approach has yielded great results in governance, healthcare, education, and environmental protection, and the EU leads the way in life expectancy at birth and low infant mortality (Draghi, 2024). Nevertheless, its income per head lags behind that of the US (uncorrected for differences in working hours; Darvas, 2023), and the EU's GDP growth rate lags

1 The EU's values are laid out in article 2 of the Lisbon Treaty and the EU Charter of Fundamental Rights.

behind those of the US and China (see Table 1.1).[2]

Table 1.1 GDP and well-being: selected summary statistics.

Continents	GDP/capita*	GDP growth	WHR score **	inequality score ***
EU	62,434	1.4	6.61	29.6
US	85,810	2.0	6.72	41.8
China	13,303	8.3	5.92	35.7

* Values for 2024; purchasing power parity; in current international dollars.

** WHR refers to the World Happiness Report-ranking score on life satisfaction.

*** Gini score, based on World Bank (2024).

Source: authors, based on World Bank and World Happiness Report (WHR).

Looking at a broad prosperity-perspective the EU performs well

For decades, EU Member States have dominated the life satisfaction rankings, with the Nordic countries, including the Netherlands, steadily in the top 5 (Helliwell et al., 2025). Their citizens not only enjoy high-income levels, but also low levels of income inequality, a better work-life balance, and a healthy living environment (cf. WHR-scores in Table 1.1). Although not all EU countries enjoy these high levels, the southeastern member states in particular have lower scores, these differences are declining rapidly: in 2015 the gap was 0.9 on a 10-point scale, and by 2024 it had narrowed down to 0.2. Overall life satisfaction in the EU is thus increasing, in comparison to the US where a decline of 0.4 has been noted. The increase in life satisfaction in the new member states even outperformed the significant increase in life satisfaction in China. The EU is also a global leader in sustainability and environmental standards, and progress toward a circular economy (EEA, 2024). Yet, economic growth rates are higher in the US and China (see Table 1.1. showing few 'broad welfare' indicators for EU, USA and China).

1.2 The EU's third way

A third way in which agriculture serves multiple purposes

With respect to its agriculture and food sector, the EU also follows its own 'third way'. In the EU, agriculture is more than food and fibre production; the sector is widely

2 Note that GDP per capita varies considerably within the EU. Another twist in the EU-US comparison is an adjustment to working hours. In Europe, employees generally work fewer hours than in the US, partly because there are more paid holidays, the typical workweek of a full-time employee is shorter, and there is a higher share of part-time workers than in the US. Several EU member states record higher GDP per hour worked than the US average. See Darvas (2023).

recognised for managing the provisioning of ecosystem services such as biodiversity preservation, landscape conservation, water storage and similar. The concept of multifunctionality and the model of agricultural production in which family farming serves as its backbone, reflects broader societal preferences and policy priorities beyond the pursuit of economic profit. This can be seen, for example, by the steady role of farm income support which supports farmers and rural communities in pursuing non-market activities such as landscape preservation, while concurrently balancing income distribution between sectors and (urban-rural) regions. Moreover, as sustainability and a balanced territorial economic development are important issues in the EU Treaty, the EU finds it important to address market failure (e.g. negative and positive externalities) with corrective policies. Given the broader societal context in which the EU agricultural sector operates, actions to address major challenges such as ensuring food security, adapting to climate change, and reducing environmental pressures, should not be limited to the primary sector alone. A more holistic food system approach is needed, premised on the principle that all actors in the system contribute to improving its outcomes.

... and in which food-related challenges are addressed from a food systems perspective

The severe political, societal and ecological challenges we are currently facing underscore the need to (re)consider the future direction of the EU agri-food system: What should the EU's mission be? Will it choose to remain true to its values and further the '2015 agenda' of SDGs and the Paris climate Agreement? Or will it cave under the pressure of the current shockwaves of the Ukraine war and geo-political 're-parcelling', and gradually sideline its green ambitions and moral values?

Today's context is one of globalisation, emphasising the interconnectedness that characterises the world economy and its main player, who are no longer necessarily nation states.[3] This development in globalisation has contributed to welfare in many parts of the world, but has also raised issues with respect to fairness and inequality. After a period of multilateralism and bilateralism to facilitate freer trade, now the world trading system is contested for the (perceived) imbalances it creates. This is currently exemplified by Trump's MAGA policy approach and return to a world in which the neo-liberal world order is contested, and countries threaten each other by imposing import tariffs. In a context of global turbulence and increasing uncertainty, prices of essential commodities tend to increase and/or become highly volatile, thereby threatening economic resilience and social stability in a continent that is structurally dependent on these imports. What do these developments mean for the

3 The race in space also intensified, though it lies beyond the scope of this report.

EU? What are the economic dependencies and social implications, how can the EU cope in the best possible way? The 2024 Draghi report "*The Future of EU Competitiveness*" addresses these challenges and offers an agenda for competitive growth with recommended technical and social innovations. Draghi's analyses focus on the EU's macroeconomics and specific industrial sectors, but the agrifood sector is not included.

1.3 The storyline

This essay explores how the EU food system can address the multiple challenges with respect to the need for food, good stewardship with respect to the environment, climate and biodiversity, and economic profitability and social viability. This in the context of a turbulent world in which, currently, cooperation seems less central and international dependencies can have negative connotations. We ask the question: Can EU agriculture produce more sustainably and still be competitive? In the context of the abovementioned challenges, this raises, firstly, the question of what type of competitiveness is needed. We argue that, given the wide set of societal objectives and concerns, a more inclusive competitiveness-concept is needed. Not one that solely focuses on short term (individual) business interests, but one that facilitates welfare outcomes of society as a whole, including future generations, and one in which economic profitability does not compromise stewardship of the environment, climate, and biodiversity. Is this feasible for the EU food system players who participate in EU-wide and international value chains? And what are the conditions that have to be satisfied to make this work?

The EU agricultural sector, together with the rest of the agri-food business chain, has a strong international position; the EU is the largest exporter of agricultural and food products. At the same time, the EU is directly dependent on imports of tropical products, vegetable proteins and oils, and indirectly on global land-use, as well as on (imported) chemical fertilisers. Geopolitical tensions reinforce concerns about these dependencies, while the loss of biodiversity, soil health, and water quality also require adjustments to the agricultural system production and consumption practices to achieve a lower ecological footprint (e.g. The EAT–Lancet Commission on healthy, sustainable, and just food systems, 2025). Policy interventions to support the long-term sustainability of agricultural production and food processing by encouraging lower input use may lead to a short-term decline in productivity and production, increasing concerns about the EU's food security in a turbulent world. However, innovations can stimulate more sustainable agricultural, food processing and consumption practices. But how these innovations contribute to an efficient, inclusive and ecologically sustainable food-system is a question that is not easily answered.

Where the Draghi report emphasises the need for innovation to increase productivity to ensure the EU remains internationally competitive (often comparing the EU with the US and China) and maintains economic growth, in this essay we look at options to sustainably strengthen the competitiveness of the agri-food sector, i.e. the ability to leverage competitive advantages and retain long-term viability. Competitive advantage is not only dependent on current cost and price considerations (or, more generally, on the ability to perform within a given set of restrictions), but more particularly on the ability to innovate and bring about (technological) change to shift or even eliminate (future) constraints (Faucheux and Nicolai, 1998). In line with Porter (1990), competitiveness at industry level may well be achieved through higher productivity or lower prices, but also by the ability to provide different, better-quality and higher-priced products. Sustainable competitiveness, thus, assesses fair competition, the relationship of resource efficiency – productivity – circularity, and how broader welfare aspects and sustainable competitiveness of the agricultural sector relate to each other. For each theme, we examine the role of technical and social innovations. We conclude with recommendations on how to promote sustainable competitiveness of the agri-food sector, while simultaneously supporting human and environmental well-being.

This Mansholt Lecture complements other studies that present a strategic vision for the EU, but that pay less attention to the agri-food sector. We argue that EU's food system deserves strategic considerations because its ability to function well is of fundamental importance to ensure food security and a transition to a (more) nature-inclusive and biobased society, as the social-ecological foundation of a vital society within planetary boundaries. In addition to Draghi's report, we also consider the February 2025 Vision on Agriculture and Food by EU Commissioner Christophe Hansen to be an important reference document. That vision also emphasises the importance of competitiveness. We argue that this concept may benefit from further 'deepening'. Therefore, in this essay, we apply the concept of sustainable competition in the EU's food system context embedded in the wider EU bioeconomy, and we explore implications for investments and trade strategies. This is a vast area and we make no attempt to strive for completeness. The main contribution is to provide food-for-thought in a time characterised by many uncertainties, and where the EU should reconsider its current position while preparing for the future.

The essay is structured as follows. Chapter 2 characterises the EU's food system, its components, their interrelationships, and the various challenges the system faces to ensure the social, economic, and environmental outcomes it is designed to deliver. Chapter 3 then introduces and explains the concept of sustainable competitiveness, applying it to the EU food system by demonstrating how all dimensions of sustainable competitiveness are relevant for the agri-food sector. The chapter concludes that sustainable competition should be viewed primarily as a "delivery model" (i.e. means) in which competition is assessed and managed based on the outcomes it generates.

Innovation is a key driver of sustainable competitiveness. Chapter 4 assesses several general aspects of innovation and their implications for innovations in the food system. We then discuss past productivity trends in EU's agricultural and food processing sector, and argue that although they have been successful, a further rebalancing towards sustainability dimension is needed. Four dimensions of innovations are then identified and discussed in terms of their capacity to sustain and strengthen sustainable competitiveness: an environmental, agronomic, social challenge, and institutional and governance innovation dimension. Because these four dimensions of sustainable competitiveness interact (i.e. potentially reinforcing but also potentially counteracting each other), they all require careful attention to achieve balanced sectoral development. A subsequent analysis links the four innovation challenges to transformative innovations originating from digital and biotechnology.

Opening up markets and sectors to exchange and competition may add risks to the EU's food system and EU food security. This could provide an argument to restrict competitiveness for selected sensitive inputs and products. Chapter 5 dives into the economic (import) dependencies of the EU food system, as well as implications for its resilience. While the EU generally performs well and maintains a stable and resilient agri-food system, it still faces important dependencies, some of which have proven to be critical.

The final chapter (Chapter 6) synthesises the narratives from the preceding chapters, highlighting the insights gained, and outlining strategic choices to ensure the EU food system remains sustainable and competitive. We contextualise these trade-offs within the EU's strengths (and dependencies) compared to the US and China. Key insights include that (i) the sustainable competitiveness paradigm is most appropriate given the EU's values and cultural context; (ii) sustainable competitiveness requires environmental, agronomic, social, and institutional and governance innovations, which can be supported by and benefit from transformative technologies; and (iii) networked collaboration is crucial because effective and efficient sustainability solutions go beyond the capabilities of individual actors and require collective action. Moreover, knowledge, expertise, and experience are often dispersed (e.g. within companies, their R&D departments, within knowledge institutions, etc.), and therefore there is a need to bring them together and stimulate (adaptive) learning and cross-fertilisation processes supporting innovation ecosystems.

Notes to the reader

The food system is a comprehensive system, covering food 'from farm to fork', including impacts on the environment and biodiversity. In this essay, we have intentionally chosen to follow a food systems approach, as this determines the context within which all activities and actors in the food systems have to be evaluated. Although in some Chapters the scope may be narrowed to specific activities or the agri-food sector as a subsystem, this needs to be considered within this broader food systems context and the expectations society has with respect to the results this system should deliver. The food system has to be seen as part of the wider bioeconomy. In some places we refer explicitly to this wider embeddedness, but the main focus is on the food system. As competitiveness implies rivalry in a commercial business and/or market context, we look strongly at the economic aspect. However, it is clear that sustainable competitiveness goes 'beyond GDP' and has to be seen within the wider context of sustainable development.

In this essay, we mainly rely on existing research, accompanied with new and updated representations of data and figures. Although, ideally, we would have been complete in terms of issues and factors related to (strengthening) sustainable competition in (EU) food systems, we acknowledge we could only address a selection. In an attempt to illustrate the width and breath of the topic, highlights and examples are used (e.g. special Boxes) related to research by Wageningen University & Research (WUR) and/or the Dutch situation. This essay was written by a quartet of WUR authors who chose not to rely solely on their own expertise and input, but to consult experts from both inside and outside WUR.

2 The EU agri-food system in perspective

2.1 The food system concept

Food systems thinking clarifies actors' relationships and drivers that shape the system
Food systems are complex entities that comprise all the processes associated with food production and food utilisation such as growing, harvesting, packing, processing, transporting, marketing, consuming and disposing of food remains. All these activities require natural resources and other (human-composed) inputs, and result in food and non-food agricultural products and/or services, income and access to food, as well as environmental impacts. A food system operates in and is influenced by social, political, cultural, technological, economic and natural environments, and is embedded in the wider bioeconomy. Food systems are present in both rural and urban areas across the globe and explicitly connect production to consumption. Food systems continuously change under the influence of 'driving forces' that emerge from these environments: factors that actors in the system (farmers, traders, suppliers, processors, and consumers) cannot directly influence, but which exert a long-term and therefore lasting influence on the form and the functioning of the food system.

Food systems literature has shown different ways of conceptualising the food system: some include more detail in food system activities, considering more complex interdependences and relationships between activities and outcomes than others, some have a greater orientation on impacts of food system activities and outcomes on natural resources, and others on the consequences of food system activities and outcomes for diets. A schematic representation of food system activities and their relationships with drivers and outcomes of the food system is shown in Figure 2.1.

In this Figure, the core elements of the activities in the supply chain are recognisable, including the food consumers. The drivers and outcomes of the food system are based on the most commonly used conceptualisations of the food system.

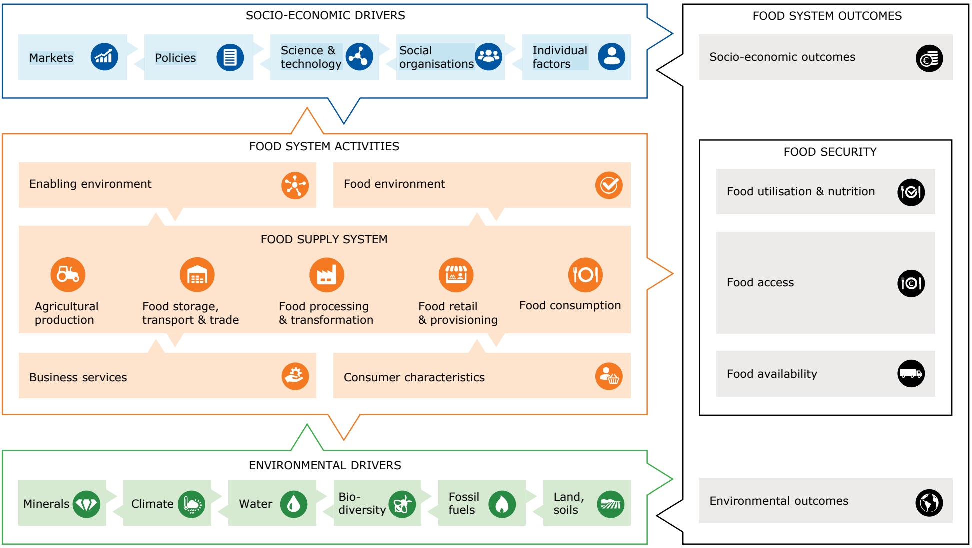

Figure 2.1. Relationships of the food system activities and outcomes to its drivers.

Source: Van Berkum et al., 2018, with adjustments.

... and point at feedback loops that help understand food system dynamics and address resilient and sustainable food systems

A defining feature of systems thinking is that it views the behaviour of a system as an interplay of interacting subsystems, in which feedback plays a key role, rather than as a simple chain of cause-effect relationships. This also distinguishes systems thinking from other approaches such as farming systems, sector or chain approaches in which interventions are often designed to make optimal use of the means of production (natural resources, labour, capital). This commonly involves applying technological innovations at the level of (family) businesses, sectors and/or chains, with a focus on raising productivity and profitability. Although these approaches also analyse the impact of interventions on the market (prices, incomes) and environment (CO_2 emissions), and the depletion of natural resources (erosion or water shortage), they tend to pay insufficient attention to feedback from the socio-economic system and/or ecosystem to the farm, sector or the supply chain. Food systems thinking zooms out from the place where the intervention occurs, thereby providing an opportunity when analysing the outcomes of policy interventions to include feedback from outcomes outside the activities that relate directly to food production and consumption. This also makes a food system approach (FSA) a valuable perspective to address resilience (robustness) of a food production system, which is about the capacity of the system to absorb short-term shocks such as an animal disease crisis or trade boycott or long-term shocks such as climate change and biodiversity loss.

2.2 Characteristics of the EU's food system

Global food systems vary greatly. They cover a broad spectrum, ranging from systems developed by communities dependent on hunter-gatherers to meet local needs, to systems developed by globalised societies cooperating in a global market. In the widely used dichotomous typology of food systems (traditional and modern; see e.g. Reardon & Timmer, 2012; Marshall et al., 2021), the EU food systems can be defined as a modern, capital-intensive, external input-intensive system, as opposed to traditional systems, where labour dominates over capital and relatively few external inputs are used. This dichotomy is clearly an oversimplification, because in EU food systems short local supply chains also exist in parallel with more complex, vertically integrated global supply chains.

The EU food system is divers, generating over €1 trillion in gross value added for the EU economy

The EU food system is diverse and consists of a variety of actors, large and small companies, and varying degrees of concentration per part of the food supply chain. The EU's agrifood supply chain includes farmers, farm input suppliers, food and drink manufacturing, wholesaling, retailing, logistics, packaging, and related services (See Figure 2.2). The EU's primary agricultural sector includes approximately 9.1 million holdings and employs around 9.2 million people. The EU's largest manufacturing sector, the food and drink industry, directly employs 4.7 million people across 300,000 companies, mostly SMEs. This industrial ecosystem not only supports upstream agricultural activities (including input suppliers of seeds, fertilisers, feed and machinery, who are not presented in Figure 2.2) but also drives downstream market dynamics within EU's single market and beyond. Taken together, the entire agrifood value chain generates more than €1 trillion in gross value for the EU economy, surpassing the economic footprint of the EU automotive industry. This underlines its strategic importance, in addition to food security, for employment and regional and EU development.

	Agriculture	Food and drink manufacturing	Food and drink wholesale & retail	Food and drink services
	Agricultural produce & raw materials		*Food & drink products*	
Activities/ focus	Crop farming, livestock, forestry and fishing	Processing and/or manufacturing of food and drink products	Distribution of food & drink products- wholesaling; in-store, stalls and market retailing	Restaurants, fast foods, bars, cafés and food delivery services
Number of enterprises/ holdings (million)	9,1	0,3	1,1	1,6
Employment (million)	9,2	4,7	8,5	8,3
Value added (billion euro)	222,8	265,8	326,5	180,6
Turnover (trillion euro)	1	1,4	2,5	0,5

Logistics, storage and transport industries | Packaging industry | Service industry

Figure 2.2 The EU Agrifood Supply Chain.

Source: Tidjani et al., 2025.

Small-scale farm structures raises concerns about economic viability and sustainability

The vast majority of the EU's farms are family farms; more than 50% of the agricultural labour force are family members. Most farms are small in nature with almost two-thirds of the EU's farms being smaller than 5 hectares (ha) in 2020. At the other end of the scale, 7.5% of the EU's farms are equal to or larger than 50 ha and farm two-thirds (68.2%) of the EU's utilised agricultural area (UAA) (Eurostat, 2022a).

These differences are further highlighted by analysing farms based on their economic size. Of the 9.1 million farms in the EU, 3.3 million had an annual standard output of less than €2,000, and another 2.5 million farms had an annual economic output between €2,000 and €8,000.[4] Together, , these very small and small-scale farms represented two-thirds (63.7%) of all farms in the EU in 2020. In contrast, 299,000 farms (3.3% of

4 The level of revenue from these farms doesn't yet tell us much about family incomes. Many small farms have secondary income, or they run a small farm in addition to their main non-agricultural income.

the EU total) each produced a standard output of €250,000 or more per year in 2020 and were responsible for the greatest share (56.4%) of the EU's total agricultural output. Differences in farm structure are also significant between Member States, with Romania, Poland, and Italy predominantly having small farms, and the Czech Republic and Slovakia predominantly having large ones. In addition to the small-scale production structure, the issue of aging farmers is also a characteristic of primary agricultural production in the EU: farmers have an average age of 57, with half being 55 or older and less than 12 percent younger than 40 (Eurostat, 2022b). Many farmers will therefore close their farms in the foreseeable future and/or pass them on to a younger generation. However, many farmers have no successor. The aging of the farming population is a problem as older farmers tend to be risk-averse and reluctant to make new investments. Younger generations face difficulties in obtaining financing for taking-over a farm.

These characteristics of the European agricultural sector raise significant concerns about the economic viability and sustainability of farms and their adaptive capacity to respond to societal pressure for greater environmental protection and animal welfare and the effects of climate change, amongst others. Moreover, farms have to reflect changing patterns in food consumption and cope with market changes that affect production costs (e.g. rising energy costs). In coming years, we can expect that the structural transformation will continue and the number of EU farms will further decline.

The EU's population is aging, slowing food consumption growth and saturating food markets. Moreover, consumer preferences are undergoing a gradual but significant transformation. Meat consumption, particularly of beef and pork, is steadily declining, while demand for plant-based alternatives such as pulses is increasing (European Commission, 2024). This shift reflects a broader trend towards flexitarianism (e.g. SmartProtein, 2023), signalling a declining importance of livestock products in European diets. The transition is motivated by increased consumer awareness of health and ethical considerations, including animal welfare, and the environmental footprint associated with livestock production (Perez-Cueto et al. 2022; Ammann et al., 2024. WBAE, 2025). Structural factors, such as the growing availability of plant-based alternatives and EU-level policy initiatives (e.g. sustainability labels; EIT Food, 2024) further reinforce this transition. While consumer preferences for sustainable and ethically produced food are evident across the EU, there is significant heterogeneity (de Boer and Aiking, 2022), often linked to cultural, geographical, and historical factors. Beyond sustainability, there is growing demand for high-quality, nutritious, functional, and fortified food products, further diversifying the internal market landscape.

Agrifood upstream and downstream industries are dominated by large companies ...
Typical of the EU and global food system is the significant concentration of companies in the input supply (upstream), processing, and food retail sectors with the top-10 largest food companies of the world (see Table 2.1). In recent years, developments in food retail have accelerated resulting in hyper-consolidation, with the four largest retailers holding a 60% market share in all but one EU Member State in 2023 (Tidjani et al., 2025). This high level of consolidation strengthens their bargaining power over farmers/traders and food processors. The EU food and drink processing industry is still quite fragmented, with 99% of companies belonging to the SME category (<250 employees). However, this average figure hides sector and Member State differences (OECD, 2024). For example, meat processing, seed processing, dairy, and beverages are highly concentrated, while this is much less so in the bread industry. In countries such as Denmark, the Netherlands, and Finland, the concentration is also much higher than in Italy and Germany. This concentration, which reflects the increasing economies of scale in these sectors, affords these processors and manufacturers substantial buyer power over smaller agricultural producers, especially when negotiating prices and contract terms. International agricultural commodity trading is also traditionally concentrated, with a few strong trading companies controlling important logistical assets (e.g. for transportation terminals and storage facilities) at the main trade hubs (OECD, 2024). There has also been rapid scaling up and consolidation in the input-supplying industry (seeds, pesticides, fertilisers, machinery), where a few large multinationals now dominate. However, these concentration ratios are still below those that, according to EU competition law, would require legal action (Wesseler et al., 2015).

... that can exert market power with potentially negative social consequences
Large corporations can produce efficiently, have the financial capacity to invest in innovation, and are competitive due to their scale. However, the high concentration of corporations in agrifood chains raises significant policy concerns because they can negatively impact food systems (e.g. Clapp, 2025; UN, 2025). First, dominant agrifood corporations can use their market power to generate excessive profits, for example, by charging higher prices or suppressing wages. Moreover, they also have the capacity to influence material conditions within food systems, among others by determining the prevailing technologies used in food production and the food environment. Furthermore, they can exert political power by actively pursuing strategies to influence food policy and governance processes through lobbying and other more indirect measures, thus weakening opportunities for broader democratic participation in food system governance. The EU should closely monitor these developments and decide how and when to intervene, if needed.

Table 2.1 Major food companies in the world.

Company name	Country HQ	Company's profile	Revenue 2025 (US$ bn)
JBS	Brazil	Meat processor	235
Nestle	Switzerland	Food and drinks	101
Ahold Delhaize	Netherlands	Food retail group	101
Archer Daniels Midland (ADM)	USA	Wholesale and processing of agri commodities	83
Sysco	USA	Food distribution to food provisioners	81
Performance Food Group	USA	Food service and distributor	63
Unilever	UK	Food service, distribution and processing	59
Tyson Food	USA	Meat (protein) processor	54
Bunge	USA	Agri-commodity trader and processor	50
George Weston	Canada	Food processor (bakery, meat)	45

Source: Companies Market Cap (retrieved on 1/10/2025).

2.3 What do we need for more sustainable food systems?

Food systems must provide nutritious and healthy food, guarantee food security for all, support the livelihoods of farmers and food workers, and be environmentally sustainable by protecting natural resources and mitigating climate change (HLPE, 2017; FAO, 2025). The EU's DG Agri Vision paper, while placing strong emphasis on strengthening farmers' competitiveness and earning capacity, simultaneously affirms its commitment to working towards a resilient and sustainable agrifood system that respects planetary boundaries and supports the EU's climate and environmental objectives. However, the EU's food system is not (yet) in good shape.

For many, affordability and a healthy diet are a concern ...

While the vast majority of the EU population is food secure, approximately one in twelve EU citizens cannot afford a high-protein meal every second day (see also Duran Laguna, 2024 for regional disparities in food poverty). Moreover, many food-insecure households suffer from the "double burden of malnutrition," a condition characterised by the coexistence of malnutrition with overweight, obesity, and diet-related non-communicable diseases. More generally, the EU currently faces a significant public health challenge related to nutrition with, in 2022, 50.6% of the population being classified as overweight (i.e. with BMI >25) and 17% as obese (BMI

>30)[5]. These percentages have increased in recent decades. Underlying structural problems of nutritional imbalances are diets that contain too much fat, sugar, salt, meat, and ultra-processed products, and too little fibre, fruit, and vegetables (Détang-Dessendre et al. 2022).

... and environmental pressure threatens agricultural productivity

EU's agriculture exerts significant pressure on the environment (soils, water, air, biodiversity). While some progress is visible, for example reductions in ammonia (NH_3) and nitrate (NO_3^-) pollution in certain regions, critical challenges remain. The European Court of Auditors (ECA, 2024) emphasises that despite EU policies (e.g. Water Framework Directive, Nature Restoration) having positive impacts, they have not yet achieved the environmental improvements necessary for long-term sustainability, and warns that persistent gaps in implementation undermine the EU's green ambitions. Reducing greenhouse gas (GHG) emissions from agricultural activities further, particularly in light of the EU's 2050 climate targets, will require systemic changes, especially with respect to ruminant livestock which are both economically vital and environmentally intensive (EEA, 2023), while ensuring the maintenance of extensive grasslands and biodiversity-friendly landscape management strategies.

While agriculture contributes to GHG emissions, climate change also directly threatens agricultural productivity. Currently, climate change is visible in unfavourable weather conditions (drought, flooding, heat stress) that can lead to significant crop or animal production losses. Agriculture and the food industry are major water consumers. Water availability and resilience will become crucial priorities for future adaptation strategies (European Commission, 2025). Soil degradation, erosion and nutrient pollution/eutrophication caused by excess nitrogen and phosphorus from fertilisers and manure application (see JRC 2024 and EEA, 2023), poses another serious threat. Biodiversity loss is one of the most visible symptoms of unsustainable agricultural intensification. It is characterised by monocultures, hedgerow removal, pesticide use, and mechanisation, and has contributed to the decline of populations of pollinators, farmland birds, and beneficial insects, undermining both ecosystem services and food production (EEA, 2025). To transition to a more sustainable and resilient food system, the EU must reconcile the dual objectives of economic prosperity and ecological sustainability, while continuing to ensure food and nutrition security, and the vitality of rural areas.

5 Overweight and obesity - BMI statistics - Statistics Explained - Eurostat.

Migration labour needs more economic and social protection...

The use of migrant labour in both the primary (e.g., horticulture) and (meat) processing sectors is another issue. This group is crucial for EU food security, but is also one that commonly live in physically and institutionally vulnerable situations; working and living conditions are often poor, and legal protection (e.g. against underpayment or dismissal) is limited or non-existent (Augère-Granier, 2021; Alonzo Martinez, 2025).

... and food waste should be prevented

In addition to primary agricultural activities, both the processing industry and food consumption have a significant environmental footprint, primarily through energy consumption and food waste. Animal production generally has a greater environmental impact than plant-based production, leading to the recommendation to include fewer animal products in the consumption pattern. Sala et al. (2023) estimate that, in 2020, roughly 10% of food supplied to retail, food services, and households was wasted. Food wasted at the consumption stage is responsible for more than 70% of the environmental impacts of food waste generation, highlighting the need to focus on prevention efforts at household and food service levels.

More sustainable food production methods are needed at every level of the food system...

A more sustainable food system requires production methods that do not harm soil, water, air quality, or biodiversity, while simultaneously producing sufficient food in both quantity and quality. This requires techniques and methods that minimise the ecological footprint at every level of the food system; input suppliers, farmers, processors, traders, logistics, and retailers. At the same time, all stakeholders must have the prospect of a sound business model. Social and economic sustainability are just as important as ecological sustainability for a sustainable food system. Innovations that contribute to a more sustainable food system must therefore address all three dimensions of sustainability. Innovations on the demand side that could lead to a more sustainable food system are also conceivable. To this end, in the remainder of this section, we emphasise the role of consumers and cities (food consumer concentrations) in a transition to more sustainable food systems.

... in addition to dietary changes for health and environmental reasons

To achieve a more sustainable food system, changes in our diet are just as important as changes in the production side. A more balanced diet with more fruits and vegetables, less meat and processed products in accordance with food-based dietary guidelines (FBDGs) as developed and disseminated by national government agencies, is an essential and supportive component of EU food security (see e.g. Dagevos and Onwezen, 2025; Dagevos, 2021, on flexitarian diets). In this context, it is also important to address the often neglected health and environmental impacts related to overconsumption of food, as "the losses... from food overconsumption are at least as substantial as those from food discarded by consumers, and therefore have comparable consequences for food security and sustainability" (Alexander et al., 2017:198). While food overconsumption is generally negatively associated with food security, this is particularly true for the unprecedented consumption of meat products, given the demand for land and water use in meat production[6]. Conversely, moderating meat consumption benefits food security, whereas less demand for agricultural land for animal feed production offers more opportunities to use land to produce food for people – or to prevent deforestation (cf. Donoso et al., 2024). The EU aims to become more self-sufficient in plant-based protein and create a more sustainable protein system (also mentioned in EU's Vision for agriculture and food, European Commission, 2025:11). However, this must be combined with health-oriented policies and interventions aimed at adapting meat consumption patterns towards FBDGs to truly improve the sustainability of the European food system.

Leverage agency of cities to contribute to sustainable and circular food systems
In food systems, although not often made explicit, cities play an important role. One of the reasons that their role is understudied is that food loss and food waste are often neglected as an unsustainable outcome of the system, while post-consumption and nutrients from human excreta are ignored. Moreover, while it is generally agreed that consumers have some power through their food choices, the role of cities is often not clear. They have little direct power over food production, logistics, or even retail rules and legislation. However, many cities are implementing food strategies and establishing food policy councils aiming at more sustainable and more resilient (urban) food systems, for example, Amsterdam and Almere in the Netherlands, Bristol in the United Kingdom, several German cities such as Berlin and Munich, and many others (Lazaro et al., 2025). These strategies are either a result of the city's own initiative, the collaboration between cities, the city acting as a facilitator between other stakeholders (De Cunto et al., 2017), or citizen-led grassroots initiatives inspiring policy engagement within the city's governance structures (Reed and Keech, 2019). An interesting example is the Dutch city of Almere, which aspires to local production of 20% of the food consumed within the city. To reach this, they experimented in the 'Oosterwold' neighbourhood by selling plots for people to build homes, provided they use 50% of the land to produce food (van der Gaast et al., 2020). In Amsterdam, three women with very different backgrounds, initiated the

6 See for instance the scholarly work by Timothy D. Searchinger, Princeton School of Public and International Affairs and Senior Fellow at World Resources Institute.

Women on Food Network, built on the belief that being a multicultural community that brings together food traditions and knowledge from around the world is a valuable asset when it comes to building a resilient food future. By connecting (female) entrepreneurs, policymakers, food growers, and cooks, they increase the visibility of women's roles in food systems, influence the urban food agenda, and support women's everyday food practices and entrepreneurship. Tailored to the local context, all these interventions signal a desire to create more sustainable and inclusive food systems.

2.4 Concluding remarks

The EU food supplies a broad variety of goods and services through a process of agriculture, manufacturing, food service, and 'final use' by a range of social actors. Together these actors are responsible for the food system's outcomes in terms of sufficient, healthy and affordable food (essential need) within environmental limits. The EU agri-food sector comprises a large number of farms and firms, a small number of internationally operating corporations, as well as governments at multiple administrative levels. Actors in the food system interact with each other through markets moderated by coordinating and integrating institutions and novel modes of governance. Another key characteristic of the EU food system is its diversity, both in what is produced and in scale.

More sustainable outcomes of the current food system require production systems that do not degrade soil, water, and air quality, restore biodiversity, and reduce GHG emissions. Food consumption patterns in which fruit and vegetables play a larger role, and processed foods that contain (too) much fat, sugar and salt a smaller role, will contribute to health and lead to less environmental pressure from agrifood activities. Managing pathways toward a more sustainable food system requires collaboration between governments and all food system stakeholders. Citizen initiatives in cities in particular can be catalytic in bringing about conscious and more sustainable food consumption choices, with spillovers to peri-urban and rural areas in the EU.

3 The need for sustainable competition

3.1 An evolving perspective on competitiveness

Competitiveness can be defined in many ways, partly because the concept's interpretation varies from the perspective of a company, sector, or country (e.g. Bhagwar and Chattopadhyay, 2015; see Box 3 below for further explanation). Definitions have also evolved over time based on the analysis of what constitutes the most important drivers (or 'inputs') of competitiveness, and what is considered its most important outcomes (or performances). Examples of drivers include competing on price or quality, while examples of outcomes include economic, social, and/or environmental indicators.

From emphasis on competing on costs ...

Historically, and even today, competitiveness is often related to the cost position of a company or country. Competing on cost means that a threatened competitive position can only be countered by (further) cost reduction. The idea of competing on cost is linked to the assumption that all companies are 'homogeneous', produce the same, and act in a 'perfect competition' market. However, the success of companies and countries in oligopolistic markets depends on product differentiation, 'competitive advantage', and capabilities generated by, among others, education and innovation. Low costs and high productivity (i.e. low unit costs) are certainly important, as are the quality and other characteristics that distinguish products (and services). An emerging consensus in the literature is that competitiveness is more than simply comparing costs and revenues at a specific point in time (Aiginger, 2018). The broader interpretation of the term evaluates the sources of competitiveness as well as their future prospects. This entails examining the markets in which companies compete, developments that influence costs and productivity, and opportunities to manage these. Competitiveness then concerns market structure (i.e. in which market price segment does a company operate), market processes or arrangements (e.g. institutions or social systems) and skills/abilities (e.g. capacities, driven by investments in innovation and education).

... to competing on quality and Beyond GDP targets

A more recent view is that competitiveness outcomes are more important than inputs, initially leading to the measurement of competitiveness using GDP per capita and employment as indicators of prosperity. The consensus now is that neither these, nor labour productivity or trade balance, are sufficient measures of an economy's overall performance, nor do they capture the ultimate goal of prosperity. Prosperity has been alternatively defined by 'Beyond GDP' targets, an approach advocated by Stiglitz, Sen, and Fitoussi (2009), and operationalised by frameworks such as the Better Life indicators and Sustainable Development Indicators (DDI) (offered by the OECD, the European Commission, and the UN).

The ultimate goal of an economy is to facilitate a thriving society by providing goods and services that satisfy human needs within environmental limits. These goals are weighted differently across countries, depending on the current situation and cultural differences, and are presented in the Beyond GDP approach or in comprehensive well-being indicators such as life satisfaction, happiness, and life expectancy. In line with this thinking, competitiveness should be seen as a dynamic concept that indicates:

> "The ability of a country to changing the composition and structure of economic activity to achieve the multiple goals of a more rounded vision of economic and social progress for its citizens, today and tomorrow (OECD, 2020)."

This inclusive perspective "competitiveness from a new perspective" can be viewed as the perspective of a socio-ecological transition. Aiginger and Vogel (2015) summarise and visualise the evolution of the concept of competitiveness, highlighting the developments in interpretation of the concept from price to quality to outcome competitiveness (Figure 3.1). In this thinking, the term competitiveness has evolved from a focus on the cost side (inputs) to a welfare-oriented concept in which the outcomes go beyond GDP goals.

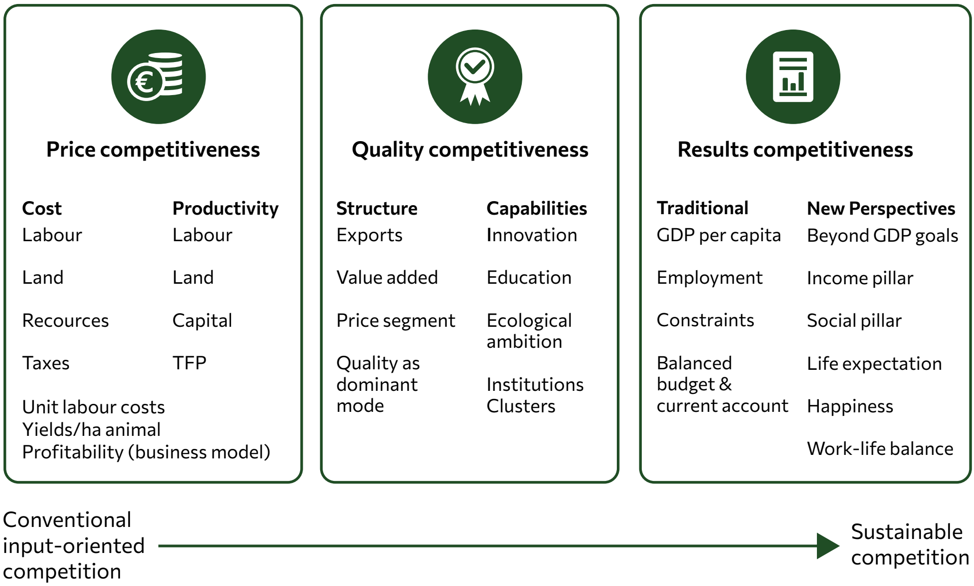

Figure 3.1 Towards a concept of competitiveness under new perspectives.

Source: authors, based on Aiginger & Vogel (2015).

Box 3 *Firms, sectors, and countries compete, but in different ways*

Competitiveness is a concept that can be applied at different levels or scales, and it is worth making these distinctions carefully. The most obvious level at which the concept is applied is that of firms, where their market share and growth are indicators of their success. The concept is also applied to countries or regions, for example, when comparing the EU with the US or China, but not in a way comparable to that of firms. From a country perspective, comparative advantage is an important concept because it can explain in which activities countries specialise or excel, and where they are dependent on others (for example, through imports). Although firms can go bankrupt if they lose the competitive battle, countries cannot fail in that sense.

In recent decades, trade has changed as technological advances – leading, for example, to more powerful computers and lower transportation costs – enabled the creation of globally unbundled value chains. Within each sector, there are firms that are more or less productive and firms that operate more or less internationally. Removing or introducing bilateral trade barriers creates winners and losers in each country, which can affect living standards in the countries involved. The impact of trade therefore varies not only between countries but also within them: due to so-called agglomeration effects, significant spatial effects of trade can occur within countries. This idea is useful because it provides an intellectual foundation for the link between business competitiveness and living standards. It goes beyond the fairly standard business climate indicators on which the emerging industry of competitiveness rankings is based. These rankings are not wrong – they are simply too superficial to be a basis for serious policymaking (see also Breckenridge, 2019).

3.2 A concept of competitiveness that incorporates sustainability considerations

Complementing the above interpretation of competitiveness, researchers and policymakers are seeking action perspectives to ensure commercial competitiveness while simultaneously protecting and maintaining the environment and social welfare (Thore and Tarverdyan, 2016). The World Economic Forum (WEF, 2011) coined the term sustainable competitiveness and, in addition to the standard competitiveness index, also included a sustainability competitiveness index that incorporates characteristics of demography, social cohesion, and environmental stewardship. Sustainable competitiveness has been further conceptualised by SolAbility (2025), who also links it to a comprehensive analysis framework and ranking system, and publishes an annual Global Sustainable Competitiveness Index, all at country level. SolAbility (2025) defines sustainable competitiveness as "the capacity to create and maintain inclusive prosperity while not depleting the ability to sustain or enhance current levels of prosperity in the future". The concept is built on six pillars: natural capital, resource efficiency, social capital, intellectual capital, economic sustainability, and governance (Figure 3.2). Several clusters, including a set of quantitative indicators, have been identified for each of these pillars.

Governance evaluates the quality of a nation's governance, including its political stability, the rule of law, and the effectiveness of its institutions in promoting sustainable development (see also Qazi and Al-Mhdabi, 2025).

Intellectual capital reflects a nation's investment in education, research, and innovation. It measures a country's ability to generate and apply knowledge to drive economic growth and technological advancement.

Natural capital refers to the stock of natural resources and the health of eco-systems that provide valuable services and materials to human society. This pillar evaluates a country's management and preservation of its natural resources, including indicators on agricultural yields, biodiversity and pollution, among others.

Social capital measures a country's ability to foster social well-being and equity across factors related to education, healthcare, social cohesion, and the overall quality of life for its citizens. Indicators measure income and gender equality, and press freedom, for example.

Resource efficiency assesses how well a nation uses locally available and imported resources, including energy, materials, and water; 'well' is defined in the sense of the food system objective to be achieved.

Economic sustainability assesses a country's economic performance and resilience by focusing on factors that contribute to economic growth without harming the environment or leading to unsustainable practices.

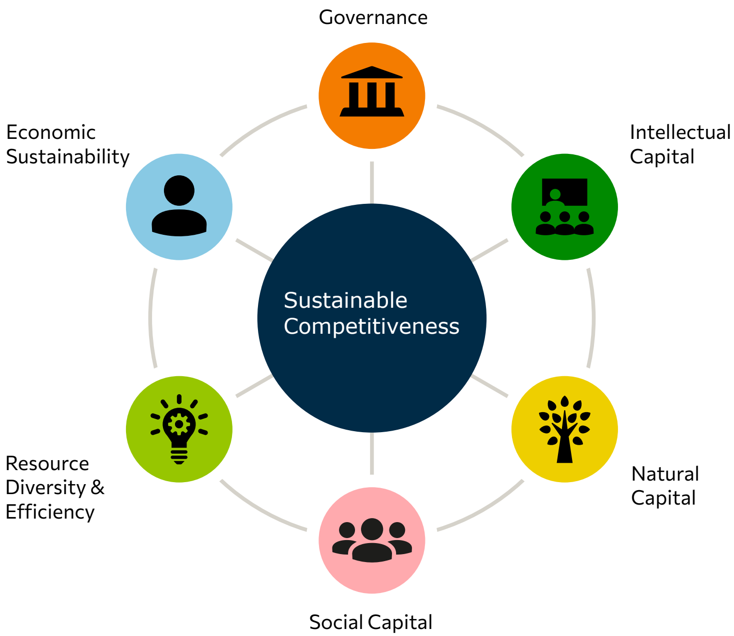

Figure 3.2 Sustainable competitiveness pillars, see SolAbility (2025).

3.3 Performance of sustainable competitiveness pillars in EU's food system

How these pillars of sustainable competitiveness can be translated into the context of the agri-food sector and the broader food system is elaborated in the following sections.

Governance: EU agricultural policy governance is currently a shared responsibility at EU, national, and regional levels, with strategy at the EU and national levels and implementation often at the national and regional levels. Agricultural policy is primarily the responsibility of DG Agri and national agricultural ministers. Policy is primarily shaped from the perspective of the producer (farmer and industry), although food safety and environmental policies also largely determine production conditions in the EU context, by EFSA and DG Environment, respectively. Recent discussions are on the extent to which agricultural policy should be a food policy that aims for, even more than current policy, among others, rebuilding climate-resilient, healthy agro-ecosystems; promoting sufficient, healthy, and sustainable diets for all; building fairer, shorter, and cleaner supply chains; and putting trade in the service of sustainable development (Fresco and Poppe, 2016; IPES Food, 2024). Broadening the scope of agricultural policy to include food policy also means that representatives and/or interests of consumers, the environment, and farmers should have more influence on the strategy, instruments, and implementation of policy.

Intellectual capital: Intellectual capital as an asset in the agri-food sector refers to the functioning of the EU's agricultural knowledge and innovation systems (AKIS). Each Member State has its own system of education, research, and innovation, and through EU level coordination, organisation, and investment, the aim is to strengthen the knowledge, innovation, and digitalisation base in agriculture and rural areas. AKIS plays a key role in the CAP implementation (see Regulation (EU) 2021/2115, which defines various interventions/actions). The innovative capacity of the European agriculture and food sector will be significantly enhanced by introducing new developments such as artificial intelligence (AI), digitalisation, and genetic (health) technology into the sector through targeted applications. The major challenge is how these innovations contribute to both economic efficiency and environmental sustainability while remaining accessible to the widest possible group of farmers, not just the wealthy and large-scale producers.

Natural Capital: The EU is host to a wide variety of landscapes. The basic conditions for productive agriculture, fertile soil, a temperate climate, and sufficient rainfall/ water resources, are present in many areas, making the EU more than self-sufficient in food production. However, the sector exerts significant pressure on the climate and the environment. In several regions, the effects of climate change are already visible; in others, intensive production methods have degraded soil health, water quality and biodiversity. As climate change accelerates, bringing more extreme weather events such as droughts and floods, farmers will be increasingly required to adapt their practices to new and challenging conditions. EU action addresses these environmental issues through long-standing policies like the CAP or regulations like the Water Framework Directive and the Nature Restoration Regulation, and policy strategies related to the EU Green Deal. While some progress is visible, for example, reductions in ammonia (NH_3) and nitrate (NO_3^-) pollution in certain regions, critical challenges remain (e.g. ECA, 2024).

Social capital: Involves networks and collaborations among farmers (e.g. cooperatives and associations), between farmers and institutions, and between farmers and consumers (short supply chains), social movements, and civil society. Traditionally, strong ties exist between farmers' organisations, policy, and the agribusiness sector; these also largely determine the discourse on agricultural policy. More recent developments include grassroots initiatives such as citizen initiatives for establishing sustainable short supply chains (e.g. Herenboeren)[7], sustainable land use (e.g. Land van Ons)[8], and so-called food policy councils, in which citizens collaborate with farmers and other stakeholders at the local level to achieve more sustainable food production and supply chains. Food policy councils have been established in many European cities, for example the Food Council Amsterdam Metropolitan Area (see Section 4.3).

Resource diversity and efficiency: In general, the EU is richly endowed with fertile agricultural land, sufficient water, and a climate well-suited to a wide variety of agricultural products. However, the intensity of agricultural practices places significant pressure on these natural resources in many EU regions, threatening future soil fertility, water quality, and biodiversity. This is further exacerbated by climate change (Schulte et al, 2019). More sustainable agriculture benefits from the efficient use of soil nutrients and water and input circularity (refuse, reduce, reuse, recycle, recover) may be an even better approach. Adoption of innovations at the farm level and along the supply chain based on a circular economy will improve resource effciency, yet institutional support such as subsidies and tax exceptions

7 Herenboeren is a movement that establishes cooperative farms with local citizens for sustainable food production. Since 2016, 23 farms have been established. Each Herenboerderij is owned by a cooperative of approximately 250 households, who collectively distribute the harvest. See herenboeren.nl/.

8 Land van Ons is a cooperative that purchases land on behalf of (currently) over 30,000 participants. Together with the farmer who leases the land, biodiversity and the landscape are restored. See landvanons.nl/.

plays a significant role in adoption decisions (e.g. Herera et al., 2023). At the same time, reducing food waste could also contribute significantly to more efficient use of scarce resources: in the EU, over 59 million tonnes of food waste (132 kg/inhabitant) are generated annually (Eurostat, 2024), with an associated market value estimated at €132 billion (EC, 2023). Recycling (urban) food waste as organic soil improvers would support both resource efficiency and natural capital, indicating important linkages among these pillars of sustainable competitiveness in the agri-food sector.

Economic sustainability: Sustainable economic competitiveness is determined by factors such as legal certainty, an efficient government, a favourable business climate, and stable financial markets. Education levels as a basis for innovation and equal opportunities/inclusivity also contribute to economic sustainability. Generally, these factors sufficiently support economic sustainability in the EU. However, when applied to the European agri-food sector, the small-scale nature, the often fluctuating and relatively low incomes, and the aging population can hinder investment in more sustainable production methods. At the same time, the CAP and other EU funds offer many financial opportunities for investing in sustainable technologies.

3.4 Changing perspectives of food system competitiveness

Sustainable competition needs choices and support

Redefining competitiveness isn't just an analytical or theoretical detail; it changes both the perspective of where the agri-food system should be heading, as well as the policy conclusions that must be drawn from the pervasive call for a country's "competitiveness". As such, sustainable competitiveness has a vision-characterising dimension. The orientation of the competitiveness concept to be inclusive with respect to its social and ecological dimensions links it with a broad welfare or *bonum commune*-perspective (see also the elaboration on this at p.35) in which this link is substantiated (Tirole, 2017). This implies that competitiveness should not be narrowly interpreted as a focus on preserving existing structures, maintaining specific market shares, or preserving the interests of European business interests. The approach to competitiveness should acknowledge the dynamic aspects inherent in the concept and not follow a static approach, but rather include a development-perspective.

Sustainable competition, in the broad sense defined above, is not a concept that will evolve spontaneously. However, mature economies and wealthy societies will have a tendency to place increasing value on quality, sophisticated or differentiated products, and productivity as inputs for competitive advantages, alongside capabilities generated by, amongst others, education, innovation, and institutions, social investments such as active labour market policies and retraining, and ecological ambitions that include high standards and emission taxes (Aiginger and Vogel, 2015). As such, social investments and ecological ambitions should not be viewed as costs, but rather as enablers of competitiveness for high-income countries, thereby contributing to human well-being, ecological excellence, and social inclusion (employment and limited income disparities).

Pursuing sustainable competition imposes clear policy challenges. First, because it involves addressing negative externalities in a clearly defined sustainability framework (needs, rights, regulations) that have to be enforced. Second, because sustainable competition, as a direction or vision concept, should derive its content, justification and support from a democratic-policy process. As such, competitiveness can be linked to the EU's strategy, particularly a strategy that is feasible and necessary for industrialised countries. Moreover, it offers tools for increasing prosperity in a localising and globalising world with many new competitors and heterogeneous preferences. With rising prosperity, basic needs are increasingly satisfied, and intangible goods such as quality of life, solidarity, and ecological sustainability become more important. Summarising, the policy conclusion is that countries can compete successfully by developing sophisticated capabilities rather than pursuing low costs, and that success can be measured by broader goals than solely monetary economic output. Putting human wellbeing more central, and going 'beyond GDP', is a movement taking place both within academia as well as within national and regional governments (see also the elaboration on this at p.35).

Linking sustainable competition to broad prosperity

The concept of Broad prosperity transcends current financial or material prosperity, and instead takes both human wellbeing and planetary health in the here and now, and elsewhere and later, into account. By highlighting multiple dimensions, it enables explicit or different choices and widens the playing field of solutions. For example, The OECD Better Life index distinguishes three dimensions: 1) Wellbeing: Current average quality of life 2) Inclusion and a fair distribution, and 3) Sustainability, also for future generations.

Table 3.1 shows how social, economic and environmental outcomes differ between the EU, US and China. While the narrow benchmark for prosperity, i.e. GDP per capita is larger in the US compared to the EU and China (see Table 1.1), broader welfare figures like overall wellbeing, life expectancy, income inequality (Table 1.1) and unemployment tell a different story. First, we see that wellbeing figures (measured on a 10-point scale) are similar between the US and the EU, but much lower in China. However, both in China and the EU, wellbeing is increasing, while it has been decreasing over time in the US. In the EU in particular, the improvement in wellbeing in the new-member states is apparent. Clearly, residents in these countries have benefitted from new investments and low unemployment levels. Furthermore, it is interesting to see how overall life expectancy in China is similar to that of the US, with less than one third of GDP/pp at their disposal. Furthermore, the table shows that US economic productivity is accompanied by large amounts of CO_2 emissions, placing a heavy burden on the planet. These data illustrate that 1) economic productivity cannot be a proxy for wellbeing, and 2) that the contribution is larger in developing countries, while it results in little wellbeing effects in rich countries.

Table 3.1 Selected Broad prosperity indicators for the EU, the US, and China.

Company name	Wellbeing 2024	2015	change	Life expectancy	Unemployment (%)	Carbon dioxide (CO_2) emissions pp
EU-27	6.6	6.4	1.04	81.4	5.91	5.6
EU-14*	6.7	6,6	1.02	82.6	6.57	-
EU-13*	6.5	5.7	1.14	77.9	4.07	-
United States	6.7	7.1	0.95	78.4	4.11	13.9
China	5.9	5.2	1.13	78.0	5.12	9.4

* Carbon dioxide (CO_2) emissions are excluding LULUCF per capita (t CO_2e/capita). EU-14 refers to the Member States entering the EU before the 2004 enlargement; EU-13 refers to the 13 eastern Member States that joined the EU in enlargements after 2004.

Source: authors based on World happiness report 2024, World Bank and Eurostat.

Wellbeing is both impacted by chances and by outcomes. Ruut Veenhoven introduced the ‘four qualities of life’, which include the liveability of the environment and the life-ability of an individual, (Veenhoven, 2000), Similarly, in the capabilities approach of Amartya Sen and Martha Nussbaum, capabilities denote a person’s opportunity and ability to generate valuable outcomes through the alternative combinations of functionings that are feasible for a person (Robeyns, 2021). In the wider literature, the importance of health, quality of housing, safety, social interactions and trust, culture and traditions (including religion), as well as access to green and nature are regarded as important ingredients for both individual and societal wellbeing.

The Agri-food system contributes in different ways to the broad prosperity of the EU:

1 It **provides** healthy and affordable food, contributing to a healthy society with people being active in the social and economic domains, both in rural and urban areas. In other words, it allows the EU to exist.
2 It **connects** people and places and contributes to (local) culture and traditions, life-long learning, to livelihoods and communities, to urban-rural interactions.
3 It **produces** sectoral inputs, biobased materials, (meaningful) jobs, income to people and small and large companies, trade, thereby contributing to the quality of the social and economic systems.
4 It **stewards** ecological systems, contributing to landscapes and climate, both in positive and negative ways.

3.5 Concluding remarks

How then can the EU's development of sophisticated societal capabilities as drivers of competitiveness and growth strengthen the sustainable competitiveness of the European agriculture and food sector? Capabilities can be deployed to increase the productive capacity of the food system, but also to facilitate societal demands for a better distribution of benefits, healthy food, and a clean environment. Looking back at the six pillars of sustainable competitiveness (section 3.2), we observe that the sustainable competitiveness of the European food system can be strengthened on each of these, but that the focus should be primarily on strengthening the EU's natural capital (due to ecological challenges) in combination with resource efficiency and economic viability. In Chapter 4, we elaborate on how strategic investments in innovation can play a role in this.

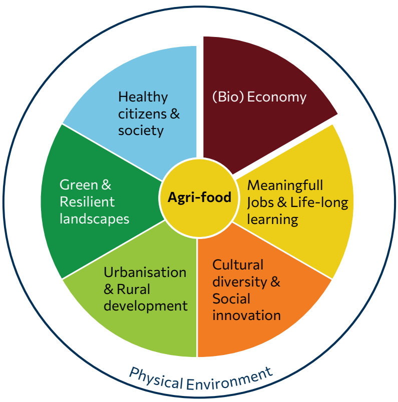

Figure Different channels through which the agri-food sector impacts broad prosperity in the EU.

4 Innovation for enhancing sustainable competitiveness

4.1 Innovation: core driver of growth and competitiveness

Innovation is a known key driver of competitiveness; Schumpeter's theory describes market dynamics as a process of "creative destruction" and "creative accumulation", where the latter refers to the different capacities to accumulate technological capabilities and to generate innovation that firms have (Dobrinsky, 2008; Krugman, 2025). Innovation is defined as the successful implementation of an idea or method that introduces a new or significantly improved good, service, or process, which ultimately creates value for citizens, customers and/or stakeholders. It goes beyond mere creativity by focusing on practical application, transforming novel concepts into tangible solutions, drives growth, and meets evolving needs in business and other sectors. Innovation is seen as a core driver of productivity growth, and, as such, a key factor in explaining competitiveness and economic development. The recent Nobel Prize in Economics has highlighted the importance of "creative destruction" for long-term growth. According to this paradigm, economic development is an evolutionary process that continually reinvents itself. In this paradigm, policy plays an important role by supporting an environment that generates innovations.

In this chapter we argue that broadening the concept of competitiveness to sustainable competitiveness increases the importance of the role of innovations. We also demonstrate the value of thinking about innovations in a differentiated way, as there are many types of innovations, each of which contribute in their own way to support and strengthen the sustainable competitiveness of the EU's food system. From the observations about the past and the current challenges the EU food system faces, we argue that innovation and productivity growth have been too one-sided, perhaps because it has been too strongly driven by market signals. After (empirically) demonstrating how innovations have served as an engine for sustained productivity growth in the agri-food sector, we then link sustainable competitiveness to four different innovation challenges: ecological, agronomic, social, and institutional innovations. We provide several illustrations to motivate this innovations-approach. Finally, we reflect on how new transformative technologies can play a role in enhancing the different type of innovations, including their adoption.

4.2 Innovation and productivity growth in agri-food systems: what do the data say?

The EU's innovation performance remains strong, but its growth is slowing down

The EU's Innovation Scoreboard (EIS) has been monitoring innovation performance across the EU, neighbouring countries, and the EU's global competitors for 25 years. As the EIS provides a standardised framework for measuring innovation performance, it allows comparisons over time as well as among Member States. As shown in figure 4.1, the EU's innovation performance remains strong, but its growth is slowing (EIS, 2025). The EU's food system is an important pillar of the EU economy, and many other sectors interact with the food system. As such, the innovation performance index is also informative for the food system.

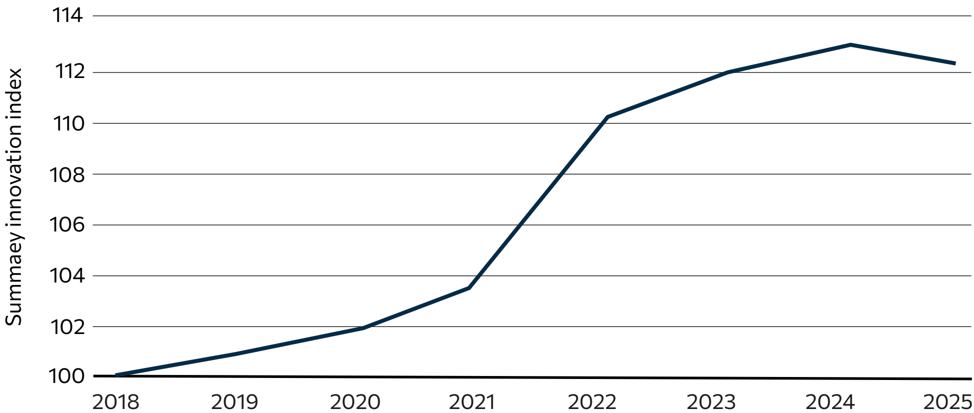

Figure 4.1 The evolution of the EU's innovation index over the period 2018-2025. The index is based on 25 indicators covering knowledge creation, entrepreneurship, applications, and intellectual property.

Source: EIS (2025).

Derived indicators such as the EU's food system profitability and labour productivity relate more specifically to its performance. According to Tidjani et al. (2025) the EU food and drink industry, an important subsystem of the food system in general, has maintained its strong position as a key contributor to EU economic development for the past 15 years by adapting to numerous economic, social, and environmental challenges. Between 2008 and 2022, the food and drink industry's value added and turnover increased by 59% and 61% respectively, showing a stronger increase than, for example, the chemicals and automotive industries (Tidjani et al, 2025). It should be noted that recent growth (since 2021) is, to a large extent, the result of increasing prices, creating a possibly biased figure as price increases may have been partly crises-driven. For more than a decade, the overall profit margins of the food and drink industry have fluctuated around 8%.

EU food and drink industry's labour productivity and its growth rate continue to lag behind that of manufacturing

Although the EU's food and drink industry remains the largest net exporter in terms of global market share, it is currently losing market share, while the US and China are gaining market share with faster growing labour productivity, higher investments, adoption in innovation, and cheaper energy costs (Tidjani, 2025). The average annual growth rate of labour productivity in the EU food and drink industry, measured as gross value added per person employed per year, was 2.2% (see Figure 4.2).

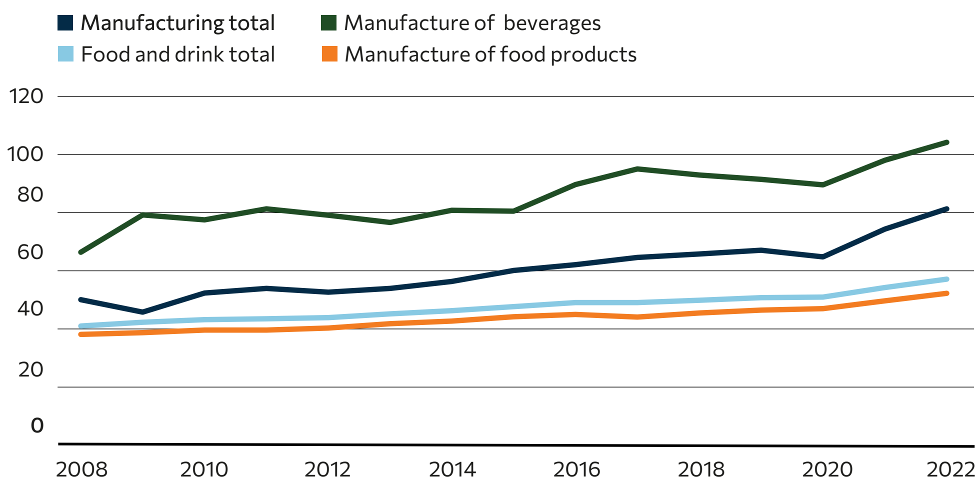

Figure 4.2 Labour productivity in the EU27 food and drink industry expressed in gross value added per person employed, in € thousand, in 2008-2022.

Source: Tidiani et al (2025, 26).

Both the sector's labour productivity and its growth rate are significantly lower than those of the overall manufacturing industry (see Figure 4.2). According to Tidjani et al. (2025), the main contributing factors to the low productivity level are the low adoption of innovations and technologies which impacts EU competitiveness relative to the US and China where industries are making greater investments in automation and digitalisation. Analyses suggest that while SMEs (99% of all businesses) generate a substantial share of the total value add of the EU food and drink industry, their low levels of efficiency and investment in new technologies also contribute to the low growth rates. Moreover, the EU's restrictive policy with respect to genetically modified microorganisms is named as a limiting factor (Wesseler et al, 2022).

The EU's single market is a strength, but can still be improved

We note many differences between individual EU Member State food systems. Based on their performance relative to the EU average in 2025, they have been allocated into four different performance groups: innovation leaders (including The Netherlands), strong innovators, moderate innovators, and emerging innovators. According to the EIS (2025), a moderate reduction in performance disparities from 2018 to 2025 can be observed, suggesting slight convergence at EU level. Nevertheless there are also indications that the internal market still suffers from fragmentation and barriers due to individual national measures and policies. As an example, the lack of front-of-package labelling policy for nutrition information at EU level leads to individual countries developing their own labelling, adding to administrative processes and costs for enterprises (Tidjani et al, 2025).

Public sector research and institutions are more important for innovations in agriculture than for other stages of the food system

Another important subsystem and core element of the EU's food system is primary agricultural production. Innovation in primary agriculture differs from innovation elsewhere in the economy (Alston and Pardey, 2010). These differences arise from three factors: the atomistic nature of agricultural production and having family farms as its dominant form of organisation; the spatial and temporal specificity of agricultural activities and the implications this has for spatial spill-overs and the demand for adaptive research and; the demand for 'maintained research' due to the role of coevolving pests and diseases and changing weather and climate conditions. These characteristics support the relatively higher importance of public sector research and research institutions for innovations in agriculture (Khanna, Zilberman, Basso, 2024). Moreover, due to a relatively narrow focus, innovations and their adoption by farmers have been mainly driven by financial motives and business-model concerns.

For long periods of history, agricultural production growth predominantly resulted from an increase in the amount of land used (Olmstade and Rhode, 2009). However, especially in the last 70 years, agricultural output (also) increased thanks to a growth of output per hectare, in addition to a slowly expanding land base (Fugli et al, 2024). This increase in land-productivity has mainly been made possible by (scientific) agronomic innovation like improved genetics and increased use of chemicals, innovation in farming practices, and finally thanks to the strong increase in use of external inputs such as machinery, fertiliser, and irrigation. Currently, about 80% of global crop production increase derives from productivity increases in yields per hectare and feed conversion (OECD-FAO,2025, 35). The agri-food system also has had to deal with drastic changes in the labour market; the availability of qualified and sufficient labour has become a driving and limiting factor for further development.

Intensification of production increased the burden on the environment

On a downside, this process of intensification has led to increasing pressure on the environment, health, and welfare. Besides the increase in land-productivity, a parallel development has been the increase in labour productivity. The latter has a more economic than an agronomic background: rising incomes outside agriculture-induced labour productivity increases as these are a prerequisite for agricultural incomes to 'participate' in the general welfare increase characterising high income countries (Hayami and Ruttan, 1985).

There are differences in the productivity growth of primary agriculture over time across regions. High income countries/regions like the EU, the US, and Japan show a relatively strong increase in labour productivity. In China, the land-productivity has been dominant over labour productivity, even though both have increased substantially. The reverse to this, is that in countries/regions like the EU and the US, agricultural labour intensity has been strongly reduced. Alston and Pardey (2010: 127) show that while there has been a certain degree of convergence in land-productivity across countries and regions, the disparities in labour-productivity have become more pronounced over time; the outflow of labour from agriculture has been important to facilitate economic growth in the rest of the economies.

Total factor productivity growth in EU agriculture varies, but can compete with that of the US

Innovations have been strongly linked to productivity-growth (i.e. how much output is produced in relation to resources or time used) as well as the quality of products and the production process. A key indicator to measure the contribution of innovations is its impact on total factor productivity (TFP). Figure 4.3 shows the TFPs of primary agriculture over the last decade in different EU Member States. This not only shows great variation between EU Member States, but also provides insights into a factor that may explain the slowdown in TFP. The EU average TFP growth rate is about 9% (or 0.9% per annum); comparable figures for the US and China are 5% and 16.7% respectively (OECD, 2024).

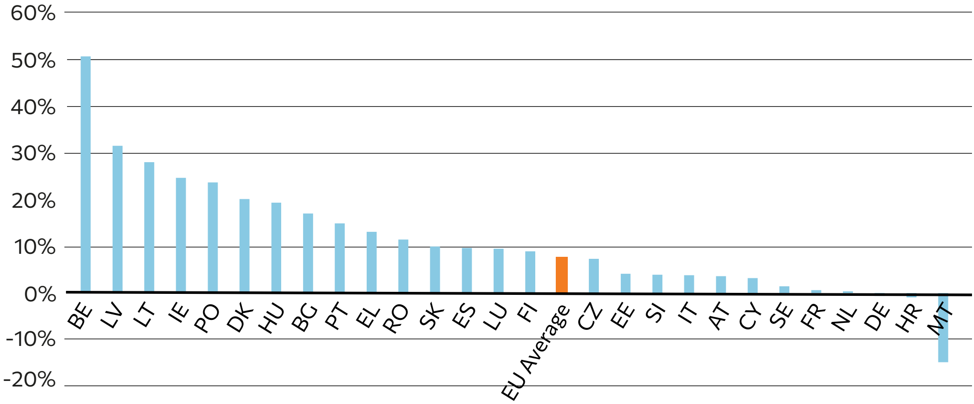

Figure 4.3 Agriculture sector TFP development during the last 10 years in EU Member States (%).
Source: Farm Accountancy Data Network (FADN).

A decline in factor productivity can be associated with improved environmental performance

On average, TFP in the EU's agricultural sector grew by 8.9% as a whole over the last decade. Belgium achieved the highest TFP growth rate, followed by Ireland, Denmark, Portugal and Greece and a number of more recent Member States including Latvia, Lithuania, Poland, Hungary and Bulgaria[9]. Some of the Member States with typically

9 Belgium has invested heavily in agricultural modernisation in recent years through the EAFRD fund. The level of these investments is comparable to that of several recent European Member States. The Netherlands, on the other hand, has invested heavily in environmental measures in recent years due to environmental pressure, which may have affected agricultural productivity. Furthermore, Dutch agriculture is already highly productive, so few additional productivity gains can be achieved.

high productivity levels, such as the Netherlands and Germany, saw little growth in terms of TFP in this period, hence, have become relatively weaker in terms of their competitive position. Due to environmental pressure, the Netherlands has imposed more stringent environmental regulation (e.g. lowered manure application standards, limiting environmental and nature-license system) to limit environmental and biodiversity deterioration, which has negatively influenced the evolution of farm productivity levels. Thus, the increase in environmental and biodiversity restrictions will be a factor that slows down traditional TFP growth. However, by taking these measures, further negative impacts on the environment and biodiversity have been avoided. By reducing emissions, this avoided harm becomes a valuable social gain: a sustainability improvement has been achieved partly at the cost of lower productivity in terms of marketable products.

It is worth noting that some of the more recently accessed Member States, which started from lower productivity levels, have invested heavily in farm modernisation, and thereby realised large productivity gains, with a resulting positive effect on TFP growth rate levels (European Commission, 2023). A final observation is that large differences of TFP growth can be found across different agricultural sectors and within Member States. This signals that the competitive positions between EU Member States are changing, even when not accounting for environmental factors. Because of this, it would be natural to see some shifts and movements of production over the EU territory, for example with intensive livestock production gradually moving from the west to the east of the EU. Finally, productivity growth is also linked to farm size i.e. economies of scale. Growth in the economic size of farms is an indicator for on-farm investments and the associated options for scale economies.

4.3 Ecological, agronomic, social, and policy innovation challenges

Although innovations are often associated with new technical solutions in machinery or seeds/varieties (so-called “hardware”), this is a partial view: yield and labour productivity improvements also arise from ‘software’ improvements, including, for instance, the advanced management or educational tools, and ‘orgware’ with which we govern our society, markets and production systems (e.g. institutional innovations). To strengthen sustainable competitiveness in a food system-context, it is important for us to focus on a wider scope of innovations (Davis et al, 2024; Khanna et al., 2024), bearing in mind the multiple pillars that support sustainable competition (see Chapter 3.3). These pillars are also interdependent: for success, technological innovations may depend on accompanying social innovations, contributing to their adoption and intended use. When focusing on innovation gaps, it is therefore important to include each of the drivers, and especially identify and focus on those which are a limiting factor. A more comprehensive measure than the TFP-indicator would be one starting from a broader concept of productivity, which also values reductions in negative externalities (e.g. less emissions). Bureau and Anton (2022) provide suggestion regarding the construction of an inclusive or sustainable TFP indicator.

Sustainable competitiveness relies on a variety of supporting innovations
By relating sustainable competitiveness, including its supporting pillars (see Chapter 3.3), to four innovation dimensions, Figure 4.4 builds on this, showing how these dimensions are affected and how they could benefit from the various transformative technologies that will impact the food system and society. The four innovation dimensions are further discussed, including some of the challenges and gaps; more specific details and illustrations can be found in Annex 1. Please note that due to time constraints, the analysis is limited in detail and scope, but should be seen as exemplary.

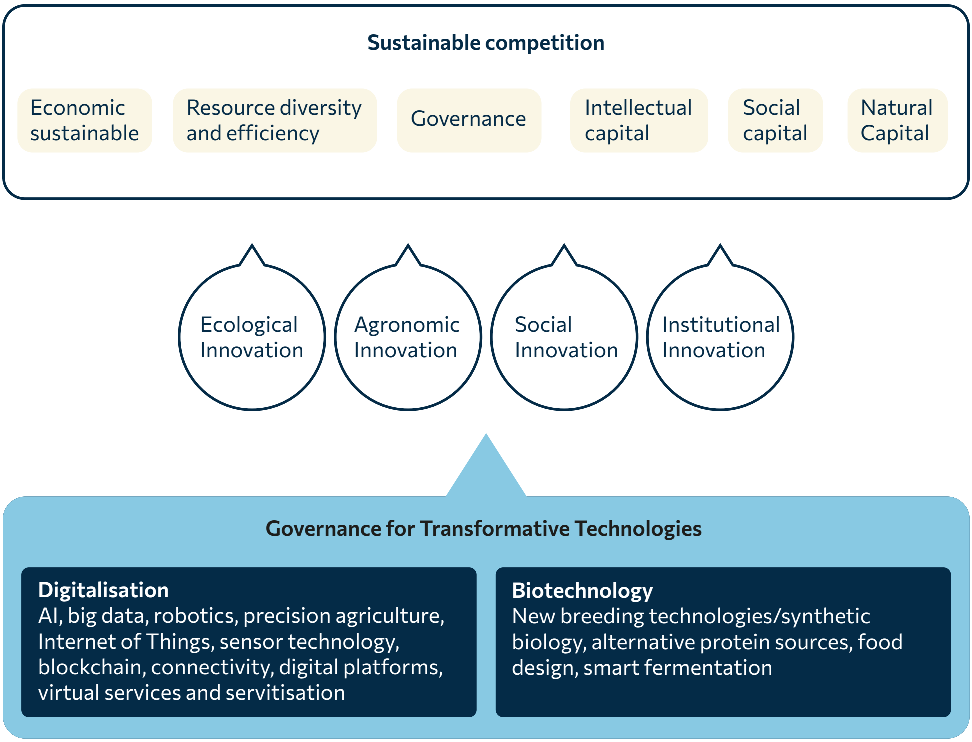

Figure 4.4 Sustainable competition, its pillars and the role of transformative digital and biotech technologies.

Ecological innovation challenges are to transform traditional intensification model into a sustainable one

In general, agronomic innovations have been successful in delivering higher output per unit of input, however this is often accompanied by increased use of purchased and fossil fuel-based inputs. Policies can make an important difference. For example, the EU's environmental policy measures (e.g. the Nitrate Directive), which started in the 1970s, have induced a significant reduction of the use of fertilisers But to achieve a sustainable competition-approach, a further and targeted rebalancing is still needed. More attention and effort has to be paid to innovations aimed at reducing negative impacts on the environment, including the harm done to biodiversity. This is identified as the ecological innovation challenge.

Several strategies have been proposed to address this challenge. One is ecological intensifications: the smart use of biodiversity-mediated ecosystem functions to support agricultural production (Tittonell et al., 2013; Boix-Fayos and Vente, 2023). This approach contrasts with the current model of agricultural intensification, which has been largely dependent on non-renewable resources (e.g. fossil fuels) and has had severe negative consequences for the environment. Ecological intensification is context-dependent and takes different forms around the world (Tittonell, 2014). As such, it requires local innovations and adaptations, as well as socio-technical and policy regimes that permit local diversity in agricultural systems and production conditions. The challenge is to scale-it-up to a level that ensures producing enough food without a significant increase in food prices.

Another strand is the role of digital solutions as a powerful means to improve sustainability, strengthen resilience, while concurrently enhancing productivity growth. Precision agriculture technologies, typically powered by the internet of things, satellite imagery, AI and data analytics, could increasingly enable farmers to improve their management, for example by monitoring weather conditions, soil health, water usage, pest infestations and crop growth, resulting in data-driven decisions that improve yields while reducing input costs, thereby contributing to minimising environmental impact (FAO, 2025). Precision agriculture is also beneficial in limiting or a total reduction of pesticide and fertiliser use.

The escalating challenges of resource scarcity and environmental degradation in agroecosystems necessitate an increase in resource use efficiency. Developing and applying circular practices aiming at closing resource loops is considered a crucial element of sustainable agriculture (Praveen et al., 2024). The value of applying circularity principles is recognised in agriculture (e.g. mixed livestock arable farming systems), but in practice it is not widely practised at farm or regional level (Vrolijk et al., 2020).

Box 2 *Green innovation in the EU*

According to a 2021 report by the European Investment Bank (EIB), the EU is a global leader in green innovation and even more so in innovation that is both green and digital. EU firms lead the US in terms of green investment and digital adoption by green firms. Compared to the US, European firms are less likely to have adopted digital technologies, but they are more likely to invest in measures for mitigating or adapting to climate change. In 2017, the EU registered 50% more patents in green technologies than the US, with Japan and China further behind. Moreover, the EU registered 76% more patents that combined both green and digital technologies than the US, four times more than China (EIB, 2021).

In his book on Europe as the 'Continent of quality', Schenderling (2025) argues that these high numbers of patents can be related to the strict (and clear) environmental EU legislation, challenging companies to innovate green solutions. These innovations not only contribute to sustainability, but also increase the EU's competitiveness, as shown in another EIB study. Cimini and Kalantzis (2024) note that both green and digital investments can increase investment efficiency, and argue that digital technologies can enhance the efficiency gains from green investments.

Agronomic innovation has to go beyond traditional productivity increases
Whereas the ecological innovation gap is closely linked to circularity and resource-use efficiency, the latter is also a component of the technological and digital innovations related to agronomic practices and economic productivity. The traditional productivity increase, which to date has been mainly addressing this gap, has been too one-sided, but not superfluous (Ittersum et al, 2025). As the OECD-FAO outlooks show, with land becoming increasingly scarce and limited over time, agronomic and (economic) productivity growth is a key driver of the increase in world food production: more than 70% of the production increase is the result of productivity growth. Given the growing need for food, this 'traditional' increase is also important for the future, not only because of the need to feed the ever-increasing population, but also given the increasing and competing demands for land for urbanisation and recreation, as well as for nature.

To address challenges, additional agronomic innovation can be found in the design, development, and implementation of new farming systems like vertical farming, ocean farming, and urban farming. In addition to these, we see innovations in agroforestry and the production of cultured meat. These concepts have not yet been fully developed, however they will have a position in the future food system, and they need to be nurtured with respect to their contribution to the broader prosperity concept.

Social innovation challenges relate to institutional innovations that promote collaboration

As argued previously, ecological and agronomic (technical) innovations alone cannot be successful without considering social innovation. Social innovation addresses societal and environmental needs within the food system, such as promoting shorter food supply chains, local food systems, community-supported agriculture, food waste reduction, and urban farming. These initiatives have the objective of creating fairer and more sustainable food systems by fostering direct relationships (and involvement) between producers and consumers, enhancing democratic participation, and providing measurable community benefits. Additional challenges are the successful implementation of new ideas and systems within institutions, organisations, or communities, and bringing diverse actors together across the agri-food system to work towards productivity and sustainability improvements.

Box 3 *Urban innovations and strengthening the food system*

While food production mainly occurs in rural areas, cities have a central position in the global food system as unique spaces where food processing, distribution, consumption, and disposal activities cluster together with research and innovation (Wensing et al., 2023). Yet to date, their potential in contributing to innovation and transformative change of the agri-food system has largely been untapped (Polman et al., 2025) due to silos within institutions (i.e. national, regional vs local governments) and research domains (i.e. life sciences vs social disciplines). However, increasingly, urban residents are becoming aware of their impact on local and global food systems. In Amsterdam, based on a first survey amongst 1195 citizens, almost 90% are worried about climate change and depletion of natural resources, and the majority wants to contribute to these challenges by changing their food choices towards less meat and more local and seasonal products.

One way to get 'Cities in the Loop' is through facilitating transdisciplinary innovations: to connect the public with private actors, citizens, and research partners. This requires the collaboration of diverse groups of stakeholders, the integration of their knowledge, and, most importantly, a continuous discussion and reassessment of common goals, for example in the context of living labs. The Amsterdam Institute for Advanced Metropolitan Solutions (AMS Institute) and in particular their Metropolitan Food Systems team is committed to contributing to these collaborations. Their living labs foster experimentation, building trust relationships, deviating from initial plans, and learning from past mistakes (Dijkstra and Joore, 2025).

An example can be found in the Horizon Europe Project Bin2Bean where three urban living labs have been setup in Amsterdam (Netherlands), Hamburg (Germany) and Egaleo (Greece,) to enable these cities' transitions towards the valorisation of their biowaste into soil improvers. In the SKY HIGH programme, researchers, lighting specialists, breeding companies, growers, horticulture technology companies, architects, and food suppliers, work together on making this type of vertical agriculture cheaper and more energy-efficient and suitable for an urban environment, with Amsterdam as a test-base. Lastly, in 2024, the municipality of Amsterdam, AMS Institute and Wageningen Research took the first steps towards developing a protein monitor to facilitate (public) catering facilities in Amsterdam to stimulate their employees to eat more plant-based rather than meat-based food.

Box 4 *Farmer collective action as a social innovation*

Over time, it has become increasingly clear that a decline in farmland biodiversity can only be reversed through cross-farm approaches, if at all. This applies to the Dutch situation in particular, where farmland birds and ecological corridors are important conservation targets (Terwan et al., 2016). Until 2016, the Dutch government followed the classical EU model and procured agri-environmental services by contracting individual farmers. From 2016, in line with EU Rural Development Regulation (Regulation EU, No 1305/2013, agri-environment-climate measures). the Dutch government currently only procures agri-environmental services by contracting with groups of farmers organised as farmer collectives (FC). By adopting this approach, there was the expectation that this may improve the policy's performance while leading to a reduction in costs (Mulders, 2018) as well as contributing to creating good habitat conditions at a landscape level for rare species (territorial based cooperation). By exploiting "the economies of configuration" (McKenzie et al., 2013), FCs can enhance effectiveness and improve efficiency of the Agri-Environmental and Climate Scheme (AECM) measures.

In addition, the FCs reduce transaction costs for participating farmers and provide a role in monitoring and evaluation as well as in knowledge dissemination (Westerink et al, 2017). FCs are, for example, responsible for controls and checks, as well for imposing sanctions in case IFs are detected to be non-compliant with respect to the FC-farmer subcontracting agreement. The FC claims payment from national and EU authorities and makes payments to farmers in accordance with the awarded subcontracts As private organisations, FCs have the autonomy to develop their own service reward rules and can apply forms of price discrimination with respect to low and high costs suppliers.

Institutional and policy innovation challenges are to define the rules of the game for a more sustainable food system

Institutional innovations can be described as the development and testing of new or alternative institutional arrangements that can change the logic of the existing system. They have been important elements of previous transitions.

Examples of these innovations are (Leeuwis, personal communication):

- The development of market-based sustainability solutions, for example by creating new private or public standard and/or associated certification schemes;
- New rules and arrangements that make the entire value chain responsible for combatting externalities (not just farmers and consumers) and that reward circularity, sustainability etc. For example, new licenses to operate, and quota systems for food processers, supermarkets, banks etc.;
- New types of price guarantees or insurance systems for sustainably produced products;
- New rules and arrangements (for example levies or taxes) that make it unattractive for stock and shareholders to invest in short-term profits;
- Mechanisms that redress the prominence of private advisory services for farmers, and that foster forms of independent advice and knowledge sharing; if we want to move away from high chemical input farming it becomes more knowledge-intensive and difficult;
- Models for giving future generations and nature a place in the boardroom of private sector companies and investors;
- New definitions of what constitutes an agricultural plot. Currently this is defined as 'a demarcated space with one main crop' which causes major administrative obstacles for farmers applying for strip-cropping or pixel farming.

Policy innovation is a special case of institutional innovation, and as the examples above show, policy involvement may be needed to facilitate institutional innovations. Moreover, unless policy is initiated to correct the innovation process, we may be unable to target the innovation towards sustainable development. This provides an argument for policy changes and for reducing any negative consequences the current policy environment has for human welfare. However, there is a second reason to argue for considering the need for policy innovation.

When evaluating EU experiences, it has become clear that successful innovations go together with a relative saving in resource use (e.g. land, labour, other inputs). However, this relative saving can result in an absolute increase in the resource being use as sectors using the resource become more competitive. This is known as the Jevon's paradox. Therefore, it could be concluded that this actually worsened the situation. However, this is an invalid conclusion as the model is comparative-static in nature and does not consider opportunity costs. The EU CAP policy serves as an example, where via expensive policy measures attempts are made to resolve problems while solutions are prevented by the same policies (Wesseler, 2022). The policy innovation challenge is that ecological constraints have to be implemented in such a way that the environmental user space is well-defined and accounted for by producers when deciding on resource use.

As a final institutional innovation-example, environmental, social and governance (ESG) reporting can be mentioned, which can be characterised as a hybrid of an institutional and a social innovation. ESG requires selected firms not only to provide financial indicators, but also to report on a set on non-financial or social, environmental and climate indicators. The goal of ESG reporting is to use data to evaluate how a company's ESG initiatives compare with industry benchmarks and targets. By making this information public, consumers and society are informed about the sustainability performance of a business and can use this information in their buying and voting behaviour, thereby exerting an (indirect) impact on firms operating at 'unacceptable' standards.

Box 5 *The CAP policy and competitiveness*

Pursuing competitiveness is a policy objective both for the EU economy in general (e.g. treaties underlying the EU single market like the introduction of a shared euro-currency, and the Stability and Growth Pact) as well as for agriculture and food (e.g. the CAP Treaty objectives). The economic development and policy environment have been conducive to this. First, agriculture has been sheltered by the EU's farmer income support policy, which increased prices for the main agricultural products at a level substantially higher than the world market level. Since the MacSharry reform of the CAP (1992), this classical price support system was overhauled and replaced by a system of direct payments. Export subsidies were abandoned and import protection lowered. This reform-direction was extended further with the Fishler reform (2003) in which these direct payments were gradually fully decoupled from production. These reforms changed the competitive regime agriculture had to face: world market prices have since become the guiding conditions. However, the direct payments introduced as a (partial) compensation for lost price support provided a continued support for farm incomes, and as such, supported their competitive position.

There is evidence that direct payments have contributed to farm modernisation (Renhart et al, 2025), and that, more generally, they are likely to have slowed down structural change, thus having a possible long-term negative indirect impact on farm competitiveness (Hansen and Weber, 2025). Support measures targeted to specific sectors such as the 'so-called' voluntary coupled payments aimed at sectors experiencing a decline in production (e.g. coupled support for (extensive) beef and dairy production), and sectoral support measures aimed at supporting specific sectors (e.g. fruit and vegetables and specific Mediterranean products such as olives and wine) pursued their competitiveness.

Not only have the agricultural and related trade policies created an enabling environment supporting farmer incomes and their competitive position, several active policy interventions in the second pillar of the CAP also affect farmers' competitive position. On the one hand, this regards specific subsidy instruments for productive as well as non-productive investments. Other policy instruments stimulating the formation and development of producer organisations are aimed at strengthening the position of farmers in the supply chain. Moreover, the agri-environmental and climate-measures-instrument has to be mentioned as it supports farmers that would like to deliver various eco-system services, with the aims of biodiversity preservation, animal welfare enhancement and climate mitigation. By providing payments covering the cost incurred and lost income associated with these activities, aside of their main objectives, they can be argued to have contributed to sustainable competitiveness. This is also true for payments associated with support for farmers operating in areas with natural handicaps. Finally, funding dissemination and sharing of knowledge activities (e.g. extension services) has contributed to the modernisation and productivity of farms.

4.4 Support from transformative technologies

To improve sustainable competition, we identified four innovation dimensions as being important for a broader innovative climate in agri-food systems. In this section, we focus on the role of technologies and concepts that have the power to support and boost innovations in a more generic way, but also have the power to be a game-changer if applied to addressing current agri-food innovation challenges.

Digital technology challenges
It is expected that a majority of innovations will have a relation with digital developments. For example, in recent decades the agri-food sector has been able to make the step from farm-oriented production with cooperatives for food processing towards modern transparent food chains (see Chapter 2).

Besides improving the physical product and logistic flow in the chain, these transparent food chains were only made possible by adding well-structured and transparent data flows. Data are a binding factor in these chains, and it is expected that in future steps towards the diverse, dynamic, responsive, transparent, resilient, sustainable and innovative regional-local based European agri-food system, data, information and knowledge will play key roles. Agri-food systems go beyond supply chain systems; they represent a network of actors working (temporarily and locally) together to serve needs of society and agri-food markets, therefore the abilities of cooperation and connectedness have become increasingly important. This subject was addressed in a previous Mansholt lecture (Wolfert et al., 2021) where it was noted that although many promising new technologies have been launched, they are hardly adopted on a large scale and that private investors like to invest in technology development with a clear prospected return on investment, and tend to pay less attention to research on the ethical, social, and environmental impacts of these technologies on society. If new digital developments are to be considered in the food, health and consumer markets, then the impact of digital developments will become even greater.

In the EU Digital community and programmes, several organisations like AI, Data and Robotics Association (ADRA), ICT-AGRI-FOOD, and the International Federation of Robotics have published their challenges and roadmaps for the near future, in which they state that AI, Data and Robotics will play key roles. In response to these roadmaps and vision statements, challenges have been identified. The scheduled developments in GenAI and Robotics appear sector independent, are implemented quickly, and no longer follow a linear path. This raises the question whether the agri-food sector will be able to sufficiently absorb this and use the technology.

This underscores the need for life-long learning and continuous investment in the European Innovation and Knowledge-system, with targeted programmes for the agri-food sector. It is clear that our European agri-food environment with its variety is a perfect fit for GenAI and Robotics to make a difference, but there is an urgent need for active and knowledgeable people and organisations that can bridge the agri-food context, its needs, and technological developments.

Biotechnology challenges

According to the EU Life science strategy (Figure 4.5), life sciences are at the heart of Europe's ability to improve lives, grow a competitive economy, and protect the planet. From breakthrough medical treatments to sustainable agriculture and climate-smart solutions, they will drive the innovations that shape a healthier, safer, and more prosperous future for all Europeans. For citizens, this means better health at all ages, wider choice of safe food, cleaner and more resilient environments, and strong, future-ready economies. For businesses, it offers dynamic innovation ecosystems and predictable paths to scaling up solutions. In addition to staying competitive, this is also a strategic investment in intergenerational fairness, as the aim is for Europe to lead with purpose, so that innovation serves people and the planet, both now, and for generations to come.

Life Sciences
The broad scientific study of life and living organisms

Disciplines: delivering the core scientific knowledge underpinning all areas
Biochemistry, molecular biology, genetics & genomics, cell biology, mocriobiology, physiology...

Applied to...

Examples of applications	Health	Food	Agriculture & Fisheries	Bio-based	Enironment
	Medicines, Diagnostics, Medical devices	Personalised Nutrition, Food Ingredients, Food biotecht	Animal and aqua feed, Plant Breeding, Biopesticides	Bioplastics, Biomaterials, Bio-based Chemicals, Bioenergy	Bioremediation, Carbon Capture, Ecosystem Restoration

Figure 4.5 Life Science EU strategy.

Source : commission europa.

The innovative power of life sciences lies in harnessing breakthrough technologies including biotechnologies, digitisation, and AI. Biotechnology, an essential tool to progress knowledge in life sciences, is also seen as a sector in itself, covering many application areas from food and health to industrial processes and cosmetics.

The EU Life science strategy states that the EU consistently ranks among the top regions globally for life science publications, and that the EU is also dynamic in terms of global high-value patents in the sector of biotechnologies, ranking second (18% share), behind the US (39% share). However, its position will soon be challenged by China which is catching up quickly (10% share). To challenge the competition, the report proposes a strategy to optimise the research and innovation ecosystem to ensure smooth and rapid market access, thereby boosting the uptake of life science innovations. As a follow-up to existing strategies, the introduction of the EU Biotech Act is expected to create a more innovation-friendly framework across biotech sectors.

When addressing agri-food innovation challenges, developments in genomics and breeding are important. Currently, new genomic techniques (NGTs) fall under the regulations for GMOs. These regulations substantially increase the costs for authorising a GMO for market release, thereby working as a "ban" on applying NGTs (Purnhagen and Wesseler, 2021). The EC understands the problem and has submitted a proposal for revising the EU GMO policy with the objective of providing better incentives for using NGTs to increase EU agriculture sustainability. Nevertheless EU companies like Hendriks Genetics, originating in the EU, still play a key role in global developments for animal breeding. Major gains are expected, especially in the multi-trait approach, that will deal with a balanced development between productivity, health, welfare and the environment. As an example, incorporating methane emission of individual animals in breeding goals is expected to have a major effect. The multi-trait approach will greatly benefit from digital developments.

Box 6 *Selective breeding of animals*

One of the challenges to food systems in high-income societies is how to value animals in terms of animal welfare, climate, environment, and their contribution to human diets (e.g. EU's workstream on livestock).

Selective animal breeding in the context of current and future farming systems can make an important contribution to finding an appropriate balance between adaptability, suitability for purpose, animal welfare, and a minimal impact on our planet. Animal breeding and genomics contribute to resolving global challenges such as sustaining biodiversity and mitigating climate change. According to the FAO report (FAO, 2023) on 'pathways towards lower emissions', breeding and productivity increase will be the two main contributors to reduce the total global CO_2 (Figure 4.6).

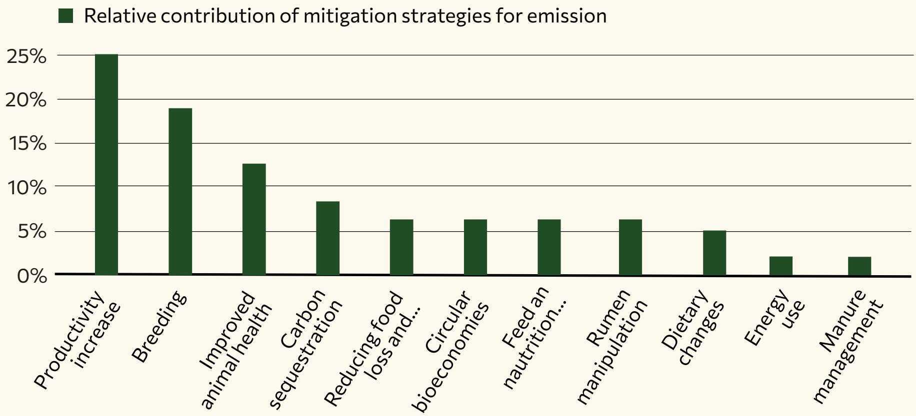

Figure 4.6 Contributions to pathways towards lower emissions (after FAO, 2023).

The WUR Animal Breeding and Genomics (ABG) Group offers a powerful combination of fundamental science and supporting real breeding programmes. ABG combines traditional selection methods with innovative key technologies such as big data, sensors, organoids, genomics, and AI to improve our biological understanding of desired characteristics and implement new breeding goals to shape future generations of animals. For some of these key technologies WUR is at the forefront of global scientific developments.

An example is the mitigation to climate change. It is vital to reduce methane emissions of dairy cattle. To achieve this reduction, farmers need efficient and cost-effective solutions. Selective breeding offers opportunities to utilise natural genetic variation in methane emissions between cows. ABG is currently researching how to make selective breeding a viable mitigation strategy by driving innovations in four areas: (1) large scale automated and real-time collection of methane emissions on individual cows, (2) developing breeding value estimation for methane emission, (3) studying the relation between methane emissions on other traits, and (4) developing and implementing practical and broadly accepted tools.

4.5 Linking innovation, research, development and absorption

The EU lags behind with respect to its R&D investment in the food and drink industry compared to the US and China

While innovation is directed towards delivering marketable solutions, enhancing productivity, and addressing sustainability challenges, it also has a direct link with private and public sector research and development (R&D). R&D often serves as a catalyst for innovation (Figure 4.7). The EU spent around $410 billion in 2023 on R&D, much less than the spending of the US ($784 billion) and China ($723 billion). Globally, a total of nine countries exceed the 3% R&D-to-GDP threshold, including EU Member States Germany, Belgium, Austria, and Sweden, and outside the EU, Switzerland.

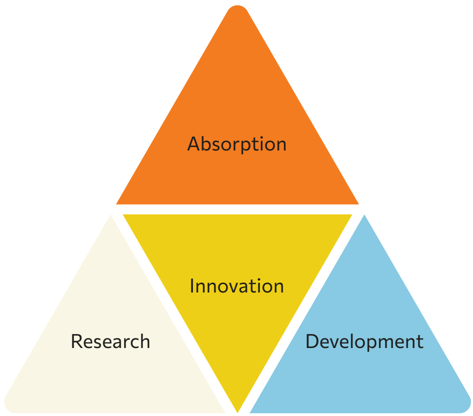

Figure 4.7 Absorption of innovations a embedded in research and development.

Source: authors.

Both the Netherlands and China exceed the 2% threshold (WIPE, 2025). The R&D investment in the EU's food and drink industry is estimated at around €3.1 billion, compared to more than €6 billion in the US and about €8.5 billion in China (Tidiani et al, 2025, 46). It has been noted that innovative activities tend to be characterised by "persistence", that is, firms with a past record of innovative performance are more likely to continue innovating. There is evidence that the intensity of innovation performance strongly depends on the level of R&D, as well as other factors such as involvement in exporting activity, the level of management training and skills, networking by firms, and firm size (Dobrinsky, 2008). In general, a firm's R&D spending enhances its capacity to absorb new technologies, both those internally developed as well as those generated externally (Dobrinsky, 2008).

To enhance the adoption of sustainable practices robust and targeted regulatory and incentive policies are needed

The adoption of sustainable business and management practices in the food system is strongly influenced by the incentive system as well as the regulatory framework (e.g. the goal-steering approach of Ros et al, 2024). Several studies indicate that the adoption of sustainable practices depends on financial incentives. The authorisation costs for biological control systems for pest and disease control in European cropping systems are, at this point in time, extremely high (Fredericks and Wesseler, 2019). Other factors such as personal preferences and attitudes, social expectations, investment potential, urge to change farm situation, knowledge to understand the solution, and (long-lasting) contact with dealers are important for changes at the farm level (Jongeneel et al, 2008). Farmers and growers may also have alternative options such as the hiring of external labour, making use of services, and/or ability to automate or robotise. In the current European markets we see increasing pressure on the availability and quality of labour, which may especially affect innovations and their absorption in labour-intensive production systems.

Box 7 *Research, Development, Innovation and Absorption of EU in perspective to US and China*

Table 4.1 presents an overview of university rankings, indicating their research power; the top 10 universities are ranked per category. It can be seen that the EU is still a leading player in research for agriculture and environmental science. However, in the field of computer science, information systems, data science and AI, US universities are much stronger. Somewhat surprisingly. Chinese universities have not yet achieved a top 10 category for the computer, data and AI science.

With regards to 'development', agri-food companies like Unilever, Nestle, Danone dominate the Food and Agriculture Benchmark. Moreover, in machinery and robotics, European companies hold a significant market position. Currently, the GenAI value chain is dominated by a few major US stakeholders, with China in the race for global leadership with a dominant position in AI patents (61.1% in 2022), surpassing the US (20.9% in 2022). On the absorption and the opportunities for Europe, the ADRA vision (Figure 4.8) shows that the strategic space for Europe in the digital development of GenAI and Robotics is in quality, safety, trustworthiness, human and social science, ethics, privacy, accessibility, energy, data efficiency, environmental impact, sustainability, and digital commons with open source (see Figure 4.8). This aligns with our message that Europe is able to use digital developments to work on innovative solutions for its agri-food systems in its diversity as well as in the context of ecological, agronomic, social and legal innovations.

Table 4.1 Ranking top 10 universities (source Ranking Agricultural Universities)

Category	EU	USA	China	Other
Agriculture	5	4	1	-
Computer Science and Information Systems	3	5	-	2 Singapore
Data Science and AI	2	5	-	2 Singapore, 1 Canada
Environmental Science	**4**	**4**	**1**	1 Singapore

Source: QS World University Rankings by Subject 2025: Agriculture & Forestry.

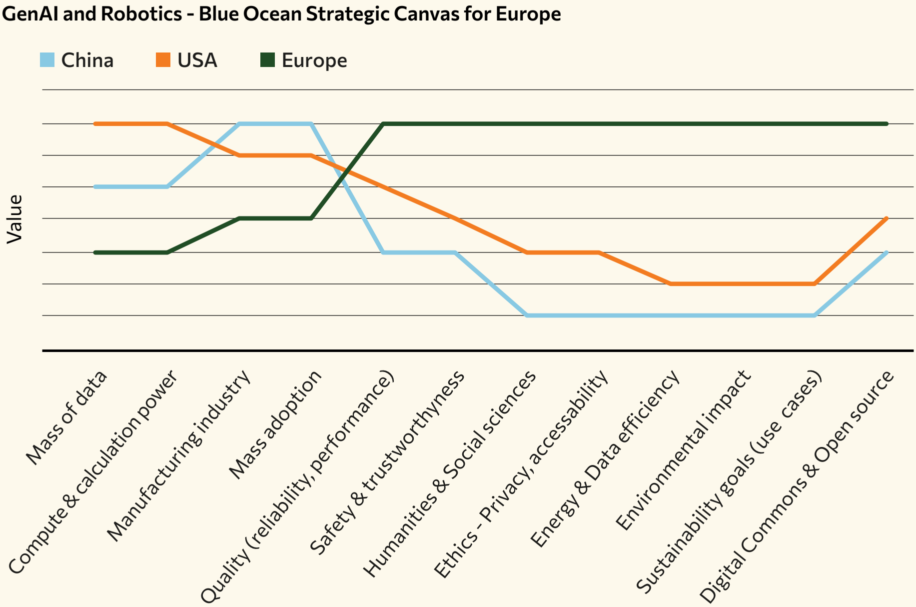

Figure 4.8 ADRA strategic Canvas for European GenAI and Robotics.

Source: ADRA vision report.

4.6 Concluding remarks

Innovations are an important generic driver of competitiveness in the EU food system. We have discussed a number of indicators to gain more insights into how innovations have affected productivity growth in the EU food system and its subsystems, the food and drink sector and primary agriculture. We note a slowdown in the EU's innovative performance, which also will impact the food system, mainly driven by a high level of regulatory burden for innovations. With regards to the food and drink subsystem, there has been a substantial increase in turnover and value add, but this has mainly been driven by recent price increases. In terms of (labour) productivity growth, the food and drink sector currently lags behind other sectors in the economy, such as manufacturing.

With regard to primary agricultural production, the EU's average TFP growth is close to 1% per annum, higher than that of the US, but lower than that of China. However, with respect to EU agriculture with its dominant family farm structure, productivity and innovation development show specific peculiarities. Competitive innovations for sustainable development are limited by a regulatory environment that is supposed to improve sustainability, but one that currently prevents it. It is argued that in order to strengthen the EU's food system, sustainable competitive innovations need to be 'channelled' to contribute simultaneously to ecological, agronomic, social and policy improvements.

The market economy favours the development of innovations as they tend to allow the inventors or innovating firms to reap the benefits of their innovations. As such, innovations are a factor in creating a (temporary) competitive advantage for its owners. To the extent innovations help reduce resource use or improve resource utilisation, economic and environmental incentives may go hand in hand. However, where this is not the case, markets will 'fail' to generate the desired sustainability improvements as they will be insufficiently adopted due to the increase in costs they induce. When efficiency increases in non-commodity outputs of the food system such as biodiversity improvements are considered important, policy interference is needed to steer the innovation process in a balanced direction. A robust and clear regulatory framework clarifying the environmental and ecological boundaries within which the food system should operate is essential to orient investment behaviour and to ensure that the innovation process is inclusive with respect to addressing sustainability objectives.

We note many important transformative innovations (e.g. digital and biotechnology developments) and more are in the pipeline. From a sustainable competitiveness-perspective, it is crucial that the food system is enabled to tap from these developments and develop targeted and tailored applications that strengthen the wider set of objectives it is expected to deliver. As such, the transformative innovations and their new and creative applications in the ecological, agronomic, social, and policy domains should be subservient to the broad prosperity-perspective characterising EU society.

5 Trade, dependencies, food system resilience and policy challenges

5.1 Introduction

Supply chains have become both longer and more complex with negative consequences for economic security

The EU is integrated in world markets and has intensive trade relationships with many countries. Trade has expanded over time, partly as a result of globalisation and multilateralism with respect to trade liberalisation (e.g. GATT/WTO trade agreements), but also changed its nature. Global value chains now play an important role, facilitated by the falling costs of long-distance communication and data transfer which accelerated in the early 1990s (OECD 2025). Large, multinational, or transnational enterprises are important drivers and coordinating devices behind this development. A result is that supply chains have grown longer, have become more internationalised, and have increased in complexity and reliance on specialised intermediate inputs. The associated specialisation has contributed to strengthening productivity, competitiveness and consumer access to a wide range of differentiated products (e.g. lower prices, large variety of products). However, in several cases, it has also led to high concentrations and growing interdependencies in the production of goods and services (EY, 2024). Moreover, the increased consolidation and cross-border ownership of companies, including those that operate critical infrastructures, has given rise to new economic security issues (OECD, 2025).

Economic security is a loosely defined concept, which includes many aspects such as critical trade dependencies and the protection of international investments in case of increasing geopolitical tensions (OECD, 2025; EY, 2024). In this chapter we focus on a narrower definition with respect to the food system, with the main elements being strategic autonomy and critical (trade) dependencies. We recognise that this introduces a limitation, but it will help to highlight basic, yet important, aspects of economic security.

Specialisation of production increased both economic welfare, and vulnerability and dependencies

Dependencies are an important part of economic life (Krugman, 2025). Economies are characterised by markets and market-exchanges, reflecting an intricate web of suppliers and demanders, sellers and buyers, who do not strive for economic independence, but pursue their well-being by exchanging goods and services with others. By doing so, they often contribute to enhancing the welfare of others, in particular if it is a fair exchange. As such, labour division can be an important source of welfare thanks to productivity gains from specialisation and scale economies. With the increase in specialisation and subsequent exchange, people, firms, as well as countries also become more interdependent. These dependencies should be encouraged and celebrated, given the (economic) benefits they can create. The metaphor of the human body has been a long-established metaphor for a healthy community, where there is a need for the different organs and parts (i.e. the mind, eye and foot) to collaborate and work well together. However, dependencies can also create risks and leverage for third parties, or even self-interested stakeholders, to abuse market power and/or trade policies that threaten EU welfare and increase its vulnerability to (geo-)political risks. In this chapter, we identify the downside of the growing (inter)dependencies in the evolution of agri-food-systems, as well as addressing how to preserve sufficient resilience.

Dependencies emphasise the importance of trust

Distortions and erosion of trust (social capital) can create harm. The degree of harm depends on factors such as the essentiality of the good in the process of production. This essentiality in turn is 'dependent' on the degree to which substitutes are available to replace the input which the product is dependent on. As noted, dependency and substitution or replacement options have become complex issues in our modern globalised economy, where products are made in a food system or supply chain-context, and the consumption of food relies heavily on fabricated food products, rather than single products. This development has also affected the evolution of food systems over time. In the overall economy and in the domain of agriculture and food, the search for profitable business opportunities based on lowest costs and the identification of consumer preferences for alternative product varieties have been key drivers.

However, this development has several implications:

- In case of a distortion creating negative impacts due to a dependency occurring somewhere in the supply chain or food system, there may not only be direct substitution options (i.e. at the stage of production where the dependency manifests itself in the first place), but also adjustment responses at other stages of the supply chain or in consumer behaviour, that can mitigate any potential impacts. So, although the dependencies have increased tremendously in our modern economy, the option for adjustments in response to distortions have also increased.
- The issue of dependencies should always be evaluated and considered in the appropriate context. For example, this implies that simply relying on an indicator such as the degree of self-sufficiency may be misleading. A country that is not self-sufficient clearly faces a dependency, as part of its food has to be imported from elsewhere. However, a country which is more than self-sufficient for animal products, but relies on imports (feed) from elsewhere for its production (e.g. oilseed meals), still faces a degree of dependency even though its self-sufficiency indicator provides no reason for worry.
- Dependencies are strongly related to a process of economising by business on resources used to produce food and fibre; they are an (unintended) outcome rather than a goal. Therefore, they need to be carefully managed. This also implies that when problems arise due to dependencies (e.g. a specific input being no longer available, or being available only in restricted/more limited quantities, or being available at increasing costs) this will have implications for reducing those dependencies. More specifically, this may increase the cost of food production and the associated price of food, with a negative impact on food access and consumer welfare.

In the remainder of this chapter, we provide a brief assessment of the dependencies prevalent in the EU's agri-food system. This helps to identify the benefits and costs (risk) associated with these dependencies and their implications in terms of the system's resilience. We then discuss the challenges this creates for stakeholders along the food chain and how policy responses may contribute to reducing undesired dependencies.

Box 8 *Specialisation, inclusion and collaboration*

Economics provides key insights with respect to specialisation, inclusion and collaboration. Labour and firm specialisation, namely people and their enterprises specialising in activities in which they are good in, was identified as a key contributor to human welfare by Adam Smith in his book The Wealth of Nations. Together with this, and instrumental in realising the benefits of this specialisation, is the development of exchange-relationships and the availability of well-functioning markets. As a side-effect, with the growth of specialisation people become more dependent on each other.

This leads to the concern that specialisation and market exchange may work negatively for countries lagging behind in productivity and which are 'not good in anything'. This puzzle was solved by David Ricardo, who developed the theory of competitiveness as comparative advantage. He shows that, from a welfare and market perspective, it would be beneficial for all countries to include the lagging country in the market exchange system as well. An important implication of his argument is that economics is 'pro-inclusion', rather than exclusive. This reasoning arising from a focus on the 'general interest' rather than group interests provides an argument to have competition policies that prevent the abuse of market power to distort their proper functioning.

Ricardo's theory of the welfare enhancing-effects of competitiveness and well-functioning markets has been refined over time, but has never been refuted. An important refinement is the Heckscher-Ohlin theorem, which further elaborates on competitiveness and trade. In this theory, countries will export those goods that heavily use their relatively abundant factors of production (including land and labour), and import goods that rely on relatively scarce factors.

The welfare-enhancing role of collaboration was more recently recognised and emphasised when game theory enriched the economist's toolkit and supply chains became more complex and globalised. But, as argued by Lans Bovenberg (in his "1 + 1 = 3" argument in Bovenberg and Van Geest, 2021,79), collaboration has always been at the core of the economy. Empirical proof can be found in the agri-food community. By collaborating, *win-wins* can be achieved which individualistic behaviour would never be able to achieve. Farmers and agribusiness are well-known for their cooperation by means of cooperatives (average market share of around 40% in EU) and also in the form of producer and branch organisations (the EU has just under 3000 recognised organisations, especially prominent in the fruits and vegetables sector, and a multiple of informal ones).

5.2 Which dependencies are most important for the EU's agri-food system?

The EU is a prominent player in the top 5 of agri-food production

The EU is a key producer of agricultural products (Table 5.1) and often ranks within the group of the big-5 producers at global level. In 2024, the value of the EU's agricultural output was approximately €532.4 billion, a slight decrease from the 2022 high of €537.5 billion. The EU's agricultural industry created an estimated gross value added of about €234.1 billion in 2024. Its significance is not primarily captured by its share in the EU's gross domestic product, which is 1.3%, but rather by the essential needs of the 450 million EU consumers for which the sector provides food.

Table 5.1 The 5 key global producers for selected agricultural products: their ranking and share of world production.

Product	Ranking				
	1st	2nd	3rd	4th	5th
Wheat	China 17%	**EU** **17%**	India 14%	Russia 11%	US 6%
Corn	US 31%	China 23%	Brazil 11%	**EU** 5%	Argentina 3%
Soybeans	Brazil 41%	US 31%	Argentina 7%	China 5%	India 4%
Rapeseed	**EU** 21%	Canada 20%	China 18%	India 14%	Australia 10%
Sunflower seed	Russia 31%	Ukraine 22%	**EU** 17%	Argentina 9%	China 5%
Raw milk (cattle)	**EU** 20%	India 16%	US 13%	China 5%	Brazil 5%
Pig meat	China 47%	**EU** 17%	US 10%	Brazil 4%	Russia 4%
Cattle meat (beef)	US 18%	Brazil 16%	China 10%	**EU** 9%	Argentina 5%
Olives	**EU** 51%	Turkey 9%	Tunisia 6%	Morocco 6%	Egypt 6%
Tomatoes	China 36%	India 11%	**EU** 8%	Turkey 7%	US 6%

Source: FAO (FAOSTAT, 2023).

The EU's important role as both exporter and importer of agri-food products

The EU's growing agri-food trade surplus signals its competitiveness-performance

Dependency is often discussed in the context of trade, where imports are an indicator of being reliant on other countries. An examination of EU agricultural trade flows reveals some interesting facts. The first is that there has been a strong upward trend in EU agricultural trade flows, both with respect to imports as well as exports. As noted, the EU has a positive agricultural trade balance, and its trade surplus has steadily grown from less than US $10 billion in the early 2000s to about US $75 billion currently. At a macro-level, this signals a good competitive performance of the EU's agri-food sector. Brazil shows a similar pattern to the EU, and also has benefitted from following market-oriented agricultural and trade policy adjustments. China is one of the world's key net importers of agri-food products (e.g. animal feeds), and the US, traditionally being characterised by a trade surplus, now has a net trade deficit.

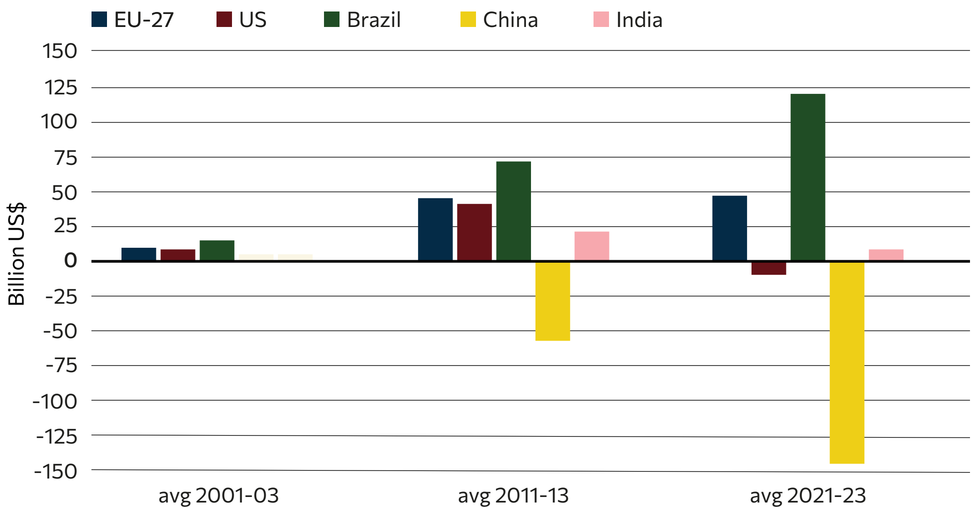

Figure 5.1 The Agri-food balance of the big-5 trading countries.

Source: authors, based on WTO.

The EU is strong in exploiting trade opportunities in agri-food to add value and increase its welfare

Zooming in further, the EU agri-food trade shows other distinct characteristics. As shown in Figure 5.2, the EU agri-food trade is a two-sided process: the EU is both one of the world's largest agri-food importers as well as one of the largest exporters.

EU exports have increased by almost 220% in the last two decades, while at the same time, the value of EU imports increased by about 170%, with the difference between the two explaining the 430% increase of the EU's agri-trade surplus (Haniotis, 2025).

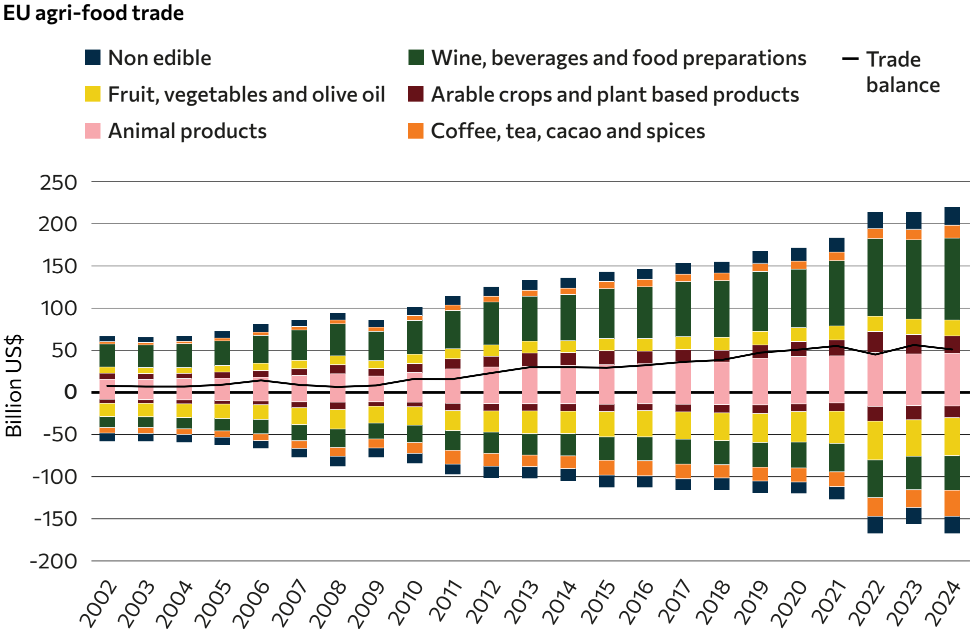

Figure 5.2 The evolution of EU agri-food trade (imports, exports, trade balance) over the period 2002 – 2024 in $ billion.

Source: authors, based on COMEXT.

Not only the EU's food system dependencies have increased, also other countries have become more dependent on the EU

The dual nature of EU agri-food trade (growth in imports as well as exports) is an obvious outcome when looking at the characteristics of the EU system. The EU, being a temperate production zone, is dependent on imports of tropical products like coffee, tea, cocoa and spices, among others. For other product categories, the EU is both an importer as well as an exporter. This can reflect seasonal issues (e.g. in fruits and vegetables) as well as quality differences and differences in degree of processing. When looking at the diversity in the origins of EU imports and the destinations of its exports, the EU mostly exports to developed high-income countries (including China) and imports from developing countries.

Two observations can be made in this respect. Firstly, the EU exploits trade opportunities to add value and increase its welfare. By following this strategy it has become more reliant on third countries for its imports. However at the same time, other countries have become more reliant on the EU for their imports. Secondly, whereas EU trade has at least partially a clear complementary character (e.g. imports of tropical products, as well as products with distinct quality) it also reflects comparative advantage patterns (e.g. the EU being an importer of oilseeds and exporter of cereals) and its strength in adding value to products.

Market balances show high EU self-sufficiency for most products

The EU's self-sufficiency in agricultural products is often more than 100 percent but may underestimate specific dependencies

The EU is more than self-sufficient for many products, implying that its home production is more than enough to cover domestic needs. For the 15 selected products presented in Figure 5.3, the average degree of self-sufficiency is around 108%. With regards to crops, the low degree of self-sufficiency for soybeans is remarkable. Note that soybean products (meal, and to some extent also oil) are an important component of the feed needed to achieve meat production. However, this implies that the high degrees of self-sufficiency for livestock products (dairy and meat; average value of 135), camouflages indirect import dependency regarding feed input.

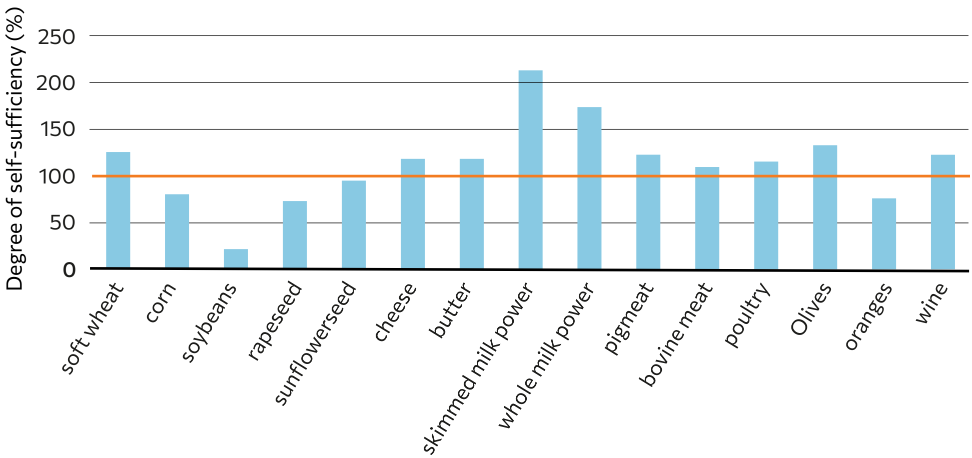

Figure 5.3 The EU self-sufficiency degrees (in percentages; see y-axis) for 15 selected products (five year averages for the period 2019-2023).

Source: EU-27 estimated agricultural balance sheets.

Even though trade is important, its role should not be overstretched: most of what is locally produced in agriculture and food is also locally consumed (see Alston and Pardey, 2014, 124); this is true for most countries in the world. As an indicator, the value of imported goods as share of the total output value can be used; in nearly all cases this is below 10%.

5.3 Sustainable competitiveness and fair trade

With respect to trade, the concept of sustainable competition raises a number of issues. First, at EU level choices have to be made with respect to the standards that should characterise sustainable competition. These standards, on quality and animal welfare, for instance, will deviate (be higher) from those of the EU's competitors which accept lower standards. Once standards are defined, there is a need to assess to what extent these higher standards impose a cost-disadvantage for home producers.

Differences in sustainability standards between the EU and its trading partners introduce non-neglectable level playing field challenges

Preserving a level playing field would require placing home producers on an equal footing with foreign producers, while higher standards should not only be a thing EU producers adhere to, but also the costs associated with these standards should be absorbed by the wider food system, from processors, to retail and last but not least consumers. This is a basic requirement of economic fairness, a cornerstone of the EU's competition policy. There are various ways to address this issue of differences in standards between countries (Swinnen et al, 2015). One is to impose a border correction mechanism (e.g. CBAM in the case of climate), which adds a cost correction to imported products produced at lower standards, aimed at reducing carbon leakage from the ambitious climate standards-policies pursued by the EU.

In cases where system-adjustments are not possible (e.g. for political or technical reasons), another option could be to support EU producers directly (e.g. with a basic hectare payment) to account for the difference in standards. This would raise EU budget expenditure, but consumers would have access to products where they do not or only partially pay for the standards cost mark-up. In these cases the EU will import at world market prices, reflecting the costs of products produced under lower standards than the EU. If this correction does not occur, a kind of Gresham's Law[10] will operate: 'bad food' will drive out 'good food', and EU producers will be crowd out of the market due to competitive disadvantage, while consumers will be served by products from low standard sourcing areas. This not only makes competition unfair, it also will not lead to achieving the sustainability objectives.

5.4 Where are the EU's main dependencies?

The macro picture shows that the EU's agri-food trade is bidirectional and diverse, with a steady increasing trade balance surplus signalling its competitive strength. And although the self-sufficiency statistics indicate that EU production serves domestic needs well, some dependencies of the EU's agri-food system can be identified (Loi et al. 2024).

This is more visible when looking at core elements (inputs) in the agri-food production process:

- For arable production the main dependency is on fertilisers (phosphate, potassium, and energy for nitrogen);
- For animal production there is a dependency on imported high protein feeds (oilseeds, soybeans, soymeal);
- For tropical products, dependencies arise from the EU's climate zone, which does not allow for the production of tropical fruits, coffee and cacao;
- For upstream stages of agri-food supply chains, there is dependency on essential feed additives;
- For both upward and downstream stages of agri-food supply chains, there is a general dependency on energy.

Note that the dependency for crops has a spill-over into animal products, since these (indirectly) depend on crops in feed ratios. See Figure 5.4 showing key dependencies and further characterisation of countries the EU is dependent on (including their shares in EU imports).

10 According to Gresham's Law, good money drives out bad money. Likewise relatively cheap 'bad food', not satisfying high EU standards, may crowd out 'good food', namely food produced according to EU standards, but more costly and thus more expensive for consumers.

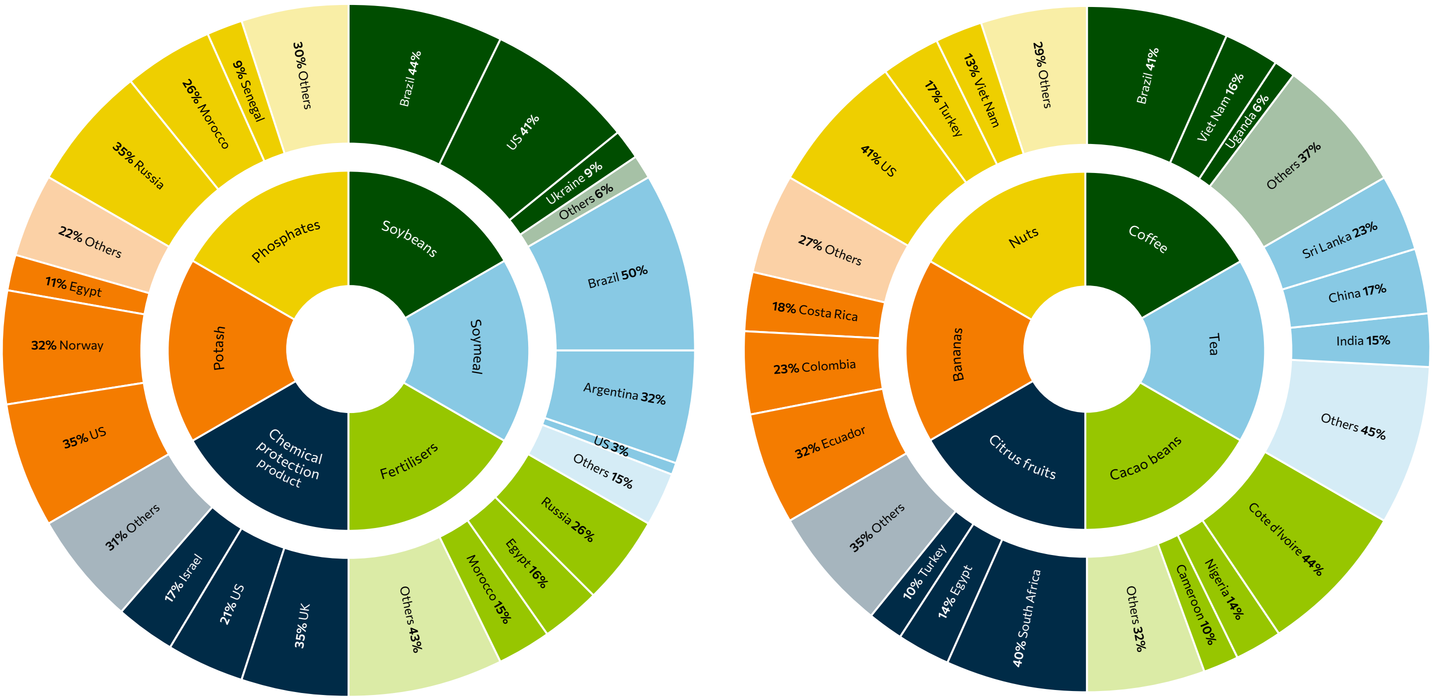

Figure 5.4 The dependency of the EU agri-food system on imported inputs for crop and animal sectors (see left panel) and dependencies related to differences between climatic zones (right panel).

Source: Eurostat comext database and own calculations by authors.

Fertilisers: Cereal production mainly relies on nitrogen (N) fertilisation, and less on phosphorus (P) and potassium (K) applications. In the EU, natural gas is normally used as an energy source in the process of producing synthetic nitrogen. Therefore, the EU's import dependency on natural gas severely affects its production of synthetic nitrogen fertilisers. According to Eurostat (2023a), the EU's import dependency for natural gas is structurally higher than 90%. In this case, EU imports originate from countries like Norway, Russia, the US, and the Middle East some of which carry a significant political risk (Lois et al., 2024). The EU not only imports ingredients, but also final products (e.g. fertiliser imports from Russia).

Protein feeds: The EU has a known protein-feed deficit, which in 2022 amounted to 16 million tons of soybeans and 17.5 million tons of soymeal. The EU domestic soybean production is about 3 million tons and is increasing. The specialisation of the EU in wheat rather than in oilseeds is a clear example of comparative advantage. The EU has relatively high wheat yields and low soybean yields compared to other suppliers such as the US, Brazil, Canada and even China. This implies that if the EU would attempt to become self-sufficient and reverse its specialisation, it would have to give up a considerable area that is now used for wheat production, generating an estimated 30 million tons global wheat shortage relative to current production levels (Haniotis, 2025). Moreover, since the EU's dependence makes it reliant on stable market economies such as those of the US, Brazil and Argentina, while its share in global soybeans and soybean meal trade is limited to about 15% (Fediol, w.y.), the risk this creates is limited.

Tropical products: The EU is reliant on imports of tropical products because it lacks the climate to cultivate many tropical fruits and vegetables, even though it may have limited domestic production. Key imports include bananas, tropical fruits, nuts, and spices. Eurostat data show that EU imports of organic tropical fruit, nuts, and spices have increased, with bananas being a major driver of this growth. Bananas are a significant item within total imports, with a large portion coming from Central and South America. Other notable tropical food imports include other fruits (dates, figs, pineapples, and avocados), citrus fruits, grapes, and berries. The EU has trade agreements with Central American countries to facilitate the import of agricultural products, including tropical fruits, nuts, and spices.

When looking at upstream and downstream stages of agricultural supply chains, some further dependencies should be noted. The EU faces significant dependency on third countries, particularly China, for essential feed additives like vitamins and amino acids, which compromises its food, livestock, and aquaculture sectors.

5.5 Critical dependencies, associated risks, and options to handle them

In order to determine an appropriate policy response, an assessment framework has to be applied to better understand these existing dependencies (Linsen et al., 2021; De Steenhuijsen Piters et al, 2021). Three criteria are of importance: (i) the critical nature of the dependency; (ii) the trustworthiness of the country delivering the concerned product; and (iii) the availability of substitutes in case the delivery of the important supplier would fail. A proxy for (i) is the share of the product or input supplied by one single nation. A proxy to measure (ii) is the estimate trustworthiness or geopolitical risk (e.g. expressed in percentage terms) of the critical single supplier-country. An indicator for (iii) is the existence of substitutes, in terms of substitute products, as well as the options for substitute production of the original product in other countries which could step in as a (further) substitute for the original single delivery country.

Fortunately the number of critical dependencies of the EU food system seems to be limited...

On the production side of the EU's food system the critical dependencies of the EU's agriculture and food system are reduced to a few products. Fertilisers, in combination with energy, are probably the most critical ones. Regarding consumers, there is a structural dependency on non-EU countries for tropical products and drinks (coffee and tea), but many countries can source these products. In all other cases, the dependencies are present, but they are not specifically critical when approached from a perspective of absolute scarcity, as either the market share of a single supplier is limited, there are many trustworthy countries supplying the product, and/or represent a low geo-political risk, and/or there are several substitution-possibilities to reduce the dependency in cases of disruptions in production delivery or calamities. This is not to deny that there are still economic risks (relative scarcity as reflected in prices) and resilience-issues associated with respect to those dependencies classified as non-critical.

... and there are multiple policy options contributing to the de-risking of critical dependencies...

With respect to the available policy responses, besides general policy measures to enhance home industry competitiveness, policy responses aimed at reducing critical dependencies could be:

- Ensure delivery guarantees by making specific agreements;
- Create reserves (buffer stocks); only possible for non-perishable products and given sufficient means and storage capacity and useful to address temporary distortions;
- Make a contingency plan for emergency production;
- Take a risk-spreading approach and reallocate production over a wider set of suppliers;

- Check and secure there is an infrastructure to replace the product by substitute products;
- Aim for self-sufficiency by creating sufficient domestic production;
- Follow and encourage strategies that more efficiently use inputs like fertiliser, animal feed/ingredients, and energy;
- Encourage circularity/reuse of inputs (e.g. using techniques to use potassium and/or phosphorus more efficiently as fertiliser raw materials, or recovering them from sewage sludge);
- Reduce demand (e.g. meat production is heavily dependent on imported soya – limiting meat consumption/encouraging flexitarianism).

Note that all these strategies require guiding policies and investments that may increase costs and thus worsen competitiveness. Consumers may also have to pay higher prices. There is therefore a trade-off between limiting import dependency and maintaining competitiveness, but this can be overcome (at least in part) through innovation (Chapter 4).

Ensuring broad market access, as markets may contribute to buffering of price and delivery shocks, is linked to bilateral trade agreements and organising these strategically (strategic partnerships). It also makes a difference whether important trading partners in the context of the dependency of a product, are geographically close or at great distance (increasing logistical risks) and whether they have a stable political and economic (e.g. trade policy) regime (e.g. avoiding export bans).

... and the EU's approach has turned out to be effective in ensuring its food system resilience

The EU has a set of arrangements in place to reduce risks (e.g. variability in prices) and manage crises (market disturbances). The EU has also pursued a strategy to extend trade partnerships with the aim to strengthen its strategic autonomy and market access with respect to inputs as well as outputs. The general impression is that these policies are adequate given the past risk profile; the EU's agri-food sector has proven to be resilient with respect to recent crises, such as the financial crisis, the COVID crisis and the Russian war crisis. However, to address current changes (e.g. the rising geopolitical tensions) a reconsideration of the risk and crisis policy may be needed.

5.6 Concluding remarks

The EU is a key producer of food and other agricultural products. As the generally high self-sufficiency indicators signal, production in most cases covers more than domestic demand. The EU is deeply integrated in world markets, and its food system is heavily involved in both import and export flows. For selected products such as cheese and wine, the EU is an important exporter. The EU is simultaneously an important importer and exporter of agricultural and food products. Trade contributes to the added value-process of the EU's food system, as well as to the provisioning of consumers with a high quality and varied food products shopping basket, at reasonable prices. Moreover, with its exports, it contributes to feeding people outside the EU with high quality products.

The EU's choice for sustainable competition reveals differences in standards between the EU and its trading partners. A challenge is to ensure fairness and a level playing field in the competitive struggle of EU farmers, food processors, wholesalers and retailers. If not, then sustainable competition will not deliver its intended results, but may lead to crowding out EU home-based production that adheres to the higher standards, and consumers being supplied with (possibly cheaper) products, but that do not live up to the EU's general level of high quality, environmental, climate, and biodiversity standards. Therefore, for sustainable competition to be tenable, corrective border mechanisms, or compensatory support measures are essential.

Even though trade plays an important role, the dependencies in the EU agri-food system are, in general terms, relatively limited. However, this can differ for specific products like fertilisers, high protein feeds, feed additives, and tropical products. Generally speaking, dependencies reflect specialisation based on comparative advantages and have a welfare enhancing effect. An assessment framework has been applied to check for critical dependencies. The key outcome of this exercise is that of all the identified dependencies, only a limited number are critical.

Several policy options are available to cope with dependencies and market variability, many of which the EU applies in its agricultural and trade policies. Changes in the EU's future risk profile may, however, create the need to reconsider or further strengthen its policy approach with respect to dependencies and resilience of its agri-food system.

6 Taking stock

6.1 Extending the vision: sustainable competitiveness

Sustainable competitiveness fits the EU's vision for the future
As argued above and as expressed by EU Commissioner for Agriculture Christophe Hansen, action should not be taken without a vision. A vision not only motivates and 'empowers' action, but also contributes to an integrated and coherent approach. According to Hansen's 'A vision for Agriculture and Food'1 the EU's future agri-food system should be 1) attractive by making farming a viable and appealing career; 2) competitive by strengthening the sector's position in global markets; 3) future-proof by embracing innovation and sustainability for long-term resilience; and 4) connected by valuing food and fostering fair living and working conditions in rural and urban areas.

Similarly, the Draghi Report presents a vision for a more competitive, innovative, and resilient Europe by focusing on boosting high-tech industries, decarbonising the economy, strengthening defence capabilities, and reforming competition and financial policies. It argues that innovation and security should be prioritised over competition enforcement and recommends making significant investments in sectors like AI and clean technology, and creating a more integrated financial market. Moreover, the report argues that sustainability and competitiveness are linked, not mutually exclusive.

Both documents refer to the importance of competitiveness and at the same time put it into a context of a broader set of objectives than GDP growth, by emphasising other priorities such as sustainability, decarbonisation, and security. In this study, we have further elaborated on the issue of sustainable competitiveness as applied to the EU food system. Thereby we aimed to deepen the reference to Hansen's competitiveness by elaborating on different aspects of competitiveness and emphasising the interlinkages between the four objectives mentioned in his Vision for Agriculture and Food. By focusing on the food system we have also broadened the analysis provided by Draghi, who focuses on the general economy, especially the EU's clean tech, battery industry, and the transport sectors, but does not pay attention to agriculture and food. Therefore, we have highlighted specific challenges and peculiarities of the EU food system in this report.

Moreover, our analysis has linked sustainable competitiveness to new technological developments expected to have a transformative-character and are likely to deeply affect economies and their food systems. It has to be realised though, that by propagating sustainable competitiveness, in the short term the challenges imposed on the food system will increase relative to pursuing more narrow type of competitiveness. For the longer term, however, the sustainable competition-approach will be much more effective and fits well with the current EU policy strategy. This explains why the actors in the food system, including farmers, are already working under conditions associated with a broader concept of competitiveness. However, they also feel the heat of the growing competitive pressure (EU Commission, 2025). As such, increasing ambitions with respect to sustainable competitiveness could even further increase this competitive pressure due to an increasing divergence between the EU and the rest of the world's sustainability standards.

6.2 Summary of key messages derived from the study

Sustainable competitiveness contributes to broad prosperity and good stewardship
In this essay, we discuss how the EU food system can be competitive and sustainable in a time of geopolitical tensions and competition for access to raw materials and markets. We argue that competitiveness should not be a goal in itself, but should be valued for its contribution to broader human and non-human welfare. This contribution is not limited to a food system that produces sufficient, affordable and healthy food; at least two other important dimensions need to be recognised as well. On the one hand, we need to recognise that the food system contributes to broad prosperity dimensions through culture and traditions by connecting people and places and urban and rural areas, as well as by producing sectoral inputs, meaningful jobs and income for people, SMEs, and regions, and by stewarding (rural) landscapes. On the other hand, we should recognise that food systems are a subsystem of the ecosystem (e.g. land and water use, reliance on nature) and, as such, need to be embedded in this subsystem. This implies that issues of sustainability, environmental

care, and climate should be inherent elements of a vision on tenable and resilient food systems. It has been argued that these 'givens' need to be accounted for in the competitiveness concept and thinking. The concept of sustainable competitiveness fits best to addressing the identified EU societal needs.

The EU food system supplies a broad variety of goods and services through a process of agriculture, manufacturing, food service, and 'final use' by a range of social actors. Together these actors are responsible for the food system's outcomes in terms of sufficient, healthy and affordable food (essential need) within environmental limits. Another key characteristic of the EU food system is its diversity, both in what is produced and in scale. Potentially, this contributes to the EU's resilience under various shocks. Moreover, more sustainable outcomes of the current food system require production systems that do not degrade soil, water, and air quality, restore biodiversity, and reduce GHG emissions. Food consumption patterns in which fruits and vegetables play a larger, and processed foods that contain (too) much fat, sugar and salt a smaller role, will contribute to health and lead to less environmental pressure from agrifood activities.

The EU internal market is often more important than third markets
With respect to the agri-food system and trade, it should be noted that most of the food produced within the EU is also locally consumed within the EU (e.g. a high degrees of self-sufficiency for most food items within the EU), lowering the relative importance of EU shares in world trade for assessing the food system's contribution to EU welfare. Moreover, when assessing agri-food system competitiveness, its role in the EU's internal market is more important than exports to third markets. When taking into account both the positive and negative contributions of the food system to broader human welfare, including impacts of production on biodiversity and the environment, the importance of the food system's locality becomes even more apparent. A well-functioning EU-single agri-food market requires perfect alignment between the EU and its Member States' policies and regulations. The impression is that a great deal is yet to be gained by creating a fair level playing field, diversification and specialisation within the EU-single agri-food market.

Therefore, innovation and collaboration are key ingredients to EU's future welfare
Notwithstanding the above, (intercontinental) competitiveness is an important factor for agribusinesses, food supply chains, and therewith also for clusters of firms (e.g. agro-complexes) as well. The report identifies the following key messages: Innovation has been and will be an important driver of competitiveness, not only in its narrow sense, but even more when treating competitiveness as a broader concept accounting for (social) sustainability aspects. We have identified four innovation

aspects and gaps, which either alone or combined, are important for strengthening sustainable competitiveness:

1 **Ecological innovation:** sustainable competitiveness requires that the negative externalities of the EU's food system are better addressed and mitigated both from a production and a consumption perspective.

2 **Agronomic innovation:** productivity increases (especially of yields, labour and other resource utilisation) are a key building block of sustainable competitiveness as they contribute both to the provisioning of food for a growing world population and saving resources.

3 **Social innovation:** sustainable competitiveness benefits from joining resources, knowledge, expertise available in different firms, sectors, and stages of supply chains. Circular collaborations are becoming increasingly important when developing, strengthening, and ensuring sustainable food production and resource use (e.g. sustainability labels and their certification along supply chains).

4 **Institutional and policy innovation:** sustainable competition requires supporting institutions (e.g. robust and sound regulations) and a facilitating and incentivising results-based policy approach. This involves combining a robust and solid regulatory framework defining sustainability standards and the user space with respect to the environment with a policy approach which abstains from the prescription of means, but rather provides maximum space for entrepreneurship within these boundaries and which facilitates innovative solutions.

Collaboration between various actors in the food system (e.g. in networks; see also 3 above) is a crucial factor. One reason is that solving sustainability challenges go beyond what individual actors can do and that transformations and efficient solutions require collective action. For that reason, it is important to follow a food system-approach as we have taken in this study. Another reason is that knowledge, databases, expertise and experience are often dispersed (e.g. within firms, their R&D branches, within knowledge institutions, etc.), and therefore there is a need to bring them together, make them accessible and stimulate (adaptive) learning processes and innovation ecosystems. In many cases this is in the interest of food system actors, but short-term narrow competitive interests may also be a bottleneck for collaborations, even though they are desirable from a societal point of view.

Circularity can drive cumulative and synergistic interactions among different dimensions of innovation in spatial contexts, mainly social and ecological dimensions, thereby becoming ‘an engine’ for sustainable competitiveness oriented at broader prosperity. This requires cooperative business models within agriculture (e.g. the livestock, manure, crop/feed-linkage), among the food system and urban actors in city-regions, as well as with actors in supply chains or production systems outside the food system.

The powerful transformative technological innovations currently being developed will impact our agri-food systems even more. In addition to R&D furthering the general developments of these technologies, collaborations are important to ensure a proper tailoring and translation of the new innovations to the agri-food domain and in the identified four innovation gaps. This not only includes targeted applications, but also the capacity of all actors in the agri-food system to absorb new knowledge and innovative products and services.

There are many dependencies which reflect the importance of specialisation and trade as this is favoured by both the EU’s internal market (with a single market for over 30 years) and the increased market orientation of the EU with respect to third markets. In general, this is welfare-enhancing and a source of income growth. However, a limited number of these dependencies have been identified as being critical, notably with respect to fertilisers, pesticides, oilseeds (protein feed), and specific feed additives. There are structural dependencies with respect to tropical products as the EU’s temperate climate is unfavourable for growing these products domestically on a sufficient scale. Dependencies create side-conditions that may co-determine the EU’s policy space and create vulnerabilities in the EU’s food system. Given growing geo-political uncertainties, this is where real threats to the EU’s food system and its food security are conceivable.

In the past decade, the EU’s food system has faced several stress tests (e.g. financial crisis, multiple disease outbreaks, droughts and heat waves in consecutive years, the COVID crisis, the Russian war on Ukraine). Fortunately, the EU has been reasonably resilient, and there has not been a single moment when the EU’s food provisioning has been endangered. This illustrates the success of the (private) actors in the food system to cope with challenges as well as the adequate response of government policies in addressing these crises. Some still view the EU as cumbersome, slow and bureaucratic, but compared to the ‘unfettered capitalism’ of the US and the ‘state-led capitalism’ of China, the EU has shown itself to be competitive, resilient and capable of playing its responsible and diplomatic role in the world, also in turbulent times.

6.3 Challenges for research and actors in the food system

Contributions from research in dialogue with society

For knowledge institutions, the notion of sustainable competition can act as a guiding principle to pursue a broad and balanced research agenda which includes both productivity and sustainability dimensions. This is true for applied research contributions to the EU's agrifood sector, as well as the much needed disruptive innovations discussed in this essay. Knowledge institutions can play a crucial role in taking part in these developments as well as (co-)developing applications that help to further ecological, productivity, social, and policy innovations. By contributing to these developments they are an essential partner in c the sustainable competitiveness of the whole food system.

A broad dialogue is needed to allow for an inclusive innovation process for transformative technologies with societal support

A continuous dialogue between research- and leading food system actors, as well as broader societal stakeholders is important because the EU food system is not a static entity, but subject to and also in need of continuous re-design and development. Dialogue is needed to build trust in solutions and stronger engagement with consumers, farmers, food chain operators, institutions, and civil society. An extra challenge is the dynamics and governance of different local systems coinciding in a European agri-food ecosystem of Member States and regional food systems.

Technology shaped human (social) lives in profound ways. Therefore, it is important to take societal concerns into consideration while technologies are still 'in the making' and can still be moulded to fit societal values. As such, we need to arrange a governance of innovation to safeguard that new and transformative technologies are appreciated and even wanted. To realise technology attuned to societal values, a Responsible Research and Innovation (RRI)-approach fosters an open, inclusive, multi-stakeholder collaboration between researchers and/or innovators and other societal stakeholders, such as citizens, policy makers, business, or NGOs.

These stakeholders discuss the question of how science and technology should be shaped in a viable way to not only contribute to solving today's problems, but also to create a world that will be desirable and safe for future generations. This means that the focus is not only on achieving outcomes from research and innovation that are socially and economically desirable and ethically and legally acceptable, but also imply that the process of research and innovation should be inclusive: it should anticipate the societal effects and reflect their desirability together with societal actors. The result of this anticipation and reflection with societal actors should be shared with researchers and innovators to allow them to consider it throughout the research and innovation process, including the design process.

A key role for actors in the food system

Different food system actors each have their own role, potential and responsibility

The food system comprises many actors and businesses, with both farmers and consumers playing an important role. As shown by many life cycle assessment studies, primary agriculture plays, either directly or indirectly, an important role in the food system's various emissions, but can, for that reason, also play an important role in improving the system's sustainability. Consumers with their behaviour act as 'voters', expressing via their preparedness to pay and via their food consumption choices the degree of food system-sustainability they prefer and support (e.g. supporting a protein transition from animal to crop-origin protein). Their choices may direct the system to a sustainability path, which can be effective and fast as the 'directive power' of the market may easily outweigh that of the policy environment. The reverse is also true: if the consumers' willingness to pay hampers upstream stages, food system supply chains may 'hesitate' adopting sustainability improvements that go beyond the low hanging fruit, which, for economic reasons only, they would like to adopt.

Consumers and farmers need to be treated fairly

Another observation made with respect to consumers and primary agricultural producers is that they are many and, measured in economic terms, small. This could make them subject to manipulation and market power abuse (e.g. unfair trading practices), especially where upstream or downstream players in the food system are concentrated. As in the first place sustainable competition should always be fair, attention should be paid to this in competition policies.

Collaboration is key for providing innovative and sustainable solutions for a competitive EU food system, here and now, elsewhere and later

Managing pathways toward a more sustainable food system requires collaboration between governments and food system stakeholders. Citizen initiatives in cities can also be catalytic in bringing about conscious and more sustainable food consumption choices with spillovers to peri-urban and rural areas in the EU. Sustainable food systems require a level playing field for primary producers and all other players in the food system's value chains, thereby creating a challenge for policy makers, amongst others, with respect to corrective border policy measures that ensure reciprocity and avoid environmental (carbon) leakage effects. This also requests for policy responses aimed at reducing critical dependencies. Although these are legitimate concerns when reasoning from a sustainable competitiveness point of view, poorly designed policy measures could unnecessarily hamper the benefits of competitiveness and international trade.

Sources and literature

Aiginger, K., & Vogel, J. (2015). Competitiveness: from a misleading concept to a strategy supporting Beyond GDP goals. *Competitiveness Review,* 25(5), 497-523.

Aiginger, K. (2018). Harnessing competitiveness for social and ecological goals: High-road competitiveness is necessary and feasible. In: Chiocchetti, P. & Allemand F. (Eds.), *Competitiveness and Solidarity in the European Union* (pp. 99-125). Routledge.

Albert, M. (1991). *Capitalisme contre capitalisme*. Paris, Editions du Seuil.

Alexander, P., Brown, C., Arneth, A., Finnigan, J., Moran, D., & Rounsevell, M.D. (2017). Losses, inefficiencies and waste in the global food system. *Agricultural Systems,* 153, 190-200. doi: 10.1016/j.agsy.2017.01.014

Alston, J.M.,Pardey, P.G. & Ruttan, V. (2010). The Economics of Innovation and Technical Change in Agriculture. In: Hall, B.H. &Rosenberg, N. (eds.), *Handbook of the Economics of Innovation,* Volume 2, 2010, Pages 939-984. Elsevier.

Alston, J. M., & Pardey, P. G. (2014). Agriculture in the global economy. *Journal of Economic Perspectives,* 28(1), 121-146.

Ammann, J., Mack, G., El Benni, N., Jin, S., Newell-Price, P., Tindale, S., ... & Frewer, L. J. (2024). Consumers across five European countries prioritise animal welfare above environmental sustainability when buying meat and dairy products. *Food Quality and Preference,* 117, 105179.

Balkenende, J.P. and Buijs, G. (2023). *Capitalism Reconnected Toward a Sustainable, Inclusive and Innovative Market Economy in Europe*. Amsterdam, AUP.

Bhawsar, P., Chattopadhyay, U. (2015). Competitiveness: Review, Reflections and Directions. *Global Business Review, 16*(4) 665–679. DOI: https://10.1177/0972150915581115**.**

De Boer J, Aiking H. Do EU consumers think about meat reduction when considering to eat a healthy, sustainable diet and to have a role in food system change? Appetite. 2022 Mar 1;170:105880. doi: 10.1016/j.appet.2021.105880. Epub 2021 Dec 21. PMID: 34942285.ETC, 2025. Top 10 agribusiness giants: corporate concentration in food & farming in 2025. https://www.etcgroup.org/content/top-10-agribusiness-giants

Breckenridge, A. (2019). Competitiveness. Still crazy after all these years? *Competitiveness | Frontier Economics,* 51(3), 921-935.

Boix-Fayos, C., & De Vente, J. (2023). Challenges and potential pathways towards sustainable agriculture within the European Green Deal. *Agricultural Systems*, 207, 103634.

Bovenberg, L., & Van Geest, P. (2021). *Kruis en munt: De raakvlakken van economie en theologie.* KokBoekencentrum. ISBN: 9789043533843

Bureau, J. & Antón, J. (2022). "Agricultural Total Factor Productivity and the environment: A guide to emerging best practices in measurement", *OECD Food, Agriculture and Fisheries Papers, No. 177*, OECD Publishing, Paris, doi: 10.1787/6fe2f9e0-en

Charter of Fundamental Rights of the European Union EUR-Lex - 12012P/TXT - EN - EUR-Lex

Cimini, F., & Kalantzis, F. (2024). The impact of the digital and green transitions on investment inefficiency (No. 2024/04). *EIB Working Papers*.

Clapp, J., Vriezen, R., Laila, A., Conti, C., Gordon, L., Hicks, C., Rao, N. (2025). Corporate concentration and power matter for agency in food systems. *Food Policy* 134 (2025) 102897.

Dagevos, H. (2021). Finding flexitarians: Current studies on meat eaters and meat reducers. Trends in *Food Science and Technology, 114*, 530-539. doi: 0.1016/j.tifs.2021.06.021

Dagevos, H. & Onwezen, M.C. (2025). Toward consumer-oriented food policies: A toolbox for encouraging the protein transition. *Sustainability: Science, Practice and Policy, 21,* 2454060. doi: 10.1080/15487733.2025.2454060

Darvas, Z. (2023). *The European Union's Remarkable Growth Performance Relative to the United States. Bruegel.* www.bruegel.org/analysis/european-unions-remarkable-growth-performance-relative-/united-states

Détang-Dessendre C., Guyomard H., Réquillart V., Soler L.-G., (2022). The CAP and Nutritional Issues. In Détang-Dessendre C. & Guyomard H. (Eds.), *Evolving the Common Agricultural Policy for Tomorrow's Challenge*s, Quae editions, Chapter 9, pp. 203-213

Davis, B., de la O Campos A., Farrae, M. & Winters, P. (2024). "Whither the agricultural productivity-led model? Reconsidering resilient and inclusive rural transformation in the context of agrifood systems." *Global Food Security 43*(2024), doi.org/10.1016/j.gfs.2024.100812

De Steenhuijsen Piters, B., Termeer, E., Bakker, D., Fonteijn, H. and Brouwer, H. (2021) Food system resilience Towards a joint understanding and implications for policy. Wageningen, Wageningen Economic Research, Policy paper, 2021-077.

Dijkstra, A. M., & Joore, P. (2025). *The Urban Living Lab Way of Working Handbook*. Amsterdam Institute for Advanced Metropolitan Solutions (AMS).

Dobrinsky, R. (2008). "Innovation as a Key Driver of Competitiveness," *UNECE Annual Report Economic Essays 2008_6*, UNECE.

Donoso, V. G., Hirye, M. C., Gerwenat, C., & Reicher, C. (2024). Amazon deforestation and global meat consumption trends: An assessment of land use change and market data from Rondônia that shows why we should consider changing our diets. *Sustainability*, 16, 4526. doi: 10.3390/su16114526

Draghi, M. (2024) The future of European competitiveness, https://commission.europa.eu/topics/eu-competitiveness/draghi-report_en. Duran Laguna (Ed.), 2024. Ninth report on economic, social and territorial cohesion. Directorate-General for Regional and Urban Policy. European Union

European Court of Auditors (ECA) (2024). Climate adaptation in the EU Action not keeping up with ambition – Special report. Brussels. www.eca.europa.eu/ECAPublications/SR-2024-15/SR-2024-15_EN.pdf

ECMWF (2025). Why are Europe and the Arctic heating up faster than the rest of the world? Retrieved from: *Why are Europe and the Arctic heating up faster than the rest of the world? | Copernicus*

European Environment Agency (EEA) (2023). A*griculture greenhouse gas emissions in Europe*. Copenhagen: EEA. www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emissions-from-agriculture

EEA (European Environmental Agency) (2024). *Europe's circular economy in facts and figures*. Briefing. www.eea.europa.eu/en/analysis/publications/europes-circular-economy-in-facts

The EU's Innovation Scoreboard (EIS) (2025). European Investment Bank (Ed.). (2021). EIB Investment Report 2020/2021: Building a smart and green Europe in the Covid-19 era. European Investment Bank.

European Commission (2023). https://food.ec.europa.eu/food-safety/food-waste_en

European Commission (2024). *EU agricultural outlook, 2024-2035*. European Commission, DG Agriculture and Rural Development, Brussels

EU Commission, (2025). Choose Europe for life sciences: A strategy to position the EU as the world's most attractive place for life sciences by 2030, https://research-and-innovation.ec.europa.eu/strategy/strategy-research-and-innovation/jobs-and-economy/strategy-european-life-sciences_en

European Commission (2025). Factsheet 'A vision for Agriculture and Food'.

Eurostat (2022a). Farms and farmland in the European Union. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Farms_and_farmland_in_the_European_Union_-_statistics

Eurostat (2022b). Farmers and the agricultural labour force - statistics.

Eurostat (2024). Food waste and food waste prevention – estimates

EY (2024) 2025 Geostrategic Outlook; How geopolitics is driving transformation. London, EYGM Ltd.

FAO. (2020). Urban food systems and COVID-19: the role of cities and local governments in responding to the emergency. *Policy Brief.*

FAO. (2023). Pathways towards lower emissions – A global assessment of the greenhouse gas emissions and mitigation options from livestock agrifood systems. Rome. https://doi.org/10.4060/cc9029en

Frederiks, C., & Wesseler, J. H. (2019). A comparison of the EU and US regulatory frameworks for the active substance registration of microbial biological control agents. *Pest management science, 75*(1), 87-103.

Fuglie, K.O., Morgan, S., & Jelliffe, J. (2024). World agricultural production, resource use, and productivity, 1961–2020 (Report No. EIB-268). U.S. Department of Agriculture, Economic Research Service.

Haniotis (2025) From Comparative Advantage to Reciprocity: EU ag-trade's goalposts are shifting dangerously. Retrieved from: From Comparative Advantage to Reciprocity: EU ag-trade's goalposts are shifting dangerously....

Hansen, H. & Weber, E. (2025). *Mehr resilienz und wandel – strategien für agrarwirtschaft und politik*. Frankfurt am Main, Rentenbank, Edmund Rehwinkel Stiftung.

Hayami & Ruttan, (1985). Agricultural Development: An international perspective, rev. ed. *Baltimore*, Md.: John Hopkins University Press, 506 p.

Helliwell, J. F., Layard, R., Sachs, J. D., De Neve, J. E., Aknin, L. B., & Wang, S. (2025). World happiness report 2025.

Herrera, S.I.O., Kallas, Z., Serebrennikov, D., Thorne, F., McCarthy, S.N. (2023) Towards circular farming: factors affecting EU farmers' decision to adopt emission-reducing innovations, International Journal of Agricultural Sustainability, 21:1, 2270149, DOI: 10.1080/14735903.2023.2270149

IPBES (2018). The IPBES regional assessment report on biodiversity and ecosystem services for Europe and Central Asia. (Rounsevell, M., Fischer, M., Torre-Marin Rando, A. and Mader, A. (eds.). Secretariat of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, Bonn, Germany)

Ittersum, van M.K., Silva, J.V. ; Bommarco, R.; Hijbeek, R.; Lundin, O.; Nandillon, R.; Bergkvist, G.; Menegat, A.; Öborn, I.; Söderholm-Emas, A.; Stoddard, F.L.; Vico, G.; Vonk, W.J.; Watson, C.A.; MacLaren, C. . (2025). Narrowing the ecological yield gap to sustain crop yields with less inputs. *Global Food Security, 45*, 100857

Khanna, M., Zilberman, D., Hochman, G., & Basso, B. (2024). An economic perspective of the circular bioeconomy in the food and agricultural sector. *Communications Earth & Environment, 5*(1), 507.

Lázaro, A., Delnoij, J., Alpízar, F., van Leeuwen, E., & Cremades, R. (2025). Policy entry points and associated interventions for sustainably transforming urban food systems. Environmental Science & Policy, 171, 104186.

Linsen, M., van Dijk, J., Reiding, A., Néhmé, H.N. (2021). Nieuw afwegingskader laat zien wanneer zelfvoorziening nodig is. *ESB, 106* (1408), 416-418.

Lisbon Treaty (2007) https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:12016ME/TXT&from=EN

Loi, A. Gentile, M., Bradley, M. Christodoulou, M., Knuuttila, M., Niemi, J, Weijberg, H. (2024) The dependency of the EU's food system on inputs and their sources. European Parliament, Policy Department for Structural and Cohesion Policies, Brussels

McKenzie, A.J., Emery, S.B., Franks, J.R. and Whittingham, M. (2013). Landscape scale conservation: collaborative agri-environmental schemes could benefit biodiversity and ecosystem services, but will farmers be willing to participate? *Journal of Applied Ecology, 50*: 1274-1280.

Mulders, A. (2018). Paper presented at the ENRD Workshop on 'The Future CAP: towards a Performance-based Delivery Model', 30 January 2018, Brussels.

OECD (2020). Beyond Growth: Towards a New Economic Approach, *New Approaches to Economic Challenges,* OECD Publishing, Paris, https://doi.org/10.1787/33a25ba3-en.

OECD (2024). Competition in the Food Supply Chain – Contribution from European Union. Unclassified paper contribution submitted by European Union under Session IV of the Global Forum on Competition to be held on 2-3 December 2024. OECD, DAF/COMP/GF/WD(2024)23

OECD (2024). Comparing the agricultural productivity, sustainability, and resilience of countries. Paris, OECD, Retrieved from Sustainable productivity growth in agriculture | OECD,

OECD/FAO (2025), OECD-FAO *Agricultural Outlook 2025-2034,* OECD Publishing, Paris/FAO, Rome, doi: 10.1787/601276cd-en.

Olmstade, A. & Rhode, P. (2009). Creating abundance: biological innovation and American agricultural development. Doi: 10.1111/j.1468-0289.2009.00501_31.x

Perez-Cueto, F. J. A. Perez-Cueto, F. J., Rini, L., Faber, I., Rasmussen, M. A., Bechtold, K. B., Schouteten, J. J., & De Steur, H. (2022). How barriers towards plant-based food consumption differ according to dietary lifestyle: Findings from a consumer survey in 10 EU countries. *Int. J. Gastr. Food Sci. 29,* 100587

Polman, D., de Schutter, L., Begemann, S., Rivas, J. D. L., van Leeuwen, E., & Wensing, J. (2025). Cities in the loop: a social science perspective on the role of cities in food system circularity. *Regional Science Policy & Practice,* 100238.

Porter, M.E. (1990). The competitive Advantage of Nations. *Havard Business Review, 1990,* 73-91.

Praveen, K., Abinandan, S., Venkateswarlu, K. & Megharaj, M. (2024). Synergy of eco-innovation with on-farming practices enhances circularity beyond conventional nutrient recovery framework. *Resources, Conservation & Recycling, 208*(2024) 107735.

Purnhagen, K., & Wesseler, J. (2021). EU regulation of new plant breeding technologies and their possible economic implications for the EU and beyond. *Applied Economic Perspectives and Policy, 43*(4), 1621-1637. doi:10.1002/aepp.13084

Qazi, A., & Al-Mhdabi, M.K.S. (2025). Exploring the relative importance of sustainable competitiveness pillars. *Journal of Cleaner Production, 443,* 140986. Doi: 10.1016/j.jclepro.2024.140986

Reardon T., & Timmer C.P. (2012). The economics of the food system revolution. *Annual Review of Resource Economics,* 4: 225-264. doi: 10.1146/annurev.resource.050708.144147.

Marshall, Q., Fanzo, J., Barrett, C.B., Jones, A.D., Herforth, & A., McLaren R. (2021) Building a Global Food Systems Typology: A New Tool for Reducing Complexity in Food Systems Analysis. *Front. Sustain. Food Syst. 5:746512.* doi: 10.3389/fsufs.2021.746512

Renhart, A., Krisztin, T. & Piribauer, P. (2025). The impact of the EU Common Agricultural Policy on regional agricultural productivity. Paper presented at the 18th EAAE Conference "Food System Transformation in Challenging Times", 26-29 August 2025, Bonn, Germany.

Robeyns, I. (2021). The capability approach. In: *The Routledge handbook of feminist economics* (pp. 72-80). Routledge.

Ros, G. H., de Vries, W., Jongeneel, R., & van Ittersum, M. (2025). Bedrijfsspecifieke doelsturing op verliezen van stikstof en broeikasgassen: Doelen, middelen en borging. Wageningen University & Research. doi.org/10.18174/685327+.

Sala, S., De Laurentiis, V. & Sanye Mengual, E. (2023). Food consumption and waste: environmental impacts from a supply chain perspective, European Commission, 2023, JRC129245.

Schenderling, P. (2025). Continent van de kwaliteit. Hoe Europa een eigen economische koers kan varen. BOT publishers, the Netherlands.

Schulte, R.P.O., O' Sullivan, L., Vrebos, D., Bampa, F. Jones, & A., Staes, J. (2019). Demands on land: Mapping competing societal expectations for the functionality of agricultural soils in Europe. *Environmental Science and Policy, 100*(2019) 113-125.

SmartProtein (2023). Evolving appetites: an in-depth look at European attitudes towards plant-based eating. A follow-up to the 2021 survey report 'What Consumers Want. November 2023. https://smartproteinproject.eu/wp-content/uploads/Smart-Protein-European-Consumer-Survey_2023.pdf

SolAbility (2025). SolAbility Sustainable Intelligence (online) https://solability.com/the-global-sustainable-competitiveness-index. Accessed August 26, 2025.

Stiglitz, J. E., Sen, A., & Fitoussi, J. P. (2009). *The measurement of economic performance and social progress revisited,* Vol. 33, pp. 1-63. France: Ofce.

Terwan, P. Deelen, J.G., Muders, A. & Peeters, E. (2016). The Cooperative Approach under the New Dutch Agri-Environment Climate Scheme. Background, *Procedures and Legal and Institutional Implications*. Ministry of Economic Affairs.

Thore, S., & Tarverdyan, R., (2016). The sustainable competitiveness of nations. *Technol. Forecast. Soc. Change 106*, 108–114. https://doi.org/10.1016/j. techfore.2016.02.017

Tidjani, F., Selten, M., & van Galen, M. (2025). The EU food and drink industry: a competitiveness analysis. Wageningen, Wageningen Social & Economic Research, Report 2025-035.

Tirole, J. (2017) *Economics for the common good*. Princeton, Princeton University Press.

Tittonell, P. A. (2013). Farming systems ecology: Towards ecological intensification of world agriculture. Wageningen Universiteit. https://edepot.wur.nl/258457

Tittonell, P. (2014). Ecological intensification of agriculture—sustainable by nature. *Current opinion in environmental sustainability, 8*, 53-61. https://doi.org/10.1016/j.cosust.2014.08.006

UN, (2025). Corporate power and human rights in food systems. Report of the Special Rapporteur on the right to food, Michael Fakhri, A/80/213 September 2025.

van der Gaast, K., van Leeuwen, E., & Wertheim-Heck, S. (2020). City-region food systems and second tier cities: From garden cities to garden regions. *Sustainability, 12(*6), 2532.

Veenhoven, R. (2000). The four qualities of life. *Journal of happiness studies, 1*(1), 1-39.

Vrolijk, H., Reijs, J., & Dijkshoorn-Dekker, M. (2020). Towards sustainable and circular farming in the Netherlands: Lessons from the socio-economic perspective. Wageningen Economic Research. https://edepot.wur.nl/533842

Wensing, J., Cremades, R., & Van Leeuwen, E. (2023). Cities can steer circular food systems at scale. Nature food, 4(1), 4-4.

Wensing, J. H. H., Bonanno, A., Drabik, D., Materia, V. C., Malaguti, L., Meijer, M., & Venus, T. J. (2015). *Overview of the Agricultural Inputs Sector in the EU*. European Union.

Wesseler, J. H. H., Bonanno, A., Drabik, D., Materia, V. C., Malaguti, L., Meijer, M., & Venus, T. J. (2015). *Overview of the Agricultural Inputs Sector in the EU*. European Union.

Wesseler, J. (2022). The EU's farm-to-fork strategy: An assessment from the perspective of agricultural economics. *Applied Economic Perspectives and Policy, 44*(4), 1826-1843.

Wissenschaftlicher Beirat für Agrarpolitik, Ernährung und gesundheitlichen Verbraucherschutz beim BMLEH (2025): Mehr Auswahl am gemeinsamen Tisch: Alternativprodukte zu tierischen Lebensmitteln als Beitrag zu einer nachhaltigeren Ernährung. Gutachten, Berlin.

Wolfert, S., Wassenaer, L. v., Burg, S. v. d., Ryan, M., Klerkx, L., Rijswijk, K., McCampbell, M., Athanasiadis, I., & Beers, G. (2021). *Navigating the Twilight Zone: pathways towards digital transformation of food systems.* Wageningen University & Research. Doi.org/10.18174/552346

Appendix 1 Exploration on innovations and the pillars of sustainable competitiveness

To illustrate how the six pillars of sustainable competitiveness (see Chapter 3) are linked to the four innovation gaps and the role of the transformative technologies discussed before (see Chapter 4) this annex explores this a bit further. No attempt is made to strive for completeness, but Table A.1 intends to show and illustrate how, in various ways, different innovations can support the pillars underlying sustainable competitiveness. As such it illustrates that for sustainable competitiveness the role of innovations is not less, but even more important than for more narrow concepts of competitiveness, as is also argued for in the main text.

Although ecological and agricultural innovations are distinguished as separate entries because of their differences in purpose, in practice these could well go together or parallel. Partly this is because resource saving ecological innovations may also have a positive impact on resource utilisation efficiency, and by that on productivity. Here also the importance of interaction effects and the aligning of regulatory and incentive policies may be pointed to. Having a robust and clear framework of sustainability constraints (ultimately defined at the level of the actors in the system (e.g. Ros et al, 2025) contributes to the creation of a business model for the adoption of emission mitigating innovation (Jongeneel et al, 2024).

A core issue to settle or balance is matching the urgencies of economic viability and ecological, environmental and climate sustainability. Note this not only holds for policy makers, but holds for all actors in the food system, as it is the collaborative approach which makes the EU's food system viable and sustainable. With respect to the economic side, the still low profitability of agriculture and the lagging incomes in the agri-food sector are an issue of policy concern, both with respect to the welfare of the farmers and workers in the agri-food complex (see Chapter 2). This is also because sufficient incomes will be a prerequisite to facilitate the desired sustainability transition, which will involve the adoption of emission mitigating farm management measures as well as investments in sustainable technologies and/or stables, which most-likely will have a low, zero, of even negative impact on productivity. With respect to the sustainability side, there are several studies emphasising that the trends are wrong with respect to biodiversity and nature conservation (see challenges denoted in Chapter 2). Also there are several indicators signaling that the condition and state of maintenance are insufficient (IPBES, 2018).

Table A1 Illustrations how different type of innovations can contribute to strengthen the six pillars of sustainable competitiveness.

	Competitiveness-pillars					
Ecological innovations	networks of innovation partners (e.g. EIP), including extension service partners and the ultimate innovation adopters	save natural capital by developing precision agriculture and scaling up biodiversity-friendly farming practices and systems in agriculture and energy saving technologies in food industry and logistics	R&D with respect to ecological innovations contributes to build/ strengthen intellectual capital w.r.t. sustainability solutions and applications	challenge governance in making new arrangements for managing the commons, and the preservation and delivery of ecosystem services, and facilitating their widespread adoption	increase delivery of eco-system services and improve the economic system's functioning by integrating knowledge about true cost and true price	contribute to circular economy proceses both within the food system and between the food system and the rest of the economy
Agronomic innovations	networks of innovation partners (e.g. EIP), including extension service partners and the ultimate innovation adopters	contributes to resource-saving technologies; create potential for sparing and sharing approaches with landsaving (yield) productivity growth	R&D with respect to agronomic innovations (aimed at yield growth and closure of yield gaps) contributes to build/strengthen intellectual capital w.r.t. sustainability solutions and applications	challenges governance to support their widespread adoption where needed; define proper legal space for new transformative technologies (NBT, Cripr Cas)	Productivity growth (e.g. yield/labour) contributes to profitability and entrepreneurial incomes	contribute to improving resource efficiency; may contribute to a better management of resources (e.g. sustainable use of soils)
Social innovations	strengthen and stimulate networks and social interactions within these networks; strengthen possibilities for collective action	Organising short supply chains; develop labels linked to biodiversity preservation, climate change and emission mitigation; stimulate organisations managing commons (e.g. waterboards)	Strengthen R&D networks; stimulates synergies between researchers and disciplines; improves partnering of scientific, applied researchers and practicioners in agriculture and food system in improving their knowledge	contribute to new governance models for supporting collective action within the food system; monitoring and evaluation (e.g. eip, LEADER, self governance?	organise producer groups; cooperatives that coordinate actions to improve sustainability and contribute to a fair remuneration along different supply chain stages	facilitate farmer/business collaboration (e.g. shared machinery) aimed at improving efficient resource use
Policy innovations	provide a legal bases for producer groups and recognition for cooperatives and associations; support innovation partnerships/ networks	protect natural capital via imposing regulatory boundaries (avoid Jevons effect); enfurhter performance based management and steward schemes; have fines discouraging non-sustainable behaviour (polluter pays principle)	EU and national R&D science policy (e.g. Horizon ao) with a special focus on life sciences contributes to strenghten and extend a knowledgebase to adress the various sustainability challlenges which benefits the food system	Stimulate and develop a policy framework, which a rich set of instruments and sufficient means to acheve a balanced people, profit, planet approach to the food system; have EU Single markets well-functioning	Ensure fair level playing field (including mirror clauses); support sustainability labeling (e.g. PGI/PDO); increase budgets for delivery of ecosystem services; penalise unfair trading practices	help to impose a proper and robust regulatory framework, clarifying the sustainability boundaries that not should be crossed (e.g. balanced fertilisation of soils; pursuing regenerative agriuclture)

Colophon

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