

The paradoxes of the protein transition maintain existing animal production and consumption systems

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The shift towards reduced consumption of animal-based products, referred to as the protein transition, is increasingly viewed as an opportunity to drive sustainable food systems transformations. Here we explore three central paradoxes of the protein transition. The first underscores the focus on substituting animal proteins with alternative sources, rather than reducing overall protein consumption. The second focuses on the search for new protein sources, rather than tackling overconsumption and overproduction. The third involves the continued export of animal proteins from Europe, a practice defended under the guise of food security, efficiency and comparative advantage. These narratives dominate public discourse, justifying existing production and consumption patterns, shaping perceptions and influencing decisions and policies that impact the future direction of our food systems. Given the influence of stakeholders' narratives in the transition, we advocate for a holistic and systemic perspective that transcends isolated and quick-fix solutions to foster coherent strategies to advance the protein transition.

The protein transition refers to a dietary shift from diets rich in animal-sourced proteins such as meat, fish, dairy and eggs to ones rich in plant-sourced proteins and alternative protein sources¹. This renewed attention echoes protein-centred initiatives of the 1950s² and 1970s³, when nutritional concerns over young children garnered attention in research and intervention programmes. Now the expected rise in demand per capita, coupled with fears of a protein deficit for a growing global population, have drawn attention back to the protein supply⁴. Where overconsumption of animal protein is evident, there are increasing calls for a dietary transition towards alternative protein sources⁵. The protein transition is simultaneously an increasingly documented scientific concept, a political topic seized on by governments, media and civil society, and a commercial product object attracting the attention of corporations^{1,6}. Interest from diverse academic disciplines highlights the transformative potential of diet modification in environmental sustainability and health outcomes, prompting a reorientation of academic research towards diverse

protein alternatives⁷. Numerous scholars have also delved into the political economy underlying the shift to alternative protein sources, revealing that this move is not merely a result of new technology or consumer preferences^{6,8} but is intricately woven into the fabric of political, economic and power relations. Government policies, market regulations and power structures in the food industry can substantially shape the transition⁹.

As the protein transition unfolds, a series of paradoxes that are much more than just academic curiosities are being encountered. In organizational theory, a paradox displays a persistent coexistence of contradictory, yet interdependent, elements within a system that emerge from competing demands or logic, such as individual and collective goals¹⁰. The existence of different narratives arises from different underlying values, reflecting the specific worldviews of the experts and stakeholders who advocate for them¹¹. As each narrative pushes for a particular transformation, the coexistence of these competing visions generates and sustains paradoxes within food systems.

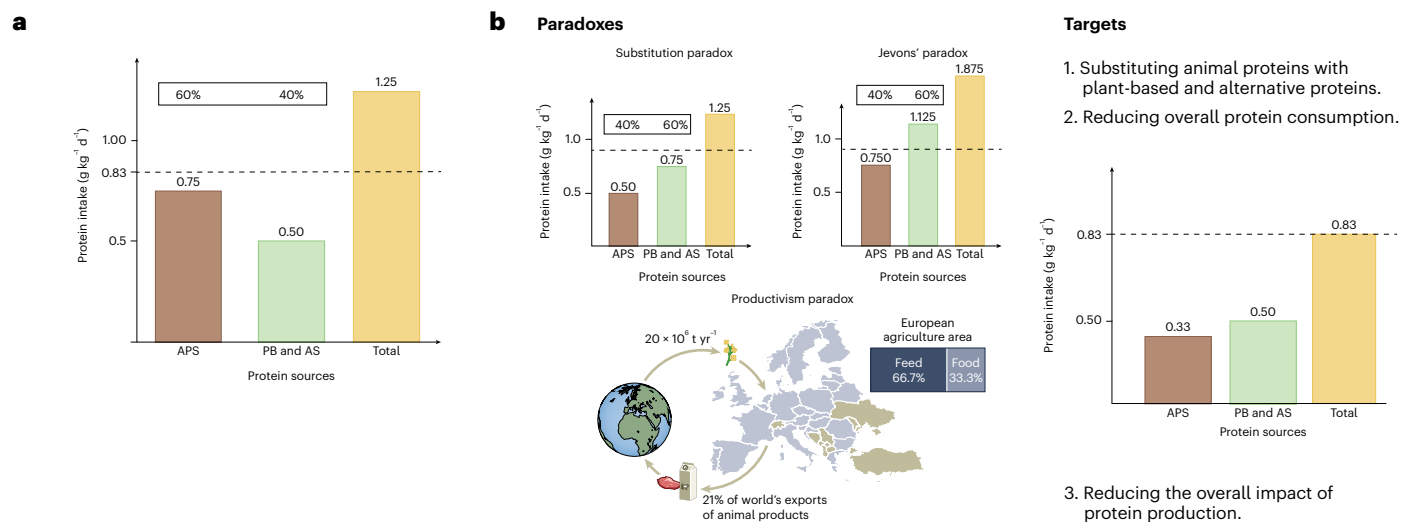


Fig. 1 | The paradoxes of the protein transition. **a**, The current situation. **b**, The paradoxes (left) and targets (right) of the protein transition. The recommended protein intake (dashed horizontal line in all plots) is from the European Food Safety Authority and Food and Agriculture Organization recommendations^{15,16}. The targets are derived from multiple sources, including refs. 1,17,20. APS, animal protein sources (including meat from domesticated animals, fish and seafood,

dairy products, eggs, and game meat); AS, alternative protein sources (including novel plant-based substitutes (often referred to as meat mimics or analogues), lab-grown proteins (such as cultivated or cellular proteins) and processed products from insects); PB, plant-based protein sources (including traditional protein preparations such as tofu and seitan, whole foods, legumes, grains, seeds or mushrooms).

This Perspective delineates the inherent paradoxes within the protein transition, exploring the historical pillars of Europe's protein production systems and scrutinizing path dependencies that result in a socio-technical lock-in and reinforce established practices. The European context offers a compelling case study, with its extensive documentation of European policies since the 1950s, the considerable influence of the European Union (EU) Common Agricultural Policy on animal and plant protein production⁹, and the notably high levels of meat and dairy consumption across EU countries^{12,13}. Throughout this Perspective all mentions of Europe specifically refer to EU member countries. Finally, we analyse narratives that sustain each of these paradoxes and present an analytical framework that integrates paradoxes, narratives and path dependency to elucidate the complexities of the protein transition. We advocate for a holistic and systemic view that transcends isolated elements to better align historical practices with new paradigms, fostering coherent strategies for navigating systemic shifts in sustainable food systems.

Emerging paradoxes of the protein transition

The paradoxes of the protein transition stem from the dichotomy of established European protein regimes, characterized by intensive animal protein production systems that are bolstered by supportive policies and trade agreements. This contrasts sharply with the increasing calls from European institutions for alternative proteins. Through 19 interviews with experts from academia and civil society, combined with an exploration of grey and scientific literature, we reveal three paradoxes that form the crux of the protein transition debate (Supplementary Information).

The substitution paradox

The first paradox lies in the focus on substitution, rather than reduction: why pursue new alternative protein sources if the problem lies in overconsumption (Fig. 1a)? Recent global reports and numerous studies underscore the negative environmental and health impacts of high consumption of animal-sourced foods^{5,14}. These sources advocate for a dietary shift towards the greater inclusion of alternative proteins—a transition that is especially pertinent in regions where protein intake, particularly from animal sources, exceeds the dietary

recommendations established by health authorities. Despite this trend of overconsumption, the prevailing discourse and proposed strategies emphasize replacing animal-based proteins with alternative sources without addressing the level of protein consumption¹. In contrast, the European Food Safety Authority, in line with Food and Agriculture Organization recommendations, set the population reference intakes for protein at 0.83 g per kg body weight per day (g kg⁻¹ d⁻¹)^{15,16}, while the current average consumption for European countries is 1.25 g kg⁻¹ d⁻¹, comprising 0.75 g from animal sources and 0.50 g from alternative sources¹⁶. In this context, achieving a rebalance between animal and alternative proteins from 60:40 to 40:60 could be achieved by solely reducing animal-based protein intakes by 55% without changing the current consumption of plant-based (or alternative) proteins¹⁷ (Fig. 1b).

Jevons' paradox

The need to tackle the unsustainability of current protein production systems is one of the drivers of the protein transition¹. This trend has spurred private and public investment in new protein sources positioned as alternatives to animal-based proteins^{6,18}, with claims of improved environmental footprint per unit output¹⁹. However, the investment surge also lowers unit production costs, increasing protein production capacity. In a capitalist framework, introducing these new alternatives entails the development of new markets and an increase in the consumption of those innovative products, reinforcing the initial context of overconsumption. This phenomenon aligns with Jevons' paradox: alternative proteins do not replace animal proteins but add to them⁶. While the environmental impact per unit produced is lower due to increased efficiency, this is offset by the impact of the overall increase in total protein production (Fig. 1b).

The productivism paradox

The primary concern regarding protein scarcity lies in the feed sector, as European livestock production currently depends on two-thirds of the agricultural land in Europe being used for crop feed²⁰, alongside imports of 20 Mt of oilseed meals per year (based on the 10 yr average of imported oilseed meals used for feed in the EU protein balance sheet)²¹ (Fig. 1b). A primary objective outlined in the European Parliament resolution for a protein strategy is to boost protein self-sufficiency, with

the aim of domestically producing part of the imported oilseed meals annually. This pursuit, allowing the maintenance of current livestock production levels, would require at least 5 million ha to be allocated to protein-rich crops (based on soybean yields in the United States of 3.54 t ha^{-1}), equivalent to roughly 5% of the current European agricultural area. Such a shift would reduce the land available for other crops and incur environmental and economic costs²². The paradox becomes clear: despite a tendency towards protein overconsumption and the ability to produce surplus animal products for export²³, Europe continues to focus on bolstering protein self-sufficiency for feed purposes while leaving the current levels of animal protein production unaddressed²⁴.

Stakeholder dynamics

Public sector

The public sector's role in the protein transition is multifaceted, intersecting with research, policy and industry regulation. Policy initiatives from the European Commission, such as the Farm to Fork strategy, advocate for a shift towards plant-based diets and actively support the development of alternative proteins, directly impacting these paradoxes²⁵. While these recommendations aim to address public health and environmental issues, they also align with the interests of key industry players. Despite intentions to diversify protein sources and reduce dependence on feed imports such as soy, the lack of explicit policies to reduce livestock numbers implies continued—if not tacit—support for the status quo within the livestock and associated cereal sectors, exemplifying the productivism paradox. Moreover, European policies, underpinned by subsidies and regulatory frameworks, continue to favour animal proteins, leaving alternative protein sources at a comparative disadvantage^{9,26}.

Finally, the focus of public research and the academic community on alternative proteins contributes to promoting them as a viable solution to environmental concerns²⁷. This approach unintentionally results in higher overall protein consumption (substitution paradox) and associated environmental impacts (Jevons' paradox).

Private sector

Agri-food companies are responding to the increasing demand for alternative proteins and dietary shifts by expanding their portfolios to include both animal-based and alternative proteins². This diversification approach not only allows companies to capitalize on evolving consumer trends and satisfy a wide range of global tastes and dietary choices, but also strategically minimizes the risk associated with a potential decline in demand for animal protein. Expanding into the fast-growing alternative protein sector and keeping all options on the table, these companies are well positioned to secure market share while protecting their business from market volatility. Retail sectors follow suit, offering consumers a broad spectrum of protein choices. The private sector therefore directly contributes to the substitution and Jevons' paradoxes.

Between opportunities and narratives

Economic and political opportunities

From the private sector perspective, the substitution and Jevons' paradoxes are intricately tied to economic opportunities in the alternative protein industry, where advocating for reduced consumption is not a marketable option within a growth-oriented economic paradigm¹⁸. In recent years there has been a notable surge of interest in alternative protein development, leading to a dedicated 'alternative protein sector'. This sector has attracted substantial investment, with US\$3.1 billion in funding secured in 2020 alone, marking a threefold increase from 2019 and a nearly fivefold increase from 2018²⁸. Nestlé, Cargill and Danone, among other companies, are proactively developing meat and dairy substitutes to meet the rising consumer demand⁶. As argued in Jevons' paradox, these alternative proteins do not displace animal proteins; instead, they diversify the portfolio of available protein options.

The substitution and Jevons' paradoxes are also part of political strategies. The initial dialogues that sparked the protein transition were motivated by the negative impacts of livestock production systems. However, narratives are now shifting towards protein autonomy and framing the situation as one of protein scarcity, overshadowing these initial concerns⁶. By treating the protein transition as a public health issue separate from livestock issues, we risk diverting focus from the fundamental environmental and ethical considerations that catalysed the movement^{6,29}, making it unlikely that the intended reduction in the overall impacts of protein production will be achieved (Fig. 1b). Addressing the livestock sector is also politically complex, as it requires engaging with the 2.6 million European farms specialized in livestock production and the additional 2.2 million detaining some livestock³⁰, as well as engaging with the vested and well-defended interests of the crop sector. Europe is a major cereal producer, 60% of which is used to feed livestock³¹. Shifting to more food crops would require the development of new varieties and supply chain adjustments³² while overcoming the political unattractiveness of implementing policies that could disrupt established agricultural economies³⁰. Such a transition would inevitably create a dichotomy of outcomes, with certain stakeholders standing to lose from a reduced reliance on livestock sectors, while others could benefit from the diversification and innovation in crop production³³.

Tensions between the status quo and sector transition

Historically, policies and trade agreements favoured animal proteins over plant proteins in Europe²³. Although current policies now endorse both—as can be seen from EU protein strategy crafted by the European Parliament's Committee on Agriculture and Rural Development—the emphasis remains uneven, with animal proteins still receiving greater focus. Building on a 2018 report by the European Commission³⁴, this strategy aims to enhance protein potential, improve conditions for protein production and embrace a circular economy that acknowledges the complementary role of plant-based and animal proteins³⁵.

However, two distinct conversations persist within this framework: one on alternative proteins in a transition context and another on making livestock production more sustainable, with little emphasis on reducing livestock production. Different narratives of efficiency, comparative advantages as a legacy of past policies, food security, food sovereignty and the risk of leakage not only reinforce paradoxes but also deepen them, as they advance inconsistent agendas and conflicting visions of future food systems.

Efficiency. Despite compelling evidence of European livestock production systems exceeding critical environmental thresholds, policymakers, the food industry and numerous agricultural science experts endorse the imperative of enhancing efficiency in animal protein production systems to respond to the rapid global growth in animal product consumption. This surge is viewed not only as inevitable but also as a positive driver of economic growth and improved access to nutrient-rich animal-derived foods, particularly in socioeconomically disadvantaged communities³⁶. Although typically quantified through feed conversion factors in the animal production sector, efficiency considerations also extend to environmental impacts, assessing outputs in relation to undesirable effects such as greenhouse gas emissions or soil pollution. The evaluation of different agricultural production systems varies depending on the environmental dimension and the chosen functional unit. While input-intensive systems tend to excel in reducing greenhouse gas emissions per unit produced and in optimizing land use, extensive systems often perform better on biodiversity indicators³⁷. The choice of the functional unit further influences the performance assessment: product-based metrics tend to showcase the efficiency of intensive systems, whereas area-based metrics highlight the environmental advantages of extensive systems³⁸. Finally, focusing on efficiency-based indicators overlooks the overall increase in production volume and associated absolute impacts (Jevons' paradox)³⁹. This

efficiency narrative is employed both to sustain current animal protein production systems and to promote the development of alternative protein sources that are considered more resource-efficient as they do not require the conversion from plant to animal protein.

Comparative advantage. According to David Ricardo's theory of comparative advantage⁴⁰, producers should specialize in goods with a comparative advantage and actively engage with trading partners to enhance social welfare⁴⁰. However, the claimed comparative advantage observed between Europe's animal protein production and the United States' plant protein production is not solely due to technological superiority but is also influenced by past trade agreements progressively establishing robust international market positions for European animal products and American plant protein products. Extensive examination of the conditions for the applicability of Ricardo's theory has shown that the assumptions underpinning its relevance are unrealistic and diverge substantially from reality, thus making the argument's relevance debatable^{40,41}.

Food security. The third prevailing narrative for sustaining current levels of animal production asserts that Europe's production capacity contributes to supplying the global market through exports, making a substantial contribution to food security⁴². This argument underscores a fundamental contrast in the perception of food security between industry and government on the one hand and the definition endorsed by the scientific community and international organizations on the other—the latter entails ensuring that all people, at all times, have physical and economic access to sufficient, safe, and nutritious food that meets their dietary needs⁴³. The prevailing emphasis leans towards ensuring well-stocked market shelves and global food exports, rather than establishing a sustainable and global system that guarantees the provision of healthy and sustainably produced diets. This perspective is rooted in the belief that increasing food production directly translates to heightened food security⁴². However, food security encompasses more than food availability, including accessibility and utilization⁴⁴. Moreover, chronic food insecurity arises from entrenched structural factors within communities, such as poverty, environmental pressures, limited property rights and land access, restricted market entry, compromised human health, insufficient job prospects and inadequate distribution networks and infrastructure⁴⁵.

Food sovereignty. The right of nations to grow essential foods within their cultural and productive diversity⁴⁶ is often invoked to justify the status quo in agricultural practices or to call for the withdrawal of environmental regulations³⁰. In times of global upheaval, such as the Russia–Ukraine conflict, the narrative of food sovereignty gains prominence as supporting Europe's strategic autonomy in food production⁴⁷. Behind this narrative lies a concern for the competitiveness of the EU's agri-food sectors, which have seen their dominance erode over the past few decades⁴⁸. In the face of rising prices and logistical challenges, food sovereignty is being reframed as a strategic lever to maintain an intensive, globally competitive livestock industry within the EU⁴⁹. This reframing shifts the focus from the authority of communities over their food systems to specific industry requisites that primarily push for the maintenance of low-cost animal product supply chains, overshadowing the original intent of food sovereignty to empower all citizens to shape their food systems⁴².

Leakage effect. Reducing production without a parallel shift in consumption patterns could lead to the unintended 'leakage effect'³⁰, by which environmental degradation (notably from deforestation in exporting countries) might intensify as imports surge to meet unchanged consumer demands³⁰. This scenario parallels the demographic transition theory, in which a lag between falling mortality rates and subsequent birth rates temporarily causes population growth.

Similarly, a temporary imbalance arises if protein production declines faster than consumption. This emphasizes the critical need to address production and consumption together to avoid simply transferring environmental degradation from one place to another^{1,50}. The central question then becomes one of responsibility: who should lead this transition to ensure accountability? Is it the role of government to legislate and regulate, to initiate and plan the transition, or should consumers drive shifts through behavioural change? Addressing these responsibilities is critical to achieving a transition that delivers tangible environmental improvements both locally and globally.

Conclusion

Although the attention on protein is not new, the conceptualization of a protein transition is driven by distinct factors, most notably the imperative for more sustainable protein production systems and consumption patterns. At its core, the protein transition focuses on consumption objectives, shifting from a diet rich in animal protein to one that emphasizes alternative proteins. The protein transition straddles the realms of scientific inquiry and policymaking. The three paradoxes explored here highlight substitution, rather than reduction, the pursuit of new protein sources despite existing overconsumption and overproduction in Europe and the sustained export of animal proteins under the guise of food security, efficiency and comparative advantage.

So far, discussions on the protein transition and sustainable livestock practices in political and scientific realms seem disconnected. Despite numerous studies evaluating the potential impact of reducing animal protein intake, we doubt that altering consumption patterns alone will suffice to achieve environmental objectives without corresponding adjustments in production. Thus, we suggest integrating the livestock transition into the broader context of the protein transition, explicitly addressing the production dimension. Academics and researchers should continue to reflect critically on their role in this transition, given the subjective nature of research and its political implications. Finally, and crucially, Europe must articulate its future goals with clarity. The current stance of simultaneously promoting a protein transition while entering into trade agreements that facilitate meat imports, along with providing substantial subsidies to some livestock sectors, may seem paradoxical not only to farmers, but also to citizens and consumers.

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Author contributions

O.D. designed and conducted the interviews. Both authors jointly conceived the conceptual framework and contributed to the final version of the paper.

Competing interests

The authors declare no competing interests.

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